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# Journal

# **J.UCS**

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*Proceedings of I-KNOW '09*

## **9<sup>th</sup> International Conference on Knowledge Management and Knowledge Technologies**

*Proceedings of I-SEMANTICS '09*

## **5<sup>th</sup> International Conference on Semantic Systems**

Graz, Austria, September 2–4, 2009

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# J.UCS

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International Conference on  
Knowledge Management and  
Knowledge Technologies

I-SEMANTICS '09  
International Conference on  
Semantic Systems

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International Pragmatic Web Conference*

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# **I-KNOW '09**

## **9<sup>th</sup> International Conference on Knowledge Management and Knowledge Technologies**

### **Preface**

The future success of organizations of any type mainly depends on the knowledge about the next market trends and latest technology developments and on how organizations apply this knowledge. Knowledge Management is a widely accepted concept to support organizations in continuously positioning their products and services within rapidly changing markets. In addition, new Knowledge Technologies, such as semantic technologies, have been widely accepted to complement “soft” knowledge management methodologies to provide organizations with technology support in order to meet the above mentioned challenges.

This year the Know-Center, Austria’s Competence Center for Knowledge Management, together with the Knowledge Management Institute of Graz University of Technology, organize the 9<sup>th</sup> I-KNOW conference. For the third time I-KNOW is held concurrently with the I-SEMANTICS – International Conference on Semantic Systems, organized by the Semantic Web Company and Salzburg New Media Lab. The intention of combining I-KNOW and I-SEMANTICS is to bring together the various communities and to close the gap between convergent research areas.

I-KNOW '09 is dedicated to the latest scientific trends, developments and challenges in the area of knowledge management and knowledge technologies. While I-SEMANTICS has its emphasis on new trends in semantic technologies from a technological perspective, I-KNOW focuses on the application of these technologies.

With an average of more than 450 international participants over the past nine years, I-KNOW has become the largest application-oriented conference of its kind in Europe. I-KNOW provides a perfect framework for networking among international researchers and practitioners working in the fields of knowledge management and knowledge technologies. Community building is fostered in special interactive events designed around particular themes. Deliberately long breaks throughout the conference and social events in the evening emphasize the role of I-KNOW as a networking platform.

I-KNOW '09 offers its participants high quality contributions reviewed by a program committee consisting of internationally renowned experts. This year, 29 full papers and 16 short papers have been selected for publication in the conference proceedings of I-KNOW. This corresponds to an acceptance rate of about 45% for full papers.

The program of I-KNOW '09 covers scientific presentations, panel discussions, keynote talks, a poster session and an international cooperation event. The authors of full papers give their presentations in thematically clustered sessions. The presentations focus on current trends and latest developments in knowledge management and knowledge technologies. They address amongst others:



- Basics and Theories
- Knowledge Work Support
- Semantic Technologies
- Knowledge Services
- Knowledge Relationship Discovery
- Knowledge Visualization
- Innovative Approaches to Knowledge Management
- Knowledge Management and Web 2.0

Many thanks go to all authors who submitted their papers and of course to our international program committee for their careful reviews. The abstracts of the contributions which have been selected by the program committee are published in these proceedings. Revised and extended versions of the best of these contributions will also appear in our electronic journal J.UCS ([www.jucs.org](http://www.jucs.org)), Section Knowledge Management. J.UCS supports the open access initiative for scientific literature and thus ensures the knowledge transfer and dissemination towards the community.

Again we managed to attract internationally outstanding researchers and managers from science and industry to give a keynote at I-KNOW '09. We are grateful that Paolo Traverso (FBK, Italy), Eric Tsui (University of Hong Kong, China) and Peter Kropsch (Austrian Press Agency) will present their points of view in the fields of Future Internet, Knowledge Management, Semantic Web and Web 2.0.

A further highlight of the program is an international cooperation event. Due to the great success in the last two years the organizers – the Styrian Economic Funding Agency (SFG) in cooperation with the Enterprise Europe Network - decided to continue this success story. Prior to the conference, interested organizations have the opportunity to generate their profile containing information about their competences, services, products, needs etc. Organizations with complementary profiles will then be invited to meet each other during a 25-minute business speed-dating. This program element fosters the conference strategy to serve as a platform for networking between researchers and practitioners.


Finally, we would like to thank our sponsors and media partners. The Academy of Europe, Go International, [contentmanager.de](http://contentmanager.de), [t3n](http://t3n), Personalmanager, Computerwelt, DOK.magazin, monitor, e-commerce Magazin. Special thanks go also to Dana Kaiser for preparing and ensuring the high quality of the conference proceedings. Finally, we would also like to thank the core group at Know-Center and the Knowledge Management Institute who is responsible for the entire successful organization of the event. This group includes (in alphabetical order) Anke Beckmann, Anita Griesser, Patrick Hoefler, Claudia Thurner and Alexander Stocker – Thank you for your continuous high motivation in organizing I-KNOW!

We hope that I-KNOW triggers many new ideas for your own research and that you'll find new opportunities for partnerships with other organizations.

Sincerely yours,



Klaus Tochtermann,  
Conference Chairs I-KNOW '09



Hermann Maurer

Graz, August 2009

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# **I-SEMANTICS '09**

## **International Conference on Semantic Systems**

### **Preface**

I-SEMANTICS offers a forum for exchange of latest scientific results in semantic systems and complements these topics with new research challenges in the area of social software, semantic content engineering and logic programming. The conference is in its fifth year now and has developed into an internationally visible event.

This year I-SEMANTICS co-hosted the 4th AIS SigPrag International Pragmatic Web Conference, which explores the young but flourishing field of computational semiotics and pragmatics. The co-location of the Pragmatic Web Conference perfectly fits into the concept of I-Semantics which is to bridge the gap between various research communities and traditions relevant to semantic systems and bring them closer to each other.

The conference attracts leading researchers and practitioners who present their ideas to more than 400 attendees. Attendees are provided with high quality contributions reviewed by a program committee featuring renowned international experts on a broad range of computational semantics and knowledge management. This year 21 high quality full papers and 9 short papers were accepted for inclusion in the conference proceedings of I-SEMANTICS, from a total of 69 submissions.

The program of the I-SEMANTICS '09 is structured as follows: In the main conference the contributors of full papers are presented in thematically grouped sessions. Submitters of short papers have the opportunity to present their research in a poster session. These presentations cover a broad range of results in semantic technologies, amongst them were topics such as:

- Corporate Semantic Web
- Social Semantic Web
- Linked Data
- Rules & Reasoning
- Ontology Engineering & Management
- Semantic Web Usage & Case Studies

Additionally the Pragmatic Web papers were grouped in a special track and a Semantic Web Industry Day was conducted using a workshop format, in order to bring application-led research to an industry-oriented audience.

For the second time I-SEMANTICS includes a Linking Open Data Triplification Challenge which is chaired by Michael Hausenblas (DERI). Three prizes were awarded to the most promising triplification results all based on existing Web applications, Websites and data sets. The challenge is supported by Ontos, punk.netServices and the Digital Enterprise Research Institute (DERI) under the patronage of Tim Berners-Lee, director of W3C. We received a number of submissions from which 8 were nominated for the final challenge. The winners were

ected by the challenge committee and will be announced at the I-SEMANTICS conference.

Beside the scientific part of the conference a German-speaking industry track and an exhibition is taking place where organizations have the opportunity to present their semantics based products and services. A special event this year is the International Cooperation Forum where potential partners for research and technology projects are brought together. This event is organized by the Styrian Economy Funding Agency (SFG) in cooperation with the Enterprise Europe Network. A special format fostering the exchange of ideas together with social events and a well-suited venue throughout the conference provides excellent opportunities for meeting people interested in semantics-related topics from different disciplines and from different parts of the world.

We are grateful to our invited keynote speakers Paolo Traverso (FBK), Eric Tsui (Hongkong University) and Peter Kropsch (Austrian Press Agency - APA) for sharing with our attendees their ideas about the future development of knowledge management, new media and semantic technologies. Many thanks go to all authors who submitted papers and of course to the program committee which provided careful reviews in a quick turnaround time.

We would like to thank our sponsors the Academy of Europe and Go International, an initiative of the Austrian an initiative of the Austrian Federal Economic Chamber und Federal Ministry of Economics and Labour. Special thanks also go to Andreas Blumauer (Semantic Web Company) who organized all industry relevant activities, and to Dana Kaiser who prepared the conference proceedings in time and with highest quality. We would also like to thank the staff at the Know-Center (Anita Griesser, Alexander Stocker and Patrick Höfler), the Semantic Web Company, the Corporate Semantic Web Working Group of Freie Universität Berlin (Markus Luczak-Rösch) and Salzburg NewMediaLab (Georg Güntner) for their efforts and their enthusiasm in organizing this event.

We hope that I-SEMANTICS '09 will provide you with new inspirations for your research and with opportunities for partnerships with other research groups and industrial participants.

Sincerely yours,

Adrian Paschke, Hans Weigand, Wernher Behrendt,  
Klaus Tochtermann and Tassilo Pellegrini

Graz, August 2009

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## **Towards a Future Internet of Services and Content**

### **Keynote Speaker**

**Paolo Traverso**

(Fondazione Bruno Kessler, Italy  
traverse@fbk.eu)

Research in Service Oriented Computing has addressed the problem of modeling (possibly with semantic annotations), composing, executing and monitoring “software services”. Software Services are software components that provide electronic access to “real services”. For instance, an airline web service for getting information about available flights and buying flight tickets provides and electronic access to the whole airline flight service. However, most of the main characteristics of real services are very different from those of the corresponding software services, such as their duration, their accessibility, their constraints and conflicts, and their connection with the real world, which makes them highly dynamic. In the vision of “Future Internet”, research should move its focus on modeling, composing, and monitoring real services, rather than software services. While Internet has a marginal role for software services, it is a key enabler for real services. It offers the unique capability to communicate in real time changes in real services and in their context, and allows the user to react immediately to these changes. In such context, novel knowledge representation and management approaches are required to model real services. And we believe that such techniques should be radically different from current approaches to semantic modeling of web services. In this context, research in service-oriented computing and in knowledge management can be no longer pursued as orthogonal efforts. An integrated effort of two communities will allow for a Future Internet of Services and Content, which will allow the Internet to play the same role for services it is playing nowadays for web pages and content.

### **About Paolo Traverso**

Paolo Traverso is Director of the Center for Information Technology – IRST at FBK, a center of about 200 researchers and developers working on engineering, content, and interaction. His main research interests are in Software and Services, Artificial Intelligence, and the Automated Verification and Synthesis of software systems. He contributed to research in automated planning with a novel technique called “planning as model checking”, which is now the basis for his work on supporting the automated composition and run-time monitoring of service oriented applications.



## **KM Education, Adoption and Research in Hong Kong: The KMRC Perspective**

### **Keynote Speaker**

**Eric Tsui**

(Hong Kong Polytechnic University, China  
mfetsui@inet.polyu.edu.hk)

Hong Kong has accelerated its transformation into the new economy in a big way. Established in 2007, The Knowledge Management Research Centre (KMRC) at The Hong Kong Polytechnic University (HKPolyU) has played a pivotal role in this transformation with its educational program, research, and professional services. This talk will comprehensively introduce the centre, outline its mission, activities and accomplishments especially in establishing the region's only blended E-Learning and Face-to-face master degree in Knowledge Management, various research projects on knowledge technologies, knowledge audit and strategy formulations. Major KM projects in the public and private sectors will be shared to substantiate KMRC's principle of treating the real world as an "open KM laboratory".

### **About Eric Tsui**

Eric Tsui joined Computer Sciences Corporation (CSC) in 1989 after years of academic research in automated knowledge acquisition, natural language processing, case-based reasoning and knowledge engineering tools. His research was supported by grants and scholarships from Arthur Young, Rank Xerox, CSC, Graphic Directions, and the Australian Research Council. He was also a gratis visitor to Microsoft Research in February, 2000. Since August 2000, he has taken up the role of Innovation Manager at Australian Mutual Provident (AMP). Eric is responsible for strategic research, knowledge brokering (between CSC and AMP), innovation management, and university-industry collaborations.

## **When Technologies Are Drivers, Integrated Concepts Are Needed for Success!**

### **Keynote Speaker**

#### **Peter Kropsch**

(Austrian Press Agency, Austria  
peter.kropsch@apa.at)

When the technical, social and economic settings undergo erratic changes, companies need fundamental development strategies to survive. As service provider in current information and communications, APA has traditionally studied probable future scenarios intensively. For the next five years we expect two fundamental influencing factors that will have an impact on the users of our services:

- The development of information technologies and the possibilities opened up by them
- As a consequence, the way people will handle current information in the future

What is necessary for us to successfully provide current information and communication services in the future? APA thinks that above all connectivity, networking and individualization are required. We are working on the assumption that information must work irrespectively of application, devices, operating systems and networks. We think that information needs will be individual to such an extent that depending on the context providers will develop completely different conceptions of relevance. Information will have to be able to define itself via metadata in such a way that it can be combined with other information in different ways – but always so as to make sense – in a variety of situations.

### **About Peter Kropsch**

Peter Kropsch was born in Wels, Upper Austria, in 1965. Following his studies at the University of Vienna in the fields of Mass Communication and Public Relations, Kropsch held diverse positions in the PR sector as well as financial editor. In 1996, he started his APA career in the Marketing and Sales Department. Already in his second year he became the head of the Business Information Department and was responsible for the areas Financial Services, Databases and Profile Services, OTS Original Text Service, and MultiMedia. In 2000, following the outsourcing of OTS, Kropsch was appointed as Managing Director of the new subsidiary, and – in the same year – was nominated as a member of the APA Executive Board. In December 2005, he was appointed as the deputy General Manager, and in 2007 he held the position of General Manager. Since the beginning of 2009, Kropsch was appointed as Chairman of the Executive Board and heads the APA together with Konrad Tretter.

## **The Emerging Web of Linked Data**

### **Keynote Speaker**

**Christian Bizer**

(Freie Universität Berlin, Germany  
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The World Wide Web is a global information space based on the idea to set hyperlinks between documents. In a similar fashion, Linked Data technologies provide for setting data links between records in distinct databases and thus connect these databases into a global data space. Linked Data therefore provides a means to overcome the fragmentation of the Data Web into separate data islands accessible through proprietary Web APIs. Linked Data technologies have been adopted by an increasing number of data providers over the last three years, leading to the creation of a global data space containing billions of assertions, the Web of Linked Data. In his talk, Professor Christian Bizer will introduce the principle ideas behind Linked Data, give an overview of the emerging Web of Linked Data, explain the state-of-the-art in applications that consume Linked Data from the Web, and outline current research topics that arise from the evolution of the Web into a global data space.

### **About Christian Bizer**

Professor Christian Bizer is the head of the Web-based Systems Group at Freie Universität Berlin, Germany. The group explores technical and economic questions concerning the development of global, decentralized information environments. The results of his work include the Named Graphs data model, the Fresnel display vocabulary, and the D2RQ mapping language which is widely used for mapping relational databases to the Web of Linked Data. He initialized the Linking Open Data community project and the DBpedia project.

# **I-KNOW '09**

## **International Conference on Knowledge Management and Knowledge Technologies**

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## **Knowledge Maturing at Workplaces of Knowledge Workers: Results of an Ethnographically Informed Study**

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**Abstract:** The concept of knowledge worker has been around for fifty years and many information and communication technologies have been implemented in order to support this type of work. Workplaces have changed substantially, but information is scarce about how actual knowledge workers handle knowledge in their workplaces. This paper presents the results of a joint study of knowledge workers' workplaces in five organisations representing a diverse sample in terms of size, sector and technology intensity. The results suggest that a number of person types with predominant ways of handling knowledge can be favourably used for designing supportive tools and infrastructures.

**Keywords:** ethnography, knowledge management, knowledge work, persona

**Categories:** L.2.1, L.2.2, L.3.4, L.3.8, M.4

### **1 Introduction**

The concept of knowledge work(er) celebrates its 50th anniversary this year [Drucker, 1959; Kelloway, 2000; Hayes, 2001; Schultze, 2003] and there are information and communication technologies (ICTs) in abundance to support the handling of

knowledge, informal or workplace learning. One can assume that there have been large changes in workplace organisation due to increasing penetration with ICTs. However, there is a notable shortage of studies that analyse what is going on in organisations in terms of workplace learning and how guidance of these collaborative knowledge and learning activities could be designed. Furthermore, empirical data about maturing of knowledge within organisational settings cannot be found in the literature. This paper presents the results of a collaborative ethnographically informed study which investigated workplaces of knowledge workers from a knowledge (maturing) perspective. In the following, the paper first gives an overview of the procedure taken in the study and the analysis of its results. Section 3 presents individual studies and selected results, specifically so-called personas and cases that are described from a knowledge maturing perspective. Section 4 then reports on the procedure we took to consolidate the results found in the individual studies as well as its outcome. Finally, section 5 concludes the paper and gives an outlook to the studies' further (potential) usage.

## 2 Procedure

Ethnographical research established in anthropology and social science was developed to investigate new cultures and social settings. The key characteristic of ethnography is active participation in social settings to understand why things happen [Jordan, 1996; Fetterman, 1999; Lamnek, 2005]. In contrast to field observation which describes what happens, ethnography focuses also on the why and how things happen. The researcher tries to become a member of the community by working with people in their natural environments, typically for long periods of time [Fetterman, 1999]. Recently, ethnography has become more popular also in disciplines other than anthropology and sociology. For example in computer science, ethnography has been one of the key approaches for designing CSCW (computer supported cooperative work) systems [Harper, 2000]. In order to balance the need for an in-depth understanding of why, how and in what ways technology affects work practices in the fast-changing world of information systems which calls for ethnographic studies with the substantial efforts and time that this type of empirical work requires, modified versions, like rapid ethnography [Millen, 2000], have been proposed to be more suitable in requirements analysis [Harper, 2000]. The main idea of that modified ethnography is to save time by narrowing the focus, use several observation techniques, work collaboratively and use tools for the analysis [Millen, 2000].

The term collaborative ethnographically informed study might fit better to our study because we performed five studies with joint perspective and guidance adhering to ethnographic fieldwork as much as possible. The time allocated had to be limited to four weeks each, though, and divided as follows:

*1st week:* At least two researchers visited each organisation to undertake the ethnographic fieldwork and to gain an understanding of knowledge maturing.

*2nd-3rd week:* Ethnographers were in contact, e.g., via e-Mail, instant messaging or telephone, with participating knowledge workers. Self-reporting was used for gaining data about specific and well-defined topics over the two week period.

*4th week:* The same researchers returned to the organisation for further ethnographic fieldwork. They discussed the topics of self-reporting, gained a richer picture of organisational activities and interview selected individuals.

This fieldwork provided us with rich qualitative empirical material which was coded, reflected and analysed. Numerous face-to-face workshops and teleconferences were held with the ethnographic teams in order to jointly interpret the data. A number of distinctive results were found, specifically knowledge maturing routines, cases, processes as well as personas.

Modelling personas is one promising approach to characterise user needs, work routines and learning styles as proposed by [Cooper, 1999]. A persona is a precise description of a user's characteristics and what he/she wants to accomplish [Cooper, 1999] and represents a class of target users that is described with rich information [Aoyama, 2007]. Besides its usage for software designers, personas can be used for communication with clients and stakeholders [Chang, 2008]. There is a plethora of related work investigating personality types from a psychological perspective [Bayne, 2004; Bayne, 2005; Bayne, 2006]. However, general personality types have not been analysed from a learning perspective and, thus, do not focus on how individuals handle knowledge (maturing), which was the main research interest for the ethnographically informed studies. Personas form important communication media within the team of designers [Blomquist, 2002]. They are useful in helping to guide decisions about a product, such as features, interactions, and visual design.

### **3 Results of Individual Studies**

This section provides an overview of results of the ethnographically informed studies conducted at six organisations selected for diversity in terms of size, sector and technology intensity (names of organisations are pseudonyms). Table 1 provides an overview of the organisations studied.

organisation	size	sector	country	# ethnographers	identified personas
IT Service Provider	large (400 employees)	IT services	Germany	3	Aisha Igor Sally
Health Care Training and Consulting	large (4,000 employees)	health care	Germany	3	Otto Silke
Tele-communication Provider	large (20,000 employees)	tele-communication	Switzerland	2	Kurt Thomas
IT Franchising	medium (130 employees)	IT	Germany	2	Axel Heather Kevin Stella
Careers Guidance Services I	large (> 300 employees)	professional services	United Kingdom	3	Edward Fiona Gina Harry
Careers Guidance Services II	large (>1,000 employees)	professional services	United Kingdom	4	Andrew Becky Colin Deborah
e-learning and consulting services	small (30 employees)	consulting services	Spain	1	Carolina Raquel

*Table 1: Studied organisations*

Each of the following sections contains a short description of the observed organisation as well as a summary of collected results and presents two selected outcomes: (1) one persona developed to represent ‘typical’ employees; and (2) a selected description of short-term, individual, and situational as well as long-term, more procedural knowledge maturing cases involving many organisational members or even units.

### **3.1 Study I: IT Service Provider (ITSP)**

ITSP is specialised on SAP solutions for utility companies and employs 400 staff. ITSP operates a computing centre, is an outsourcing provider and has administration/hosting, consultancy, development and application support teams. Nine employees were studied by three ethnographers who aggregated characteristics of several knowledge workers and created three personas: Aisha, the anchorwoman; Igor, the communicative type and Sally, the do-it yourself type (names again are pseudonyms).

Igor, a persona which represents a communicative type could be identified and based on real-world individuals working as technical consultants directly with customers. Igor works as an IT consultant in the consulting department and his many of his daily tasks are not standardised. He works in different project teams and has to



continuously acquire new knowledge, especially about clients' circumstances. If Igor has a problem and he needs knowledge to solve it, his first approach is to ask people currently in his room. If nobody in the room has a reasonable answer or knows another person who can help, he initiates a discussion about the topic regardless of what tasks his colleagues are currently engaged in. In many cases, solution ideas could be generated or the discussion team can refer to somebody. Igor has a good network and maintains relationships with other people. He uses breaks to get information about other people's work and activities or to discuss own work problems. Thus, he has a comprehensive picture of ongoing activities and is constantly well informed. His motto is "There are no stupid questions, only stupid answers."

One long-running case being an example for a maturation of knowledge is the process describing the introduction and development of the portal technology. The process started with the employment of a university alumni interested in portal technology. He sparked interest by his team leader and his head of department who let him pursue the topic. After searching for existing information within the company, by the vendor of the solution and talking to colleagues, the portal technology was found to be promising. He was sent to a training course by the software vendor. It was then decided to use this knowledge within a pilot project creating a prototype for internal use. When this project became a success, plans for a commercial solution were made with the company's main shareholder as a first customer. The original employee responsible for introducing the portal technology became manager of this project. In parallel, the internal pilot project was enhanced with the effect of further training employees in applying this technology. After successful implementation of the customer project, further plans for an enterprise roll-out were made in which the initial employee was included. With the maintenance of the first productive solution, several challenges within the company arose, which forced changes in the internal processes, as this technology needed different support and communication structures due to its integrated nature.

This case (over a duration of approximately 1.5 years) states a maturation within three dimensions: The *product knowledge* concerning the portal technology and its documentation is developed by several projects. *Employees* learn about new technologies and advance personally. Finally, *processes* were adapted.

### 3.2 Study II: Health Care Training and Consulting

The second study was conducted at the training and consulting center of a hospital with 4,000 employees in total. The studied unit is responsible for organising, planning, and implementing advanced vocational training events (mainly for nursery care), but also offer mentoring and coaching services; these are for both internal and external customers. Five employees were observed by three ethnographers, which allowed for immersion into everyday activities and training. All have several years of professional experience and a well-developed social network within and outside the organisation. From the observed individuals, we could aggregate two personas: Silke, characterised by a sense of perfectionism, and Otto, exemplifying the impact of organisational constraints and the behaviour of his superior on motivation.

Silke had completed her academic studies after a vocational training. She still tries to stay in contact with her former occupational group in order to stay up-to-date

with practice. For her, it is essential to have clear structures for the paper-based and digital part of her workplace. These structures are both based on subject (as a kind of reference book) and chronological (for business transactions). This applies both to documents and emails. Although currently these structures and document archives are mostly used by her alone, she would also like to have access to similar sources of her colleagues in order to avoid redundant work. She finds shared folder structures with several levels difficult to use because the criteria for structuring are not always her own. Also, labelling of files is frequently a source of problem. She also has a deep concern about data safety and, thus, keeps an archive of all documents in paper form. When working on her emails, she always checks all mails in the spam mail folder in order not to lose any message. She often has problems with the usability of computer software. Clear structures within applications that do not change with software updates are crucial as she lacks deep knowledge about computers. She has high personal standards and aims at continuously improving her work practice. Thus, she regularly reflects on how tasks were carried out and what could have been improved. Based on those insights, she updates templates and process descriptions. Where possible, she discusses her experiences with others. This sense of perfection also applies to her everyday task management. She meticulously plans her tasks and appointments each day, and prepares each meeting with elaborate notes. She always uses paper and pencil for plans, as she needs the feeling of satisfaction of ticking off completed items.

The following case illustrates the impact of personal motivation on knowledge maturing: As part of the ward manager course, participants have to do a “hospitation” (mixture of job shadowing and internship). As a result of group work and based on a similar approach by a colleague, the trainer had the idea of introducing reports on “hospitations”, mainly based on the intrinsic motivation to make the training services even more useful for participants. In order to work out a template and guidelines, the trainer asked a colleague for an example of such reports and then searched the Internet in order to evaluate the suitability of the example. Then, the trainer drafted some initial guidelines, which were compared with the other examples and revised until an agreed quality standard was met. Then, these guidelines were applied, and participants were required to produce reports based on these guidelines. Reports were assessed. The experiences were consciously reflected upon to feed into an improvement cycle.

### **3.3 Study III: Telecommunication Provider (TP)**

TP is a leading telecoms company with 20,000 employees delivering a full range of services and products for mobile, fixed and IP-based voice and data communications. Employees were studied by two ethnographers. These employees are involved in the “Customer Experience Design Process”, which is a standardised process to develop and maintain new market services. The aim is to promote the TP brand with customers and to improve customer experience. Two cases have been researched: (1) customer experience design in which product managers are responsible for a running product (life-cycle management) and product development in the sense of new customer experience. (2) Project management comprises assigning project managers to projects, if necessary recruiting new project managers and checking project status.

For each case, one persona could be identified: Kurt represents product managers of the customer experience design and Thomas represents project managers.

The responsibility for project managers and their projects as well as recruiting new project managers requires a wide variety of knowledge. Therefore, Thomas is highly skilled and experienced. He acquires knowledge on existing products, technological developments and visions as well as market trends by reading and reviewing internal documents about projects and organisations as well as consulting appropriate sources like internal portal entries, newsletters, books, magazines, blogs, and forums. Knowledge about his colleagues and about other people is highly relevant for him for, e.g. assigning appropriate people to projects. Therefore, he maintains relationships in his social networks through informal meetings, workshops and by using Web 2.0 technologies, like forums, online-communities and blogs.

Thomas' motto is that a phone call is more efficient than 10 e-mails. Therefore, if he identifies a problem which occurs in a project, he firstly calls the responsible project leader. Smaller problems are discussed directly on the phone, otherwise he makes an appointment to bilaterally discuss the problem. If the problem cannot be solved bilaterally, he invites a couple of people involved in the project and tries to find a solution together. As a last resort, he invites external experts.

### **3.4 Study IV: IT Franchising**

The studied organisation is an IT-related company and its main branch of business is franchising for retailer in the area of IT and software development to support this branch. It has about 130 employees in eight departments and supervises about 2,100 retailers. One of the most distinctive features of the organisation was their decision to introduce a MediaWiki platform as the organisational knowledge base to foster a Web 2.0 community style organisational culture. Five individuals from five different departments were observed.

Overall results provide detailed insights into a heterogeneous working structure, which only partly allows to extract and support knowledge maturing processes. Observed employees differed particularly in their processes for solving problems and getting information. This depended not only on the department, but on individual attitudes on how to work most efficiently and their affinity to using computers. Four personas (Axel, Heather, Kevin and Stella) were created to differentiate the characters and one is presented in the following.

One creative employee is Axel; a knowledge worker in the department of e-business. His tasks require him always to be on the search for news and to stay in contact with business partners to know their special interests and problems. His demand for learning is almost always because of a request or a problem or some news he read on an Internet site. He loves to research new information in his area of work and interest. If Axel has a problem, he always uses communication channels like chat, email, Twitter or the telephone to solve it. Only when he cannot solve the problem, he uses Google or another search engine. If he does not find an answer, but knows that it is important for his work, he often tries to contact a person who might help him in one of the well known business social network platforms.

Axel often changes running tasks and works on them concurrently. Sometimes, this behaviour brings him in conflicts as he does not answer fast enough and does not concentrate on prioritised tasks. However in most cases, it results in matured

knowledge artefacts as he often corrects his results in a personal review process. He is very censorious concerning software, tools and services. He likes trying new ones, but the benchmark is his actual way of work and he expects them to integrate in to it seamlessly.

An example case of a knowledge maturing process starts during his every-morning-check of his favourite blogs. Axel finds a blog article concerning new features of a browser. He opens a text editor and starts to collect the information he thinks important for his colleagues. Therefore, he starts to write an internal blog article on his computer in a file to ensure that he does not lose the text before he publishes it online which shows the need for sustainability of knowledge artefacts. During writing, he always changes between the text editor and the browser to add more fragments into the new article. Moreover, he searches for additional information in the Internet to reflect and present the topic as complete as possible. Before finally publishing it, he corrects it and reads the text several times to change format, syntax and wording and, therefore, increases quality and readability. This process can last several hours as he switches between his tasks occasionally.

### **3.5 Study V: Careers Guidance Services**

Study V consisted of two independent organisations in the same sector. Careers guidance services I provides free impartial and confidential advice, careers guidance, support and personal development services to young people aged 13-19 years and to those up to 25 years who have learning difficulties and disabilities. The organisation employs over 300 staff and is geographically spread, which offers distinctive problems in its operation and knowledge maturing activities. Sixteen employees were studied by three ethnographers; the results of which were combined with an earlier in-depth study of the organisation. Careers guidance services II is a national organisation delivering career guidance and employability services. The aim of these services are to help and support individuals to make informed choices and decisions, and to be prepared and ready for work in a changing and dynamic labour market. These career guidance and employability services are available to people of all ages. Personalised services are delivered in conjunction, and in consultation, with a range of partners. Careers guidance services II has over 1,000 employees and was studied by four ethnographers.

The overall findings suggest that employees tend to employ individual and personalised strategies for knowledge development and sharing, particularly as confidence and competence in the use of technologies varies greatly. Data analysis revealed five types of knowledge maturation, eight personas and some use cases. Personas, including a practitioner, senior manager, marketing and IT specialist, exemplify how individuals rely on collective knowledge to carry out their everyday jobs, in developing and sharing knowledge through their work and involvement in overlapping and asynchronous professional networks.

Gina, a persona developed around the work processes of an experienced practitioner, had gained a specialist work-based qualification and regularly participated in professional development activities. Gina operates with good knowledge of her local area and the opportunities available to young people. She is responsible for maintaining a section of labour market information in hard copy accessed and used by others working in that area. Knowledge is researched and

developed through a range of acquisition processes using various tools, such as the Internet and hard-copy resources, plus talking to professional colleagues. Criteria are applied to enable selection of reliable and valid information. At the local level, this information is shared, but not stored or disseminated by any other means. Regular team meetings are considered essential to share new knowledge and keep up-to-date with developments, initiatives and opportunities for young people in the locality. Although this is considered essential knowledge for practitioners, there are few means in which to share or disseminate to the wider organisation. Here, individuals play a vital role in organisational knowledge maturation, as they hold the information and knowledge, and determine what will be shared and with whom.

A corresponding case of knowledge maturing captures how a practitioner responds to a request from a client/customer for a specific piece of information. The practitioner would go through several stages of knowledge maturing comprising: searching for relevant sources of information and (ideally) applying quality criteria, before information is aggregated in a meaningful way and integrated into existing knowledge; manipulating organising, or rearranging, these sources of information for interpretation and the expansion of new knowledge; analysing newly acquired knowledge to integrate with broader sources of information; storing and sharing new knowledge in a robust system; reflecting on their learning and newly acquired knowledge, which may result in further research and consolidation of new knowledge into a different form; presenting new knowledge to the client/customer making professional judgements about its form and manner; re-presenting knowledge through a process of sophisticated mediation for different purposes; sharing emerging understanding, or particular knowledge, with colleagues; and finally, networking by engaging in a systematic dissemination of knowledge.

### **3.6 Study VI: E-learning and Consulting Services (ECS)**

E-learning and Consulting Services is a small company with 30 employees. It has provided e-learning solutions and consultancy services for the construction sector since 2001. ECS has developed a technology platform that is offered via a service application provider model to its clients, allowing them to implement training and courses as well as knowledge management capabilities. Their objective is to empower companies to exploit their knowledge assets so they can improve their creation, transformation and distribution throughout the organisation. The employees were studied by one ethnographer. Based on the collected data, two personas were identified: Carolina and Raquel.

Raquel holds a bachelor degree in education and specialised studies on multimedia related areas and technologies. She works as a course producer and consultant for ECS. She works in different project teams and spends 80% of her time in her office. She organises her own workspace with hierarchies based on sources, topics and projects. Raquel uses her own criteria to solve a problem, but continuously shares them with her colleagues and manager and asks for their opinions. One of the most common routines is the creation of story boards of course processes and user interaction. Raquel is very open to work-related comments, questions, anecdotes, etc., likes to help and is not afraid to ask directly for help if she needs a hand, has doubts, or does not find the solution.

One observed case deals with the creation of on-line courses. This process started with a meeting between the client, the director and consultants in order to gather the requirements for this part of the project. The consultant then created a profile of the objectives of the course. After that, he created an index of the course content. For each specific item on the index, a block of content was developed. The content was delivered as .doc and .ppt and then was revised and refined by ECS and the client. Finally, the content was converted for use within the learning management system. This is one of the most common types of projects for ECS, hence, it is a well established process.

#### **4 Towards a Unified View of Personas Across Studies**

While the results of the individual studies seem interesting in isolation, we found it particularly useful to compare the results, specifically the personas, across the diverse set of organisations that were studied. The proposition here is that due to the seemingly increasing standardisation of hardware, basic and application software that is typically used by knowledge workers, their work environments are increasingly similar while they preserve distinctive styles of handling knowledge and learning that are dependent not only on personality, but also on the roles, social structure and work context.

The ethnographers jointly identified 21 personas (Figure 1). They were described according to 17 characteristics. These characteristics were classified with respect to [Pruitt, 2006]: (1) identifying details: name; motto, (2) roles and tasks: role; workplace; task management, (3) skills and knowledge: education and professional background; learning; knowledge; formal training, (4) context and environment: reaction to requests; communication strategy; content types; structures; important tools and (5) goals and motivations: problem solving; motivation; attitude towards technology.

Twenty-one personas were considered too many to be kept in mind in detail. [Randolph, 2004] suggests to concentrate on one or a small number of primary personas. Pursuing the aim of selecting primary personas, three of the ethnographer teams clustered them according to their perceptions with more or less support by structured approaches. Although personas vary in the way they perform tasks as well as in their behaviour, needs and objectives, it was possible to identify pools of personas with similar characteristics. The approach adopted by UIBK is described in more detail.

As a starting point for clustering, the personas were characterised according to three dimensions taken from the knowledge maturing process [see Maier, 2007]. Each dimension represents two phases of the knowledge maturing process as opposites. Each persona was then classified with regard to these three dimensions using an ordinary scale.

These data were used to create a graph as a visualisation of similarity of personas' characteristics. Finally, the generated graph showed three groups of personas that were named as follows: (1) aggregation & combination, (2) communicative & serendipitous and (3) routinised & isolationist (see figure 1, right-hand side).

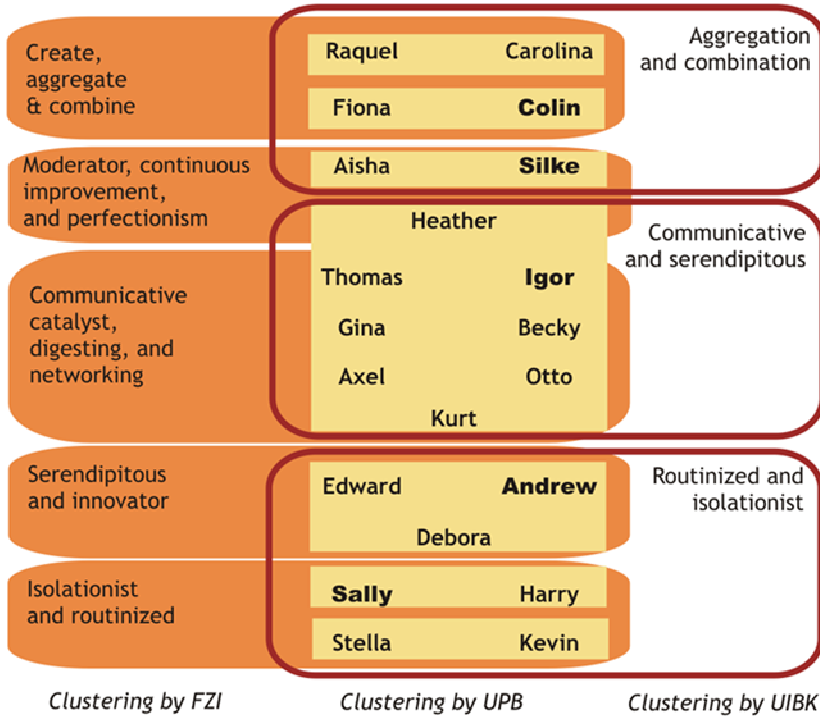


Figure 1: Clustering of Personas (for acronyms see affiliations of authors)

The FZI approach for clustering was focused on the two aspects contribution to knowledge maturing and how we could support the personas. It turned out that the five types of knowledge maturation using IT that were identified in the two organisations studied in the UK (see figure 1, left-hand side) were useful to describe the knowledge maturing aspect. There is some evidence that this typology can be transferred across other organisational contexts examined in this study and, thus, provides another good basis not only for clustering personas, but also for further exploring knowledge maturing styles:

1. *Serendipitous* Knowledge is developed and shared (typically) as part of a developmental process for a product or service and thus in an ad hoc and haphazard way. For instance, technical issues and problems are reported by email and telephone, and dealt with by one member of the team. This resolution is not recorded or shared with others unless it happens to be discussed or queried by someone on the team.
2. *Conscious* This is represented by communication and sharing of information in many formats both internally and externally to the organisation, which accords with an explicit (organisational) strategy. For instance, an individual has a clearly defined process and plan for communicating and sharing information external to the organisation.

3. *Network* Individuals heavily rely on information and knowledge being shared within local networks and held by individuals, determining what would be shared, when and with whom, but being often unaware of what they know, or how they acquired this knowledge. Knowledge maturation occurs in pockets across the organisation, but locally shared information and knowledge is not disseminated to the wider organisation.
4. *Isolationist* Here, individuals have no understanding that information and knowledge could, and should be, shared. For instance, project results and examples of good practice were not shared within the organisation.
5. *Visionary* Individuals or groups understand potentials and possibilities of IT in the process of knowledge maturation both within the organisation and externally, but are constrained by policy, finances or organisational culture. For instance, the value of implementing a new service at the forefront of technological developments is agreed, but organisational policy delays or halts its implementation.
6. value of implementing a new service at the forefront of technological developments is agreed, but organisational policy delays or halts its implementation.

The approach used by UPB is mainly based on three characteristics of the 21 personas allowing to observe how persons take part in and foster knowledge maturing processes in their social network: (1) How do the individuals solve problems?, (2) How do they react to requests?, and (3) What communication strategies and approaches to knowledge sharing do they use? Depending on the impact on the social network each persona had considering the three questions above, it was assigned to a particular cluster. By iteratively assigning personas in a group of similar personas or creating a new cluster of personas with different observed behaviour, 7 clusters were identified.

The three approaches result in quite similar clusters (see figure 1). Persona pools based on the five types of knowledge maturation were used as a basis for selecting primary personas during an informed group discussion involving ethnographers representing every studied organisation. The personas were evaluated according to their characteristics. Finally, the persona (depicted in bold letters) that was found to represent the respective cluster best was chosen as primary persona.

## 5 Conclusions

This paper presented selected findings of a collaborative ethnographically informed study. Both, method and results seem worth further exploration. Personas and cases seem to be useful instruments in order to render discussions about, e.g., use cases of tools intended to support knowledge work. This is in line with the benefits of using personas identified by Cooper as well as by Pruitt and Adlin [Cooper, 1999; Pruitt, 2006]:

- Personas help make user-centred design possible by putting users, or more precisely information about targeted users, at the centre of design.



- Personas enable team members to share a specific, consistent understanding and can be used to help guide decisions, e.g., about the product's navigation scheme and visual design.
- The development of solutions can be guided by how well they meet the needs, attitudes and behaviour patterns of Personas.
- Personas provide a human "face" so as to focus empathy on the people represented by the demographics.

Personas might be especially useful as an anchor instrument in order to convey goals, needs and context of using the intended system from the perspective of personas (that are grounded in real work experiences) with roots in the application environment of real-world organisations. They also stress the importance of being aware and master complexity of diverse styles of learning and handling knowledge dependent on the roles and contextual environment of the knowledge workers when designing an organisational and technical infrastructure for supporting knowledge workers. In the future, we intend to systematically reflect on our extension of rapid ethnography into a method of collaborative ethnographically informed study as well as the graph based approach to cluster and, thus, consolidate the results of distributed qualitative empirical activities.

### Acknowledgement

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# What is Organizational Knowledge Maturing and How Can It Be Assessed?

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**Abstract:** We introduce the concept of organizational knowledge maturing based on the idea of developing knowledge assets. We explain the dimensions that have to be considered and introduce the Knowledge Maturing Dimension Framework to measure the maturity level. Finally we describe service classes as the building blocks of a future organizational learning and maturing environment (OLME).

**Keywords:** Organizational Knowledge, Knowledge Maturing, Knowledge Assets, Knowledge Maturing Dimension Framework

**Categories:** L.0.0, M.2, M.3

## 1 Introduction

Knowledge is the key factor in every organization. Whereas in former times machines have been the key asset of a company since more than two decades knowledge has clearly taken this role. Undoubtedly knowledge is needed to perform the business tasks correctly and efficiently and managing organizational knowledge is as important as managing the business processes. However, it is not enough to manage existing knowledge but also to mature it in order to keep pace with (continuous and even accelerated) business changes. Therefore it is important to clarify what knowledge maturing is and what it means in an organizational context.

The question what knowledge maturing means, is related to the problem how to identify knowledge assets (KA), which appear as artefacts, cognifacts, and sociofacts [Nelkner, 09], and how to measure the existing levels of knowledge maturity, regardless whether the focus is placed on a whole organization, an organizational unit, or just a certain topic. To this end we introduce the Knowledge Maturing Dimension Framework (KMDF).

As we know what knowledge maturing is and what the current status in an organization is, we can define methods for knowledge maturing and support the development of maturing services. In the following we describe (individual and organizational) knowledge as rational capacities and show its close relation to action. Then we introduce the knowledge maturing process and describe its consequences for organizational learning. Furthermore, we describe knowledge assets and maturing

stages as well as the KMDF and compile the maturing services as basis of a future organizational learning and maturing environment (OLME).

## 2 Knowledge and Knowledge Maturing Concept

There are two different views on knowledge: one is *subjective* and regards knowledge as a dynamic concept focussing on process and contextual aspects; the other is *objective* and sees knowledge incorporated in documents and other artefacts independent of any human interpreter [Nonaka, 06]. The approach to knowledge that we apply takes both aspects into account as we will show in Section 2.2. The central assumption is that we need knowledge because it is a precondition for action [Riss, 05]. This holds for individuals as well as for organizations.

Starting from the concept of action, we understand it as a process of intended concretion of an actor's goals based on the actor's respective capacities. Actors can be either individual persons or organizations. The relation between action and knowledge we refer to has been recently discussed by [Kern, 06], arguing for the characterization of knowledge as rational capacity. This view emphasizes the fact that a capacity (and so knowledge) only becomes manifest in its actualization. The decisive difference to the objective concept of knowledge consists in the insight that knowledge is not a static resource that is stored in databases but that it is intrinsically entwined with action. On the other hand, the concept reveals that knowledge cannot only be identified on the basis of artefacts such as documents or models but also indirectly on the basis of performed actions. In this way both explicit and implicit knowledge can be taken into account [Polanyi, 66] in the knowledge maturing process.

We will show that these considerations possess a considerable relevance for the way how we understand and support knowledge maturing. To understand knowledge maturing, we first have to look at the concept of learning, i.e., acquisition of knowledge. According to the concept knowledge as rational capacity to act we distinguish two modes of learning [Reber, 93; Eraut, 04]:

**Implicit Learning:** By continuous actualization of a capacity the respective knowledge develops further. Such development can be due to changing demands coming from the agent's environment, e.g., increasing the complexity of the respective actions. Such a development can finally lead to qualitative change in the agent's capacity. For example, an occasional writer can become a professional author.

**Explicit Learning:** Another way to acquire new knowledge is by instruction. In this case the agent learns to perform new actions by following explicit descriptions while actualizing other already existing capacities. By repeated combined actualization the respective capacities usually merge to a new capacity.

The knowledge maturing process [Schmidt, 05] is distinguished from mere learning by the fact that it regards individual and organizational knowledge development as directed, i.e., derived from and coordinated with respect to an organizational context. This does not mean that all personal learning is determined by the organization but that the organization takes all forms of learning into account and tries to leverage synergies between them. Although learning always takes place in organizations it is an observation that it is not consequently fostered in an organized and systematic way today [Schmidt, 09]. The central challenge that we face in this

respect is the large variety of different learning types and styles and their general relevance to organizational knowledge maturing. [Maier, 08].

In the following we want to investigate how a maturing process based on a concept of knowledge as rational capacity can be realized in an organizational context.

## 2.1 Organizational Knowledge Maturing

The knowledge maturing process [Schmidt, 05] is distinguished from learning by its focus on knowledge development in an organizational context or more specifically as a knowledge development process guided by the organization. Although learning takes place in every organization it is an observation which does not happen in an organized and systematic way but rather spontaneous [Schmidt, 05]. We will investigate how a maturing process can be realized in an organizational context. An organization must be seen as a system with complex internal processes that, however, appears as a whole to the external world.

The capacity of the organization is determined by the individual capacities of its members but also by the coordination and communication capacities of the organization itself. Obviously the organizational knowledge goes beyond the collection of individual knowledge. The concept of knowledge as a rational capacity of an agent and not as a state plays a major role in this respect since capacities rely on the process of actualization and develop with these actualizations. Moreover, it emphasizes the fact that knowledge can be recognized on the basis of users' activities, even if the knowledge itself might not become manifest in any form. Third it realizes that the transfer of knowledge is not generally realized by the provision of corresponding knowledge artefacts but requires action. [Orlikowski, 02] stands for a similar view stating that knowing is not a static capability or stable state of actors but a dynamic social entity that results from the entwined practical engagement of actors in the organization.

In the MATURE project we investigate the knowledge maturing process with respect to three different levels: the individual level, the community level, and the organizational level. Here we distinguish communities from organizations by the fact that organizations aim at joint action whereas communities only aim at the exchange of experience. Maturing processes take place at all three levels. There are two targets that the maturing process addresses: the individual member who is to be supported by a Personal Learning and Maturing Environment (PLME) and the entire organization supported by an Organizational Learning and Maturing Environment (OLME).

In order to establish a coordination of organizational knowledge development, we first have to consider in which form organizational knowledge can develop. Here we can identify three types:

**Organization Indwelling:** This aims at the continuous improvement of organizational capacities due to continuous actualization and further development induced by continuous changes in the environment. The decisive task of the OLME with respect to Organizational Indwelling consists in making the development of the organizational capacities transparent for the organization, i.e., in particular for its management.

**Knowledge Gaps:** Often the requirements that are enforced by the organizational environment cannot immediately be answered by the organization due to missing

knowledge. Here the central task consists in the identification of upcoming organizational knowledge gaps and suggestion how to address the problem, e.g., by offering training for individual members or buy-in of external expertise as individual persons or entire organizations.

**Upcoming Opportunities:** Generally the knowledge of the individual members in the organization covers aspects which are not realized and leveraged by the organization since they might be out of scope. However, such capacities provide opportunities for future organizational development, e.g., new technological trends may appear in the capacities of the individual members at an earlier stage than they are recognized by the organization. In this respect it is the task of the OLME to identify such opportunities.

In order to fulfil these requirements the OLME must provide services that support the respective knowledge maturing tasks. However these services must operate on available information sources that can provide the data for the required analysis, as indicated above. In the following we will turn to these information sources and how they can be analyzed.

## 2.2 Artefacts, Cognifacts and Sociofacts as Knowledge Assets

In order to find information about capacities in an organization we have to identify knowledge assets related to these capacities. [Nelkner 09] provides some theoretical background how to find a categorization of these carriers as artefacts, cognifacts, and sociofacts. In the following we refer to this approach pointing at its organizational aspects. The KA can be described in the following way:

**Artefacts** consist in codified information that can enable members of the organization to acquire new capacities. Artefacts are not capacities but they can be regarded as enablers of capacities. Often this requires additional communication. A central development step for artefacts consists in the access to private artefacts. They must be identified in organization without violating individual privacy demands.

**Cognifacts** refer to the individual expertise of individual member in the organization. Since cognifacts as individual capacities are not directly accessible they can only be indirectly identified by the corresponding actions. Although competency management systems are available a formal description of skill is often difficult and vague. Here activity-based competency systems offer more opportunities, i.e., competencies are determined on the basis of activities or tasks that a person has accomplished.

**Sociofacts** are even more difficult to identify since they represent collective capacities. Nevertheless there are various ways to get information about sociofacts, e.g., the identification of communities of practice. We can also investigate collaborative actions or tasks, e.g., the development of a new product or the organization of a workshop. As in the case of cognifacts sociofacts can only be determined through their effect on the organization.

According to the capacity approach the maturing of knowledge is often related to the actualization or application of capacities. Such actualizations can point at further requirements (e.g., if specific tasks cannot not be effectively executed) or at opportunities (e.g., if persons performed tasks outside the organizational scope). In this sense activities are general indicators for the maturity of artefacts, cognifacts, and sociofacts, even if the two latter are not directly accessible. Generally an

insufficiently developed capacity is likely to lead to problems in execution. The central challenge consists in the identification of existing or required capacities from the observed activities.

### 2.3 The Knowledge Maturing Model

The knowledge Maturing process usually develops along different stages which have been described in the MATURE knowledge maturing model [Maier, 07]:

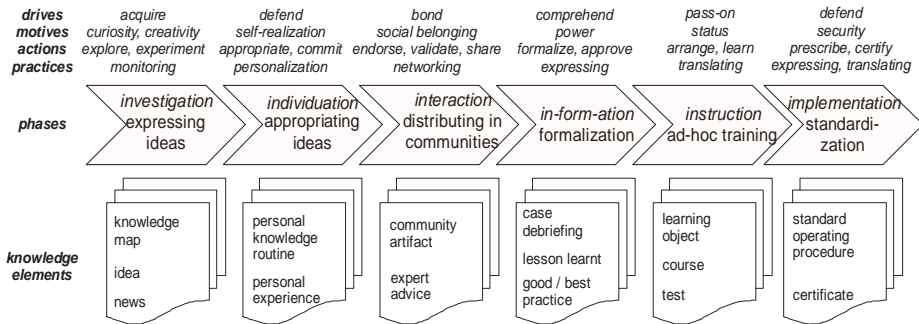


Figure 1: The knowledge maturity model.

We have taken the stages in Fig. 1 as starting point to derive the demands that we find in organizations. Further development of the model is already in progress. Our interpretation of the model results in the following characterizations:

- **Investigation Stage:** Knowledge at this stage is mainly individual, often formulated in an abstract way, and not yet actualized. This also affects the corresponding actions which are often characterized by occurring problems since the capacities are still immature. For the organizational context this stage is often too immature to be suitable for further analysis.
- **Individuation Stage:** At this stage knowledge becomes part of individual activity. This means that it has been actualized several times but has not become general practice or experience. Nevertheless it might happen that the same practice is applied by several persons independently of each other. If this knowledge is codified then usually in personal documents or logs. The corresponding actions are more settled as in the investigation stage but still individual.
- **Interaction Stage:** At this stage a transition from individual actualization to community level appears. This process is accompanied by codification that supports experience exchange. The respective knowledge can be identified in artefacts as well as individual activities. Interaction mainly takes place in peer groups. This means that the knowledge artifacts are not very elaborate since the peers' communication is based on a common understanding. The corresponding actions and capacities spread in peer groups. Corresponding actions are still individual but related information starts to spread within the organization even if it is only comprehensible for restricted groups.

- **Information Stage:** At this stage the codification in artifacts becomes more elaborate and already serves dissemination of the respective information. This is the stage in which collaboration comes into play since the codification supports understanding beyond directly cooperating partners. Typical artefacts for this stage are task patterns [Schmidt, 09].
- **Instruction Stage:** The reached knowledge maturity allows for the dissemination beyond peer groups. Knowledge artifacts reach a stage that allows the transfer of knowledge to novices in a specific area. This stage requires that the respective knowledge has become aware to the organization. Corresponding actions are no longer performed in the respective peer groups but spread due to public access to the respective instructions.
- **Implementation Stage:** The artifact has been standardized to be available for automatic processing or delivery. Since the transition to this final stage is especially costly it requires specific inspection with respect to the expected usage of this asset. At this stage actions are replaced by automated processes.

It is observed, that the transitions between the different stages are fuzzy. Especially the transition between Interaction, Information, and Instruction Stages are often not always clear since in general the respective groups are not homogenous, i.e., there is a continuous transition between peers and novices. In general determination of an organization's level of knowledge maturity is difficult. To address this problem we introduced a multi-dimensional framework to assess the status quo and potentials for knowledge maturing in an organization.

### 3 The Knowledge Maturing Dimension Framework (KMDF)

Before we can define services for knowledge maturing and assess their potential, we must answer some general questions, e.g., 'Do we know, what we know'? Where do we stand with regard to knowledge availability, use and learning? How can we measure the status quo, how can we support and improve knowledge maturing and how can we measure improvements? What are appropriate learning methods for companies? Which methods and tools can be applied in our environment?

The answers to these questions depend on a variety of influencing factors, ranging from soft factors such as 'trust' to hard factors such as 'documentation'. A lot of research is dedicated to a proper treatment of implicit knowledge in a company but comparable little research deals with sophisticated concepts for maturing existing explicit knowledge. In addition explicit knowledge (i.e. documented knowledge) in any form can be regarded as a good starting point for assessing organizational knowledge and its maturing.

The framework distinguishes six dimensions dedicated to measure explicit knowledge only [Brun, 09]. However, it would be no problem to add further dimensions if appropriate. The current dimensions of knowledge potentials are:

- maturity of knowledge management
- knowledge usage
- availability of information
- maturity of knowledge organization
- information management



- conciseness of knowledge

For each dimension we defined five maturity levels. The sequence of the introduced dimensions is of no importance. To assess the status quo of knowledge management in an organization the multi-dimensional framework can be used. Regardless whether the maturity of the whole organization, of an organizational unit, for all knowledge objects or only for a certain topic each of the dimensions can be evaluated.

The approach has been successfully tested in a small student project, where some processes of an organization have been considered which then were rated with the KMDF. It could be shown where the organization stands and hints could be given for further development of the maturity of knowledge. The applicability of the KMDF will now be tested in a larger project.

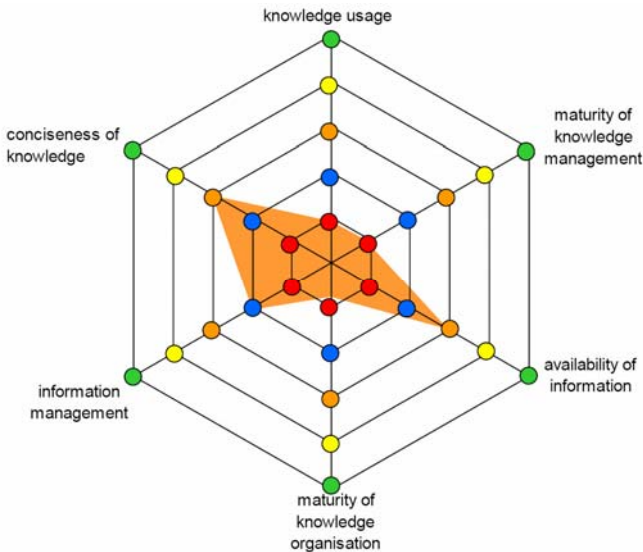


Figure 2: Example of a Knowledge Maturing Assessment using the KMDF.

In the following we shortly describe each dimension and directly give an example how the framework can be used. Let's assume a project team wants to assess the status quo of their knowledge management to reach better performance. All project members have access to the project information via a project wiki. Documents are shared using SVN. Remote meetings are held using a collaboration tool; all meetings are recorded, minutes are taken and published in the wiki. Fig. 2 gives an example how the Knowledge Maturing Dimension Framework is used to illustrate the assessment.

1. The **'knowledge usage'** dimension assesses the integration of knowledge management activities into the operational work. This dimension corresponds to the integration of process and knowledge management which is the main focus of process-oriented knowledge management [Abecker, 02]. To reach the lowest level of maturity (level 1) as in the example it is

sufficient that finding relevant knowledge is supported by general-purpose search engines, information is exchanged via email or using a collaboration **tool**.

2. The dimension '**availability of information**' comprises levels from explicit documentation, transparency, accessibility, integrated information up to automated metadata generation. The example shows that level 3 of maturity is reached for this dimension as all (project) relevant information can be accessed directly e.g. via the intranet portal.
3. It is the objective of '**maturity of knowledge organization**' to make knowledge intellectually accessible by using a conceptual structure that makes large amounts of knowledge assets comprehensible and manageable. Knowledge organization deals with (1) building and modelling systems of concepts as well as (2) their mapping to subjects of reality. Methods for knowledge organization can be arranged in a spectrum with increased semantics. In the example at that time there is only a weak conceptual structure of the project knowledge repository, mainly the organization of the project wiki.
4. The dimension of '**information management**' considers the structure, security, redundancy, integrity on conflict resolving of information and classifies five constructive levels. Looking at the example considering structure and security it can be said that level two is reached. That means that (project) information is structured (in the project wiki) and its access is protected by a login.
5. There exists no standardized description scheme for '**conciseness of knowledge**' in the literature. A valuable source which is appropriate for our purpose is the list of criteria for measuring the information quality given by the DGIQ<sup>1</sup>. Our approach was to select the following eleven criteria in order to assess the quality of content. (The rates accord the example; 1-5):
  - Appropriate Amount: rate 5 (the amount of information satisfies the projects requirements)
  - Believability: rate 5 (all information is validated by project members)
  - Completeness: rate 5 (information is complete for adequately performing a certain task)
  - Concise representation: rate 2 (the relevant information is provided in an adequate and easy-to-handle format).
  - Consistent representation: rate 2 (the same information, e.g. the documentation of an idea, is presented in different ways and a lot of information is in the state of development and still has to be consolidated).
  - Ease of manipulation: rate 3 (the effort for changing and adapting information using a wiki and SVN is not very convenient).
  - Unambiguous Interpretability: rate 4 (there is a clear interpretation what to do for the information provided).
  - Objectivity: rate 5 (information is value-free and based on facts).

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<sup>1</sup> Deutsche Gesellschaft für Informations- und Datenqualität, German association for information and data quality (transl.)

- Reputation of Source: rate 5 (the source of information and the processing system are highly reliable).
- Timeliness: rate 5 (the information provided is up-to-date).
- Understandability: rate 2 (the information is easy to understand by the targeted audience with respect to the consortium's member but not by the associate partners, especially not by the application partners).

The overall conciseness of knowledge has an average weight of level 3.

6. The '**maturity of knowledge management**' is related to the quality of the knowledge processes and the knowledge organization. The KMMM<sup>®</sup> (Knowledge Management Maturity Model) is an example for assessing knowledge maturity levels [Ehms, 08], [KMMM, 09]. For the example an initial level is reached by organising the (project) knowledge in a structures way (within the project Wiki).

Based on the evaluation of the status quo, it is possible to identify weaknesses and strengths as well as maturing goals and strategies. On this basis we developed 5 classes of **Maturing Services** to support the maturing process to implement a maturing process in an organization:

**Monitoring Services:** They identify new or changing KA and their relations as the basis for goal-oriented maturing measures;

**Integration Services:** They ensure the consistency of KA and aim at the resolution of knowledge island, e.g., communities dealing with the same topic but unaware of each other or matching of knowledge needs in activities and hidden KA that could support these activities;

**Refinement Services:** They support the development of KA with a specific focus on the aggregation of knowledge provided by maturing services and offered to the developer of KA;

**Dissemination Services:** They ensure that KAs are transferred to the requesters or other people in the organization who are affected by them;

**Negotiation Services:** The previous services are supported by additional negotiation services in order to tackle problems that cannot be resolved automatically.

The 5 service types are related to the model provided above. This becomes clear if we consider these services in more detail as in the examples of monitoring services. The full specification of these services, however, will be accomplished in the ongoing work of the project MATURE.

## 4 Conclusions

We have shown that organizational knowledge resembles individual knowledge in many aspects, in particular regarding its relation to action. This relation is expressed in the characterization of knowledge as rational capacity to act. It does not only specify the goal of knowledge but the way how we can identify knowledge in an organization. We have explained the difference between organizational learning and knowledge maturing and explained how knowledge becomes manifest in three different knowledge assets (KA): artefacts, cognifacts, and sociofacts. Moreover, we

have pointed out that KA develop along 5 knowledge dimensions, described in the Knowledge Maturing Dimension Framework.

Generally it is not useful and not even feasible to mature all knowledge dimensions in an organization at the same time. Therefore the Knowledge Maturing Dimension Framework helps to check whether necessary preconditions of the knowledge maturing process are fulfilled. Identifying weak (or strong) dimensions is essential for supporting the maturing process. Knowledge as rational capacity to act holds true for knowledge maturing itself: knowing of its facilities is a condition for implementing maturing services.

Thus, we have identified three classes of maturing services supporting *monitoring, integration, refinement, dissemination, and negotiation*. These services work on the different KA and implement the maturing process along the known stages. They are derived from the introduced theoretical background and we regard them as the basis of a future OLME.

### Acknowledgements

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# Applying Organizational Learning to Enterprise Knowledge Maturing

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**Abstract:** We first describe the state of the art of organizational learning, mentioning the theories and types of it. The need of organizational learning, contributing processes and the main processes are further explained. Various methods of organizational learning are introduced. A template for a short description is proposed, which gives an overview about existing methods. The template then offers the possibility to indicate which method can be applied on Enterprise Knowledge Maturing.

**Key Words:** organizational learning, methods of organizational learning, types of organizational learning, processes of organization learning, organizational learning views, dimensions of knowledge potentials, method template

**Category:** L.0.0, L.3.4, M.1, M.3

## 1 Introduction

In today's fast-paced world, innovation and development speed has become extremely important for successful business. The fundament of innovation is knowledge as a result of learning [Pautzke, 1989]. The learning attitudes of organizations are known as Organizational Learning (OL). OL has already become popular since a quite long time. The basis has been described by [Argyris and Schoen, 1978], who defined OL as "the awareness and correction of mistakes". Later, [Fiol and Lyles, 1985] defined learning as "the process of enhancing of activities through better knowledge and understanding". They described that OL leads further through development of complex interactions than the sum of individual learning. [Dodgson, 1993] mentions that learning is essential for the maturing knowledge of a single person but also for the whole organization. [Probst and Büchel, 1997] defined OL based on the systems theory as the "interaction between individual and organization". Further views on OL have been defined by [Prange, 1999], [Lave and Wenger, 1991] and [Beck, 1997].

### 1.1 Relationship between Individual, Group & Organization

The approach of [Sessa and London, 2006, p. 6] describes the importance of the relationship between individual, group, organization and environment. Organizational learning builds on group learning which again depends on individual learning. How they contribute to each other is also mentioned in [Brass et al., 2004].

Preconditions for continuous learning are the environment's need for change and the system's readiness for change. If the system is ready and the need is high, a desired result might be achieved; otherwise frustration, learning failure or standing at a status quo will be the result.

The definition of individual, group and organization are given to support the understanding of the relationship between the methods and the three different elements.

- An **individual** is a single person.
- A **group** is a team, e.g. in a project, with a defined start and end.
- We defined an **organization** as an enterprise, a department or division.

## 2 Types of Learning

[Argyris and Schoen, 1978] defined learning as the detection of errors. They introduced tree types of learning:

**Single-loop learning (adaptive learning)** : Single-loop learning occurs when errors are corrected and detected within a given set of governing variables like policies and goals.

**Double-loop learning (shift / generative / proactive learning)** :

Double-loop learning occurs when additionally of detecting and correcting errors, norms and policies will be adapted and improved.

**Deutero learning (learning how to learn / transformative learning)** :

Deutero learning occurs when double-loop learning and single-loop learning is under revision.

## 3 The Trigger for OL and how to support it

As described in [Sessa and London, 2006], the need for OL appears in different situations and there exist various models for organizational change and development. Different processes support the OL. On the one hand, some processes of an organization contribute to organizational learning. These supporting processes can be developed and adjusted in a way they optimally support OL (see 3.2). On the other hand, OL processes exist which handle the information and knowledge management inside an organization and its elements (see 3.3).

### 3.1 The Need for and the Development of OL

Different situations may drive the need for organizational learning. A few among others are changing governmental situations, economic downturns and economic fluctuation in general, expansions, acquisitions or mergers, where a national

company evolves into a multinational enterprise and is confronted with a variety of law and business practices or changing competition on the marketplace.

Learning is often involved with the change and development of an organization. That might affect processes, policies, hierarchies, structure, communication practices, products and goals of organizations. The development is linked with a progression through different stages of learning. Such steps are introduced in the MATURE-Project and the proposed dimensions of knowledge potentials [Brun et al., 2008].

### 3.2 Contributing Processes to OL / (Organizational Capabilities)

Different processes in an organization support OL, also mentioned in [Argyris and Schoen, 1978]. OL can occur when individual and group learning is embedded into routines, structure, culture and the strategy of organizations. The following contributing processes are strongly linked to each other.

**Development of the strategy:** As mentioned in [Sasser2006: 160], members of an organization often have a shared vision. Therefore every individual has a collective view of how the organization should work.

**Development of the organizational structure:** The structure has to ensure that OL is supported with enough resources, i.e. the right people at the right place at the right time.

**Development of the organizational culture:** [Argyris and Schoen, 1978] propose two different Models I and II to describe mental models. In Model I leaders don't accept feedback, where in Model II the behaviour is open to others, evaluating comments and trying alternative actions, what constantly leads to organizational learning.

**Development of the personnel:** The leaders of a company are powerful promoters of an organization and should use their archetype function to drive an organization towards a learning orientation, by being a continuous learner.

### 3.3 OL Processes

[Huber, 1991] describes four processes and corresponding sub-processes which contribute to organizational learning and handle the knowledge management. An iterative process may continuously improve each of these OL processes.

**Knowledge acquisition:** Through the acquisition of knowledge, the organization is able to learn.

**Information distribution:** The distribution of information is the process where information is directly shared amongst units and employees, also in informal ways [Brown and Duguid, 1991].



**Information interpretation:** Received information must be interpreted. Individuals have different information background and formation of knowledge and therefore might interpret the information in different ways.

**Organizational memory:** Knowledge has to be stored in repositories for future use, also called "Corporate Knowledge" by [Hamel and Prahalad, 1994].

## 4 Methods of OL

There exist different methods of organizational learning with different input, output and stakeholders, from very simple to more complicated ones. A collection among the various methods that exist for OL are first listed in a table (see table 1) and then shortly described. They should give a good overview about the possibilities of existing methods. Later on we propose a template for describing each method, where we exemplary describe the Open Space Method.

	Individual	Group	Organization
Individual Feedback	x		
Buddy System	x		
Mentoring	x		
Coaching	x		
Job Rotation	(x)		x
Knowledge Groups		x	
Catalogue of Strengths and Weaknesses (SWOT)		x	x
Story Telling		x	x
Lessons Learned		x	x
Knowledge Landscape		x	x
Open Space Method		x	x
Pensioners System			x
Best Practices			x
Ideal-Organization			x

Table 1: Header: Who will be affected / Whose knowledge will mature; Rows: Different method of OL

### 4.1 Method Description

Thanks to **Individual Feedback**, an individual can recognize the effects of its actions and choices, and realizes continuous learning through the adoption of activities, to change from negative to positive output. Without feedback, organization members cannot evaluate whether they should repeat their behaviour or modify it, accordingly no learning occurs.

In a **Buddy System** two people operate, monitor and help each other. They

may work as a single unit and both benefit from an increased knowledge base.

**Mentoring** is quite similar to the buddy system. Two persons have different experience- and hierarchy-levels, but the relationship is not based on superior and employee. Also if the more experienced person may have a role of a godfather, professional and personal knowledge can mature for both of them.

**Coaching** is a stronger version of mentoring. A professional coach trains individuals but also groups, by using assessments, setting goals, focusing on plans, behaviour and further instruments.

**Job Rotation:** If employees switch for a predefined time to another job, they get a different view of how things are done. It mainly supports organizations to mature knowledge, as the exchanging employees interchange knowledge, but also the individual's knowledge is being enhanced.

A catalogue of **Strengths and Weaknesses** will be identified, which can be used to identify the room for improvement. (The other part of the SWOT-Analysis, Opportunities and Threats, consider the external factors).

**Knowledge Groups:** Employees doing the same or similar work meet periodically to talk about how they do their work. Problems and possible solutions are discussed; best practices may be an output of such groups.

**Story Telling:** Performing this method, a story teller explains implicit knowledge often in a form of a metaphor, sometimes supported by music and images. The talker explains a situation based on its experience, the audience listens to it to adopt the behaviour but also to scrutinize the procedure.

**Lessons Learned:** Often after a project some lessons learned are made explicit. These help for further work not to fall into same traps and to continuously improve standard procedure and other tasks, which leads to an organizational knowledge maturing.

A **Knowledge Landscape** represents the knowledge inside an organization. It helps to locate experts and to identify holes of missing organizational knowledge expertise.

The **Open Space Method** can be performed with any group size. Initiators, which can be anyone, have some proposals or ideas. If many ideas exist, they will be clustered. Then working groups find together and formulate the result.

Every participant of such a group can feel free to switch to another group during the development of the results. The results are all putted on a wall, so that everybody can read and discuss about them. At the end, all results are taken together, and in the plenum the best of them are evaluated, for which new groups can be formed who concretise the ideas and which are presented on a later stage.

**Pensioners System:** Applying this method, former employees, already in their pension, are fetched back for different reasons. This could be the lack of experts on the labour market or the missed circulation of information.

**Best Practices** are written down so that anyone has access to them and can perform best practices. Basis for best practices is acquired and matured knowledge. Some input might be supplied by the knowledge groups.

**Ideal-Organization:** Each member of an organization should present his view of the ideal organization. This helps for the further development of the vision of an organization and shows the wishes of each individual.

## 4.2 Method Template

The template (see figure 1) consists of attributes which have to be described for every method used in OL. The following section describes how it should be used. Starting from the top, the template indicates whether

- a method can be used for an individual, a group or an organization,
- for which type of learning it is appropriate (single-loop, double-loop, deuterio learning) and
- in which of the aforementioned OL processes it is applicable.

Then, each attribute of the template consist of several related questions which should be answered. Once for each method the template has been filled,

- it firstly helps to get an overview about the various methods and helps to structure them.
- Secondly, by considering pre- and post-conditions, the relationships between the methods can be identified.
- This then thirdly indicates which method can be used in a given situation of an organization and serves as a reference.
- The task & goals and benefits attributes answer the question why a certain method should be applied.
- The whole description also provides information on how and where a method can be used.

Method-Name				<input type="checkbox"/> Ind	<input type="checkbox"/> Grp	<input type="checkbox"/> Org
Type:	<input type="checkbox"/> Single <input type="checkbox"/> Double <input type="checkbox"/> Deutero	Process:	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Acq.	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Distr.		
			<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Interp.	<input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> Store		
Pre-conditions (entry criteria) / Trigger (int. / ext.)						
<ul style="list-style-type: none"> <li>- Which are the triggers for applying this method?</li> <li>- Are the triggers intern (strategy, expansion, ...) or extern (from technology, government, economy, marketplace)</li> <li>- Conducted pre- methods as entry criteria?</li> <li>- Further entry criteria?</li> </ul>						
Tasks & Goals						
<ul style="list-style-type: none"> <li>- What are the tasks that have to be performed?</li> <li>- Do the tasks have to follow a specific order? Have they to be repeated?</li> <li>- Which goal should be reached?</li> </ul>						
Utilities						
<ul style="list-style-type: none"> <li>- Which additives are needed?</li> <li>- Which ones are mandatory, which ones are optional?</li> <li>- How do they support the method?</li> </ul>						
Constraints						
<ul style="list-style-type: none"> <li>- Which constraints have to be considered for performing the method?</li> <li>- Former (positive/negative) experiences of employees?</li> <li>- Time constraints? Minimal, Maximal duration?</li> <li>- Group size?</li> <li>- Location?</li> <li>- Needed skills of the participants?</li> <li>- Needed skills of the host (e.g. moderator)?</li> </ul>						
Affecting / Support for (strategy, structure, culture, personnel?) (ind./grp./org.?)						
<ul style="list-style-type: none"> <li>- The maturing of which part of the organization is affected?</li> <li>- Which part is supported?</li> <li>- Who will be affected?</li> </ul>						
Post-conditions (exit criteria)						
<ul style="list-style-type: none"> <li>- What has to be achieved to successfully complete the method?</li> <li>- Do Pre-conditions of further methods have to be considered?</li> </ul>						
Benefit						
<ul style="list-style-type: none"> <li>- What is the benefit for the individual, group and/or organization?</li> <li>- How do they mature?</li> </ul>						
Reasons for not using the method						
<ul style="list-style-type: none"> <li>- Former bad experience of employees?</li> <li>- Conflicts, regarding to the given constraints?</li> <li>- Unwanted post-conditions?</li> </ul>						
References						
<ul style="list-style-type: none"> <li>- References to artefacts where the method is further described</li> </ul>						

**Figure 1:** Method template

The proposed template is related to the pattern language which was introduced by [Alexander et al., 1977] as follows: "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice. [Alexander et al., 1977]" On these grounds, [Fricke, 2000] introduced with the 'Pedagogical Pattern Maps' a similar method for the education field.

As an exemplary method, the Open Space Method is described with the OL-template (see figure 2).

Open Space Method		<input type="checkbox"/> Ind	<input checked="" type="checkbox"/> Grp	<input checked="" type="checkbox"/> Org
Type:	<input type="checkbox"/> Single <input checked="" type="checkbox"/> Double <input checked="" type="checkbox"/> Deutero	Process:		<input checked="" type="checkbox"/> Acq <input checked="" type="checkbox"/> Distr.
		<input checked="" type="checkbox"/> Interp.	<input type="checkbox"/> Store	
Pre-conditions (entry criteria) / Trigger (int. / ext.)				
<ul style="list-style-type: none"> <li>- No bad experiences with this method from participating employees</li> <li>- Trigger to take ideas from nearly every individual</li> </ul>				
Tasks & Goals				
<ul style="list-style-type: none"> <li>- Introduction Phase               <ul style="list-style-type: none"> <li>a. Present the method</li> <li>b. If not already done, look for methods</li> <li>c. Clustering of topics by finding similarities, if necessary</li> </ul> </li> <li>- Working Phase               <ul style="list-style-type: none"> <li>a. Working groups are formed</li> <li>b. They formulate results which are put on a wall so that everybody can read them</li> <li>c. The results can be discussed</li> </ul> </li> <li>- Finishing Phase               <ul style="list-style-type: none"> <li>a. All results are collected and put into one document</li> <li>b. Decide about which ideas should be further considered, based on the number of nomination as well as the importance and other factors</li> <li>c. Enhance the ideas in working groups into concrete tasks, goals, visions</li> <li>d. Present the developed ideas in a the audience and decide about further development</li> </ul> </li> <li>- The goal is to have a set of further steps which have to be done, might also be a proposal for the future strategy or other output</li> </ul>				
Utilities				
<ul style="list-style-type: none"> <li>- Room</li> <li>- (optionally copier)</li> <li>- (optionally notebook)</li> <li>- (optionally camera)</li> <li>- Pin board</li> </ul>		<ul style="list-style-type: none"> <li>- Paper</li> <li>- Moderation cards</li> <li>- (optionally glue)</li> <li>- (optionally cutter)</li> <li>- Small rooms for "expert groups"</li> </ul>		
Constraints				
<ul style="list-style-type: none"> <li>- The number of employees is open</li> <li>- The method must be explained to all participants</li> <li>- The duration of the collection of ideas should just take as long as useful ideas come up and the employees are not bored</li> <li>- The location has to be adequate to perform a successful idea collection but to also have the possibility to work on in smaller groups</li> </ul>				
Affecting / Support for (strategy, structure, culture, personnel?) (ind./grp./org.?)				
<ul style="list-style-type: none"> <li>- The method can be performed for the group or the organization</li> <li>- It might mainly affect the strategy, but also the personnel, which is able to bring in their ideas</li> </ul>				
Post-conditions (exit criteria)				
<ul style="list-style-type: none"> <li>- As soon as next steps are chosen the exit criteria is reached</li> <li>- The output should be in a form so that it can be used for further steps; it must therefore be easy understandable</li> </ul>				
Benefit				
<ul style="list-style-type: none"> <li>- The group or organization matures thanks to new input</li> <li>- The individual feels respected and more committed to the group or organization</li> </ul>				
Reasons for not using the method				
<ul style="list-style-type: none"> <li>- Not enough time</li> <li>- Former bad experience of employees</li> </ul>				
References				
<ul style="list-style-type: none"> <li>- <a href="http://www.np-strategie.de/aktuelle_downloads/OpenSpace.pdf">http://www.np-strategie.de/aktuelle_downloads/OpenSpace.pdf</a></li> <li>- <a href="http://www.cs.uni-paderborn.de/schulen/sem/downloads/openspace.pdf">http://www.cs.uni-paderborn.de/schulen/sem/downloads/openspace.pdf</a></li> </ul>				

Figure 2: Exemplary method: Open Space method

## 5 OL Methods supporting “An integrated Approach to assess the Potential of an Enterprise to mature Knowledge”

### 5.1 Assess the Potential of an Enterprise to Mature Knowledge

In [Brun et al., 2008], an “integrated approach for assessing and maturing enterprise knowledge with regard to various dimensions” is proposed. This knowledge management radar “could serve as a management dashboard for showing the as-is-state, to justify the direction as well as the extent of future knowledge management activities”. The six dimensions of the radar are defined as shown in figure 3:

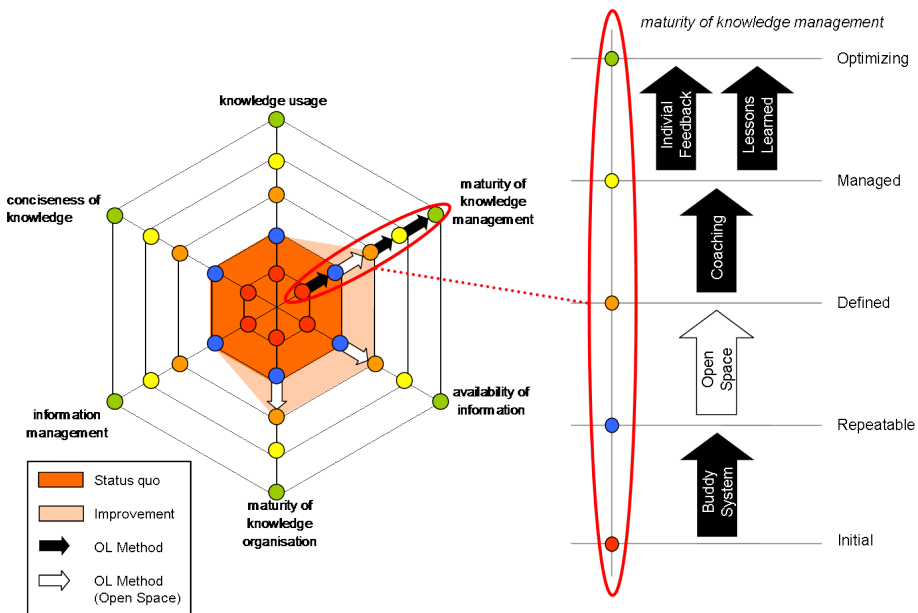


Figure 3: The six dimensions of knowledge potentials and an exemplary OL Enterprise Knowledge Maturing Path extended from [Brun et al., 2008, p. 3]

For each dimension, five steps are defined which represent the knowledge maturity in the specific dimension. As described in [Brun et al., 2008], the **Knowledge Usage dimension** “assesses the integration of knowledge management activities into the operational work.” The levels start from ‘General-purpose storage and retrieval’ up to ‘User-specific and context-adapted knowledge assistance’. The **dimension of Information Availability** “comprise levels from

'Explicit documentation' up to 'Automated Metadata Generation'." The **dimension Maturity of Knowledge Organisation** "leads from Keywords to Ontologies. Knowledge organisation deals with (1) building and modelling systems of concepts as well as (2) their mapping to subjects of reality. Methods for knowledge organisation can be arranged in a spectrum with increased semantics." The dimension of **Information Management** "considers the structure, security, redundancy, integrity on conflict resolving of information and classifies five constructive levels from 'Structure' to 'Conflict solving and continuous proactive development'." Another dimension for measuring the maturity of knowledge is the **Conciseness of Knowledge**. Here "the quality of content and an adequate representation are investigated."

## 5.2 Adapting OL Methods to Enterprise Knowledge Maturing

Our method template supports the Enterprise Knowledge Maturing (EKM) approach by indicating which method of organizational learning supports the maturing process in a specific dimension on a specific level. It therefore indicates how an organization is able to progress from one level to another. To clarify we give an example of an enterprise which is, based on its own evaluation, situated on Level 2 on all dimensions as shown as status quo in figure 3. We now apply the Open Space method as described in detail above. This method is useful for organizations which stand in such early stages of knowledge maturing and can be applied to three dimensions: The maturity of knowledge management, the availability of information and the maturity of knowledge organisation. After performing the Open Space method we can assume that the organization has reached the next level in these dimensions, or has at least evolve in this direction, as shown with the improvement area in figure 3. Note that beside a dominant dimension also other dimensions are affected in a moderate way.

Reaching the next level depends on several factors like the status before and the correct application of the method among others. It must also be considered that OL methods or OL in general might not help in every possible stage an organization can be situated in to achieve a next level. As mentioned before, OL methods can support the maturing process in a specific dimension on a specific level. Figure 3 shows on the left-hand side on the dimension 'maturity of knowledge management' an example of a possible path of using OL methods. Not every OL method can be used at every level of enterprise knowledge maturing. The introduced method template supports the method selection process. As we see in the exemplary OL-path on the right-hand side in figure 3, it is even possible to use more than one method at a specific level. It could also be the case that a selected method has a precondition that another method has to deliver as an input in advance.

### **5.3 Prevent Enterprise Knowledge Contraction**

As explained in section 5.2, the organization is situated on specific levels in each of the dimensions. A reached level is obviously not a stable state. Therefore it should be another target to stay on the actual enterprise knowledge maturing level. OL methods like Job Rotation, Buddy System, etc. can be used to stay on a specific level.

## **6 Conclusion**

The term 'Organizational Learning' has been defined in different ways and for different purposes. By providing a method template we want to give an overall view about existing OL methods and their possibilities. The description of the methods indicate how they can be used, for which actor and in which context. The template also integrates the types of learning, the supporting processes and the OL processes, described in the state of the art part. This information should help to choose the most appropriate methods for an organization situated in one of the seven dimension of knowledge potentials on a specific level. Applying the suitable method will therefore help to reach a next level and mature the knowledge.

## **7 Future Work**

A description of all the methods with the given template will represent a reference list of all relevant methods, including their pre- and post-conditions, tasks, constraints and further information. An 'OL-EKM-Map' (see figure 4) similar to the 'OL-EKM-Path' on the right-hand side of figure 3) can be created mainly by using the pre- and post-conditions of the methods. This helps organizations 1) to find needed appropriate methods, 2) to understand which methods already must be adapted in the organization to use a more developed one, but also by showing which methods are more appropriate in earlier or later stages, and 3) to inform for which group size the methods can be used. Such a map could be implemented without much effort in a modelling tool like ATHENE [Hinkelmann et al., 2007] by designing a meta-model for it. Using a meta-model, the map can easily be adapted for the needs of individual organizations. Such a map will also be able to indicate missing methods in the organization.



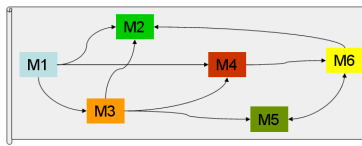


Figure 4: Organizational Learning - Enterprise Knowledge Maturing - Map (OL-EKM-Map)

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## **Understanding Maturity Models Results of a Structured Content Analysis**

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**Abstract:** Maturity models are popular instruments used, e.g., to rate capabilities of maturing elements and select appropriate actions to take the elements to a higher level of maturity. Their application areas are wide spread and range from cognitive science to business applications and engineering. Although there are many maturity models reported in scientific and non-scientific literature, the act of how to develop a maturity model is for the most part unexplored. Many maturity models simply – and vaguely – build on their, often well-known, predecessors without critical discourse about how appropriate the assumptions are that form the basis of these models. This research sheds some light on the construction of maturity models by analysing 16 representative maturity models with the help of a structured content analysis. The results are transformed into a set of questions which can be used for the (re-)creation of maturity models and are answered with the help of the case example of a knowledge maturity model. Furthermore, a definition of the term maturity model is developed from the study's results.

**Keywords:** capability, maturity model, knowledge maturing, structured content analysis

**Categories:** H.1.0, H.3.1, M.9

### **1 Maturity modelling and knowledge maturing**

Maturing has been used as an analytic, explanatory or normative concept in several domains, the most well-known of which is software engineering, e.g., Nolan's stage theory [Nolan 1973], the capability maturity model integration (CMMI, <http://www.sei.cmu.edu/cmmi/>) or the Software Process Improvement and Capability Determination model (SPICE, <http://www.isospice.com/>). The identification of 74 different maturity models from domains within the spectrum of (business) information systems and computer science shows the great variety and widespread use of maturity models available in the literature. However, this list only provides the tip of an iceberg due to the fact that there are many more maturity models in other domains, e.g., biology, sociology or psychology [Greenberg, et al. 1974, 331pp].

An analysis of a sample of maturity models has shown that many models differ with respect to their characteristics. But at the same time also several similarities within these models have been found which in part can be explained by the fact that many authors of maturity models simply build on their predecessors without much thinking about the appropriateness of their design decisions. This suggests that the concept of maturity modelling should be reflected and reassessed.

As a deeper understanding of maturing and maturity models is necessary for the creation of a new or revised maturity model, goals of this paper are to give an overview of the different conceptions of maturing and fundamental principles of maturity models and show the applicability of the results with the help of the case

example of a knowledge maturity model. The paper presents the results of an in-depth analysis of 16 maturity models for their individual characteristics in order to gain information about the nature of maturing and maturity modelling. The results are then used to inform future development of maturity models in the domains of (business) information systems and computer science with a special emphasis on the field of knowledge management, i.e. knowledge maturing. Aspects of how these findings could be used to inform the creation of new or the revision of existing maturity models are discussed with the help of the example of a knowledge maturity model. Section 2 gives an overview of the procedure taken for the analysis of maturity models. Section 3 presents and discusses the results of the structured content analysis of 16 maturity models. Beyond that, section 4 proposes a definition for the term maturity model, before section 5 concludes this paper.

## **2 A study design for the analysis of maturity models**

The investigation into the nature of maturity and the act of maturity modelling was performed with the help of the structured content analysis method. This section presents the applied study design for the investigation of 16 maturity models.

Analysis in the scientific world is often distinguished into qualitative and quantitative approaches. Quantitative research strategies are based on the model of the natural sciences and therefore facilitate the testing of hypotheses. Qualitative research strategies are based on the model of the social sciences and follow an inductive approach of research. This approach could also be described as an understanding approach which is often used to build hypotheses. [Schambach-Hardtke 2005, 18].

The aim of the current research is to explore and analyze existing models and to investigate characteristics and not to test hypotheses which would require a prior investigation. This procedure of identifying characteristics demands a qualitative approach. We decided to rely on textual descriptions of maturity models as sources for our investigation rather than empirical evidence in order to be able to cover more models and compare them. A suitable method focusing on the analysis of contents and the identification of criteria is the structured content analysis [Mayring 2008, 82pp]; its general procedure is depicted in [Figure 1].

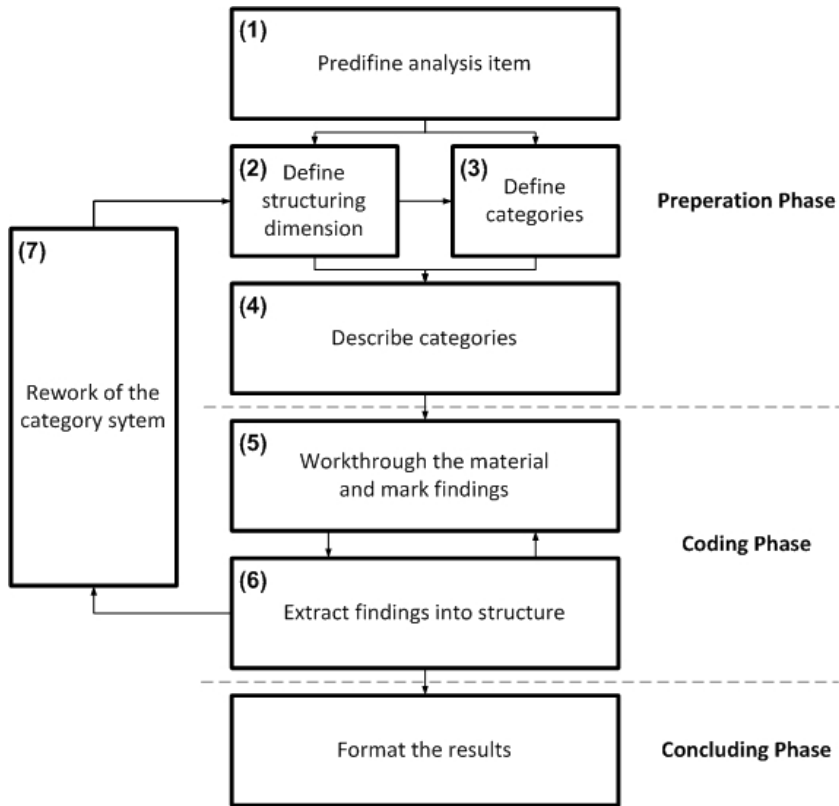


Figure 1: Process flow of a structured content analysis [Mayring 2008, 84]

Structured content analysis starts with the definition of the *analysis items* (1), which are those items that provide descriptions about the model itself. The smallest analysis item can be a single word while the potentially largest item is the entire model description.

In the next step, information associated with an analysis item is extracted from the model context and put into another structure determined by several *structuring dimensions* (2) and its underlying *category system* (3). In this paper, the structure was determined by the analysis question “Which characteristic patterns can be observed by comparing maturity models?” that comprises four sub-questions:

- *What does the term maturing mean?* Aim is to find the underlying concept of maturing employed by the model.
- *Which element is maturing?* Aim is to classify the subject of maturing into person, object or social system and some more detailed categories.
- *What are the main features of a maturity model?* Aim is to find a construction plan for maturity models. Because the authors were not aware of any similar studies, no codes were available, hence an inductive approach was needed to develop these.

- *How is the model used and supported?* Aims to answer the question why some maturity models are applied in practice while others are not. For example for [Krcmar 2005], formal certification is a critical factor.

After the preparation phase which ends with a verbal *definition of the derived categories* (4), the material is *worked through* (5 and 6) for a first time. As new categories may arise during this first run, [Mayring 2008, 83] proposes an iterative approach that allows *rework of the category system* (7). This inductive process is typical for qualitative techniques [Lamnek 2005, 91].

The material was worked through in three phases [see Figure 2] while the number of codes first rapidly increased (phase A), then slowly got more and more stable (phase B) to be finally condensed to a concluding level (phase C). The revision points between the phases were set at 13% (2 models), 50% (8 models) and 100% (16 models) of the models worked through.

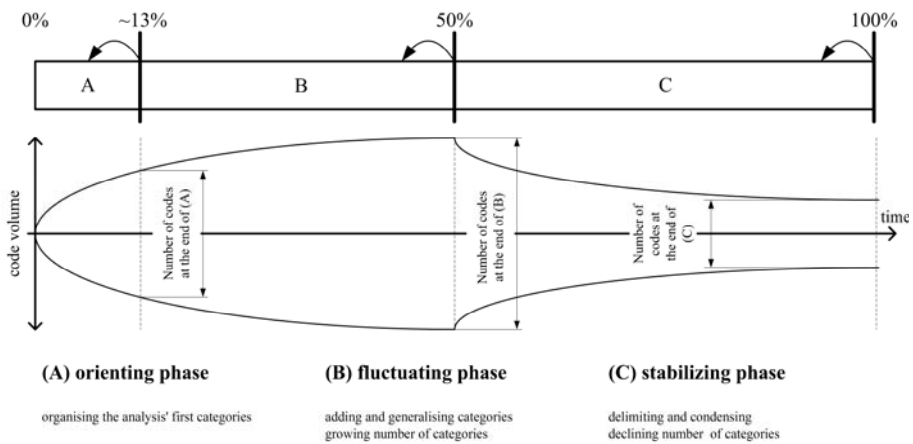


Figure 2: The three steps of the coding process. based on [Hädrich 2008, 222pp]

As suggested by [Dey 1993, 120], the analysed models were selected randomly in order to avoid a coding bias which might have arisen from how the models were selected and would have strained the development of the category system.

An Internet search was carried out in order to get an approximation of the basic population of maturity models as basis to draw a sample resulting in a list of 76 maturity models, further subdivided into three categories:

- maturing of *persons* (8 models found)
- maturing of *objects* (22 models found)
- maturing of *social systems* (46 models found)

The classification into these three categories is in line with knowledge as maturing element that can either be connected to a person, an object or a social system [Maier 2007, 198pp]. In order to equally imply all knowledge media into the

content analysis, identical numbers of models were drawn from each subset. The sample based on this trisection finally contained 16<sup>1</sup> models [Table 1].

Model Subset	Acronym	Approximated Diversification	Source of information <sup>2</sup>
Person	PSP	2120	[Humphrey, et al. 2005]
	PCMM	561	[Curtis, et al. 1995]
	SFIA	70	[SFIA 2007]
	Dreyfus Model	31	[Dreyfus, et al. 1988]
	Cross Model	0	[Cross 2007]
Object	SPICE	971	[Coletta 1995]
	UMM	138	[Earthy 1999]
	EMM	77	[Marshall, et al. 2004]
	SMMM	40	[April, et al. 2005]
	bIMM <sup>*</sup>	19	[Chamoni, et al. 2004]
Social System	CMM	13600	[Paulk, et al. 1993]
	COBIT	830	[ITGI 2007]
	Nolan Model	602	[Nolan 1979]
	TMM	184	[Burnstein, et al. 1998]
	CM3	84	[Kajko-Mattsson 2002]
	OIMM	37	[Clark, et al. 2001]

<sup>\*</sup> Model was added to the list subsequently

*Table 1: The sixteen selected maturity models to be analysed*

In order to maximise meaningfulness of the gained results, only the five most cited models in each category were used as input for the content analysis. The ranking was based on the number of search results returned by Google Scholar using the model's name as search term.

### 3 Study Results

On the basis of the structured content analysis applied to 16 selected maturity models the following model characteristics could be found which are illustrated with the help of a number of questions. Some characteristics show similarities, others show differences between the analysed models.

A model characteristic was categorised as similar among the analysed models, if the relative frequency of appearance of one code of the sub question was at least 65%. Those sub questions that complied with this criterion are subsumed in [Table 2].

<sup>1</sup> Initially, the sample contained five models from each category. During the analysis, one model, suggested to describe the process of object maturing, was found wrongly classified. As the model was already analysed, it had not been rejected from the analysis table. Instead, the next model from the list of object maturing models was analysed.

<sup>2</sup> Each model was analysed on the basis of two textual sources. Here, only the most recent of these two sources is listed.

category and code		model name											Frequency (ABS)					
		CMM	COBIT	CM3	Dreyfus model	EMM	Cross Model	Nolan Model	QMMM	PSMM	PSP	SFTA		SMMM	SPICE	TMM	UMM	
How do elements change in time?	change in number	1															3	
	change in nature		1		1		1						1				8	
Direction of change	increasing change	1	1	1	1	1	1	1		1	1	1		1	1	1	13	
	decreasing change												1				1	
Maturing object	person				1		1			1	1	1					5	
	object	competence																0
		document																1
		infrastructure															1	2
	social System	product					1											1
		service											1					0
		group																0
		team																0
	community																0	
	process	1	1	1					1						1		5	
	routine																0	
	structure																1	
Complemented Model	no model is complemented	1	1	1	1	1	1	1	1					1		1	10	
	CMM									1	1		1	1	1		4	
Model design	iterative (one path)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14	
	cyclical (many turns)																0	
How do levels built on other levels	upper level comprises lower level	1	1	1				1	1	1			1	1	1	1	10	
	upper level is new concept				1		1				1						3	
How to come from one Level to another?	defined goals have to be fulfilled	1	1	1				1	1	1	1		1	1	1	1	11	
	matures implicit				1		1					1					3	
Is there a "not existent" stage?	there is a "not existing" stage		1			1									1		3	
	there is no "not existing" stage						1			1	1						3	
Degree of detail	one trigger per stage																0	
	many triggers per stage	1	1	1				1	1	1	1		1		1	1	10	
	no triggers per stage				1							1					2	
Number of Goal Levels	metric values	1	1	1		1		2		1	1		1	1	2	1	17	
Method of goal benchmarking	metric based		1					1		1			1				4	
	non-metric based	1	1	1	1		1		1	1	1	1	1	1	1	1	12	
Model use	conceptual model				1		1	1									5	
	applied model	1	1	1		1			1		1	1	1	1	1	1	10	
What is the model description based on	experience from praxis	1		1				1				1		1			6	
	standards												1			1	2	
	literature (e.g., other models)		1	1	1	1		1	1		1		1		1	1	10	
Certification available?	certification is available										1			1			2	
	no certification available		1		1		1	1					1		1	1	7	

Table 2: Similarities among maturity models

If the relative frequency of appearance of one code within a sub question was smaller than 65% the sub question was added to the differences list [Table 3]. The purpose of this analysis is to inform the design of maturing models. In the following, the main results are presented in the form of questions that can be posed when designing maturity models which are answered on the basis of the example of the knowledge maturity model presented by [Maier, et al. 2007]. The analysis increases modelling precision and shows avenues for further development.

category and code		model name													Frequency (ABS)		
		CMM	COBIT	CM3	Dreyfus model	EMM	Cross Model	Nolan Model	OMMM	PSMM	FSP	SFTA	SMMM	SPICE		TMM	UMM
What means maturing?	change in quality	1		1													4
	change in capability		1			1	1										7
	change in risk				1												2
	other change	1						1	1								3
Conceptual Mother Model	has no conceptual mother model	1			1		1	1			1	1		1			7
	CMM		1	1		1				1			1		1		6
	SPICE					1										1	2
	Other model								1							1	2
Model User	Organisation internal assessment team	1	1	1		1			1	1	1	1	1	1	1	1	12
	Organisation external assessment team	1									1	1	1	1			5
	model is not used practically				1		1	1									3
Complemented Model	no model is complemented	1	1	1	1	1	1	1	1					1	1	1	10
	CMM									1	1		1		1		4
Number of stages	<b>metric value</b>	5	6	3	5	6	3	6	5	5	4	7	5	6	5	6	5.5
Is there a "not existent" stage?	there is a "not existing" stage		1			1								1			3
	there is no "not existing" stage						1			1	1						3
What do level descriptions include?	trigger descriptions	1	1	1		1				1	1			1	1	1	9
	activity descriptions (tasks, processes)	1	1			1				1	1		1	1	1		9
	conceptual level description	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	13
Level skipping	explicitly allowed											1				1	2
	not recommended	1							1	1							3
Are there parallel maturing processes possible for one unit	parallel maturing is possible	1	1		1	1	1	1	1		1	1		1	1		8
	parallel maturing is not possible	1		1									1		1	1	5
Where do assessment data come from	interviews													1	1	1	3
	documents													1			1
	questionnaire	1													1		2
	data							1									1
Tool support	supported by assessment model	1	1									1		1	1	1	6
	supported by software tool														1		1
	not supported by tool				1		1	1	1								4

Table 3: Differences among maturity models

**What is the nature of maturing?**

- How do elements change in time? *Knowledge elements change in nature while they advance through the knowledge maturing process.*
- What does maturing mean? *Maturing means change in formality, distribution, commitment, legitimation, understandability and teachability of the maturing subject, i.e. of socially constructed knowledge in an organisation.*
- What is the direction of change? *Maturing means an increase of formality, distribution, commitment, legitimation, understandability and teachability.*
- What is the maturing subject? *The maturing subject is a knowledge domain in the sense of knowledge about a topic in a socially distributed activity system.*

**How is the model designed?**

- Has the model a conceptual mother model? *The knowledge maturing model is not related to any other maturity model.*
- What is the model used for? *The model can be used as an analytic model to help structure the analysis of existing organisational and technical infrastructures in support of goal-directed learning on a collective level.*



- Who uses the model? *The model can be used by people taking on the role of guides helping to foster and reduce barriers for knowledge maturing.*
- Does the model complement other models? *The model does not complement another model.*
- How is the model designed? *The model is designed as a sequence of phases which do not necessarily build on each other. Each phase can use outputs provided by all other phases as inputs for knowledge maturing activities in this phase.*
- How do the stages build on each other? *The stages of the model are independent from each other as the upper stage cannot be traced back to the lower stage.*
- How does the subject proceed from one level to the next? *The maturing element matures implicitly between the stages. However, there can be explicit decisions to take a knowledge domain from one phase to the next one.*
- What is the number of stages? *The knowledge maturing model has five stages.*
- Is there a „not-existing“-stage? *The model has no “not existing”-stage.*
- What do the level descriptions include? *The level descriptions of the knowledge maturing model include conceptual descriptions of the stages.*
- What is the degree of detail of the trigger description? *The model has no triggers between its stages.*
- Is level-skipping allowed? *The model does not mention level skipping.*
- Are there parallel maturing processes possible for one unit? *Within one organisational unit, there might be different knowledge domains which are in different knowledge maturing stages.*
- What is the number of goal levels? *The model has no goals assigned to its stages.*
- What is the method of goal benchmarking? *The model uses a non-metric way of goal benchmarking.*
- Where do assessment data come from? *The model is not practically used yet, so assessment has not been specified yet.*

#### ***How is the model used and supported?***

- What is the model used as? *The model is used as a conceptual model.*
- Is tool support available? *The model is not supported by a tool.*
- What is the model description based on? *The model is based on practical experience.*
- Is certification available? *There is no certification available for the model.*

## **4 Implications for maturity modelling**

Aside from a first definition proposal given by [Ahlemann, et al. 2005, 15], the nature of maturity models has not been theorised well in literature until now. Maturity models are seen as models that reflect certain aspects of reality, often called capabilities, and define qualitative attributes which are used to classify a competence object into one of several clearly defined classes. These classes are typically brought

into a sequential order [Ahlemann, et al. 2005, 13p]. Although several institutions developing maturity models (e.g., SEI, PMI) have tried to close this gap, the foundation of their contributions has often not been based on the richness of maturity models available, but only focused on their own models.

This work intended to define maturity models on the basis of the empirical data that was gained in the structured content analysis. Therefore, a sample of 16 maturity models was investigated. The characteristics and patterns of the observed models were extracted from the model description and put into a well arranged structure through a content analysis. From this, the following definition of maturity model has been developed:

*A maturity model conceptually represents phases of increasing quantitative or qualitative capability changes of a maturing element in order to assess its advances with respect to defined focus areas.*

Typically, the maturing element is a person, an object or a social system. The focus area determines which indicators for maturity can be used to assess a maturing element. Examples of focus areas are maturity of processes, of digital resources or of people's competencies. The model structures the maturing elements' developments into a suitable number of phases which are commonly separated by non-metric based trigger conditions and brought into a sequential order. A maturing element can develop into any phase of the model, if it fulfils all trigger conditions of the lower phases plus the ones of the actual phase. It is also important to understand that maturity models can be either used in a descriptive way explaining changes observed in reality or in a normative way. In the latter sense, the maturity model is intended to guide owners', managers' or other committed individuals' interventions into making changes in maturity of maturing elements more effective or efficient.

## 5 Conclusion

This paper targets a striking gap in theory building about maturity models and can be understood as a first step into the investigation of the nature of maturity and maturity modelling. The coding table, containing the questions to this analysis shows how many aspects have to be accounted in connection with the creation of a maturity model. These aspects can be used as checklist for selecting a maturing model, for comparing maturity models or for designing maturity models.

Besides the already mentioned coding bias, especially a model selection bias challenges the findings of this work, as the analysed sample of models determines the codes that have been found during the analytical process. If the size or the composition of the sample would be changed, the codes might also change. Thus, the results of the structured content analysis, although already considered useful, e.g., for designing maturity models for the domains of knowledge, knowledge-intensive processes or knowledge infrastructures., can be used as input for a quantitative study with a larger sample of maturity models. Propositions that can guide such a quantitative research can build on the basis of the findings presented here.

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# **A Visually Supported Interactive Risk Assessment Approach for Group Meetings**

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**Abstract:** This paper introduces a new process-oriented visualisation method for risk assessment in groups. Today, in corporate risk assessment there is a lack in visual facilitation methods for collaborative assessments of risks. Existing visualisation methods emphasize analytical purposes. However, they are not useful for the facilitation of risk assessments in a group, such as the board of management. The described risk visualization approach offers a visual dialogue oriented approach to improve the quality of organisational risk-assessment in groups and goes hand in hand with already established risk management processes and systems. Secondly, this paper introduces the “ETH Baugarten Value Lab”, where we tested the tool on touch displays.

**Keywords:** Risk Management, Knowledge Visualisation, Touch Displays

**Categories:** B.0, B.m, H.0, H.4, H.5, M.O, M.9

## **1 Introduction**

This paper introduces a new process-oriented visualisation method to improve organisational risk assessment in groups. It also introduces the “ETH Baugarten Value Lab”, as a state-of-the art space for such risk assessment meetings.

The responsibility of a corporate risk management lies in the hand of the board management. They are responsible for identifying, evaluating, and assessing the risks as well as deriving actions to handle these risks. The implementation of the risk management and such actions is the duty of the executive board. It normally delegates it to a few risk managers in the organisation who generally implement a technical fact based risk management process and software based technical systems. When there is a board meeting these experts usually provide the information for the decision making process in this meeting. Normally, they have to synthesise the information from these systems, assess if it can be true, and write a report.

We have identified three main challenges: (1) **Getting the Big Picture:** The risk management systems generally get more and more detailed and complex. Monthly risk reports easily exceed 100 pages. At the same time the people have less time to study these reports. The responsible people can easily loose the overview. It can be dangerous if these people rely on the presented recommendations from the experts or

their technical system without listening to their gained experience and their intuition. But how would a tool look like that provides such an overview? (2) **Risk Assessment with different stakeholders:** More and more stakeholders get involved in the risk assessment process, such as the board of management, the executive board, the auditing firm and others. All of them have diverging backgrounds, risk perceptions and professional experiences. How can the quality and involvement in a risk assessment meeting be increased and decision making be assisted? Research has shown that visualisations can be very useful for the co-ordination of a group and for group decision-making [Eppler and Burkhard 2005; Eppler and Burkhard 2007]. (3) **Creating risk reports:** According to a new Swiss regulation (“Art. 663b Ziff. 12 OR”), Swiss companies must provide a risk evaluation as one part of their annual report. The auditing firm has to also verify that a company has a risk management and internal control system (Art. 728a OR). The auditing firm has to assess the risk management and inform the board of directors of the company with a detailed report on the finances, the internal control system as well as the result of the revision. However, there are no best practices on how to create such risk evaluations together with the responsible people as the basis for writing a risk report.

In this article we will propose approaches to solve these challenges.

## 2 Risk Visualisation: Related Works

Eppler and Aeschmann provide an overview on existing and different risk visualisations [Eppler and Aeschmann 2008]. They have also reported that there is only little research when it comes to risk visualisation, probably because: “risk is both very difficult to visualize and extremely challenging to describe” [Horvitz 2004]

In organisational risk management people often use one generic type for mapping risks in one or the other slightly modified or elaborated version. This generic type can be seen in [Fig. 1].

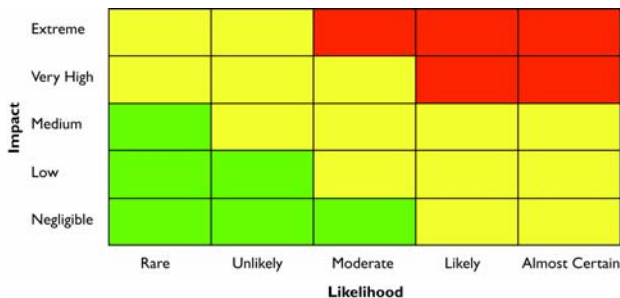


Figure 1: Generic Risk Map often used in companies (Source: Author)

Such as Risk Map uses a table format with two axes, one represents the likelihood that a risk occurs, the other the impact of a risk. Some people directly write the risks with textual descriptions into the cells, others use visual elements such as bubbles or points to represent the risks. Sometime researchers also add additional information such as temporal information, but the basic concept remains the same.

These risk maps are good. However, they also have disadvantages: (1) they are normally the RESULT of the work of one or few experts who prepare information for the management and not of the responsible people in the management. (2) The format is static and not interactive and hence does not work very well as a tool for facilitating the PROCESS of evaluating and assessing the risks in a group, for example an executive board. (3) The representation is very analytical and abstract and thus not useful for broader communication purposes and for establishing risk awareness within an organisation. (4) The representation focuses on the risks but gives no information how the risks are encountered with related projects or actions.

The lack of risk visualisation research motivated us to develop our proposed risk visualisation approach.

### 3 Risk Visualisation Approach

Our risk visualisation approach is a visual computer supported and process-oriented method. The screenshot in [Fig. 2] shows the main view of the tool. It is important to stress that the tool has no built-in “intelligent” methods that calculate probabilities or other issues whilst moving items. The motivation was exactly the opposite: “Less is more”. The goal was to find a metaphor, which can be understood instantly by everyone and secondly to only provide minimum functionalities and features to avoid distraction and to support a lean process.

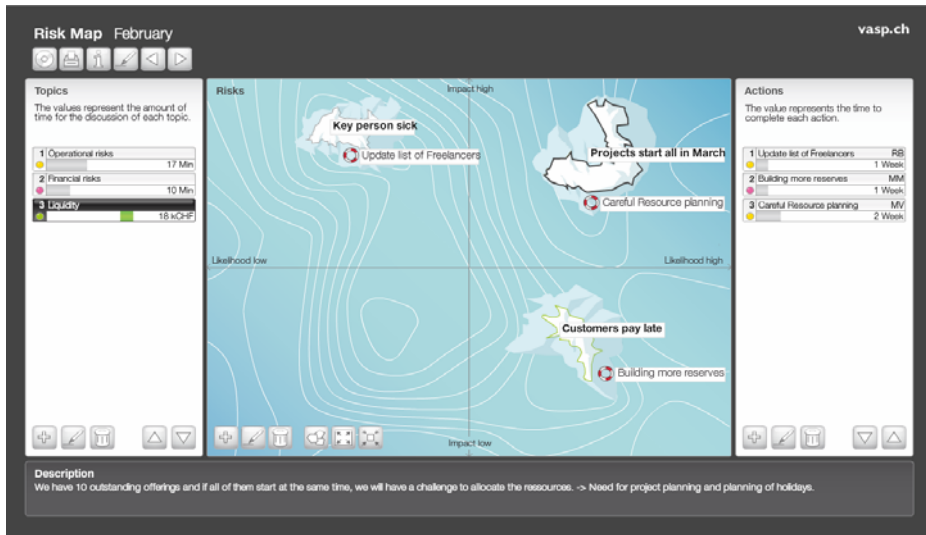


Figure 2: Risk Visualization Tool (Source: [www.vasp.ch](http://www.vasp.ch)).

The motivation was to develop a tool, which is as simple as the screen capture tool “Snag-It”, which allows only one function. Therefore, the research contribution is the simplicity of the proposed approach and not new technical functionalities, sophisticated algorithms or new three dimensional spatial abstract visualisations.

### 3.1 Three Step Process

The three main frames visually guide, from left to right, through the three-step approach:

**Step 1: Defining the risk clusters.** Based on the information (e.g., a reports from a risk manager) the group has to discuss and decide on the meeting agenda and the clusters of risks to be assessed, because there exist different risks. Examples for such risk clusters are: Strategic risks (e.g., image, prices, competitors, etc.), operational risks (e.g., CRM, distribution, intellectual property, human resources etc.), financial risks (e.g., concise and correct reporting, illegal transactions, data security, etc.), compliance risks (national and international regulations, internal rules, etc.). The users add for each major topic to be discussed a slider bar as seen in [Fig. 3]. Then, they can use the mouse (or finger on a touch display) to adjust the values of the slider. This can be an amount of time (e.g., in minutes) or financial information such as the expected cash reserves by the end of the month (e.g., in kCHF) as seen in [Fig. 3].

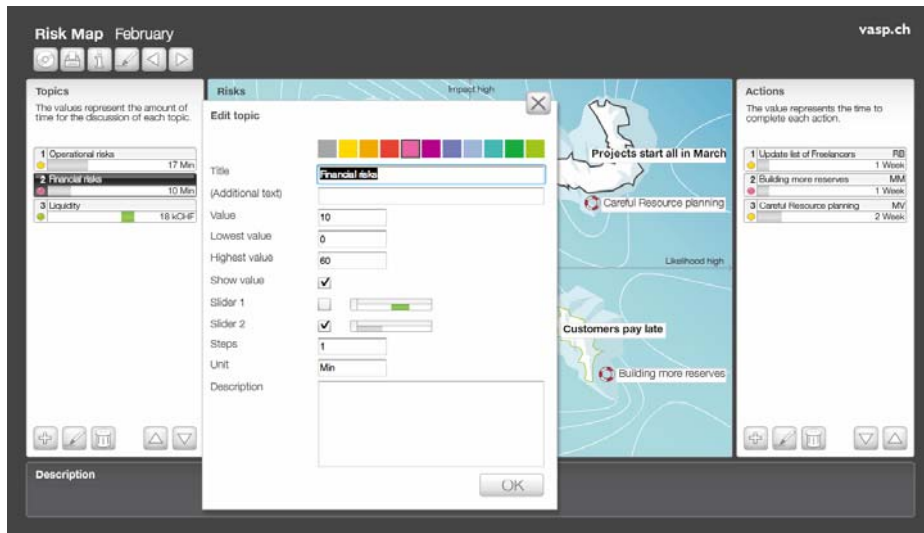


Figure 3: Interactive “slider bar” (under Topics and Actions) and a window to edit it.

**Step 2: Identifying, evaluating and assessing the risks.** After the topics have been defined the users start discussing one topic after the other and identify the major risks. For each risk they can add an iceberg by clicking on the iceberg button in the iceberg view. A new iceberg appears in the middle of the screen and the user can give the risk a name and add a textual descriptive or qualitative assessment in an additional comment field. This description appears on the bottom of the screen, once the iceberg is selected. After the participants have discussed this particular risk, the people adjust the size of the iceberg according to the perceived importance, i.e., the bigger the iceberg the more important it is. Then, they position the risk on the underlying matrix (impact low – impact high / probability low – probability high). They then continue to



add new risks and adjust the position and size of all risks iteratively until they feel comfortable. Only then, they continue with step 3.

**Step 3: Developing actions to handle the risks.** After the users have identified, evaluated, and assessed the major risks they discuss about necessary actions to manage the identified risks and allocate resources. To do so, they use the third view where they can add slider bars for individual actions. Each slider bar relates to one action and the value of the bar represents the amount of time (e.g. weeks) or money allocated for the respective action. Finally, the responsible person is defined and added with the initials (e.g., RB on top right of action slider bar). We found that the chosen approach is the simplest approach to discuss the transparent allocation of limited funds or limited human resources.

In the additional field the users can add a description with milestones or other information.

### 3.2 Interface

This section explains the elements of the interface.

The main view uses the visual metaphor of icebergs. Each iceberg represents a risk. Each risk can be changed in its size according to its importance by selecting the risk and clicking the resize button. The background image with the ocean serves as aesthetic and emotional tapestry for the superimposed matrix with two axes. The isobars have only an aesthetic function. The labelling of the axes, as well as all other text in the tool, can be edited in the preferences.

Below the title are buttons to save, print (pdf), and edit preferences and buttons to navigate to the next or previous view. In the preferences, all texts and other settings can be adjusted. The next or previous view button allows navigating through different (e.g., monthly) risk assessments.

In both, the left and right frame (topics and actions) [Fig. 3], the user can add items by adding "slider bars". They consist of a title on the top of the bar and an interactive slider below. The user can adjust the name and scope of each slider (start value, end value, steps, and units) by selecting a slider bar and clicking on the edit button. The value of each slider bar can interactively be adjusted with the mouse (or on a touch display with the finger). The users can also change the vertical order of the slider bars with the arrow button.

Within all three frames the user has buttons at the bottom for example to add new items (e.g. adding or removing a slider-bar or iceberg), edit the data per item (such as title, start or end value of the slider, description or textual evaluation of the risk), change the position of the item, resize the iceberg or delete items. At the bottom is a field for detailed descriptions for each item.

### 3.3 Technology

The tool is a Flash application (.swf) programmed in Adobe Flex AS3. The local storage of data is solved with "Local Shared Objects (LSO)", so called Flash cookies.

### 3.4 Use Case

The executive board of an enterprise with about 250 employees meets for a two-hour risk assessment session on a touch display. The basis for this workshop is a report

with 50+ pages provided by the risk manager of the company. The participants have received this report by mail before they attend to the meeting. Prior to the workshop, the CEO has prepared the list of topics in the Risk Visualisation Tool. The workshop starts. Ten minutes after the workshop has started, the group has agreed to all topics to be discussed, after they have added two additional topics. Then, they go through the three-step process as described before. At the end of the meeting they click the print button and print an aesthetic poster as the instant meeting minutes.

Now, the CEO has a mutually elaborated risk assessment. He has now to prepare for the management board meeting. Therefore he sends the expert's report and this new poster (pdf) to the management board for the preparation of the meeting. In the management board meeting the attendees work with the same Risk Visualisation Tool. The board members now assess the risks by repositioning the icebergs and adjusting the evaluation in the description window. The CEO serves as moderator and instantly updates the information. They also add new risks, which have been neglected in by the executive board. Finally, the management board agrees on the final version and print it again as version two of the map. After the meeting the CEO shares all information with the auditing firm.

The auditing firm appreciates a lot the complementary simplified overview. They do the audit. Finally, when they have to present their conclusions of the audit they use again the same tool to present the Big Picture of their identified major risks, complementary to traditional approaches to present their conclusions.

## **4 ETH Value Lab: A Space for such Group Risk Assessments**

This section introduces the “ETH Baugarten Value Lab”<sup>1</sup> [Fig. 3]. We introduce this lab because we tested the tool in this lab to compare the pros and cons of using video projections compared to touch displays. The hypothesis was that a touch display is a better technology for facilitating such group meetings than a video projector. We therefore adjusted the tool so that it runs on the ETH Baugarten Value Lab.

### **4.1 Concept**

The “Baugarten Stiftung” wanted to donate a “classroom of the future”. This space had to re-invent the idea of a classroom and set new standards for knowledge creation in groups, such as risk assessments in groups. The chair of information architecture developed the concept and implemented the lab together with external partners.

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<sup>1</sup> <http://www.valuelab.ethz.ch>



*Figure 3: ETH Baugarten Value Lab with five touch display (Source: [www.ia.arch.ethz.ch](http://www.ia.arch.ethz.ch)).*

Conceptually, we wanted to create an architectural space with daylight, high ceiling, large interactive touch displays and a videoconference system. The design imperative was to create a functional and aesthetic space.

#### **4.2 Technical Implementation**

The ETH Baugarten Value Lab is located at ETH Zurich in Switzerland. The concept has been described in [Halatsch and Kunze 2007; Halatsch et al. 2008; Burkhard and Schmitt 2009]. The architectural space is about 6m wide, 10m long and 6 m high. The lab consists of a multi touch table and a multi touch board, HD video projectors and a video conferencing system. The interactive table consists of two 65-inch LCD displays (resolution of each display: 1920x1080 pixels) with an optical touch overlay and multi-touch functionality. The table also has two buttons to adjust the heights of the table so that people can either sit or stand around the table. The interactive board uses the same technology but consists of three 82-inch LCD displays (resolution of each display: 1920x1080 pixels). LCD-screens have been chosen because rear projections have disadvantages such as daylight sensibility, noise, service costs for lamps. Also the room had a limited size that did not call for the rear projection construction. The whole system is connected via fibreglass to a central server in the basement of the building. On this server currently three operating systems are installed: Macintosh OSX 10.5, Windows XP/Vista and Linux. The basic configuration offers the user two modes: either he or she uses the five screens as (1) ONE virtual desktop or as TWO virtual desktop (e.g. for running a Windows

operating system on the board and a Macintosh OS on the table). Additionally, three HD projectors, a video conferencing system and a Dolby surround system are installed. The video projectors can present information from an external notebook, from any of the touch screens or from the video conferencing system.

The ETH Value Lab was launched in October 2008. It is used for research and teaching within ETH. It can also be used from external people from universities or industry.

## 5 Discussion

We have not yet done a broad usability study and avoid to present tests with a few students. But we have demonstrated and discussed the tool with about 40 higher managers from larger companies. The population consists of mostly males and few females; all of them were between 32 and 65 years old and have a professional background of 15 to 40 years in the service industry; 90% of these people are from Switzerland and 10% from Singapore. Secondly, we used the tool ourselves in about 10 meetings and gained insights from written feedbacks of people who tested the tool in real business situations (without our super vision). The tool was used four times in group workshops in the Value Lab. Our findings so far are:

(1) People understood the metaphor immediately and had no difficulties to link the metaphor to risks. The people liked the metaphor and the design. This is also true for the people from Singapore. (2) Two third of the people expected that the icebergs are linked to an intelligent algorithm. After explaining that it follows a “less is more” or “only one functionality/Snag-It” approach, they understood the very focused purpose. (3) Most of the people did not understand the three steps intuitively without a short explanation or the simple read-me explanation. Most people had difficulties to define the categories because they were thinking of too complicated risk categories. (4) After working on a real example almost all people stated that this approach makes a lot of sense to them and also liked the simplicity. A few people wanted to buy the tool. (5) Some people asked why not simply using circles instead of icebergs. We then tested with them the same application with circles instead of icebergs and the same people stated suddenly that they prefer the iceberg metaphor because of emotional and aesthetic reasons. In conclusion, it seems that the metaphor and three step approach works. The tool needs however a better introduction and maybe also a list of risk categories to chose from. Some people proposed to provide it online to facilitate group collaboration over distance.

In our Value Lab tests we found that all people prefer to work on the touch display when they could choose between the video projection and touch displays in the Value Lab. We also found that people prefer to work on the touch display table and not on the touch display board after they have been working on both settings. The reason for this is that the table supports more natural discussions because the people can stand around it and see one another into the eyes. When they can choose between sitting at the table or standing around the table (the heights of the table can be adjusted) the participants preferred to stand around the table, because it is more dynamic. When standing around the table, people did not report difficulties to read the visualisation up-side down.

## 6 Summary

This paper has introduced a visualisation approach for risk assessment in groups as well as the “ETH Baugarten Value Lab” as a space where such risk assessments can be done. We presented the limitation of today’s widely used risk maps and proposed a three step approach which facilitates the process of an organisational risk evaluation and risk assessment through the management and executive board and the external audit agency. The described risk visualisation approach offers a new process oriented approach and a software tool that leads through this process. Our approach improves the quality of organisational risk-assessment and complements already established processes and systems.

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# **Drawing Distinctions: The Visualization of Classification**

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**Abstract:** Classifying phenomena is a key step to building new knowledge, especially in the early stages of a research process. It can bring about multiple advantages and insights, such as overview and comparison. Yet it also poses several risks and constraints. Thankfully, challenges can be over-come by re-classifying items in a domain with alternative classification principles, which lead to new insights or perspectives, as well as highlight previously neglected considerations. This process can be supported by graphic representations. Visualizing the drawn (and redrawn) distinctions can make a classification accessible and versatile, which makes it easier to compare with other classifications. Visualizing classifications can augment the entire research process, including hypothesis formation, testing, interpretation and result reporting. There is no systematic overview of methods to represent (especially qualitative) classifications graphically. This paper fills that gap in the literature. We distinguish between four types of visual classifications, based on their differing ability to emphasize hierarchies or group relations. We label these four types as compilations, configurations, layers, and trees. We analyze their benefits for the research process and point out potential risks to consider when using visualization for classifications purposes in social science research.

**Keywords:** Classification, taxonomy, typology, graphic representation, research

**Categories:** A.1, E.1, M.4, M.9

## **1 Introduction**

A key step of many social science research endeavors is the systematic classification of different items in a domain or area. This can be done deductively, in the form of a theory-based typology, or inductively, through the creation of an empirically grounded taxonomy. Examples abound. In qualitative research, classificatory frameworks are a widely used form (see [Marradi, 90], [Nowotny, 71]). In quantitative research, cluster analysis is a handy example of an approach that is explicitly supporting classification. Highly cited cases include Bloom's classification of educational objectives [Bloom, 56], Searle's classification of speech acts [Searle, 75], Shrivastava's classification of organizational learning systems [Shrivastava, 83], Holt's typology of consumption practices [Holt, 95], or Shneiderman's taxonomy of information visualizations [Shneiderman, 96]. Classification is so often integral to the way that social scientists perceive, interpret, and organize subject matter.

Many researchers take a step further and represent classifications using graphics. Graphics may show the hierarchy of grouping, emphasize underlying attributes of

items, or highlight relations among groups (see [Card, 99] or [Tufte, 90]). Many different graphical formats are employed. These range from simple two-by-two matrices and tree structures to complex grids and coordinate systems or may even include elaborate visual metaphors. Arguably the most famous graphical classification schema for research is Mendeleev's periodic table that systematically classifies the basic elements in chemistry in a u-shaped grid structure. (The table organizes elemental atoms by the number of protons in their nucleus.) Highly cited graphic classifications from the social sciences include Michael Porter's five-part classification of market elements [Porter, 80], Mintzberg's classification of organizational configurations [Mintzberg, 79], or Rogers' S-curve typology of innovation acceptance styles [Rogers, 95]. Despite the growing popularity of classification visuals, this method is not being used to its full potential. Moreover, it is often used inappropriately.

In this article, we argue that the visualization of classification is crucial for the advancement of social scientific research methodology as a discipline. Yet, despite its importance, visual classification is an insufficiently researched subject. We submit that different graphic forms provide significant advantages when drawing distinctions. For example, whereas a matrix or grid forces the researcher to combine two or more attributes to form a group or type, a Venn diagram enables the researcher to reflect on items that exhibit one, two, three or more attributes. As another example, a tree structure emphasizes hierarchy and sub-groups, while a pyramidal classification emphasizes how one class builds or depends on another. Researchers may not be aware of these and other properties of diagrams when developing or presenting their classification. As a consequence, they may not fully benefit from the versatility that visualizations can provide for the development of typologies or taxonomies. This is especially so when switching between different visual formats. The switching gives researchers the opportunity to extend their classifications or detect inconsistencies, among other benefits.

We present a systematic overview of the formats available for depicting classifications visually and highlighting the properties of each format. Our article is structured as follows. In the next section, we briefly define classification and describe its role as part of the scientific method. Section three offers an overview of visual forms for classification, including examples and guidelines for their use within the research process. Section four is dedicated to the risks and limitations of using visualization for classification-oriented research. The final section summarizes our contribution and draws some conclusions. In terms of limitations of this paper we highlight the fact that we focus mostly on qualitative classifications and their graphic rendering.

## 2 Classification as a Scientific Method

Classification, according to [Bailey, 94], designates the ordering of entities into groups or classes on the basis of their similarity. The research goals of classification are the minimization of within-group variance and maximization of between-group variance. In other words, classification aims for within-group homogeneity and between-group heterogeneity within a given domain. This task can be achieved in various ways. A *quantitative* approach usually consists of proceeding inductively and developing classes from empirical data. Cluster analysis is the most obvious example

because it is a statistical procedure that is explicitly designed to place cases into similar groupings. For instance, marketing researchers use cluster analysis to group consumers into various categories according to their spending habits, income levels, and lifestyle attributes (among other variables). These groupings can then be used to develop a formal taxonomy that can be further tested and applied practically. A *qualitative* approach may consist of a deductive, theory-based, “top-down” framework into which items are placed. The latter classification is often referred to as a *typology*, while the former is usually labeled as a *taxonomy*, although numerous studies use both terms loosely or even interchangeably.

There are several noteworthy qualifications about the distinction between typology and taxonomy. [Doty, 94: 232] define typologies as “conceptually derived interrelated sets of ideal types each of which represents a unique combination of the attributes that are believed to define the phenomenon.” A taxonomy, according to [Sanchez, 93], is simply an empirically derived grouping. While a typology may be oriented towards some normative end (such as market success in the case of a typology of business strategies), taxonomies tend to be descriptive. The goals of a taxonomy, according to [Chandra, 05:247], are to introduce structure into a body of facts, as well as to build a unified and homogeneous view of the domain of interest.

In contrast to mere categorization, classifications tend to be more systematic and stable, and lead to groups with clear boundaries and inclusion or exclusion rules [Jacob, 04: 528]. According to [Bowker, 99] classification refers to the spatio-temporal segmentation of the world. This segmentation, according to most scholars in the field, has to exhibit the following traits:

1. there are consistent, unique classificatory principles in operation;
2. the categories are mutually exclusive (non-overlapping);
3. the system is complete (all items can be placed in a group).

These are minimal requirements for a sound classification based on the original work of [Sneath, 73]. [Gregory, 06] goes further and states that a high quality classification must also be useful (i.e., it should aid analysis), contain meaningful and natural category labels and groupings, and consist of hierarchies that are appropriate (i.e., most important divisions are shown at the highest levels). In addition, the logic for placing elements in categories should be clear, as should be the characteristics that define each category. Likewise, [Meyer, 07: 28] mentions validity, simplicity, relevance, and difference as key traits of a typology. The validity of a typology depends on the unambiguous definition of categorization criteria (referred to as classification principles above). It requires that a typology be consistent with established theories in a field. The criterion of simplicity refers to the conciseness and comprehensibility of a classification. A classification, in other words, should contain a limited number of categories that are easy to distinguish. The criterion of relevance implies that only the most influential items should be included in a typology. According to Meyer, focusing on the important has a higher priority than being complete in the case of a typology. Difference, finally, refers to the fact that a typology should highlight the major differences in views, while paying less attention to issues on which more agreement exists. The focus should be on contradictory



assumptions and conflicting norms. In other words, only the aspects with a high discriminatory value should be considered. This is reminiscent of the definition of information as “a difference that makes a difference.”

There are various reasons why a researcher may want to develop a classification. The table below summarizes the main benefits that can result from a classification. The compilation is based on [Bailey, 94], [Bowker, 99], [Jacob 04], [Doty, 94], [Gregory, 06], [Sneath, 73] and [Meyer, 07]. We tentatively distinguish between simple benefits for description or representation and benefits for further analysis and evaluation of items or groups in a domain.

<b>Classification benefits for representation</b>	<b>Classification benefits for analysis</b>
Parsimonious description of items in a group; structured overview of a domain, reducing complexity of an area	Enabling new perspectives on a domain
Highlighting differences and similarities among items	Facilitating comparisons among items
Highlighting under-explored areas	Helping to understand relationships among items and groups
Presenting an exhaustive list of dimensions	Generating types as criteria for measurement and analysis
Inventory and management of types	Prediction of future instances of identified types

*Table 1:* A compilation of classification benefits

In spite of these numerous advantages, the classification approach has also been heavily criticized [Bowker, 98]. The primary risks associated with classifications are their tendency to: render concrete those things that are in short-term flux, long-term evolution, or poorly understood; and to reify things that are not so neat and tidy in the first place. Classifications may have an inertia that marginalizes alternative viewpoints and under-emphasize important attributes. [Chandra, 05] criticize the loss of information because of the generalization inherent in classifications. Classifications can also lead to framing effects. These effects limit creativity and “thinking outside of the box” (or rather “outside the tree structure”). A classification may lead to stereotypical thinking and false dichotomies.

How can researchers best profit from classification? How can they do so while avoiding drawbacks and pitfalls? One answer is to make use of the versatility and conciseness of visualization. In the next section, we explore this possibility and show how to use diagrams to develop and present research-based classifications. The adequate use of visualization can improve the quality of classifications and help to avoid frequent classification errors, such as: mixing levels of abstraction; switching classification principles; including unrelated items; attributing elements to the wrong group; or generating an incomplete classification system; to name but a few common shortcomings of research classification.

### 3 The Visualization of Classification

The visual depiction of groupings based on similarity can take on many forms and shapes. This ranges from traditional tree structures to elaborate logic or set diagrams (such as Venn or Euler diagrams). It can also include multi-dimensional scaling cubes and classifications based on parallel coordinate clusters. There are many two- and three-dimensional shapes that can be used fruitfully to make distinctions between groups and show how they differ. A key distinction is the one between *hierarchical differences* (based on levels of abstraction) and *relational aspects* (such as similarity or relative importance or size). Note that some visualization formats for classification are not so easily applied in the social sciences (such as cladograms that depict the evolution of an object, particularly a biological organism).

In our survey of visual classification formats, we distinguish between four kinds of visual representations found within the social sciences. These are based on the aforementioned distinction of whether (and to what degree) each visual emphasizes hierarchy or other relations among groups (see Figure 1).

- First, we have grouped those visualizations together that do not provide a hierarchic structure and do not emphasize relationships between elements or their groups. We label these simple groupings as *Compilations*, emphasizing the fact that they only provide a relatively unstructured compilation of items based on their similarity. Typical representatives of this group are the (two-by-two) matrix or a grid.
- *Configurations* is the label we have chosen for visualizations that do not provide a hierarchy, but emphasize (to varying degrees) relationships among groups or classes. A configuration is a particular arrangement of items that has an explicit structure which facilitates comparisons between items or groups, or shows some overall pattern among the groups. Typical forms in this group are Venn and Euler diagrams or structures that are based on a metaphor (such as a temple, ladder or puzzle) to convey an additional insight about the groups' relations.
- There are also groupings that only emphasize hierarchy which we label *Layers*. Simply put, layers group items hierarchically without showing additional relationships between the groups. The pyramid would be one simple example of visualizations in this group.
- The last set of classification graphics can be labeled as *Trees*. Trees show both hierarchy (in terms of levels of abstraction) and relationships, such as relative size of a group (as with a tree map) or closeness of groups (as with a dendrogram).

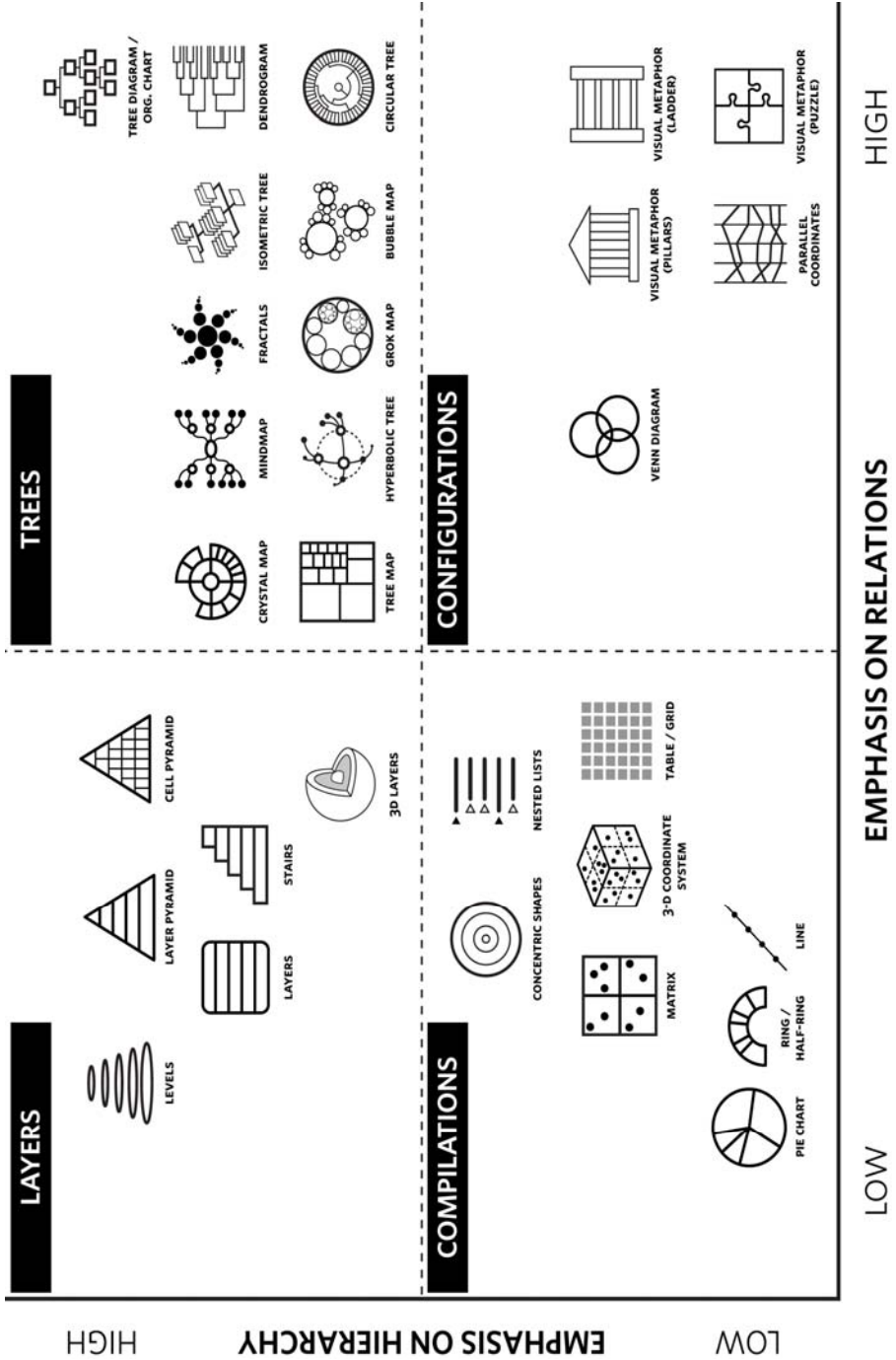


Figure 1: An overview on different graphic representations of classifications

The positioning of the different visualization formats in our framework is still tentative and ultimately depends on the actual use and adaptation of a graphic classification template to a particular research context. It should thus not be over interpreted or read with expectations of high accuracy. Nevertheless, the grouping provides an informative first segmentation of the various visual forms available to represent classifications graphically.

Deciding when to apply each of the four types of visual classifications requires a consideration of at least three factors:

The first factor is the *nature of the research* to be considered. For example, the analytical approach may be inductive or deductive, or the nature of the research observations may be qualitative or quantitative. Some formats (such as dendrograms) are useful for inductive, quantitative purposes, whereas others (such as matrices) may be more conducive to qualitative deductive work.

The second factor is the *type of classification scheme* involved. Certain research techniques lend themselves to particular classification schemes, and vice versa. A normative typology can, for example, be represented in a pyramid, while an empirical taxonomy could be first depicted in a multi-dimensional-scaling (MDS) cube.

The final factor is the choice of *visual technique* to be considered as it relates to the researcher's analytical goals. For example, the researcher may want to show an overview or focus on particular details.

The table below summarizes the key contributions of visualized classifications for each generic research step in the social science research process, and describes the benefits that can be achieved when visualizing classification in each phase.

<b>Research Phase</b>	<b>Benefit of Visualizing Classifications</b>
1. Exploratory	As in grounded theory, a visualized classification helps the researcher to detect and (re-) organize recurring patterns.
2. Error Detection	Visualized classifications can be used by different coders to detect and register errors.
3. Theory Development	Visualization helps the researcher determine whether a classification scheme complements the larger theory prior to the testing of that theory. It helps researchers draw connections between different theories and see differences and similarities.
4. Data Collection	Visualization can improve the collection process by helping researchers record observations in a way that complements human cognition.
5. Theory Testing	Identifying correspondence between data points and categories (and finding outliers) can be done more efficiently with visual methods that map or match data to a classification scheme.
6. Reporting	In many cases, visualization communicates a classification scheme (or research results involving the scheme) more efficiently and accurately

*Table 2: The role of classification visualization in different research phases*

#### **4 Limitations and Risks of Visualizing Classifications**

As with any analytical technique, there are limitations and risks associated with visualization in the classification context. Most of these risks are inherent to visualization, although a few are posed by common misuses or misunderstandings of visualization techniques. This list is by no means exhaustive. It is a list of some of the “marquee” risks and limitations that researchers ought to consider carefully.

<b>Risk</b>	<b>Explanation</b>
Reinforcing the reification fallacy/ fallacy of misplaced concreteness	Treating an abstract concept or classification scheme as a concrete, real entity is a type of fallacious reasoning. This is called the <i>fallacy of reification</i> or, using Whitehead's term [97], the <i>fallacy of misplaced concreteness</i> . Visualization can lead to greater risk of this fallacy occurring because it makes the intangible seem more tangible.
Reducing flexibility/locking in classifications	Visualization can potentially undermine the evolution of a classification scheme when the graphic does not easily accommodate adding, subtracting, and combining categories. A particular choice of graphic can also restrict expansion of a classification scheme because it is difficult to change the spatial dimensions (e.g., the length of a list) or spatial resolution (e.g., the density of points). A related problem is the premature visualization of a classification scheme that restricts flexibility before the classification is finalized.
The problem of visual forced-fitting.	When an established classification scheme encounters a novel instance that is not easily accommodated, it may be necessary to change the scheme. When change is necessary but a researcher insists on situating the new case within the inadequate scheme, it is called the <i>problem of forced fitting</i> . There is a case of forced fit that is specific to visualization: the situation whereby a novel instance seems to fit logically into a classification scheme but does not fit well within a visualization.
The problematic handling of miscellany in visuals	Many forms of visualization do not accommodate outliers very well, and may do much worse with large numbers of disparate outliers. In some cases, the choice of visual may result in the exclusion of outliers.
Trivialization and over-simplification	The choice for a specific graphic format may lead to neglecting certain aspects in the classification.
Misrepresentation of similarities or differences	A classification scheme may indicate something about the <i>degree</i> of within-group similarities and differences, or the degree of between-group similarities and differences. Yet, the corresponding visual may suggest something else about these similarities and differences.

Table 3: Potential risks of visualizing classifications

Considering these risks in the graphic rendering of a classification can consequently help to profit more fully from the aforementioned benefits.

## 5 Conclusion

In this paper, we have outlined the crucial role that graphic representations can play in the development, refinement, validation and communication of research-based classifications. We have given a tentative overview on possible graphic forms that can be used by researchers to construct or convey their taxonomies or typologies. We have also outlined how the functions of graphic representations of classification change according to the research step supported by them. Another contribution of our work has been the identification of key advantages and risks that come about through the use of visuals in this context.

One main implication of this paper is that we have articulated a re-classification imperative. That is to say, researchers should resist a premature closure in their choice of a graphic schema for their classification. They should keep their options open according to their ongoing observations and insights. Most importantly, we urge researchers to consider the benefits of visualization on the way that classifications are formed. While some visualizations invite the researcher to combine classification criteria (such as a matrix or a Venn diagram), they may also neglect to ask for different hierarchical levels. Conversely, some visualizations may emphasize a tree-like structure and neglect overlapping areas or groupings based on mixed criteria. The intent of this article is to sensitize researchers to these (often implicit) issues of graphic representation of classification. We acknowledge that our list of graphical forms is not exhaustive and is only a first step towards improving the way that classification graphics are used in the social sciences. We also acknowledge that our positioning of these forms along two axes (hierarchy and relationships) is a first, rough segmentation that must be subject to subsequent analyses and refinement.

In future research, we would consequently like to more systematically compare the different graphic forms for classifications (in terms of their respective functions and limitations) and describe their features more formally (such as their level of complexity, their biases, their affordances, etc.), as well as match them more accurately with different research scenarios or needs.

One feasible research method to do so could be performance experiments, where different groups of researchers need to make sense of the same data set, using differing visual templates for their classification tasks. The respective objective and self-reported measures could then be used to derive a performance- and task-based ranking of different visual schemas for classification.

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# Requirements for Diagrammatic Knowledge Mapping Techniques

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**Abstract:** Based on an analysis of existing tools and approaches and literature from the areas of design and cognitive science, we identify a set of functional requirements to be met by diagrammatic knowledge mapping techniques and tools in order to be cognitively adequate for extensive personal knowledge management. This collection of requirements can be used to evaluate existing tools or as a guideline for the design of novel knowledge mapping approaches and tools.

**Keywords:** visual knowledge mapping, personal knowledge management, interaction design

**Categories:** M.4, H.5.2, L.1.0, L.3.1

## 1 Introduction

Many struggle with maintaining orientation in today's ubiquitous information overload. Visual mapping techniques can be of help wherever outlining or structuring a topic is needed or where information is to be interrelated and an overview to be gained. This is often the case in self-directed learning or a closely related discipline, which has only recently gained researcher's attention: personal knowledge management. Especially in knowledge-intensive tasks it becomes crucial to unburden our limited working memory [Miller 1956]. This can be done through the use of cognitive tools [Lajoie 1993] and by shifting work-load to highly automated cognitive processes such as our sense of spatial orientation, because these automated processes do not hinder conscious ones [Shiffrin & Schneider 1977].

In order to clarify the scope of this paper, we will shortly categorize it within a the framework proposed by [Eppler & Burkhard, 2004], detailed in [Burkhard, 2005]. Firstly, "knowledge visualization" is distinguished from "information visualization". The latter usually deals with visually presenting typically large amounts of preexisting structured data (often stored in databases). There is a wealth of approaches and algorithms for information visualization corresponding to different data structures and properties – for an overview see e.g. [Shneiderman 2003]. However this is not our topic here. *Knowledge* visualization constitutes techniques that do not primarily visualize pre-existing structured data but knowledge, which a priori resides in people's minds. A detailed distinction between knowledge- and information visualization can be found in [Burkhard, 2005]. However we need to slightly widen their

definition of knowledge visualization here: They write “Knowledge Visualization examines the use of visual representations to improve the transfer and creation of knowledge between *at least two persons*” (p. 242, emphasis added). However, especially in the growing field of *personal* knowledge management, the intended “recipient” of a visual knowledge artifact is typically the author himself, who made a sketch to support his current cognitive process or who created a diagram to facilitate the recall of his own knowledge. As this appears to be a valid application of knowledge visualization techniques, we propose to drop this constraint and will expressly include this personal use case here.

FUNCTION	KNOWLEDGE TYPE	RECIPIENT	VISUALIZATION TYPE
Coordination	Know-what	Individual	Sketch
Attention	Know-how	Group	Diagram
Recall	Know-why	Organization	Image
Motivation	Know-where	Network	Map
Elaboration	Know-who		Object
New Insight			Interactive Visualization
			Story

Figure 1: The Knowledge Visualization Framework of [Burkhard, 2005 p. 245].  
Marked are the categories primarily focused in this work.

We have in mind the general use of diagrammatic knowledge maps, created by an individual modeling his knowledge in visual and more or less structured ways in the tradition of mind-mapping, concept mapping, knowledge mapping and the like (described below). As depicted in Figure 1, this focus can be categorized in the abovementioned Knowledge Visualization Framework as follows: The **purpose** (“function”) is primarily the structured externalization of knowledge in order to later Recall or better re-construct the knowledge from the visual artifact. However also the aspects of Elaboration and New Insight are touched by this as well as an important aspect that seems to be missing in the framework: serving as a thinking aid or cognitive substrate that unburdens the knowledge worker’s working memory. The **knowledge type** used in such artifacts would typically be “Know-what”, i.e. factual knowledge or keywords and concepts. As such knowledge maps can be rather flexible and generic (depending on the actual technique), also other kinds of knowledge could be used. Although the **recipient** of the artifact could be any number of people in principle, the use case we address is an Individual user dealing with her knowledge artifacts which are targeted either at herself or at others who share enough common context and prior knowledge to interpret the artifact. **Visualization Type**: Although the original approaches of our targeted field mostly have the word “map” in their name, they would in this framework fall into the category of Diagrams, where typically discrete abstract items are depicted with their interrelations. However also the category “Map” that in the framework refers to more geographically oriented techniques would be touched.

This focus implies two fundamental characteristics: (a) Structures are typically not homogenous: Instead of instances of a common schema, items are usually of varying or unspecified types and their interrelations are often also vague. (b) The actual items often do not carry all relevant information themselves but are rather used as *knowledge cues* in the sense of mnemonic devices: Because the actual knowledge in its full richness is only stored in the users' memory, and can not simply be externalized, it is in many cases sufficient to externally store and provide such cues to re-activate the original knowledge in the user's mind.

This article deals with requirements for diagrammatic knowledge mapping techniques as detailed above. It is about how to enable users to map and edit their own structured knowledge representations in a cognitively adequate way. Though it may be applied more generally, for this work we have use cases in mind, where a mapping tool is used to manage a potentially large and heterogeneous collection of information items, which can serve as a large personal knowledge repository.

From the 1970ies on, a number of visual mapping techniques has evolved, some of which have found wide-spread use and have proven their usefulness e.g. as learning aids in numerous studies. According to their basic topology, most of them can be related to the following three fundamentally different primary approaches:

**Mind-Maps** have a hierarchical model. Labeled branches and sub-branches are drawn extending from a single central node. Mind-Mapping is an established technique for brainstorming, outlining, note taking and clustering. The concept of Mind-Mapping has been made public by Tony Buzan [Buzan & Buzan 1996].

**Concept Maps** are nets. They consist of labeled nodes and labeled edges linking all nodes to a connected directed graph [Novak 1977].

**Spatial Hypertext** does not explicitly connect items at all. It is a rather academic approach not so wide-spread as the two above but well-researched and included here because of its purist design: A spatial hypertext is a set of text nodes that are not explicitly connected but implicitly related through their spatial layout e.g. through closeness and adjacency – much like on a pin-board [Shipman & Marshall 1999].

An overview over these and related approaches, their cognitive psychological foundations, studies about their effectiveness along with an evaluation of corresponding software tools can be found in [Haller 2003]. It contains a comparison of these approaches and 13 software programs for certain typical knowledge mapping tasks. From these results, related literature, personal use of such tools and some user-studies, the requirements described in the next section could be deduced. They can be used as evaluation criteria for existing visual knowledge mapping approaches and tools, but also as requirements for the design of novel ones.

The **Cognitive Dimensions** framework [Green 1989, Blackwell et al. 2001, Blackwell 2006] is a tool for designers of notational systems to reflect on certain crucial aspects of such systems. These dimensions were expressly not designed as a fixed set of recommendations but as a loose bunch of neutral dimensions, e.g. "Viscosity" (resistance to change). While definitely related work, not all dimensions are relevant here. Those, who directly correspond to our criteria are referred to in the respective section.

## 2 Requirements

We split these requirements in two parts: conceptual ones, directed rather at the general approach, and more technical ones, directed rather at concrete software implementations. Although some of these requirements may appear self-evident, none of them was fulfilled by all of the existing approaches and (mostly commercial) tools evaluated by [Haller 2003], and none of these fulfilled all of them.

### 2.1 Requirements for Visual Mapping Approaches

#### 2.1.1 Free Placing

The main point of visual knowledge mapping is to organize information spatially. For a user to be able to use his own cognitive map [Tolman 1948] for orientation in his information space, it is desirable that information objects can be positioned freely according to the user's preference. Items should also maintain their positions – at least relative to their surrounding – when the map is modified (e.g. extended), otherwise orientation by remembering positions will barely be possible.

#### 2.1.2 Free Relations

It has often been stressed how important it is for learning to interrelate information items [Ausubel et al. 1980] [Reigeluth 1983]. Also, one of the most important factors for being able to remember a piece of learnt information, is to successfully link it to prior knowledge. Thus it should be possible to link any item to any other one, and that in different ways – namely in different levels of formality:

**Formalized Links** are links that are typed with a standardized relation. Such fixed sets of standardized relations have been proposed e.g. by [Jüngst (1998)] and studied by [O'Donnell et al. (2002)]. Especially when the information in the map is to be processed by semantic technologies e.g. on a semantic desktop system [Sauermann et al. 2005], formally defined relation types need to be used. However the use of only formalized relations also limits expressivity and studies have shown that users often do not stick to defined meaning of these relations but rather use them like informal ones [Gaines & Shaw, 1995].

**Informal Labeled Links** often suffice, since the use of semantic technologies is often not needed. Thus it is important to be able to just draw 'normal' links and freely label them like it is done with the widely used method of concept maps.

**Unlabelled Links** e.g. in the form of plain arrows should also be possible since they often suffice for certain purposes and forcing the user to enter an explicit label would both increase his cognitive load and the visual complexity of the map. One of the reasons why Mind-Maps are so wide-spread and easy to use, is exactly that relations between nodes do not have to be specified. Also, [Wiegmann et al. 1992] have found out that users with lower verbal abilities can achieve better learning results with maps when using unlabelled links.

**Free Nodes** that do not have any explicit relation to other nodes and that can just be scattered around should also be possible e.g. for unobstructed brainstorming. Relations between items can always be implicitly expressed through their spatial

layout as in Spatial Hypertext [Shipman & Marshall, 1999] or added later in a separate step.

Thus: The mapping technique should allow the use of user-defined visual languages tailored to the domain at hand. It should support the use of such visual languages by facilitating the process of choosing pre-existing relation types. Using link labels not formally defined should be possible but clearly distinguishable. Using links and link labels at all should be optional.

The mark on Cognitive Dimension *Hidden Dependencies* should be low here, meaning that relationships between items should be easily visible. However always showing all relations might lead to serious visual clutter (e.g. what is sometimes referred to as the “spaghetti syndrome”). Thus it is desirable that certain relations might only get visible on demand (c.f. 2.1.4 Overview / Abstraction and 2.2.3 Focus / Filter).

### 2.1.3 Annotations

Annotations can be all sorts of marks or notes that strictly speaking do not belong to the actual content. They can be used for highlighting e.g. through marking a certain area with color. They can also just be text notes carrying additional information like explanations, details or personal remarks that do not belong to the map itself. For reasons of clarity, it should be possible to hide and show annotations on demand. When an annotation is currently not visible, its existence should still be hinted at in order to avoid it to fall into oblivion. Such annotations would rank as *Secondary Notation* (extra information in means other than formal syntax) in the Cognitive Dimensions framework.

In many software programs, text annotations are shown in an area separate from the map. However this has three disadvantages: (1) The space for that is usually occupied even when no annotation is shown – this wastes valuable screen space. (2) Only one Annotation can be seen at a time. (3) Because of the “split attention effect“, additional cognitive effort is needed to connect the annotation with item it refers to, compared with showing annotations in the immediate vicinity of the corresponding items [Chandler & Sweller, 1992]. To avoid that, annotations should either be placed in the direct vicinity of the items they refer to, or visually linked to them e.g. by a connecting line [Mazarakis 2009].

### 2.1.4 Overview / Abstraction

Especially when maps are used extensively, e.g. for personal knowledge management, the issue of overview gains major importance. [Ben Shneiderman’s 1996] famous “visual information seeking mantra” that he found to be globally relevant in visual information systems goes: „*Overview* first, zoom and filter, then *details on demand*“. A central aspect of getting an overview over something and seeing its overall structure, is the ability to abstract it into clusters. *Abstraction* is also one of the core Cognitive Dimensions. The mapping technique should support to arrange items in levels of hierarchy in a way that when large collections of items are displayed, their macro-structure becomes salient. To that end, the technique should support to not only express fine structure (relations between single items) but also content structures on higher levels of abstraction, e.g. between groups of items:

**Clustering** – From cognitive psychology of memory, clustering or “chunking” is known as the fundamental classical way to make large amounts of information items manageable for our limited capacity working memory [Miller 1956, Anderson 2005]. Translated to visual mapping, this means a technique should allow to cluster several items into a chunk. This can be done implicitly e.g. by arranging them according to gestalt principles [Metzger 1953], or explicitly in a way that a number of single items are assembled as sub-items of a group. Such a group would then itself be *one* item that from a higher perspective can be treated as a unit. Like this it becomes possible to have *single* links or annotations referring to *multiple* abstracted items e.g. to a complete process that “inside” is represented through several items.

**Sub-Maps** – Taking this principle of clustering to the next level, and regarding whole maps as clusters, we get to arranging whole (sub-)maps in superordinate (meta) maps. And for three reasons, these sub-maps should not just be referred to with a hyperlink but actually integrated in the superordinate map: (a) They can be recognized visually by their unique form rather than by words, which is more appropriate since maps are visual artifacts. (b) Like that it is possible to represent not only links between whole maps but also from or to single items across maps. (c) The user can zoom into and out of detailed regions (sub-maps) coming from an overview perspective so to visually integrating these details with their more general context – much in the sense of the zoom metaphor in [Reigeluth’s 1999] elaboration theory of learning.

### 2.1.5 Scalability

If a knowledge management technique is to be applied to whole knowledge repositories, e.g. as a personal knowledge store, it has to be conceptually fit to handle large numbers of items. Successfully used in this area are usually non-visual systems like Niklas Luhmann’s “Zettelkasten” (German for slip box, a system of cross-referenced paper cards) or today’s wikis that have found quite wide-spread use in recent years. Unfortunately, it is very hard to gain overview over such collections because in these approaches only one item is presented at a time and only its cross references (links) lead to connected items. To combine the scalability of these approaches with the overview of visual ones, zooming-based methods would be an option.

## 2.2 Requirements for Visual Mapping Software

While the above criteria mainly referred to mapping techniques as such, the following are directed rather at concrete software implementations. They are about human factors and specifically about avoiding cognitive overhead, i.e. all cognitive load of the user that is not directly related to the actual content but rather to dealing with the software as such. In knowledge-intensive activities, this is even more crucial than otherwise, in order to leave as much of the user’s limited working memory [Miller, 1956], to the actual task at hand. For the user to be able to fully concentrate on a map’s content, the software should aim to relieve him of all actions not directly related to the content. Operating the software should in general not involve more interaction than absolutely required.

### 2.2.1 Simple Editing

This refers to the Cognitive Dimension *Viscosity* (resistance to change). In order to support reuse and elaborative maintenance of a knowledge model, the mapping system should have a low viscosity, i.e. it should be easy to make changes in the artifact:

**Brainstorming** – To easily and quickly capture thoughts, it should be possible to add a new item with one single (or double) mouse click or one key stroke. The label should then be entered without any further intermediate steps. Multiple keywords (or sentences) should be entered in succession, separated only by a single Keystroke and recognized by the software as separate items, that can later be refined or have more structure added.

**Extending Maps** – To be able to elaborate or extend existing maps, it should be possible to add new items in any position. Specifically for approaches that support free placing, this may not be trivial, since there might not be enough space initially. Here, the software should aid the user as good as possible e.g. in rearranging existing items in the immediate vicinity to make way for the additional ones. Hereby it is important, that the existing items maintain their relative positions at least roughly, so they still correspond to the initial layout and thereby to the user's cognitive map.

### 2.2.2 Connecting External Content

Many external knowledge resources are electronically available – locally like files or remotely like web pages. For these it should not only be possible to be *referred to* from a map – like maybe a paper book, they should also be *accessible* from the map, and thereby from their thematic context. This can be done at least by hyperlinking to them, which would still impose a context switch on the user, when the referred media would open in an other viewer (e.g. a web browser). Because every context switch causes cognitive overhead, ideally they should be avoided – as technology permits – by integrating appropriate viewers into the mapping software. Like that, external visual media (like pictures, web pages, documents or even videos) can be viewed in context.

### 2.2.3 Focus / Filter

The second point in [Shneiderman's 1996] information seeking mantra, “zoom and filter”, addresses the process of deliberately narrowing the focus to the essential. A mapping software should allow to filter out contents that temporarily are not of interest, to avoid distracting the user with unnecessary complexity. This can happen in different ways: in the sense of adjusting a focus, where the unfocussed becomes hidden or reduced, or in the sense of filtering, where objects are faded in or out due to certain properties they carry. Reducing the display to the essential increases the Cognitive Dimension *Visibility*.

### 2.2.4 Integration of Detail and Context

[Reigeluth's (1999) elaboration theory of instruction stresses the importance of putting new contents into context before going into details. These acts of orientation, of integrating details into their context, can place a challenge especially when dealing

with large or complex collections of information [Furnas 1986, Thüring et al. 1995, Chimera & Shneiderman 1994]. For a mapping tool that means: How can the user be supported in not losing the context while dealing with details of a map that is too large to fit on one screen?

**Zoom** – An answer to that is a smooth zooming function. Smooth means continuous, and steady, because when the picture jumps too fast, or in big leaps, visual continuity is lost and reorientation is required by the user. The same holds for scrolling and panning. These smooth transitions come closest to what our sense of spatial orientation is made for in real life, where we get a continuous coherent visual stream while physically changing perspectives, approaching details or take a step back from something to see it in its context. Moving in the map should be similar to moving in natural environment, because only automated processes not interfere with controlled ones [Shiffrin & Schneider 1977].

**Big Picture** – A side-effect of zooming is that when zoomed in on an area, its visual context is lost. To get back to an overview perspective, additional navigation might be required. This interaction effort to reach an overview perspective and come back to the details at hand should be reduced to a minimum.

**Levels of Detail** – Like described above, it can be helpful to fade out information that is currently not of interest. However to maintain the context, it might be better to still show some or all surrounding items, but in a less detailed way in order to avoid unnecessary complexity and waste of screen space [Chimera & Shneiderman 1994]. In this approach, initially the whole greater context is visible and details are only revealed on demand. When applied to mapping techniques, overview can be improved by letting the user choose the level of detail of each area. Like that, e.g. the essential elements of a (sub-) map can be made more salient by fading out the lower details. “Details on demand” is also the third part of [Shneiderman’s 1996] mantra.

To relieve the user of this manual adaptation of levels of detail, this can also be done automatically using a degree-of-interest function based on the current focus. For this approach the term “semantic zoom” has been coined. There are even more approaches to the integration of detail and context [Simpson 2001], e.g. so-called fish-eye views. However most of them are still in a state of research prototypes. At least some means of adjusting levels of detail should be supported by every mapping tool.

### 2.2.5 Interoperability

Most people already use other existing software for various aspects of their personal or organizational knowledge management, or will do so in the future. Also, different tools are suited for different tasks, which are usually interrelated across types and modalities (like an e-mail can be related to a process described in a map and an event that represented in a calendar). Because of that, mapping tools, like personal knowledge tools in general, can increase their usefulness greatly by allowing the interchange of content with other such tools. This can happen in various ways, e.g. by connecting to interfaces of existing tools, by using file formats like xml that are easy to process by third parties or even through the use of semantic technologies, which even allow interchange on the level of concepts and meaning.



### 3 Conclusion

Based on an analysis of existing tools and approaches and literature from the areas of design and cognitive science, we have identified requirements and functionalities of an ideal visual knowledge mapping technique and corresponding software. While, depending on the point of view and the concrete goal, this list might have to be extended, we think it can serve as a pragmatic set of criteria to be used to compare existing tools and methods or to be taken as a basis for the design of novel mapping techniques. Actually bringing all these requirements together and implementing them still poses a great challenge of course. Also a final evaluation of such novel approaches and particularly of the claim, that the sophisticated recombination of elements from existing approaches is really more effective, can only be done with concrete implementations and thorough user testing. With “iMapping”, [Haller & Abecker 2009] have already introduced such an approach the design of which has been based on these requirements. Its technical implementation is currently being finalized and evaluations are being carried out. First evaluation results (that are currently still in the publication process) where an iMapping prototype has been tested against the market leading mind-mapping application “MindManager”, seem to encourage this design.

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## Patterns of Shape Design

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**Abstract:** A fundamental problem in processing 3D shapes is insufficient knowledge engineering. On the one hand there are numerous methods to design and manufacture 3D shapes in the real world. On the other hand, numerous digital methods for representing and processing shape have been developed in computer graphics. Most of these methods make certain assumptions about the kind of 3D objects that they will be used for: A surface smoothing algorithm, for instance, is not well suited for assemblies of rectangular blocks or for pipe networks. However, it is currently not possible to *formulate* the properties of a given shape explicitly in an commonly agreed way.

This paper is a first step towards classifying structural descriptions of man-made shape. By listing construction principles and principles for their combination it follows a phenomenological approach. The purpose is to illustrate the inherent complexity of the domain, and to lay out the foundation for subsequent thorough knowledge engineering.

**Key Words:** shape semantics, design patterns, shape design, man-made objects

**Category:** I.2.4, I.3.6

### 1 Introduction

The goal of this article is to prepare the grounds for semantically richer methods of describing the properties of 3D shapes. It is necessary to build a sustainable bridge between the fields of *knowledge engineering* and *shape processing*.

Shape processing algorithms typically make implicit assumptions about the properties of a shape. The signal processing approach to surfaces, for instance, understands surfaces as 2D signals, and *frequency bands*, i.e., high- or low frequencies of a surface, are important concepts. *Symmetry detection* algorithms reveal the structure of architectural buildings, some can even deal with deformed bodies of humans or animals. *Instance detection* algorithms find identical objects and sub-objects in unstructured triangle meshes (more examples in sec. 2).

These *shape analysis* algorithms can identify detailed shape properties. This could deliver important information for subsequent *shape processing* by using a markup facility for explicit description of shape properties. However, the analysis algorithms suffer from the inability to store their results in an explicit way.

It would be very useful to have a more sophisticated and differentiated *shape vocabulary* for describing semantic properties: shape algorithms could be applied to only those parts of a heterogeneous 3D model that they are designed for.

The dominant method today for describing shape is as a list of low-level geometric primitives, i.e., point clouds or triangles for sampled (scanned) surfaces, or parametric surfaces like NURBS or spline patches in industrial applications. These geometric primitives have no semantics attached: Sophisticated reverse engineering is necessary, e.g., to determine that a given “triangle soup” describes in fact a pipe network, a collection of boxes, or a bent sheet of metal.

An idea for solving this situation came from the observation that there are not all too many fundamentally different ways of manufacturing man-made shape.

### 1.1 Motivation: Design Patterns

The original motivation for this paper came from a seminal book in software design, *Design Patterns, Elements of Reusable Object-Oriented Software* from the “Gang of Four” (GoF), Gamma, Helm, Johnson and Vlissides [GHJV95]. It is based on the observation that experienced programmers tend to think in certain patterns when solving complex software design problems. The GoF names 23 patterns, 14 of which have become really standard since 1995 – and hundreds, if not thousands of more specialized patterns have been developed since then.

Some interesting parallels exist between software design and shape design. Shape professionals also need to solve the complex design problem of conceiving a 3D object in a way that it (i) fulfills its functional specifications, (ii) can be manufactured, (iii) is physically sufficiently stable, (iv) aesthetically pleasing, and (v) not too expensive. In addition to their creativity they have a certain pool of proven methods and techniques that they can apply and combine to reach these goals. Consequently, all man-made shapes exhibit a certain regularity. Our hypothesis is that most of the abundant variety of existing shapes is created using only a limited set of fundamental shape design patterns.

Just as is the case with software design patterns, the value of shape design patterns would be to facilitate the communication about shape. The idea is to replace the current technology-driven by a purpose-driven shape terminology: Instead of technical concepts like voxel spaces, moving least squares or adaptively sampled distance fields, well known in the graphics community, one could emphasize, and express, the difference between cast, forged, and milled shapes, or the pros and cons of class-A design versus block design. Consequently, the pre- and post-conditions of shape processing algorithms, of shape conversion and retrieval, could be formulated in purpose-driven terms.

We would like to use *shape-related ontologies* to make the fact explicit that, e.g., a concrete shape (Cheops pyramid) is one instance of an abstract shape

family (four-sided pyramid). The great challenge is that a universal shape ontology must in fact be very elementary and basic: To be more generally applicable than any domain-dependent ontologies, it must consequently be amenable to and useful for non-experts, i.e., for ordinary human beings from all cultures.

## 1.2 Conjecture: Shape Design is Rule Design

A simple experiment reveals how constrained the capacity of human beings to design shape really is: The task is just to *take a pencil and to draw about two dozen points on a blank sheet of paper*. The proband may choose to arrange the points in any way he or she likes. – One might think that the outcome of the task is pretty arbitrary. However, it is not; Fig. 1 shows some typical results.

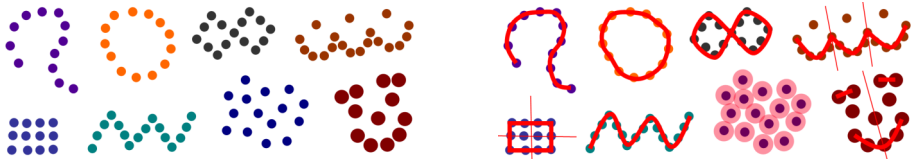


Figure 1: The **place-the-dots** game. Left: Typical “arbitrary” dot patterns produced by average humans. Right: Underlying design principles.

The proband apparently immediately designs a rule, rather than only one shape. It is obviously a good idea to partition the obtained designs into classes of similar basic patterns. This leads to the conjecture that every human-designed shape is inevitably an instance of a more general shape class with many variations. The “variation directions” correspond to the dimensions of the shape’s design space. In that sense, designing a shape inevitably means in fact designing a rule.

## 1.3 Determinants of Shape Design

A taxonomy of shape design methods must take into account the following factors that influence the shape of a physical object:

- **Design intent** subsuming function, purpose, semantics, meaning, significance: A pillar and a pipe have different meanings but are both cylindrical. Very different objects can have the same shape.
- **Planning tools** and their expressiveness limit the space of realizable objects: Things that can not be planned can not be built. Things that are easier to plan are more likely to be built.
- **Fabrication constraints** determine which of the ideas and plans can be transformed into real-world objects in a commercially viable way.

The interplay between those factors is complex. Intelligent design solutions can turn fabrication constraints into stylistic features: timber framed buildings, romanesque churches and roman aqueducts are examples of styles also resulting from limitations of fabrication technology. These limitations also influence the *space of conceivable shapes*: Shape professionals obviously do not waste their time conceiving shapes that will never be realized.

## 2 Related Work

Ontologies for shape processing have so far primarily followed a part- or feature-centric approach. A larger initiative pursuing the vision of *shape ontologies* was the Aim@Shape project, a FP6 Network of Excellence funded by the European Commission [AIM06]. It was inspired by a school around Bianca Falcidieno and Michela Spagnuolo. They propose, e.g., in the context of shape retrieval, the notion of a *shape prototype* represented as attributed graph with nodes containing descriptors for local shape features, so that searching can be mainly reduced to graph matching [BMSF06, MSF07]. Albertoni et al. [APP<sup>+</sup>05] present the Aim@Shape *Digital Shape Workbench* framework for shape search with domain-dependent ontologies. In this spirit Camossi et al. [CGM07] present an ontology for the functionality of shapes with derivations, e.g., of the following kind:

Product  $\rightarrow$  Functionality  $\rightarrow$  FunctionalArea  $\rightarrow$  FormDescription

FormDescription  $\rightarrow$  ( PatternInfo, HoleInfo, StabilityInfo, SymmetryInfo )

The functionality is derived again from shape decomposition into features such as convex or concave areas or tubular areas, etc. Cheutet et al. [CCG<sup>+</sup>06, CLC<sup>+</sup>06] (also Aim@Shape) support the shape design process with domain-dependent ontologies. Their 2D sketching tool “knows” about the typical feature lines of a car, so that user can assign a meaning to a 2D sketch, which is further processed using a shape grammar. An interesting approach for the simplification of large CAD models ist presented by Posada et al. [PTWS05]. They use ontologies to generate different views on a given model, e.g., for an engineer or for a management person. This requires the recognition of shape parts, e.g., tube structures or connectors, which are replaced by simplified parts, left away, or shown in detail to generate the different views.

In contrast to these feature-centric approaches we aim at a procedural description of shapes, taking into account the assembly and manufacturing process. In any case the goal is to find atomar shape building blocks. However, we argue that shape features (*convex part*) or CAD features (*bore hole*) are generic but may be too fine-grained, whereas functionality (*gearbox*) is too coarse-grained, and in fact a domain-dependent interpretation. Shape design patterns might be a reasonable view in between low-level local features and high-level functionality.

### 3 A Catalogue of Patterns of Shape Design

The following list of shape design patterns is not a true taxonomy: It is reasonably comprehensive, but it is still incomplete. It is partly overlapping, and it provides no hierarchy of sub- and sub-sub-methods. There is also no distinction between generic principles, used by humans since ages, and technical fabrication methods; most patterns have both aspects. – They are still very useful because (i) they are elementary, and (ii) they reflect the complexity of shape design.

#### 3.1 Block Pattern

Arrangement of primitive objects from a fixed set of combinable prototype building blocks, usually rectangular boxes, but often also cylinders, spheres, cones etc. Objects may touch but do not intersect, and they are typically aligned (grid).

**Examples:** LEGO, brick walls, toy bricks; overall structure of many buildings

#### 3.2 Bending Pattern

Flat, connected sheet (or wire) of material which can be bent smoothly (or sharply), but can not be stretched. Mathematically, bent sheet are *developable surfaces*, any surface point has one tangential direction with zero curvature.

**Examples:** Paper craft models, bent sheet metal, but also strip of flat panels

#### 3.3 Trimming Pattern

Trimming is cutting a hole out of a (possibly curved) surface, or just marking a potential hole. The boundary of the hole is called *trim curve*. The trim curve may be defined implicitly, e.g., from two 3D objects overlapping in space.

**Examples:** Sewing patterns for dressmaking, blanking, punching, hole cutting

#### 3.4 Tubular Design Pattern

A tube is basically a curve in space with constant thickness (radius). A pipe is hollow inside, requiring also an inner radius. A more general sub-type with variable cross section profile is called *sweep* or *generalized cylinder*.

**Examples:** Scaffoldings, pipe networks, support structures of freeform buildings

#### 3.5 Layer Pattern

Multiple layers of different materials, or of materials in different orientations (*anisotropic materials*), stacked on top of on each other. Layer thickness can range from thin to thick, but it is mostly constant over the covered region.

**Examples:** Ply wood, multi-layer walls, material deposit; pearl, tree bark



### 3.6 Pressure Pattern

Deforming a piece of material by strong force, temporarily or permanently. Can be done with positive and negative forms (dies). They may affect one side only to inscribe a pattern (coining). Not meant: Trimming or injection die casting.

**Examples:** Pressing car parts, like engine hood, from sheet metal; crash test

### 3.7 Repetition Pattern

An object or operation is repeated over regularly spaced intervals. Very general principle, can be just 3D copy-translation-paste, or a multi-stage industrial manufacturing process applied in regular intervals to a workpiece. Typical is linear repetition, but it can also be applied along a curve (circle: radial repetition). Sub-types of repetition are 1D curved sequences and 2D grids or tilings.

**Examples:** Garden fence, stories and windows in a facade, holes in a ventilation grille, tongue-and-groove panels; stairways of all kinds; car rims

### 3.8 Symmetry Pattern

Right and left parts become congruent when a reflection operation is applied. Often uses a straight symmetry plane, but can also be more general: Deformed body, point/radial symmetry. Symmetries can be nested (double symmetry).

**Examples:** Building facades, furniture, ornaments; animals; road pavements

### 3.9 Material Removal Pattern

Taking away material successively, e.g., by means of a moving tool. This has a volumetric aspect when much material is removed, e.g., with deep intrusion, and a finishing aspect when the surface is modified only slightly.

**Examples:** Sculpting a statue using a chisel, milling a shape out of a block; machining (metal), grinding, abrasive cutting; drill hole, bore hole, digging

### 3.10 Erosion Pattern

Material is displaced under the influence of a constant force or a material stream acting on the surface. This has a smoothing effect in that peaks and spikes are flattened out, and ridges and grooves are successively filled with material.

**Examples:** Erosion of mountains under the force of weather and gravity

### 3.11 Local Growth Pattern

A surface continuously deforming outwards forming bumps or elongated structures. May be repeated on smaller scale to form a network of branches. Although usually continuous, it can be conceptually seen as a local replacement operation.

**Examples:** Animal growth, plant growth, growing street networks in a city

### 3.12 Fair Surface Pattern

Highest-quality curved surfaces, often visibly exposed, with elaborate finishing. The curvature must vary smoothly, without jumps or creases (scale dependent), but may incorporate feature lines (*creases*). Fair surfaces are usually subject to design considerations, requiring visually pleasing shadow lines and reflections.

**Examples:** Visible parts of consumer goods; hulls of cars, ships, airplanes

### 3.13 Clothoid Pattern

Curve segments with smoothly (linearly) increasing (or decreasing) curvature are used in road and railway design. Prototype is the spiral, special case is the circle. Also used as section curves for curvature control in high-quality surfaces.

**Examples:** Curves that allow turning the steering wheel at constant speed

### 3.14 Sectional Design Pattern

Section curves are typically drawn on a set of parallel 2D planes in space. Consecutive sections are connected with a smooth surface (*lofting*). For controlling complicated free-form surfaces, also planes in arbitrary position are used.

**Examples:** Architectural and engineering drawings (front, side, top); ship hull design, aircraft wing design; computer tomography

### 3.15 Extrusion Pattern

A surface part is cut out and lifted (*trimmed offset surface*), and the sides are closed by a side strip of constant width. The extrusion height can also be negative (*inset*). Extrusions can be very long, so that the side strip is dominating.

**Examples:** All kinds of profiles; aluminium profiles, double-T-beam

### 3.16 Casting Pattern

Filling a prepared cavity (negative form, *mold*) with liquid material that solidifies. The mold is removed by destruction, or it is opened and pulled away (may be complex), which severely constrains the shape (3° demolding angle etc.).

**Examples:** All plastic parts of consumer goods; cast metal, cast concrete

### 3.17 Suspension Pattern

A suspension shape is formed by elements only subject to tension, not compression or bending. A hanging flexible chain forms a *catenary*. An inverted catenary is the arch shape with zero shear forces between stones. A suspended thin surface is deformed only by gravity and by the outward pulling forces at its boundary.

**Examples:** Suspension bridges, tents, tensile architecture, bicycle wheel

### 3.18 Forging Pattern

Successive local deformations by means of a hammer. Forging reduces thickness, so it always starts from a more compact shape to obtain a more stretched out shape. Localized pressure design, with greater control and design freedom.

**Examples:** Wrought iron fences, gates, rivets, and chains, goldwork, gold foil

### 3.19 Congealing Fluid Pattern

Locally modifying the solidification of a fluid (or the melting of a solid) by applying force (pressure), temperature, electricity, or chemicals. The resulting surface is very smooth and resembles that of a viscous fluid.

**Examples:** Lava, dripstone, glass blowing, soldering

### 3.20 Lathe Pattern

Material is successively removed from a spinning block using a fixed (but movable) cutter. The result is a *surface of revolution*, i.e., a 2D curve rotated around an axis. Material can also be added to obtain such a revolved shape.

**Examples:** Knobs, table-legs, decorated bars, everything that needs to spin with precision, but also pottery (potter's wheel)

### 3.21 Design by Similarity Pattern

A shape is designed by taking another shape as model. The source shape is not simply copied, but adapted to new requirements. Used to create a new member of a shape family, or to adapt a shape to look as if belonging to that family.

**Examples:** All doors look alike, hidden doors resemble the wall; the Atomium (Brussels) looks like an atom, the Cheops pyramid resembles an ideal pyramid

### 3.22 Motion Path Pattern

A shape is determined by the necessity of another shape to be able to move. The free space is often formed by the moving shape in all its allowed positions. A shape may also constrain a motion, so that only allowed positions can be taken.

**Examples:** All doors, drawers, elevators, vehicles; rails, moving rods, hoists; roads, pathways, corridors; all assemblies that allow dis-assembly

### 3.23 Offset or Frame Pattern

A fixed-width strip runs along the boundary of a shape, like a frame or a band. The strip can be realized in various ways. At corners, it may join sharply (miter, angle bisector) or rounded. This pattern is often used together with extrusions.

**Examples:** Frames and framings, decorative profiles, front sides of furniture; pavement around a building, or along a road

### 3.24 Edge Decoration Pattern

Visual emphasis of an edge by applying a profile, from simple bevel to a doubly-curved cyma (applied using a router). Even more complex are decorative mouldings in architecture with concave profiles and repeated ornamental decorations.

**Examples:** Beveled, chamfered, rounded edge; waterfall, bullnose, triple edge; Cavetto, ovolo, cyma, ogee molding; Kyma ionico, rope profile, meander

### 3.25 Clay Pattern

Deforming a homogeneous material with high plasticity. Volume is preserved, but may also use cutting and coalescing. The shape can be deformed using a wide range of *clay modeling tools*, but also with bare hands (low precision).

**Examples:** Initial stage of designing industrial shape; artwork; clay huts

### 3.26 Weaving Pattern

A flexible band (weft) is interlaced horizontally with vertical support bands (warp), alternatingly one being in front of the other. The resulting structure can be quite stable. Very complex spatial weaving or knitting patterns are possible.

**Examples:** Knitting, textiles, shape weaving; baskets, woven furniture (Rattan); rebar grids for reinforced concrete; braiding, to wattle hair

### 3.27 Hollow Shape Pattern

The shape of an empty space is often carefully designed, since solid objects and free space complement each other. Architectural design often starts in fact by designing the empty space, and to successively group solid objects around it.

**Examples:** Rooms, corridors, halls, cavities, air ventilation

## 4 A Catalogue of Composition / Decomposition Patterns

Real-world objects are typically designed using not a single, but a combination of multiple design patterns, possibly employed on different levels. The overall shape might follow a different pattern than detail solutions on a smaller scale. In fact, when performing the exercise of decomposing a number of real-world objects into the patterns used for designing them, one will quickly realize that the combination of patterns itself follows certain patterns. Some of these *composition patterns* are presented in the following. – Note the parallel to the *pattern of patterns* in software design introduced by the GoF [GHJV95].

#### 4.1 Style Pattern

A style is a preset of design decisions to make sure that similar design problems are solved in a similar, consistent way. A style is typically a collection of distinctive patterns that allow various ways of combining them (*style elements*).

**Examples:** Greek style, Romanesque style; ionic, doric columns; timber frame style, Art Deco; Gothic style allows constructions only with compass and ruler

#### 4.2 Partitioning Pattern

For functional, technical, aesthetic, or manufacturing reasons it can become necessary to split up a larger shape into smaller separate pieces. The gaps between the parts is typically filled in a systematic way, e.g., using the seam pattern.

**Examples:** Doors and windshield of a car are separate pieces, but conceptually they form part of the seamless car's exterior design surface; a computer mouse should fit the natural shape of the hand, but it is not manufactured as one part

#### 4.3 Seam Pattern

Direct connection of separate shapes along a common edge or boundary. For functional, technical, aesthetic or manufacturing reasons it may be necessary to connect separate parts tightly. A special case of a seam is a visible gap (*interstice*) that is kept intentionally, e.g., around a car door.

**Examples:** To sew, weld, bind pieces together; basted, bevel, bond, and brazed seams, also building seams; connecting overlapping metal sheets with bolts

#### 4.4 Blend Pattern

A transitional shape connecting two or more separate shapes. A smooth blend matches neighbouring shapes as seamlessly as possible (*tangent-, curvature continuity*). A decorative blend detracts from a crack by emphasizing it. A concealing blend continues the structure of the surfaces to become indistinguishable.

**Examples:** Stucco blends between wall and ceiling; a rolling-ball blend connects smooth surfaces with tangent continuity; separate walls can be seamlessly blended by applying the identical plaster to them and to the blend

#### 4.5 Assembly Pattern

Agglomeration of separate pieces that are designed to fit together. Pieces are joined permanently (gluing, welding), or non-permanently (screws). Special case are articulated assemblies (mechanisms) with parts designed to move.

**Examples:** All machines, almost all industrial goods

#### 4.6 Penetration Pattern

One shape gives way for another, physically or just conceptually. Physical penetration requires removing a part of one object, or of both (creating an aperture, cutting away some part). Conceptual penetration occurs when a part of a shape looks like a separate shape, or as if it was part of another shape.

**Examples:** Holes for pipelines, power lines, supporting beams, downpipes; elevator shafts, staircases; openings, passageways, undercrossings; woodworking joinery, e.g., dovetail joints to connect wooden boards

#### 4.7 Guiding Structure Pattern

Often a larger conceptual shape is not realized directly as one physical object, but it is employed only as a guide for the placement, orientation, and alignment of smaller structures. In many cases a reduced, more abstract underlying shape is used for designing or dispersing numerous concrete shapes.

**Examples:** Overall shape of a building, car, machine; U- and L-shaped buildings; stadium, amphitheatre; bricks forming a curved wall; graph of street network; often perfect mathematical shapes are used as model for an (necessarily imperfect) physical shape; example: circle vs. round arch, also Cheops pyramid; geometrical gardens (French Renaissance), tree shaping, shrub shaping (*topiary*)

#### 4.8 Systematic Variation Pattern

A set of shapes that are all different but share major design features. One reason is to obtain a coherent appearance but to avoid simple copying, another is changing purpose. A simple case is repetition with systematic parameter variation (width, height), but variations can also be much more complex and subtle.

**Examples:** Garden fence with planks of different lengths so that ends form a curve; story variations in a decorated facade; areas with homogeneous building styles; the off-road version of a family car; Gothic windows with *window tracery*

#### 4.9 Hierarchy of Shape Design Patterns

Decomposition of a large complex object into sub- and sub-subparts, according to functional, technical, aesthetic, or manufacturing criteria. Each part can employ its own pattern of shape composition (inner nodes) or shape design (leaves). This yields a *part-of* hierarchy created either in a bottom-up fashion (aggregation), or top-down (decomposition); in practice often a mixture is used.

**Examples:** Aircraft carrier, oil platform, space station; engineers, and also 3D artists, work in a coarse-to-fine manner, from overall shape to small-scale detail

#### 4.10 Hierarchical Replacement Pattern

Schematic shape hierarchies can be described using symbols and replacement rules (*shape grammar*). Every shape carries a symbol, and rules specify how a shape with one symbol is replaced by sub-shapes carrying other symbols. Often the union of the sub-shapes occupies the same space as the replaced symbol.

**Examples:** Floor layout, facades of buildings; urban land use; aircraft design

### 5 Conclusion and Future Work

We have performed the tedious exercise of analyzing the structure of numerous real-world shapes, and compared them with manufacturing technologies and geometric modeling methods. As a result, we have identified a set of 27 patterns of shape design and 10 shape composition patterns.

The patterns are designed to be as universal and generally applicable as possible. Their claim is that they are immediately understandable by basically everybody. This is an important step towards making also *shape ontologies* readily understandable and, thus, to support their proliferation in mass market compatible standards, applications, and file formats.

However, this exercise was just the beginning since the patterns now have to prove their expressive power in practical applications, for example:

- **Case studies in shape analysis**

More experience must be gained in applying the pattern scheme. A major challenge is ambiguity: A stairway may be seen as a sequence of individual stairs (repetition), but it may also be seen as massive block of cast concrete.

- **Formal ontology for shape design patterns**

Some formalization is needed to make the scheme amenable to algorithmic processing. It may be difficult to map it to standard ontologies because of its procedural and parametric nature, and the interdependencies and ambiguities.

- **Recognizing the function of a shape**

The stability of an armchair may come from carved wood, welded metal tubes, or injection-cast plastic. Seat and armrest, however, are smooth, finished surfaces of a certain size; so design patterns may indicate the function of a shape.

- **Shape editing by pattern correspondance**

Once the used patterns are identified, they can be edited or replaced. A sequence or a grid can be replaced by another, seams by bonds, assemblies by cast solids. A smooth surface can guide a curved grid, or vice versa.

We hope that the shape design patterns inspire a new *decompositional* view on everyday shapes around us, one that keeps asking: *How is this thing made?*

## Acknowledgement

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## **ChainGraph: A New Approach to Visualize Shared Properties in Resource Collections**

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**Abstract:** Common graph visualizations tend to produce edge crossings and overlaps when used to display resource collections that are highly interrelated via shared properties. This hampers visual exploration and understanding of relationships between resources and can negatively affect information and knowledge management. In this paper, we present a new approach that visualizes resources and their shared properties in chains to prevent dense graphs and to better support the exploration of relationships. We explain the basic idea, describe an appropriate algorithm and discuss optimization issues. Furthermore, we report on a comparative evaluation showing that this kind of graph visualization supports particularly the visual tracking of relationships and the identification of commonalities between resources.

**Key Words:** graph visualization, resource collections, information management, shared properties, relationship discovery, interrelated resources, chain arrangement, visual exploration

**Category:** H.3.3, H.5, M.7

### **1 Introduction**

Many activities in information and knowledge management are concerned with discovering, understanding and exploring relationships within resource collections [Marchionini 2006]. Often, relationships are based on shared properties, for instance, e-mails might be linked by same subject headings or sender addresses, books might have the same author or publisher. However, finding and following these relations can be difficult for system users, mostly due to the constraints of the presentation forms that are used to display the resources and their properties. For instance, tables, matrices, and spreadsheets are highly efficient for many sorting, searching and filtering purposes but are poor in visualizing relationships along multiple dimensions. Alternative presentation forms are needed, particularly for the visualization of relationships that result from shared properties.

#### **1.1 Using Graphs to Visualize Shared Properties**

Graphs are highly appropriate to visualize multiple relationships within a limited set of resources [Mutton and Golbeck 2003]. A common way of presenting resources and

their properties as nodes connected by edges is shown in Fig. 1a: All resources that share a certain property are linked to it and are therefore also indirectly related to each other via this property (e.g., resources A, B, C, and D are all connected via property 3 in Fig. 1a). This kind of graph visualization is well-known and widely used for showing different types of relationships in a variety of fields. However, when used to visualize resources that are highly interrelated via shared properties, this visualization type has two main limitations regarding readability and usability:

- A high number of shared properties leads to many n-ary relations, resulting in a rather dense graph.
- A dense graph increases the probability of crossing and partially overlapping edges and nodes and can thus hamper visual tracking of relations or even lead to misinterpretations [Frasincar et al. 2006].

In order to overcome these limitations we developed an advanced graph visualization – the *ChainGraph* – that particularly supports the exploration of relationships and commonalities between resources by arranging their shared properties in chains (see Fig. 1b). Basically, it visualizes indirect, n-ary relations between resources as one-to-one relations and thus resolves high densities and edge crossings. Shared properties can easily be identified and interrelated resources can be explored by following the chains.

In the following, we present this approach in more detail. First, we explain the general idea, describe a generation algorithm and give an example in Section 2. In Section 3, we report on results of a user study where we compared the ChainGraph approach with a common graph visualization, in particular with respect to their ability to support the exploration of shared property relations in highly interconnected resource collections.

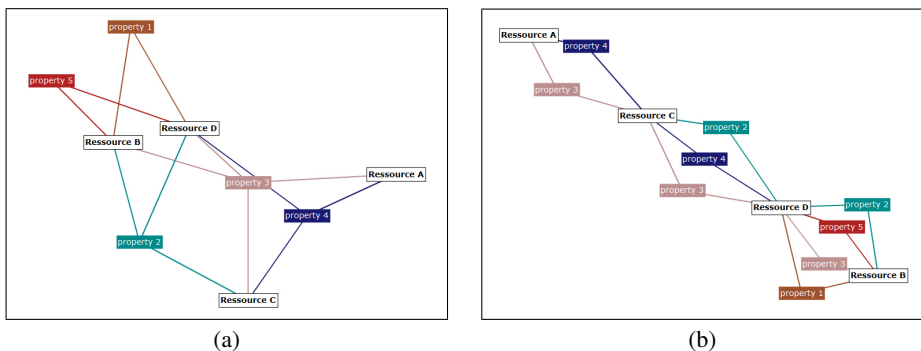


Figure 1: Visualizing resources and shared properties with (a) a common graph and (b) the ChainGraph in a force-directed layout [Fruchterman and Reingold 1991]

## 2 The ChainGraph Approach

The basic idea of the ChainGraph approach is best described by comparing it with a common way of visualizing resource collections in a graph as it is shown in Fig. 1a. In common graph visualizations, each resource and each property is typically represented by exactly one node. If a property is shared by many resources, the force-directed layout [Fruchterman and Reingold 1991] arranges the resource nodes radially around the property node (cp. property 3 in Fig. 1a). In the ChainGraph, by contrast, property nodes are connected with only two resource nodes at most. This is realized by multiplying property nodes in the visualization: Every property that is shared by more than two resources is represented by several nodes arranged in a chain that connects the resource nodes (cp. property 3 in Fig. 1b). Although this multiplication increases the total number of nodes and edges in the graph, it can significantly reduce the graph's density and the number of crossing and overlapping edges compared to common visualizations. As a consequence, connections within a chain must be interpreted in a transitive manner, i.e., all resources along one chain are related to each other via the same property, independently of their order.

However, in opposite to common graph visualizations, the order in which resources are added has a strong impact on the layout of the resulting ChainGraph. This is best illustrated by a small example.

### 2.1 Example

Suppose we have a set of resources, each of them with certain properties, as it is shown in Table 1. Furthermore, suppose that these resources should be visualized in a ChainGraph with shared properties arranged as chains.

	Property p1	Property p2	Property p3	Property p4	Property p5
Resource A			+	+	
Resource B	+	+	+		+
Resource C		+	+	+	
Resource D	+	+	+	+	+

Table 1: Resources and shared properties

Fig. 2 shows two alternative ways of adding resources to generate a ChainGraph. The resulting visualizations both display the data that is given in Table 1, however, the left layout is rather hard to read whereas the right one shows an optimal ChainGraph. Being aware of these differences, we developed an algorithm that generates ChainGraphs with optimal layouts for given sets of resources and shared properties.

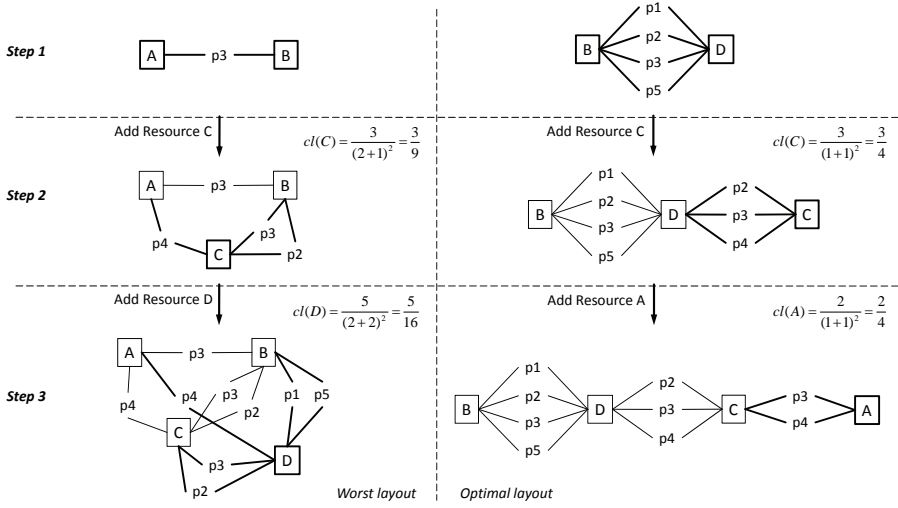


Figure 2: The order in which resources are added to generate a ChainGraph highly affects the quality of the resulting layout.

## 2.2 Algorithm

The algorithm first defines what data is given and what should be computed (see Algorithm 1). Note that the ChainGraph is described as a set of chains connecting the resources. Thus, every property is represented by a chain, independently of the number of resources that shares a property.

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### Algorithm 1 Definitions

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- 1:  $R = \{r_1, \dots, r_l\}$  // given set of resources
  - 2:  $P = \{p_1, \dots, p_m\}$  // given set of properties
  - 3:  $f : R \rightarrow \mathcal{P}(P)$  // given mapping: every resource has certain properties
  - 4: // ChainGraph definition:
  - 5:  $C = \{(e_1, \dots, e_n) \in R^n \mid n \in \{1, \dots, l\}\}$  // set of chains connecting the resources
  - 6:  $g : C \leftrightarrow P$  // bijective: there is one chain for each property
  - 7:  $addAtFront : (x, (e_1, \dots, e_n)) \rightarrow (x, e_1, \dots, e_n)$
  - 8:  $addAtEnd : ((e_1, \dots, e_n), x) \rightarrow (e_1, \dots, e_n, x)$
- 

Starting from a set of resources  $R$  and their properties  $f(R)$ , Algorithm 2 adds the resources step by step to the chains. In every step, two decisions need to be made: which resource to add next and where to add it. Generally, we want resources that share many properties (i.e., have many commonalities) to be placed as close as possible to each

other. This is already relevant when drawing the first pair of resources. Consequently, we start with the two resources that share most properties (see Algorithm 2, line 1 and 2, or Fig. 2, step 1).

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**Algorithm 2** Adding resources to the chains
 

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**Require:**  $R, f(R), C$  // a set of resources and their properties, plus the empty chains

- 1:  $InitialPair = \{a, b \in R \mid \forall c, d \in R : (|f(a) \cap f(b)| \geq |f(c) \cap f(d)|)\}$
- 2:  $addToChains(InitialPair, C)$  // pair of resources with most shared properties
- 3:  $UnboundR = R - InitialPair$  // set of resources that is not bound to chains yet
- 4: **while**  $Unbound \neq \emptyset$  **do**
- 5:    $next = null$
- 6:    $maxCLevel = -1$  // initial max constraint level
- 7:   **for all**  $x \in Unbound$  **do**
- 8:     **if**  $constraintLevel(C, x) > maxCLevel$  **then**
- 9:        $next = x$  // new most constrained resource
- 10:        $maxCLevel = constraintLevel(C, x)$
- 11:     **end if**
- 12:   **end for**
- 13:    $addToChains(next, C)$  // add most constrained resource
- 14:    $Unbound = Unbound - next$
- 15: **end while**

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Besides the number of shared properties, some additional issues need to be considered when selecting the resources that should be added next. With the *constraintLevel* we defined a heuristic value that selects resources in an order that leads to an optimal ChainGraph layout. Given a set of chains  $C$ , the *constraintLevel* of a certain resource  $x$  is computed by the following formula:

$$constraintLevel(C, x) = \frac{numSharedProps(C, x)}{(\minNumConnectedRes(C, x) + |Alternatives(C, x)|)^2}$$

The formula weights the selection priority of all resources that have not already been added to the graph based on the following three heuristic strategies:

1. *numSharedProps*: If a resource shares many properties with the already drawn resources it also produces many new edges (i.e., many shared properties = higher constraint level).
2. *minNumConnectedRes*: If a resource would get connected to only a few of the already drawn resources it would produce a more parallel arrangement of the chains (i.e., few connected resources = higher constraint level).

3. *Alternatives*: If there are only few alternatives to add a resource in a way that it gets connected to the found minimal number of already drawn resources (*minNumConnectedRes*) it should be added as early as possible (i.e., few connection alternatives = higher constraint level).

In each generation step, the *constraintLevel* is calculated for all resources that have not yet been added to the graph (see Algorithm 2, lines 4-12). The resource with the highest *constraintLevel* is added next (line 13)<sup>1</sup>.

### 3 Evaluation

In a first evaluation, we tested if system users understand the general visualization approach of the ChainGraph and if they benefit from it when exploring resource collections that contain shared properties. We performed a comparative user study where we visualized resources and shared properties both with the ChainGraph and a common graph visualization (as shown in Fig. 1). Since we were particularly interested in how well the graphs support the visual tracking of shared properties and the identification of commonalities we defined the following three user tasks:

1. Find the pair of resources that shares most properties.
2. Find all properties that are shared by a given pair of resources.
3. Find all properties that are shared by a given triple of resources.

Twelve participants, mainly students, took part in the study, with an average age of 29 (ranging from 22 to 47). All subjects had experiences with graph visualizations, by a general familiarity of 7.7 (median of 8.5) on a scale of 1 to 10. We presented the two types of graphs along with the three tasks to all participants. Each graph type and each task were shortly introduced and explained by an example. To control learning effects, we interchanged the presentation order of the two graph types and randomly assigned the participants to one of the settings. We kept the number of resources and properties constant (six each) but varied the number of interrelations (i.e., the ratio of shared properties). Overall, we thus applied a 2x3x3 within-subject design with variables *graph type*, *task* and *shared properties ratio*. The participants had to complete an evaluation sheet after solving all three tasks with one of the two graph types. They were additionally asked to compare both types in a final questionnaire.

#### 3.1 Results

Overall, the ChainGraph performed very well in the user study. Nine of the twelve participants preferred using the ChainGraph to solve the tasks of the study. It also reached

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<sup>1</sup> The resource is added in a way that it gets connected to the found minimal number of already drawn resources (*minNumConnectedRes*).

slightly better results in the evaluation sheets: Fig. 3a shows the user ratings on the four dimensions *attractiveness*, *control*, *understandability* and *effectiveness* that were generated from the items of the evaluation sheet (higher value = better rating).

Furthermore, the participants quickly understood the ChainGraph layout and did not report serious difficulties in using it to accomplish the tasks; the colored edges proved to be helpful in following the chains (cp. Fig. 1b). Although the compactness of the common graph was considered positive, the study participants complained about the high number of crossings edges and overlapping nodes in this type of visualization (cp. Fig. 1a). Regarding the average time that was needed to accomplish the tasks, the ChainGraph performed significantly better in the first task (see Fig. 3b). This indicates that the specific ChainGraph layout assists particularly in the identification of commonalities. Of course, the results are limited to the tasks of the user study and need further validation in real use cases with other user groups.

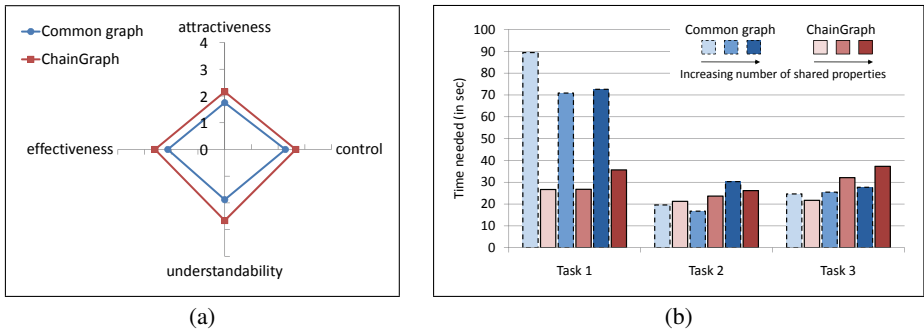


Figure 3: Results from the comparative study: a) user ratings for both graph types on the four evaluation dimensions, b) time needed to accomplish the tasks

## 4 Discussion

With the ChainGraph we introduced a new visualization approach for shared properties in resource collections. Since the ChainGraph represents shared properties by multiple nodes it avoids an agglomeration of resource nodes around property nodes and thus reduces the graph's general density. This decreases the probability for edge crossings and overlaps and therefore fosters readability and usability of the graph visualization.

### 4.1 Limitations

Depending on the distribution of properties, the ChainGraph approach might provide only limited support or no benefits at all. For instance, the ChainGraph visualization

would be identical to a common graph visualization in distributions where all properties are shared by exactly and only two resources; albeit such distributions are very unusual in real application scenarios. Another case are resource collections with no shared properties: The ChainGraph approach supports the exploration, discovery, and understanding of relationships and commonalities based on shared properties but offers no specific visualization for properties that are not shared at all. A general limitation of the ChainGraph is its relatively large size that results from the multiplication of property nodes. We developed the ChainGraph for the visualization of a limited set of resources of interest but not as a visualization for the whole structure of large resource collections.

## 4.2 Related Work

A lot of research has been conducted with the aim of drawing more understandable and readable graphs [Di Battista et al. 1994]. The reduction of edge crossings is one major goal in many of the proposed optimizations. Several algorithms have been developed that tackle this problem with various heuristics (e.g., by simulated annealing [Davidson and Harel 1989], by multidimensional scaling [Kruskal and Seery 1980] or by a combination of heuristics [Tunkelang 1992]). However, none of these optimization approaches applies mechanisms that multiply nodes or arrange nodes in chains to improve relationship discovery and exploration. With the ChainGraph we thus proposed a visualization approach that is of particular interest to the field of information and knowledge management. It might provide a valuable alternative to common presentation forms for resource collections when relationships and commonalities between the resources are in the user's interest.

## 4.3 Future Work

In this paper, we focused on the description and evaluation of a static ChainGraph visualization. We have not discussed benefits resulting from an interactive implementation where certain chains of properties can be shown or hidden and gradually extended by the user in order to follow some "information scent" [Pirolli et al. 2003]. A closer look at the information seeking strategies that users apply when exploring resource collections with the ChainGraph remains a topic for future work.

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## **Visualizing Organizational Competences: Problems, Practices, Perspectives**

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**Abstract:** Although receiving significant attention in management research, the organizational competence concept still remains difficult to apply, due to the vagueness of the theoretical construct, and due to the lack of pragmatic procedures to make it actionable. According to recent research, knowledge visualization may mitigate the elusiveness of the competence concept by assisting the identification, management, and communication of competences. In this paper, we thus review the academic literature in search for conceptual representations designed to support organizational competence mapping at the intra-, and inter-organizational level. By taking a synoptic overview of the collected representations, we single out the building blocks of competence visualization, and develop a corresponding classification. Drawing on this classification, we position twelve existing competence representation methods in an integrative framework to assist practitioners in selecting the right representation method and to inform scholars about future research and development needs.

**Keywords:** Organizational competences, competence management, competence visualization, competence mapping

**Categories:** M.0, M.3, M.4, M.8, M.9

### **1 The Need for Competence Visualization**

Introduced by Prahalad and Hamel on the basis of the resource-based view of the firm, the concept of core competence has received widespread recognition within the academic literature in the management domain. In their seminal article, [Prahalad, 90] defined a core competence as the collective learning of an organization, providing “the glue that binds existing businesses, and the engine for new business development”. More importantly, core competences lead to sustainable advantage, because they are resistant to imitation, central to customer value, and conducive to market penetration. Therefore, accurate analysis of core competences is necessary in order to profitably exploit internal resources, and to correctly identify external opportunities [ibid]. Whilst the relevance of the competence perspective is never contested, the actual detection of competences can be quite difficult due to the vagueness of the theoretical construct. As pointed out by several researchers, the competence concept remains at an abstract level, leaving practitioners without clear guidance for the application stage [Klein, 98; Javidan, 98; Mills, 02; Tampoe, 94; Walsh, 01]. Recognizing the need for operational definitions, concerned scholars in

diverse domains set out to develop procedures for assisting competence management. According to a broad definition, *competence management* has the primary objective to identify, maintain, and develop competences in agreement with the corporate strategy [Berio, 05]. In the domain of *knowledge management*, knowledge-based techniques can be used to understand and manage the firm’s competence configuration in order to create sustainable advantage [Roos, 92; Berio, 05; Sawyer, 06]. In a similar way, a research stream in *strategic management* deals with the clarification of the competence concept, and the definition of practitioner guidelines for competence management [Javidan, 98; Tampoe, 94; Torkkeli, 02; Walsh, 01]. In the field of *computer science*, IT-based competence management systems are designed for collecting, analysing and representing large amounts of data about organizational competences [Klein, 98; Lindgren, 02; Pareto, 07]. Alongside the literature streams described above, *competence visualization* is gradually emerging as a meta-discipline which explores the use of visual representations to support competence management. In this regard, *visual frameworks* for competence management are found within - and at the intersection of - knowledge management, strategic management, and computer science [Fig. 1]. By comparing the three literature streams, we can identify key topics regarding the *content*, *methodology*, and *theoretical* soundness of competence visualizations, as described below.

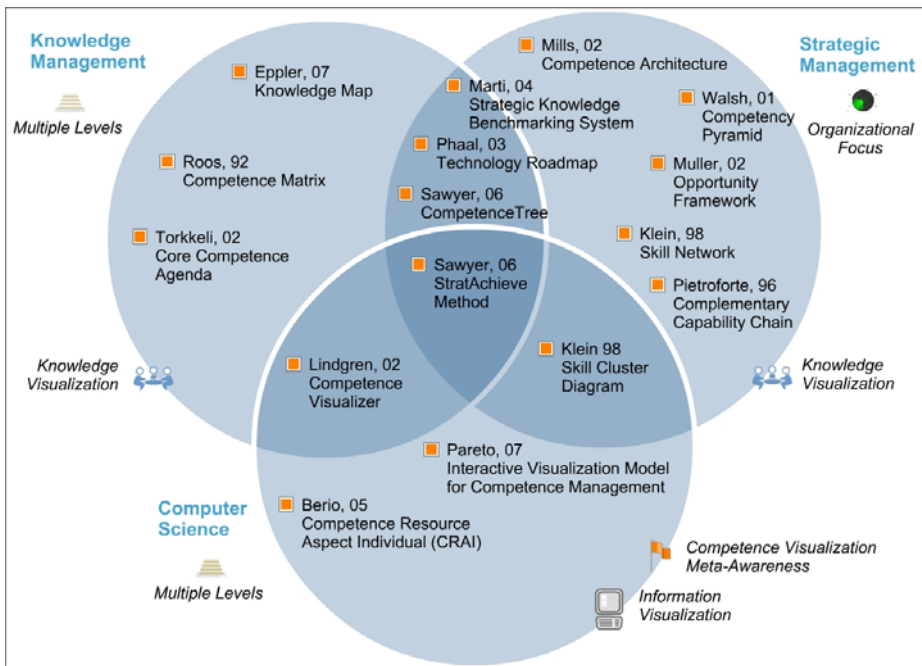


Figure 1: Visual Frameworks for Competence Management: A Literature Mapping

*Visualization content.* Whereas the strategy literature focuses essentially on organizational competences, knowledge management and computer science attempt to integrate the three levels of individual, team, and organizational competences [e.g.

Lindgren, 02; Pareto 07]. In particular, computer science exhibits a high level of interdisciplinarity, as several contributions include findings from organization studies, knowledge management and strategic management, in the attempt to define an ontology of competence modelling [e.g. Berio, 05; Sawyer, 06].

*Visualization methodology.* On the one side, computer science is focused primarily on information visualization, namely the interactive representation of competence data for amplifying cognition about organizational competences. On the other side, the organizational or strategic literature is oriented towards knowledge visualization, intended as the joint production of visual representations for sharing knowledge about organizational competences.

*Visualization theory.* A difference can be drawn between computer science and organizational research (i.e. most of knowledge management and strategic management) as regards the degree of meta-awareness about competence visualization as a scientific domain. The research stream in computer science explicitly points to the necessity, as well as to the challenge of effectively visualizing data in competence management systems [Klein, 98; Lindgren, 02; Pareto, 07]. As an example, [Klein, 98] underline the relevance of visual depictions to cognitive processes, and accordingly shift their focus toward competence metaphors and diagrams, beyond the computer-based representation of data. Conversely, the organizational literature is less concerned with the systematic application of visualization methods to competence management; although with few exceptions [Eppler, 07; Mills, 02; Phaal, 03], organizational researchers generally develop visual frameworks without making systematic reference to visualization theory.

Despite receiving a rather unsystematic treatment in the organizational literature, graphic depictions may play a catalyst role in identifying, managing, and communicating organizational competences. With the term graphic depictions, we refer - in this paper - to conceptual, diagrammatic representations of organizational competences, produced in a non-automated manner, with or without the use of dedicated software. The reasons for focusing on knowledge visualization - as opposed to information visualization - are threefold, and all take into consideration the fundamental essence of competences. First, conceptual representations give account for the knowledge intensity of competences, defined in terms of collective learning [Prahalad, 90], actionable know-how [Roos, 92], and skill network [Klein, 98]. A non-automated mapping approach supports the sense making and clarification process about such collective learnings and can lead to new meta-knowledge. Second, while information visualization supports the representation of known competences, knowledge visualization assists the detection of unknown competences, thus bringing the identification process a step forward. Third, knowledge visualizations can be seen as experimental proto-stages for information visualization applications, providing conceptual frameworks for representing data in competence management systems [Klein, 98].

A variety of crucial *benefits* can be associated with the use of visualization by, for example, cross-functional teams concerned with the overall process of competence management. First, visualization may facilitate *competence identification*, and ultimately contribute to the constitution of 'organizational self-knowledge' [Rulke, 00], by increasing managers' awareness of organizational competences. Conceptual representations assist the elicitation of tacit knowledge [Mengis, 07] and clarify the

connections among organizational competences and resources [Mills, 02]. In addition, conceptual representations may promote a shared understanding of competences, by acting as “boundary objects” [Carlile, 04]. Conceptual representations provide a common structure with the potential to facilitate knowledge integration across individual, functional and organizational boundaries. Visualization also allows for reviewability and revisability [Mengis, 07], thus facilitating the collective refinement of the elicited competences. By re-examining arguments with the use of visual frameworks, team members can build common ground [ibid], and ultimately achieve a co-constructed understanding of organizational competences.

In addition to facilitate competence identification, visualization may assist *competence management*, with particular reference to the processes of competence alignment, exploitation, and exploration. Competence visualization may facilitate the integration and alignment of distinctive competences with an organizational strategy. As an example, the competence tree by [Sawyer, 06] visualizes operational and core competences in a hierarchical connection to the corporate vision, and to the success factors in a competitive domain. Competence visualization may also support the competence agenda by directing the exploration of novel competences, and guiding the exploitation of existing competences. In this regard, the core competence agenda matrix by [Torkkeli, 02] relates novel and existing competences with novel and existing product markets. By assisting competence planning, visualization ultimately helps avoiding ‘competence traps’, defined in terms of a dysfunctional imbalance between knowledge exploration and exploitation [Liu, 06].

Finally, visualization may support *competence communication* to external audiences, thus contributing to build the perceived distinctiveness of an organization. The clear illustration of organizational competences can foster stakeholder relations, by facilitating the attraction of potential investors, clients, and employees. In particular, competence visualization may be pivotal for strategic alliances, supporting the *inter-organizational communication of competences*. In this context, visualization may facilitate the decision to enter a strategic alliance, enabling prospect partners to understand each others’ resources, foresee competence complementarities, and estimate the potential value of an alliance. Visualization may support on-going collaboration, by assisting corporate partners in appreciating reciprocal competences, and identifying a suitable direction for their joint activities. Competence visualization may permit to connect co-workers across the partner organizations, and to define interaction rules for expanding the collaboration beyond specific projects; as summarized by a manager of the Philips-Swarovski partnership interviewed by us: “Competence visualization is central for the early stages of a strategic alliance, serving not just planning purposes, but also mutual understanding and trust building”.

## 2 Current Practices of Competence Visualization

Having illustrated the importance of graphic competence representations in intra- and inter-organizational settings, we now proceed with a critical review of the competence visualizations thus far developed in the academic literature. For this purpose we have screened methods across the domains of strategic management, technology management, knowledge management, and alliance management research. In particular, the current review is focused on competence frameworks, intended as

conceptual instruments for assisting competence management. In searching the academic literature, we have collected a total of twelve frameworks with substantial applicability to competence management in the intra- and inter-organizational setting. Since a detailed review of the collected frameworks is beyond the scope of the present article<sup>1</sup>, an attempt is made to provide a general overview of competence visualization, by introducing a simple overview classification [Tab. 1]. We have developed this classification in order to identify the building blocks of competence visualization. As a result, the classificatory dimensions capture the fundamental components of competence representations, and converge to define a tentative ontology of this domain. As an organizing principle for this overview, we use the five main interrogatives of what, how, why, for whom and where.

What?	How?	Why?	Whom?	Where?
Core competence	Hierarchical	Identification	Int. Audience	In praesentia
Competence	Supportive	Development	Ext. Audience	In absentia
Supportive comp.	Temporal	Allocation		
Operational comp.	Matching	Communication		
Resources				

Table 1: Classification of competence visualization elements

The *what dimension* refers to the content represented in a competence visualization. In particular, *core competence* is the collective knowledge of an organization, essential to the implementation of a strategic vision, and critical for long-term survival [Prahalad, 90; Tampoe, 94]. By contrast, a *competence* is functionally-based, and represents ‘ordinary’ knowledge which contributes to organizational success, although without being conducive to sustainable advantage per se [Mills, 02; Tampoe, 94]. A *supportive or dynamic competence* is meta-knowledge with the potential to enhance ordinary competences, with applicability to a wide range of organizational activities [Mills, 02; Winter, 03]. Finally, *operational competence (or skill)* is procedural knowledge with reference to a series of processes and routines whereby the organization coordinates the interaction among resources [Javidan, 98; Torkkeli, 02]. In this context, *resources* represent the building blocks of organizational competences, and include tangible resources such as plants, technology, and equipment, as well as intangible ones, such as culture, values, and beliefs [Mills, 02].

The *how dimension* refers to the coordination mechanisms whereby the objects represented within a competence representation – either competences or resources – are connected into meaningful relations. The visual framework may underline *hierarchical* relations, linking competences via vertical and horizontal connections in a pyramidal or tree-shaped structure [Mills, 02; Sawyer, 06; Walsh, 01]. Alternatively, the competence graphic may represent *supportive* relations, e.g. by

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[1] Due to space constraints, the collected frameworks are not all illustrated. However, the collection of competence frameworks can be either requested from the authors or accessed via the webpage <http://www.knowledge-communication.org/OrgCompetenceVisualization.pdf>.

depicting competences as a series of interlinked nodes, forming a network structure [Klein, 98]. The competence visualization may emphasize the *temporal* dimension, by relating competences either in a linear, or in a cyclical manner. For example, [Pietroforte, 96] portrays competences in a linear relation along the value chain, while [Marti, 04] depicts a reinforcing cycle between customer analysis, individual competences, core competences, and financial results. A competence visualization may represent *matching* relations, supporting the connection of relevant elements to facilitate the generation of new insights. As an example, the opportunity framework by [Muller, 02] enables managers to match the core competences of future partners, as a means to elicit the innovation opportunities related to a strategic alliance.

The *why dimension* addresses the purpose of a competence visualization, i.e., the managerial processes supported by it. In particular, the *identification* process consists of making organizational competences explicit, a primary function which provides the ground work for the subsequent processes. The *development* process consists of competence exploration, directed at the acquisition of important competences, whereby the organization can close crucial gaps, and strengthen its competitive position. The *allocation* process consists of competence exploitation, requiring managers to conceive novel uses of the existing competences, in order to leverage a competence for multiple products and across several markets. The *communication* process allows managers to convey competences to various audiences.

The *whom dimension* makes reference to the primary audience addressed by the competence framework, either *internal* or *external* with respect to the organization. On the internal side, a competence framework may be directed to department managers, cross-functional teams, employees, and particularly to newly recruited employees. On the external side, a competence framework may be intended for a variety of stakeholders, including alliance partners, suppliers, (potential) investors, and the public at large.

The *where dimension* indicates the fruition context of the competence depiction, with a basic distinction between *in praesentia*, synchronous interactions, versus *in absentia*, asynchronous interactions. In the first case, the competence visualization is co-constructed in a face-to-face context, such as workshops, meetings, and seminars. In the second case, the competence framework is used in a mediated context, such as via the organization's website, intranet, or via its publications.

Besides its function to synthesize existing approaches, the classification depicted in [Tab. 1] may also provide general directions for the production of competence visualizations. As a general rule, a competence depiction must address the five questions underlying the classification dimensions, in order to effectively support competence management. In particular, the competence manager should be aware that different purposes, target groups, and contexts require the selection of different visualization formats. For example, competence allocation by senior management requires *in praesentia* visualizations with links to the competence agenda, while competence communication to the public at large demands simplified visualizations with high impact. Furthermore, the classification dimensions may serve as a guideline for structuring the evaluation of the competence visualizations found in the academic literature. By taking an overall outlook at the collected visualizations, it is possible to identify at least two areas of improvement: With respect to the *what dimension*, the current visualizations generally neglect the representation of *supportive competences*,

with the few exceptions of [Mills, 02] and [Bernhardt, 09]. Overall, the current visualizations suggest a *static* depiction of competences, failing to represent the dynamic processes whereby an organization strengthens, and adjusts its competence configuration. With respect to the *how dimension*, the current representations of *coordination mechanisms* are somewhat tentative, neglecting the actual processes whereby organizational competences are integrated, deployed and recombined. The visual representation of coordination mechanisms should be further explored, beyond the sketchy categories currently reported under the how dimension. For example, a future representation may capture the knowledge intensity of the coordination mechanisms employed for managing competences. Knowledge-intensive coordination is required to recombine competences for innovation purposes, while routinely-based coordination enables the connection of resources and competences for ordinary procedures.

### 3 Towards an Integrative Framework for Competence Mapping

#### 3.1 The Framework in Overview

Drawing on the classification described above, this section proposes an integrative framework for the use of competence visualizations, [see Fig. 2]. It is integrative in the sense that it provides a comprehensive view on existing (and potential) competence visualization methods according to their purposes and depiction schemes. As illustrated in [Fig. 2], our framework was obtained by positioning the *how* and *why* dimensions of the previous classification along two axes. The *how* dimension reflects the coordination mechanisms utilized for connecting competences visually, and ultimately defines the graphic structure of the competence visualization. The *why* dimension points to the processes supported by the competence visualization, consisting of competence identification, management and communication. By combining the *how* and *why* dimensions, we have been able to position the competence visualizations available in the academic literature according to their purpose and form. In the framework above, we also include the content (or what dimension) of each of the twelve methods that we have identified. The categorization of the methods in the grid is not mutually exclusive, as a competence visualization may serve more than one purpose and may make use of multiple coordination or depiction mechanisms. The core competence agenda by [Torkkeli, 02], for example, supports competence allocation and development, whereas the competence architecture by [Mills, 02] depicts both hierarchical and supportive relations. Nevertheless, the framework presents the dual advantage of *synthesis* and *scalability*, meaning that it captures existing methods, and that it can be used to better understand the function of (or need for) future ones. Above all, the integrative framework provides valuable support to practitioners who want to use visualization systematically for competence management. It facilitates the selection of one or several competence visualizations with regard to the task at hand. It also shows where multiple methods are available (such as for competence identification), and where more research is still needed (such as in the competence development and communication area). The framework can thus provide valuable pointers for future development efforts by researchers. Further research, however, is needed for the



integrative framework to reach the maturity stage. At present, it is subject to an ongoing revision, and the underlying dimensions are regularly checked, and eventually refined against the addition of further elements. Moreover, in future research, we will perform surveys among practitioners, in order to assess to which degree the competence visualizations really support the processes indicated in the framework (as claimed by the respective authors).

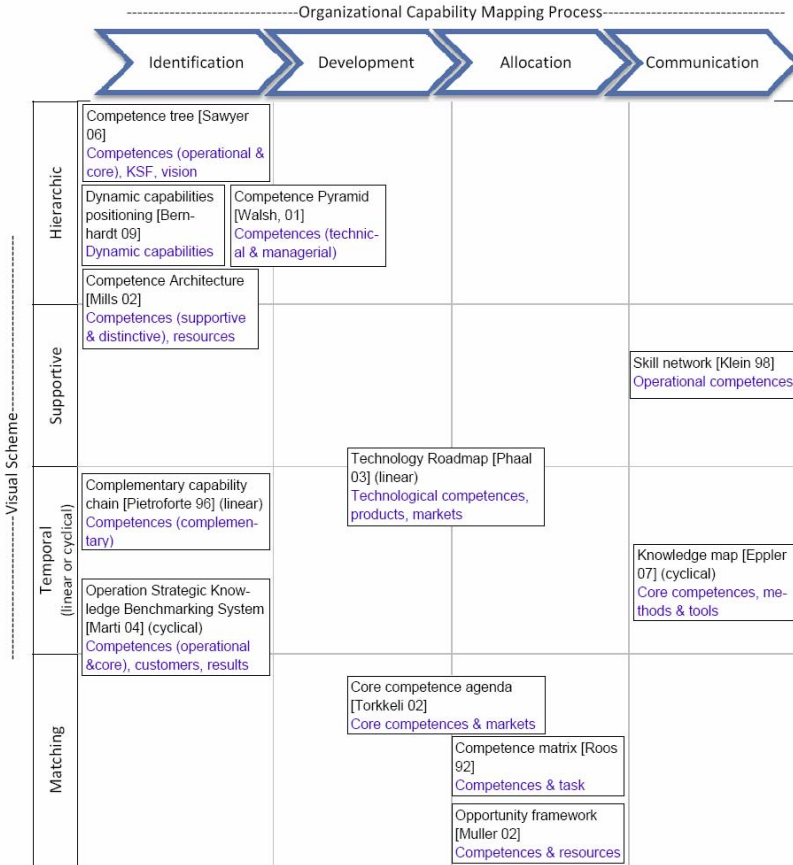


Figure 2: An integrative framework of competence visualizations

### 3.2 Illustrating the Integrative Framework for Competence Mapping

In this section we describe the integrative framework in greater detail, by illustrating diverse visualizations according to the *what*, *why* and *how* dimensions of competence mapping. In order to cover the broad scope of the integrative framework, we have selected competence visualizations which serve diverse purposes and present various graphical schemes [Fig. 3]. Besides illustrating the building blocks of competence mapping, the following descriptions should clarify the rationale behind the positioning of visualization techniques within the integrative framework.

The *competence architecture* by [Mills, 02] is a conceptual framework assisting practitioners in identifying organizational competences, along with the underlying resources. Defining competency as a network of resources, [Mills, 02] propose to represent competency like a triangle, containing a variety of circles to symbolize resources. As a first step, practitioners identify distinctive competences - perceivable by customers - and accordingly uncover the underlying resource network. Therefore, practitioners explore supportive competences, which reside deeper in the organization, and provide the implicit ground for strategic resources. As a general rule, the triangle “supportive competence” is drawn with the apex penetrating the triangle “distinctive competence”, in coincidence of the most relevant resources. In a progressive way, practitioners expand on the competence architecture, by drilling down competences, and exploring competence-resource relations. In summary, the competence architecture supports the *identification process*, by connecting competences in a *hierarchical order*, and showing *supportive relations* within the resource networks.

Intended to support strategic planning, *technology roadmapping* is a visual technique for mapping and linking technological competences, product developments, and market opportunities [Phaal, 03]. While technology roadmaps are customizable to fit a wide range of organizational contexts, the generic structure is comprised of three layers, and explicitly includes the temporal dimension. The top layer relates to industry trends and drivers, whereas the bottom layer represents the organizational knowledge base. The middle layer acts as a bridging mechanism and relates to the tangible systems developed to address industry trends and drivers, such as engineering processes, operational capabilities, and products. By drawing connections among the three layers, senior managers explore innovation opportunities, and accordingly plan for *competence allocation* and *development*. As depicted in [Fig. 3], the visual scheme of technology roadmaps underlines the *temporal dimension* according to a linear perspective, and displays *supportive relations* among competences, products, and markets.

The *opportunity framework* is a n-by-n matrix, created by [Muller, 02], to support alliance managers in identifying innovation opportunities based on complementary competences between prospect partners. In order to produce the matrix, the alliance manager lists organizational competences on the vertical axis and repeat for the prospect partner on the horizontal axis. By cross-checking the listed competences, the alliance manager identifies complementary competences with an innovation potential. In the corresponding cells, the alliance manager writes an innovation opportunity, and eventually comes up with an innovation map to be realised via the strategic alliance. In summary, the opportunity framework visualizes *matching relations* between competences, and supports the *allocation process* via the recombinant exploitation of existing competences for innovation purposes. Besides the unilateral application suggested by [Muller, 02], the opportunity framework may be used simultaneously by prospect partners, as a basis for discussing the viability of a strategic alliance.

The *skill network* by [Klein, 98] enables an organization and its members to understand competences as a network of interrelated skills. It allows them to visualize the dynamics whereby skills flow through an organization to create a product advantage. The skill network builds upon the systematic analysis of competence data, collected via structured interviews with organizational informants. In particular, the

diagram is produced by applying a mathematical technique to compute what skills contribute the most to product development, and the extent to which skills tend to be used in combination. Graphically, the diagram represents skills as triangles, and skill connections as straight lines converging in a broader network. In this regard, the visual scheme emphasizes *supportive relations* among skills, and serves the purpose to *communicate* competence data across the entire organization. According to [Klein, 98], while numeric data can easily lead to detail views, the corresponding visualization can convey the big picture, and build up greater commitment.

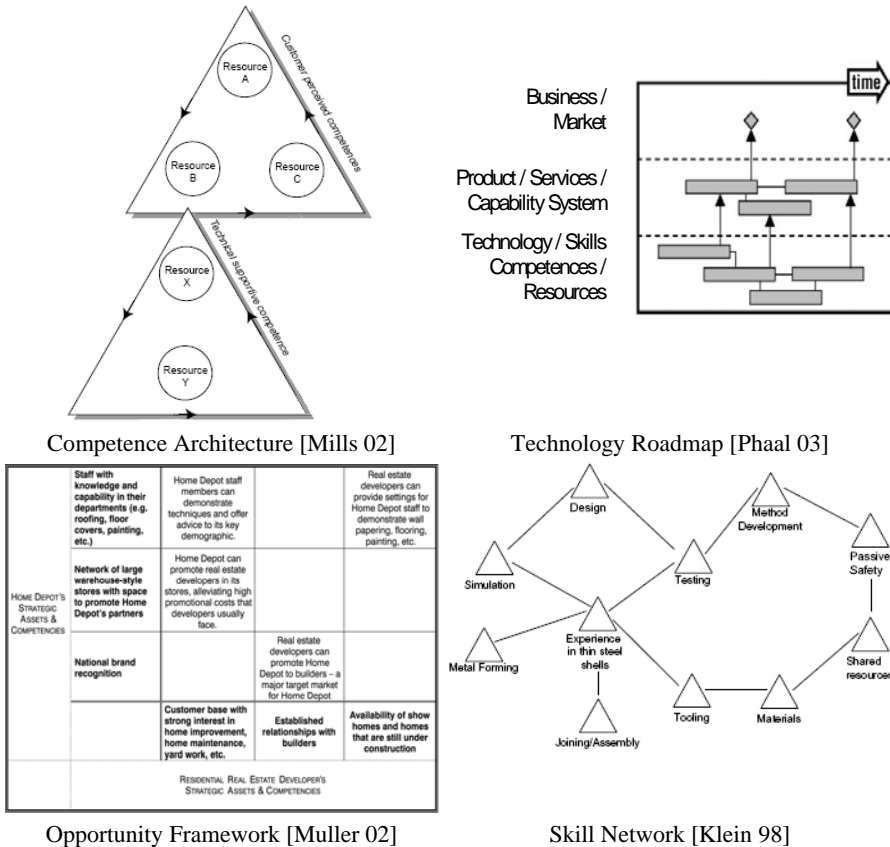


Figure 3: Selected Examples of Competence Visualizations

By taking a general view at the integrative framework [Fig. 2], it is possible to draw tentative associations between the visual schemes and the mapping processes served by competence visualizations. While the competence frameworks reported in [Fig. 2] differ substantially with regard to their aesthetic appearance, consistent patterns can be observed by looking at the individual phases of the mapping process. On occasion, the observation of the collected frameworks provides the starting point to formulate tentative suggestions for the development of novel frameworks:

*Competence identification.* As visible in [Fig. 2], a large cluster of competence frameworks supports the identification process by underlying hierarchical relations in the visual scheme. As pointed out by [Walsh, 01], “much of the difficulty in identifying competences arises from the hierarchical and multidimensional nature of competencies”. Accordingly, the identification frameworks operationalize the competence concept by suggesting a visual hierarchy whereby the competence components are singled out in building blocks, and connected to the overarching strategy.

*Competence development.* As suggested by [Fig. 2], only a handful of visual frameworks is currently available for competence development, therefore making pointless any attempt to identify consistent patterns. However, the linear temporality portrayed in technology roadmapping seems a promising perspective, since competence planning is by itself a future-oriented activity. Moreover, novel frameworks may assist competence development by visualizing the gap between the current and desired competence portfolio.

*Competence allocation.* Interestingly, the allocation frameworks collected in the academic literature are communed by a visual scheme supporting the representation of matching relations. In this regard, existing competences are checked against relevant benchmarks - such as industry trends - to foresee allocation opportunities with the potential to fulfil strategic objectives. As a next step, visual schemes may account for the systemic recombination of existing capabilities, in order to support the implementation of exploitative strategies based on core competences. In other words, novel frameworks should not only point out what competences are relevant, but also focus on processes whereby competences can be combined, rearranged, and exploited.

*Competence communication.* The communication frameworks in [Fig. 2] consistently propose simplified representations to facilitate understanding of organizational competences among target audiences. In this regard, the adoption of *visual metaphors* presents the potential to improve competence communication, by assisting the transfer of implicit knowledge, and amplifying the cognition process. Being “tools for cognition”, visual metaphors facilitate connection to personal knowledge, and ultimately increase retention on the receiver side [Eppler, 07].

## 4 Conclusion

Besides delineating the theoretical underpinnings of competence visualization, the present article provides a threefold contribution to this emerging discipline: First, the article provides *descriptive value* in the form of a collection of twelve existing competence visualizations spread across various literature streams. Second, the article provides *analytical (or synthetic) value*, as the building blocks of competence visualizations are singled out and arranged in a classification [section 2]. Third, the article presents *prescriptive value*, as the integrative framework in [section 3], albeit tentatively, provides guidance for selecting among different competence visualization formats. It also shows areas where more research is needed. Future research could strengthen the theoretical foundations of competence visualization by exploring the advantages and disadvantages associated with competence mapping in intra- and inter-organizational settings. Moreover, future work could validate our framework, and eventually develop parameters for evaluating visualizations regarding their

contribution to competence management. Ultimately, future research should strive to systematize the practice of competence visualization, by defining a standard toolset of visualization frameworks for assisting the different phases of competence management.

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# Towards Need-driven Knowledge Sharing in Distributed Teams

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**Abstract:** Knowledge sharing between individuals has traditionally been conducted using face-to-face conversation. In the networked society – initially formed by telegraphs and the phone and nowadays powered by the Internet – many acts of knowledge sharing are carried out in a mediated fashion. While this typically introduces a number of problems in the knowledge sharing process, it also offers certain advantages. In this paper, we describe a framework for analyzing different modes of knowledge sharing. Furthermore, we line out the concept of “need-driven” knowledge sharing to address limitations in current mediated knowledge sharing approaches.

**Keywords:** Knowledge sharing, knowledge management, distributed work, information need

**Categories:** H.3.3, H.3.5, H.5.3, M.2, M.6, M.7

## 1 Introduction

Need-driven knowledge sharing is a fairly simple concept. It describes that knowledge shared by someone with another person is tailored towards an actual information need of that person. This is obviously the case in face-to-face conversations which account for a large number of knowledge sharing incidents.

However, it turns out that knowledge sharing has become less need-driven with the success of mediated communication. Especially the advent of specialized information seeking environments such as search engines has separated knowledge sharing from actual information needs [Happel 2009a]. Given the increasing number of distributed work settings, we consider this a major cause for the knowledge sharing troubles in large organizations. With a rising degree of distribution, technical and social parameters such as communication bandwidth, trust and context diminish. Thus, direct and personalized knowledge sharing approaches become difficult to realize and do not scale up to larger groups of people. Therefore, many organizations turn towards document and content sharing systems such as shared folders, knowledge repositories or organizational memory systems [Maier 2003]. However, their successful introduction often fails due to non-participation of information providers (see e.g. [Orlikowski 1992]).

We argue that one major reason for these failures is the decoupling of knowledge sharing from actual information needs – i.e. a lack of need-driven knowledge sharing. A number of studies show, that people are willing to share if they know that their contribution meets concrete demands [Dearman et al. 2008, Olson et al. 2005]. In this paper, we will line out strategies how both – *scalable* and *need-driven* knowledge sharing – can be achieved in combination.

Therefore we start by briefly discussing distributed work as such and by differentiating coordination and knowledge sharing. Afterwards we give a detailed overview of knowledge sharing and discuss several approaches and their weaknesses. Finally, we apply the concept of need-driven knowledge sharing (NKS) to document and content sharing, which we illustrate with two application systems.

## 2 Distributed Work

The development of complex products and services is tightly related to the concepts of modularity and division of labour which lead to a specialization of workers and firms [Baldwin and Clark 2000]. If collaborating workers are separated by organizational or physical distance, this is called distributed work. Research has shown that a distance of 30 meters is sufficient to significantly reduce informal communication [Olson and Olson 2000, Allen 1977]. Distributed work has become popular in recent years due to several reasons such as cost reduction, availability of human resources or intra-organizational collaboration. The modularization of complex artifacts is thus often mirrored by a modularization of the project teams, which produce these artifacts [Herbsleb and Mockus 2003].

Many distributed and outsourced projects suffer from coordination problems because the overall coordination capacity is lower due to a reduced communication bandwidth [Olson and Olson 2000]. Since distributed teams are less efficient than collocated ones, collaboration research is focusing on tool-support for creating “virtual 30 meters” [Herbsleb and Mockus 2003]. Core challenges in realizing these virtual 30 meters are coordination and knowledge sharing among the team members. While modularization requires coordination and knowledge sharing for effectiveness, it indirectly impedes their efficiency (c.f. Figure 1).

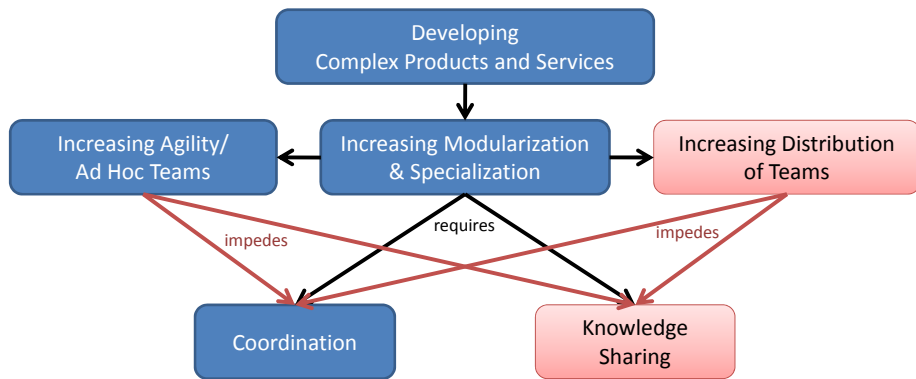


Figure 1: Distributed Work requires but also impedes Knowledge Sharing

The need for coordination stems from the modularity of the artifacts under development. The decomposition of artifacts creates dependencies, which require coordination. Coordination can thus be defined as “the process of managing dependencies between activities” [Crowston and Malone 1994]. Accordingly, most



coordination requirements can be traced back to explicit dependencies among the subsystems of artifacts and can be objectively recognized by the coworkers. Coordination issues are central to collaboration research, which e.g. analyzes suitable coordination mechanisms for different kinds of dependencies [Thompson 1967] and tools for supporting communication, awareness and workflow management.

While coordination problems in distributed settings are understood and supported in a considerable way, we argue that further support for knowledge sharing is required. In contrast to coordination, knowledge sharing is not directly rooted in explicit dependencies of technical artifacts, but in dependencies among organizational entities. The modularity of the organizational subsystem has a deep impact on the communication patterns of an organization, since it forms channels and filters along organizational interfaces to reduce complexity by selecting relevant information [Henderson and Clark 1990]. However, this has negative impact on knowledge sharing across organizational units, since the average information flow runs dry with increasing organizational or geographical distance. Also, knowledge sharing needs are highly subjective, since they depend on the experience and capabilities of the involved persons, what makes them more difficult to address. Distributed work settings amplify barriers for knowledge sharing such as reduced motivation and trust [Cabrera and Cabrera 2000]. The allocation of knowledge can thus be inefficient when collaboratively developing a system in a distributed organization. In the remainder of this paper, we will thus focus on the interrelation of knowledge sharing and distribution (c.f. light boxes in Figure 1).

### **3 Knowledge Sharing**

The topic of knowledge sharing is widely investigated in the fields of organizational studies and information systems. It can be defined as a “dual problem of searching for (looking for and identifying) and transferring (moving and incorporating) knowledge across organization subunits” [Hansen 1999].

Personalization and codification are typically described to be the two core strategies for knowledge sharing [Davenport and Prusak 1997]. The personalization strategy primarily relies on personal communication to share implicit knowledge, which only exists in the “heads” of individuals. In turn, the codification strategy targets explicit knowledge which is captured in documents. Information technology is an important enabler, especially in cases where regular personal communication is not feasible, such as in large organizations or distributed settings [Alavi and Leidner 2001].

#### **3.1 Knowledge Sharing as a Communication Process**

We consider knowledge sharing as a communication process between information seekers and providers (c.f. Figure 2). Information seekers typically initiate communication with a representation of their information need (“query”). Information providers return “answers” based on their interpretation of the queries.

While in face-to-face settings, a providers’ contribution is typically tailored towards the request of the information seeker, this is typically not the case in

distributed, asynchronous settings, where information providers are decoupled from information seekers and their requests.

Therefore, mediation technologies play an important role in distributed knowledge sharing. This can be as simple as providing a plain communication channel between both actors, but also more complex *mediation services* such as awareness and notification features or persistent *mediation spaces*, such as newsgroups where people can discuss information needs.

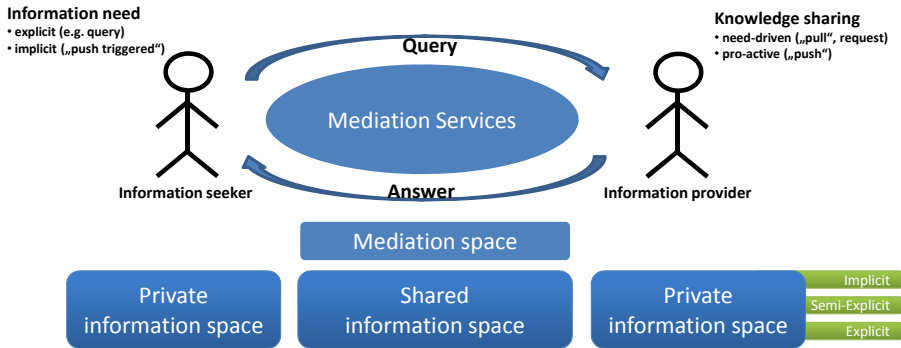


Figure 2: Knowledge Sharing as a Communication Process

For satisfying information needs, people can draw either from their personal information space or a shared information space. For the personal information space, we distinguish explicit information or artifacts (e.g. documents), implicit information which is not yet formally captured and semi-explicit information which denotes explicit actions of a user that could be automatically captured and thus easily shared with others (e.g. actions to solve a certain problem).

Concerning engagement in a knowledge sharing activity, both actors can either take a passive or an active role. In most cases, an information seeker explicitly formulates his or her need which is then answered by an information provider. However, information needs might also be implicit – i.e. when a user has a certain problem and is not aware that helpful information exists. Assistance systems are typically used to support users in this scenario. Conversely, information providers can actively “push” certain information, because they think it might be helpful for others.

### 3.2 Knowledge Sharing Approaches and Media

In this section, we will discuss and compare different approaches and settings for knowledge sharing in more detail. We will initially describe the derivation of our comparison framework and afterwards present the results of our discussion as summarized in Table 1.

#### 3.2.1 Comparing Knowledge Sharing Approaches

We characterize different knowledge sharing media by general properties and by what we call “mediation properties”. These mediation properties are grouped according to the process steps of knowledge sharing, as defined by Hansen: searching for

knowledge (which we call “pre-transfer”) and transferring knowledge. For both steps, we distinguish mediation services which address a) the information seeker, b) the information provider and which c) actually mediate between both.

We found that existing comparisons of different media types were either too general [Dix et al. 2004] or too focused on coordination tasks than on knowledge sharing. Media richness [Daft and Lengel 1986] or media synchronicity theory [Dennis and Valacich 1999] are comparing different media for the purpose of identifying the most suitable one for a given collaboration task. In particular, these theories do not address the specification and satisfaction of information needs.

The knowledge maturing framework [Maier and Schmidt 2007] assigns media to distinct levels of “knowledge maturity” for knowledge sharing purposes. However, the approach is focused on knowledge creation and does not address any information seeking aspects. While not being the focus of this paper, combining results from media richness theory, knowledge maturing and or work could yield a useful framework for guiding the choice of knowledge sharing media in particular settings.

### 3.2.2 Properties of Knowledge Sharing Approaches

We describe four different knowledge sharing media archetypes which can be assigned to either the personalization or the codification strategy. The archetypes roughly follow the distinction between collocate/distributed and synchronous/asynchronous media [Dix et al. 2004]. The arrows represent the level of support for the given mediation properties, expressing a good (arrow up), medium or low (arrow down) support. These judgments are based on our argumentation which follows below. As with the archetypes – which might have overlapping properties in reality settings – the description of mediation properties does not claim universal truth, but serves as a basis for our forthcoming discussion.

**Face-to-face communication:** As initially described, face-to-face communication in a collocated setting is the primary approach for knowledge sharing. It is synchronous, limited to a small number of people and typically involves only the information seeker and the information provider themselves. As for the pre-transfer phase, face-to-face communication does not support this very well. Instead, collocated workers usually have a large shared context which allows them to heuristically select persons to ask in case of a certain problem (or resp. to proactively share knowledge with). In the actual transfer phase, effort for provision and consumption is high – i.e. the provider has to invest effort in providing information and the seeker has to pay explicit attention. On the other hand, negotiation is well supported by direct communication, since both participants can use a broad set of communication means (e.g. voice, gestures) to reach a shared understanding.

**Instant Messaging/Chat:** For electronically-mediated synchronous (or near-synchronous) knowledge sharing using e.g. instant messaging (IM) or chat, similar limitations apply in the pre-transfer phase. It is limited to a small number of people and does not scale up well. There are typically no hints on who could be asked or what is offered in this media. Therefore, one usually combines it with some sort of expert finder system or yellow pages to alleviate for that. As for the transfer, mediated communication is less efficient in supporting negotiation, due to a lower communication bandwidth [Olson and Olson 2000]. Consumption is slightly less costly, since reading the message requires less attention.

		Mediation properties (including exemplary mediation services and spaces)						
Strategy	Media	Properties	Pre-Transfer			Transfer		
			Demanding (Seeker)	Matching (How to find suitable sources)	Offering (Provider)	Consumption (Seeker)	Negotiation (How to specify what to exchange)	Provision/Creation (Provider)
Personalization	Face-to-face communication	Synchronous 1:1; specific; personal	⬇	⬇ <i>(Expert finder)</i>	⬇	⬇	⬇	⬇
	Instant Messaging/Chat	(Near-) Synchronous 1:1; specific; personal	⬇	⬇ <i>(Expert finder)</i>	⬇	↔	↔	⬇
Codification	Forums/Q&A/Mailinglists	Asynchronous 1:n; specific; personal/ anonymous	↔ <i>Mediation space</i>	↔ <i>Search</i>	⬇	↔	↔ <i>Mediation space</i>	↔ <i>Shared inform.space</i>
	Document and content sharing	Asynchronous 1:N; generalized; anonymous	⬇ "Alerts"	↔ <i>Search/Recommendation</i>	↔ <i>Indexing, Annotation</i>	↔	⬇	⬇ <i>Shared inform.space</i>

Table 1: Properties of different Knowledge Sharing Approaches

**Forums/Q&A/Mailinglists:** On the codification side, forums, question & answer systems and mailing lists form our first category. They share the characteristics of being asynchronous and being restricted to a small- or medium number of people. While these media theoretically can support large groups, a specific knowledge sharing incident will get difficult to manage if too many people are involved. The pre-transfer phase is well supported on the side of the information seeker, since e.g. forums allow to persistently store demands (but also offerings/”announcements”) in a “mediation space” [Burnett 2000] (c.f. section 3.1). This can be leveraged to match suitable information providers. Similarly, answers are persisted in a shared information space. As for the transfer, the situation is similar to mediated communication, while provision might be slightly easier – e.g. due to reusing or referencing earlier or similar contributions.

**Document and content sharing:** Finally, document and content sharing such as realized e.g. by file shares, groupware systems, Wikis or knowledge repositories form another category. They are distinct from all other categories by decoupling information seekers from information providers. Transferred knowledge is typically kept within a shared information space and not bound to a specific seeker or contributor. Thus, knowledge is typically less specific for a given case, but covers rather generalized issues. Therefore, it can easily scale up, since the number of seekers is not limited by the communication bandwidth of a provider. Concerning our two phases, the pre-transfer phase is rather badly supported. Seekers can typically not persist demand information to attract potential contributors<sup>1</sup>. On the other hand, contributors implicitly offer knowledge by exposing their documents or content. Surrogates of these artifacts are typically used to provide a simple matching as e.g. used by keyword-based search engines. As for the transfer, consumption is a rather minor issue, once and if the information seeker has identified suitable information. Provision of information is badly supported in the sense of guiding providers in what to share. On the other hand, disseminating shared information is quite easy. The largest issue remains in the negotiation phase, as bridging terminological problems between both actors is difficult when both information seeker and information provider can not directly communicate. This is one reason why metadata annotation techniques received lots of attention in the context of search to allow for alternative descriptions of meaning.

To summarize, the personalization approaches in general allow for specific knowledge sharing with rich negotiation opportunities, while badly scaling up to larger numbers of people and not really supporting the pre-transfer phase. Document and content sharing on the other side scales up well, but is less suited to satisfy more specific needs in a considerable time. Forums/Q&A systems and mailing lists are in between by scaling up to a medium level. They are unique in providing rich means for demand specification in the pre-transfer phase. Therefore, it is e.g. easy to compile “Frequently Asked Questions” (FAQs) out of such systems.

In terms of need-driven sharing, the three categories on top score high in the actual transfer phase (negotiation allows to easily specify sought information). However, the personalization media are not need-driven in the pre-transfer phase –

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<sup>1</sup> With exceptions like „retroactive“ search systems (e.g. Google Alerts [Yang and Jeh 2006])

i.e. information seekers and providers are typically not systematically matched based on the actual need and capability, but rather by coincidence (i.e. social or physical distance). Forums/Q&A systems and mailing lists allow for a better need-driven knowledge sharing, since providers can select information needs they can satisfy based on the specified demands.

Document and content sharing scores the lowest in terms of need-driven sharing. Information seeking and information provision/creation are typically totally separated processes. However, document and content sharing is the most efficient and best-scaling knowledge sharing approach for large distributed teams.

## **4 Need-Driven Knowledge Sharing**

In order to improve knowledge sharing in distributed teams, we want to investigate how the desired properties a) efficiency of document and content sharing and b) effectiveness of need-driven knowledge sharing can be combined. In particular, we want to design mediation services which alleviate for the disadvantages of document and content sharing by making it more need-driven.

As lined out in the previous section, publishing information put into document and content sharing systems is seldom driven by concrete demands, although one would expect that most information is put there order to get retrieved. On the other hand, search interfaces (as matching service in the pre-transfer face) are usually very limited in their modes of interaction such as issuing a query and clicking results – although there is high demand for such features [Evans and Chi 2008]. There is typically no way in which search interfaces allow information seekers to signal potential information providers the need for information. Queries as the most important communication artifact in these settings do not have a persistent, first order representation.

Thus, document and content sharing suffers from a fundamental gap between the creation of information in information systems and its retrieval and access. This gap results in a problem of representing desired information (from the perspective of the information seeker) and in a problem of knowing which information is desired (from the perspective of the information provider) – i.e. in a lack of need-driven knowledge sharing. Our main challenge is thus how to establish a feedback loop between the processes of information seeking and information provision.

In section 3, we have described that time and effort is one of the major barriers for knowledge sharing. It is clear, that in an enterprise setting, resources for knowledge creation and sharing are limited. Thus, knowledge sharing activities should be prioritized towards knowledge which satisfies the most information needs.

Furthermore, studies have shown that people generally like to share knowledge with others, but only if they know that it will be useful for them [Dearman et al. 2008, Olson et al. 2005]. In the past, many knowledge sharing initiatives failed since users could not see any value in sharing with others [Orlikowski 1992].

Therefore, we introduce the concept of “need-driven knowledge sharing” (NKS) to document and content sharing in order to address both of these issues. NKS is based on actual information needs of users of a system and thus makes sure that shared knowledge meets a concrete demand. Furthermore, analyzing information needs of different users helps to prioritize which knowledge would be most relevant

for the whole organization or community. We thus expect that a system based on NKS will improve and foster knowledge sharing.

We introduce the following major design principles for NKS:

- **Minimize effort:** In order to achieve the most impact with the least effort – i.e. efficient knowledge sharing – it needs to be guided in terms of demands. Since covering all information needs would exceed the knowledge sharing capacities in most environments, we want to provide clues about which are the most important information needs that cover a large aggregate information need.
- **Motivate to share:** Providers should be motivated to share relevant knowledge with information seekers. Traditional KMS and knowledge sharing practices often require sharing information without signaling any benefit to the provider. Thus, those practices are often perceived as self-purpose with unclear value. In opposite to this, we want to give the potential information provider more concrete information that can help to estimate the benefit of sharing certain knowledge.
- **Retain privacy.** KMS implementations often lack acceptance, since contributing knowledge to public or shared spaces means losing control about it. However, many information providers want to retain such control, since information might be premature or sensitive.

Based on these principles, a number of novel mediation services and spaces can be envisioned – some of them summarized in Table 2. These either focus on the information seeker (such as a better specification of information needs or their persistence in mediation spaces) or the information provider (e.g. displaying most wanted information needs or providing capturing assistance).

Phase		Mediation service/space
Pre-Transfer	Demanding (Seeker)	Better specification of needs
	Matching (How to find suitable sources)	Shared mediation space for information needs
	Offering (Provider)	Sharing recommender system
Transfer	Consumption (Seeker)	-
	Negotiation (How to specify what to exchange)	Aggregation of most relevant information needs/display of most wanted information
	Provision/Creation (Provider)	Capturing assistant Semi-automatic, context aware capture

Table 2: Mediation services and spaces for need-driven knowledge sharing

In the following, we shortly present two different approaches, which describe concrete realizations for some of these mediation services in a document and content sharing scenario.

#### **4.1 Woogle – Marrying Wikis with Enterprise Search**

Woogle is a prototype system which we developed to combine the advantages of Wikis and Enterprise Search [Happel 2009a, Happel 2009b]. Both are two popular IT solutions for information access within organizations. Enterprise Search targets to make available existing information for reference and reuse. On the other hand, Wikis as web-based, collaborative authoring tools are getting increasingly popular to acquire and accumulate new information. While both systems have a gatekeeper role in accessing organizational information, Wikis have a strong focus on creating information, but neglect efficient retrieval (especially information outside the Wiki) while search engines focus on providing efficient access to existing information but until recently do not address collaboration and information provision at all.

In our combination approach, the Wiki provides the user interface for searching within enterprise information (including the Wiki itself). Each user query is optionally assigned a special Wiki page, which allows persisting the information need. Thus, a mediation space is created, where users can further elaborate and discuss about information needs. Also, the built-in awareness and collaboration features such as user notifications can be easily applied to the search process.

#### **4.2 Inverse Search – Diffusing Private Artifacts to Shared Information Spaces**

Our second prototype which we shortly present addresses the phenomenon of “hoarding” information in private spaces – especially files on a local desktop resp. in private folders. Typically, such information is not addressed at all by knowledge sharing strategies and approaches, and there is no way for information providers to easily find out which documents would be worth sharing, although these documents could help satisfying other’s information needs.

In order to tackle this issue, we designed Inverse Search [Happel 2008] to support information providers in sharing documents from their private information space. Basis for our approach is a mediation service which allows information providers to retrieve aggregated unsatisfied information needs from an (enterprise) search engine. Information providers can then match their documents against the given set of information needs to get a ranked list of documents worth sharing. Inverse Search thus works in the opposite direction of conventional search, where information seekers match queries against a given corpus of documents.

## **5 Conclusions**

In this paper, we described that distributed work settings raise the need for knowledge sharing while making it also less efficient. While knowledge sharing in collocated settings is often directly driven by the needs of information seekers, this is not the case in codified, asynchronous document and content sharing. Given the fact that distributed work already starts at 30 meters of distance, it is an issue for any larger organization.

By comparing different knowledge sharing approaches, we found out that these differences are rooted in the properties and mediation features offered by the different knowledge sharing media. To this end, we coined the concept of need-driven



knowledge sharing and discussed its application to document and content sharing. We briefly introduced two different tool prototypes – Woogle and Inverse Search – to illustrate this approach. While these tools are currently subject to evaluation efforts, other recent works stress the problems of limited collaboration opportunities in search (e.g. [Dearman et al. 2008, Evans and Chi 2008]).

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# **Structured Knowledge Transfer for a Continuous Organisational Development: Methodology in Theory and Praxis**

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**Abstract:** An internally developed knowledge transfer methodology ensures at Credit Suisse that irreplaceable know-how (implicit and explicit) remains within the firm – even when keypersons leave, e.g. retirement, internal job mobility, extended absence or general leaving.

The methodology tested in theory and in praxis was developed by supporting over 70 keypersons and became part of the organisation in 2008. By covering general aspects of knowledge transfer as well as enhancing the human capital development in the business, the methodology provides a basis for organisational development: Due to transparent tasks and functions efficient and sustainable changes are possible.

**Keywords:** knowledge transfer, organizational development, succession management, personal development, transfer coaching, learning organization, knowledge management

**Categories:** M.0, M.2, M.5, M.8, M.9

## **1 Optimize internal knowledge transfer**

Someone with key knowledge (expert or manager) leaves the firm in three months time. When asked how important projects will run afterwards and if contacts will be kept within the organisation, the answer is: "Yes, we are currently preparing a transition list with all the relevant tasks. We will check it one month before the expiration of the contract."

The keyperson has left. The successor has taken over two months ago. During a coffee break with the successor reality speaks for itself: The successor's induction hasn't been prepared at all, the task overview was incomplete and out-of-date. He finished works that his predecessor should have done. The work motivation lowers if there is no project overview and one has to listen to comments from the project stakeholders such as "your predecessor struggled as well".

The successor's induction could have been more efficient and gainful for all participants with the following:

1. Identify the predecessor's tacit knowledge and analyze the strategic transformation: Which activities will continue or cease?

2. Appreciation for the predecessor's work: overview and transparency of his projects, activities, biggest achievements ...
3. Create an overview for the successor: from an overview to detailed functions and activities.
4. Due to a more efficient induction the successor will be motivated and able to participate and decide at an earlier stage.

What ever the reason for a key person's leave may be, there is a huge loss of knowledge for the company. That's bad but it gets even worse: how do you know which employee owns key knowledge and what are the entrepreneurial risks if there is no transparency?

Not only is the implicit knowledge lost but the explicit, documented one cannot be used or applied efficiently, because it's not found or the relevant contacts and the context are missing.

### 1.1 Introduction

During the induction of a new employee documented knowledge (such as instructions or descriptions) and tacit, experience based knowledge (e.g. personal network in a crisis) will increase.

The value of documented knowledge (dark blue) increases rapidly in the first phase due to the new employee's need for explicit knowledge during daily work. Tacit knowledge will be built (light blue). The new employee will know his way around the company, build up a network and become an expert in his own field.



*Figure 1: Induction of a new employee*

With an advanced induction the employee's valuable tacit knowledge increases, he knows important contacts and acquires knowledge and correlations of specific situations.

On the other hand, explicit, documented knowledge isn't required as much as before, the employee gains more experience every day:

1. The value of the employee's experience based knowledge increases by time
2. The value of the documented knowledge decreases (information in systems or data carriers)

If a key person is absent for a longer period (e.g. illness, vacation) or leaves the company (e.g. retirement, internal mobility, resignation) the manager faces the challenge to recruit new staff. Luckily there is still a job description from the predecessor available. Is it up to date? On what projects and details worked the departed employee? Who were his stakeholders? Who knows his daily challenges?

### 1.2 Knowledge gap due to employee turnover

An employee turnover brings the frail dealings with knowledge to light: Who owns the expert knowledge of the missing manager or expert? The deputy who managed two out of ten projects when the expert was absent and therefore only has a limited view of the predecessor's overall responsibility?

Valuable experience based knowledge (implicit knowledge) is lost once an employee leaves the company. Documented (explicit) knowledge is useless because nobody knows where it is, how it can be applied or who the relevant contacts are. The successor starts his job with documented information that is partially up to date, if available at all. Colleagues support as good as they can to close the knowledge gaps. That is not only time consuming but expensive.

During his induction, the successor – as his predecessor before him – runs through a learning process including many repetitions and inefficient workflows: The wheel seems to be reinvented.

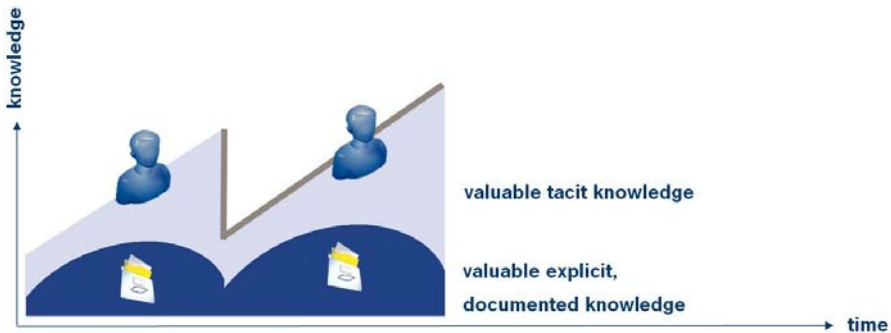


Figure 2: Successor's knowledge gap and knowledge increase

### **1.3 Optimized knowledge transfer: minimize the knowledge gap**

The optimized knowledge transfer enables a successor to identify and get access to the valuable part of the predecessor's knowledge. Before looking at the methodology in the details, what is the return on investment, seen from three different perspectives?

There are a number of advantages from the company's perspective

- Keep the predecessor's expert knowledge
- No inefficient or unnecessary induction
- Efficient transfer of a number of projects or a business area
- Increase motivation of employees: less inefficient work (do not repeat the predecessor's mistakes or time consuming learning's; acquire more and quicker decision competences
- Transparent functions and workflows
- Recognize and tap potential for process improvements and customer orientation
- Human capital and organisational development based on facts and transparency
- Close the gap between entrepreneurial vision and day to day work

Advantages from the successors's perspective

- Shorter, more efficient and motivating induction
- Motivation due to faster and sustainable decision making
- Benefit from the personal network of the predecessor
- Be on the same business level as colleagues are, but in a shorter time

Advantages from the predecessor's perspective

- Job reference with substantial projects, skills and competences
- Appreciation and motivation due to interest in one's work
- The visible transparency in expert knowledge and the creation of a detailed reference, supports the future career planning

This results in a win-win situation for all participants.

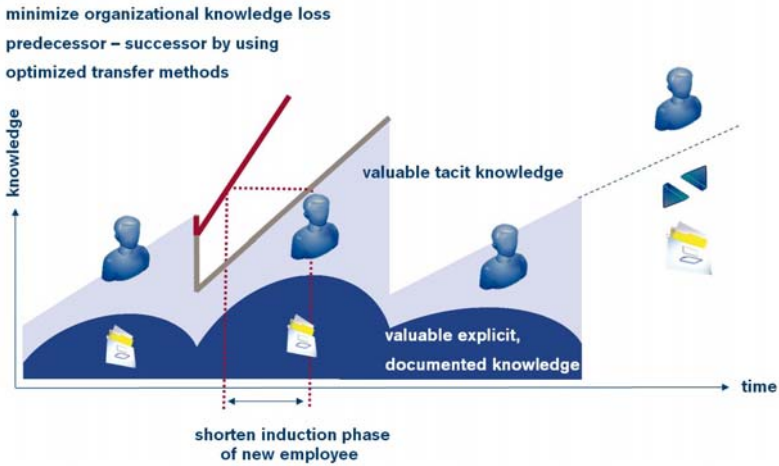


Figure 3: Potential of an optimized induction through knowledge transfer

#### 1.4 Optimized knowledge transfer – knowledge transfer at Credit Suisse in detail

The knowledge transfer methodology used at Credit Suisse is based on the analysis of internal business processes and consists of:

- A. Initialisation of knowledge transfer with line manager, predecessor and (if available) follower
- B. Three phases:
  1. Identify valuable knowledge
  2. Moderated / not moderated transfer
  3. Transformation of implicit to explicit



Figure 4: Methodology with Initialisation and three phases

### Initialisation

Line manager, predecessor and moderator discuss and agree on, which activities and functions are relevant for the successor:

- Strategy of the organisation
- Purpose of the knowledge transfer from the line manager's perspective
- Initial status
- Resources
- Adaption of methods to circumstances and persons involved

All participants commit to the agreed approach and resource estimate. The successor will then invite to further transfer sessions. As he benefits most from the sessions, he will strive towards a correct organisational setting. The line manager can be invited optionally as this raises more visibility and ensures the realisation of the sessions even under hectic daily work circumstances.

### Phase 1

Identify and map valuable knowledge, define appropriate methods for knowledge transfer in a first phase.

The knowledge map offers an overview of the relevant knowledge and lists the priorities for the transfer. The map shows internal and external stakeholders, processes, contacts, best practice, crisis scenarios, systems, available information (e.g. intranet, SharePoint repositories, documents on file drives or Wikis).

Ideally predecessor and successor are present when the valuable knowledge is identified. The successor gets first hand information. The creation of the knowledge map will give him a better understanding of his new working area and his predecessor's tasks.

Moderation in this phase is crucial: The moderator is responsible for the development of a significant knowledge map. This sets the base for all further steps, such as setting priorities and defining an appropriate structure. The external view of a



neutral moderator has been rated as very valuable: important questions are asked and answered openly. The moderator is in a perfect position to ask these important pain point questions.

Identify valuable knowledge is key for any further activity and is therefore done carefully and detailed. One to two half days are required for this task.

After completing the knowledge map including a prioritization, all participants agree on the next steps and define the necessary resources in detail.

### **Phase 2 – Knowledge Transfer**

In the second phase the important knowledge (classified as valuable for knowledge transfer) is transferred to the successor – either to a single person or a team – by using the agreed methodology in phase 1. The knowledge map will be itemized in the transfer document. This document is part of the entire knowledge transfer. The successor updates continuously, even after induction time.

Moderated and non-moderated knowledge transfer methods can be distinguished in this phase:

1. Moderated methods for complex knowledge, such as processes, crisis scenarios, personal network...  
This knowledge will be transferred with known methods from knowledge management, coaching and moderation. The choice of methods depend on the content, involved persons and the general conditions: story telling, SWOT visualisation, best practice, worst practice, visualisation of the personal network, survival guide, balanced score card and other methods.
2. Non moderated methods: Suitable for fact based knowledge with simpler context, e.g. application handling.

### **Phase 3 – Transform Knowledge**

In the third phase the predecessor's knowledge will be transformed to written and explicit knowledge, provided that the effort is reasonable and justifiable. This transfer document guides the successor through the whole knowledge transfer. It might be prepared before phase two, right after the creation of a knowledge map and the prioritization. The transfer document paves the way for the successor by giving an overview of the new field: transfer status, information, context, contact persons, scenarios, etc.

The transfer document can be reused at a later stage, when a deputy or a new successor joins the team or department: the knowledge transfer comes full circle, phase 1 restarts with new participants, but with an easier beginning for the newcomer.

## **2 Current Experiences**

The methodology supports human capital development as well as organisational development: the organisation's tasks and functions will be more transparent and therefore can be changed with more sustainability.

More than 70 knowledge transfers have shown, that employees basically pass on their knowledge gladly, provided that all the involved persons get a profit in following the methodology.

To focus on the predecessor's activities and tasks was considered by most persons as an appreciation of the achievements during daily work. This roundup can be integrated in the job reference.

In any case it is essential to evaluate the potential of a knowledge transfer during the initialization phase. If the basic conditions are negative, e.g. the predecessor is not willing to participate, it is recommended to refrain from a knowledge transfer and to suggest other not moderated methods outside of the framework. This situation didn't occur in daily work, except for a few exceptions (2 out of 70 knowledge transfers).

Only if predecessor and successor take a personal interest in passing on or making use of the expert knowledge, the methodology can unfold its full potential.

Customers mentioned, that the realized transparency allows a qualified performance appraisal, based on personal skills and project work: An employee develops his skills and abilities and is supported accordingly. The Linemanager recognises the benefits of supporting the employee because of the transparent functions and activities. Therefore most concerns about unknown or dangerous risks are resolved.

Last but not least the line manager's interest in his employee's functions and achievements showed a highly positive impact on the employee's motivation and working attitude.

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# Work Experience Reuse in Pattern Based Task Management

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**Abstract:** Pattern based task management has been proposed as a promising approach to work experience reuse in knowledge intensive work environments. While initial work has focused on the conceptualization and development of a generic framework, the process and user interaction of the task pattern lifecycle has not been addressed. In this paper, we introduce task copy augmented by Abstraction Services as a novel approach to facilitate task pattern creation and maintenance in a semi-automatic fashion. Also, we develop the architecture to demonstrate the underlying ideas by leveraging the advantage of semantic technologies.

**Keywords:** Task Management, Experience Reuse, Task Pattern, Knowledge Work, Semantic Technologies

**Categories:** M.3, M.8, H.5.3, K.8.0

## 1 Introduction

With the emergence of the “knowledge economy” and “knowledge society” [David, 02] driven by Internet-based information and communication technologies, rapid transfer of knowledge is enabling organisations and enterprises to achieve objectives quicker and at lower cost, thus gaining competitive advantages. Traditional Knowledge Management approaches have been regarded as inadequate to support knowledge work efficiently, especially with respect to experience transfer in knowledge-intensive work [Schutt, 03]. To make knowledge transfer more efficient we have to take the respective work context explicitly into account and have to represent it properly. This consequently gives the rise to a growing demand for, and extensive research on explicit modelling and processing of work experience [Sun, 05].

A central challenge is that work experience is typically tacit, unstructured, and hard to capture and communicate. This determines the particular challenges in experience modelling, representation and reuse. To address this issue, attention has been paid to the capture and modelling of relationship between activity and knowledge as: successful action certainly requires specific knowledge, and work

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experience is incrementally gained from the execution of work processes [Wiig, 04] [Riss, 05a].

Recently, the Pattern Based Task Management (PBTM) approach [Riss, 05b] has been proposed as a means to transfer and reuse valuable work experiences, especially for knowledge-intensive work. It introduced the task pattern as a key concept for modelling and representing work experiences. Due to their proximity to task execution, these task patterns are better suited to transfer task related knowledge since they guide knowledge workers in a concrete way through their work activities. In the NEPOMUK project, we have consequently followed this approach making extensive use of semantic technologies to bring the handling of information, tasks, and task patterns closely together. Approaches based on Business Process Modelling proved to be inadequate to support processes in knowledge work because of their contingent characters. The separation of process and information assumed in these approaches does not work since the processes crucially depend on the information gained during the execution. Therefore the PBTM considers information objects as a crucial point in task guidance, and leaves the actual execution decision to the user. Due to the entwinement of task management and task pattern creation and maintenance, PBTM can only be realized on efficient task management. Hence, effective technologies and easy-to-use tools to support task pattern lifecycle within task management are foundational to the PBTM approach [Jarodzka, 07].

The approach is currently used in the MATURE project with the goal to establish a global experience lifecycle as proposed in [Ong 07]. However, such a lifecycle requires the extensive participation of users and their contribution.

The remainder of the paper is organised as follows. Section 2 introduces the PBTM approach and discusses its challenges. Section 3 describes key concepts and interrelationships of the architecture for the proposed approach. Section 4 outlines concrete implementation details and demonstrates how each proposed concept can work together to facilitate work experience reuse. We discuss related work in Section 5 and conclude the paper in Section 6.

## **2 The PBTM Approach**

PBTM was proposed under the observation that knowledge work is characterized by ad hoc processes and the proceeding of which centrally depends on the information gained in the course of execution. However, this does not mean knowledge work is completely irregular but only that regularly repeated process structures appear in certain isolation of as well as in strong dependence on available information. Even if the regular patterns that appear in these processes are not systematic to suffice for process modelling, it is nevertheless worth to record them and make them available to other users. These patterns mainly appear on task level so that this is the level on which the PBTM supports reuse. Consequently, we call them task patterns. If a particular process pattern has been repeated several times, it can be regarded as the best practice for a particular type of tasks and for a specific group of users. Typically, established work practice is formally described in process models and made available by workflow systems. However, workflow systems which depend on predefined models are expensive and rigid. Hence, they are inadequate to support flexible and

dynamic work processes such as knowledge work since these processes are subject to regular changes. The PBTM emerged with the aim to overcome this barrier.

The task pattern is a key concept of the PBTM approach, which provides a template of abstract information and describes common properties of similar tasks. It can be used as a basis of creating new task instances. In real world applications, a task pattern is likely to become very complex and thus requires considerable user interactions during the task pattern creation and maintenance processes [Riss, 07]. A task pattern's lifecycle usually starts from manual creation by specifying generic views of similar tasks. Task patterns, therefore, are represented as a carrier of the user's work experiences. When the task pattern is applied as a template of creating new task, the embedded work experiences can be reused for the task to execute.

Additional efforts required in the task pattern maintenance have been addressed as the major challenge of enabling the PBTM approach. This is because knowledge workers are usually focusing on the tasks at hand and are likely to reject the abstraction of existing tasks, e.g., contribute to task patterns, as part of their activities. Such activities merely add more administrative overhead for which the immediate benefit is not always clear. Therefore, individual costs must be reduced to as low as possible, and one of our proposed solutions is to populate task patterns in a semi-automated fashion.

### 3 Realizing PBTM in a Semi-Automated Fashion

#### 3.1 Task Copy and Task Reuse

Towards the aim of reusing past experience and work structures, knowledge workers are unlikely to consider abstracting previous tasks to task patterns as an initial step. Therefore, we hypothesize that knowledge workers will refer to similar ongoing or completed tasks whose goals or contexts match those of their tasks at hand. This provides a point of reference from which the knowledge workers may exploit opportunities to transfer and therefore reuse their efforts and experiences from earlier activities by directly copying information from previous tasks. This is called task-oriented experience reuse or task copy.

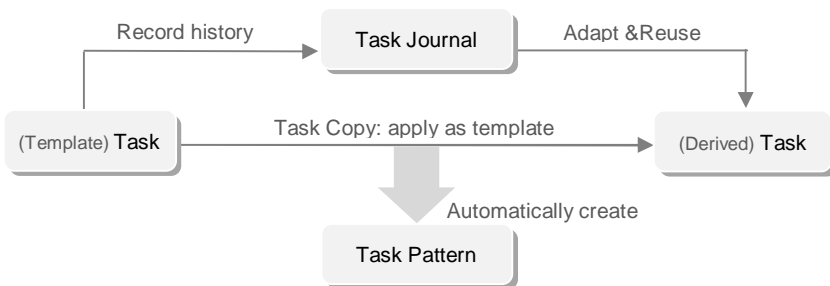


Figure 1: Task Copy based Experience Reuse processes

If we use task copy as the basis for work experience reuse, the next natural question is how such a copy operation will be realised. There are two options. First, entire task structures and details are duplicated, with the assumption that everything is implicitly relevant to the next task context; second, the user is responsible for explicitly selecting every detail to be copied. The former is likely to be useful for a small set of tasks. This is because it will likely result in information overload for a user. It results in a situation which requires the user to spend potentially more effort customising the duplicated task than to start a new one. The second option could also overwhelm users as it requires them to consider too many details from previous tasks, thus leading to a situation similar to that of the first. This reflection informs us that a more helpful position to consider the reuse of past work structures is somewhere in between these two extremes.

To that end, we proposed the concept of Task Journals [Riss, 08] as the basis on which records of past work experience can be made more comprehensible. Task Journals describe previous task activities and information objects used during task executions in the order of their usage. For example, it describes at which point in time a website *x* was attached as a bookmark to task *y*. Therefore, Task Journals can explicitly describe how a particular task is completed and in which order the respective steps are executed. Thus, it is possible to leverage the historical information to facilitate the creation of task pattern.

Since every task differs in its context and details, the user is unlikely to be able to reuse the details directly from a template task (from which the new task is copied), via its task journals. Instead, we expect that the user will be required to adapt the information captured in task journals from the template task to suit the context of the new task. For example, the user may select a different document template as the basis for a report in the new task. This final step of user adaptation is therefore necessary to enable the task journals to be contextualised in the new work context.

### **3.2 Task Evolution in Task Pattern**

The task-oriented experience reuse described above is a low-cost approach of enabling experience reuse since descriptions of executed tasks can be used as they are. However, there are two major shortcomings. One is that this approach requires active user adaptation in each subsequent task, and consequently the results of each adaptation are lost. The other is the potential violation of the users' privacy since the task descriptions may also contain personal notes and other private information. This has motivated us to combine the strength of the task copy process with the task pattern concept which records user adaptations for task evolution. On the one hand, a task pattern can be automatically created whenever a task copy process happens, e.g., when a task is applied as a template task to another task, as shown in Fig.1. On the other hand, the public task pattern can be further enriched through collaborative efforts within an organisation, and therefore the adaptations of each subsequent task can be captured in this way.

Since a task pattern is automatically created from the task copy process, it is capable of capturing the evolution of a group of similar tasks. We define a collection of similar tasks as a task family which consists of a number of tasks derived from the same template task. This relationship can be captured in the task pattern model and represented in an ontology. For example, when a task pattern is automatically created,

a template task is associated to the task pattern. The semantic relations can explicitly describe that the template task is the basis of creating the task pattern. Moreover, tasks derived from a template task are represented as derived task in the task pattern model. In this case, a task pattern not only presents the generic knowledge of similar tasks but also records the evolution of a task family by describing the relationships between tasks. These task-task semantic relations can be further leveraged for task similarity computation.

### 3.3 Reflecting Task Knowledge in Abstraction Services

In the proposed task copy process, the reuse of task-oriented knowledge is enabled by transferring information captured in task journals from template task to derived task. Task journals play the role of experience carriers which describes the history of task execution, e.g., an email is attached to a task. Since information recorded in task journals could be rather concrete, it is insufficient to present a generic view of task knowledge. For this purpose, we propose the concept of Abstraction Services (see Figure 2) to, on the one hand, present generic task knowledge in task patterns, and on the other hand, provide salient details of a required task artefact, typically a resource such as a document or person. In short, the Abstraction Services must have the ability to describe generic information of a task pattern and visualize the generic knowledge into concrete examples which is so called *Candidate*. An instance of *Candidate* can be automatically extracted from task journals or manually generated. For example, in the task copy process, information resources embedded in a particular task journal can be automatically transferred to Abstraction Services with candidates pointing to information resources. In this way, past task knowledge can be explicitly visualized by the concept of *Candidate*.

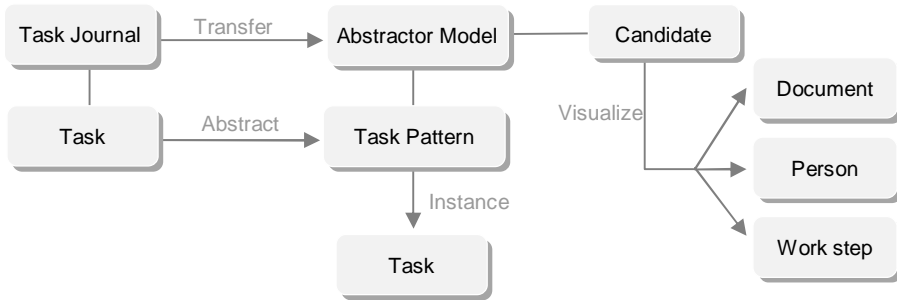


Figure 2: Models: Task Pattern & Abstraction Services

## 4 Implementation & User Scenarios

The Task Model Ontology (TMO) [NEPOMUK D3.1, 07] defines a number of schemas to describe general properties of task, task pattern (task pattern is modelled in the TMO extension) and other relevant concepts in supporting task management. We extend the TMO by introducing new attributes of task pattern and the new



concept of Abstraction Services into the model. The ideas described above had been implemented in the NEPOMUK Semantic Task Management Framework [Ong, 08]. In this section, we will describe a user scenario to demonstrate how task pattern and Abstraction Services work together to enable work experience reuse in the KASIMIR [Grebner, 08] task management system.

### 4.1 Automated Task Pattern Creation via Task Copy

In order to make the proceeding clearer we will give an example how task patterns are created and used. John Doe, a researcher in SAP Research, uses KASIMIR (see Figure 3: A), to manage his daily work. In KASIMIR, the upper panel is the task list which includes a number of completed and running tasks. The lower panel shows the details of the selected task. For example, the current selected task, *Write Nepomuk D3.3*, is the one John is working on, and task details such as task collaborators, related documents are showed in the lower panel.

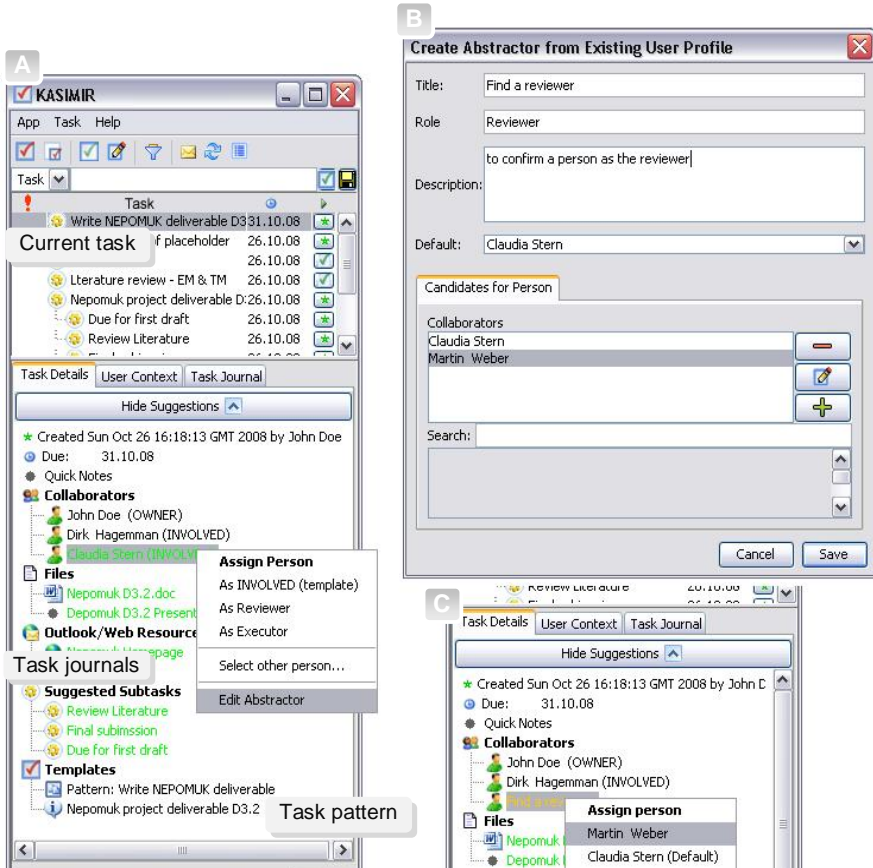


Figure 3: The prototype system of Task Pattern and Abstraction Services application.

In the task list, the completed task: *Nepomuk project deliverable D3.2* records all task details, such as collaborators, documents, sub-tasks and other information resources, in its task journals. John selects the completed task as a template to his current task: *Write Nepomuk D3.3*. Here, a task pattern is automatically generated and shown in the bottom of the lower panel. Meanwhile, task details captured in task journals have been displayed with green colour as recommendations. For example, Claudia Stern was a project reviewer in the completed task, and she has been recommended by the system as a participant in the current task. Therefore, previous task knowledge can be captured by and transferred via task journals, i.e., the items in figure 3 highlighted by green colour. This process makes past work experiences reusable in planning and executing new tasks.

## 4.2 Task Pattern and Abstraction Services

A user can manually modify an automatically created task pattern by specifying the task pattern's name and description from a more generic level. Besides that, a task pattern can be associated with *Abstractors* provided by the abstraction services. For example, manually add a contact as the *Person Candidate* to an abstractor as shown in Figure 3:B. We also introduce an alternative way to support Abstractor Services, which is recommend potential candidates mined from task journals. In the user scenario, Claudia is recommended as a possible reviewer in the new task but she is busy in another project and won't contribute to the new task. Hence, John selects 'edit abstractor' menu and the system automatically generates Abstractor Services with adding Claudia as a possible collaborator. When John goes back to the KASIMIR (Figure: C), the lower panel shows the Abstractor Services named with 'Find a reviewer'. This allows the Abstractor Services to suggest a person who can work as a reviewer for the new task. By right clicking the 'Find a reviewer' icon, a task collaborator can be directly assigned from the candidate list, e.g., Claudia or Martin.

## 5 Related Work

The UAM project [Moran, 05] [Moody, 06] [Cozzi, 06] employs a pattern based approach to managing and reusing valuable work experiences. It proposes the *activity pattern* as the abstract representation of work experience and exploits semantic technologies to enrich tasks and patterns in a semantic way. In UAM, an activity pattern is simply represented as a checklist with a number of work steps, along with actors and resources. Activity patterns are controlled by a group of experts who are responsible for the creation and maintenance of activity patterns. This requires efforts made from both the activity pattern experts and providers [Convertino, 07]. In PBTM we follow a flexible and low-cost approach to task pattern management, e.g., a task pattern can be generated in a semi-automatically fashion by leveraging the past task knowledge captured in task journals. We also introduce the Abstraction Services into task pattern model, which helps users to identify resources required in the task pattern.

Another related approach is the Collaborative Task Management (CTM) that presents a conceptual framework for unobtrusive support of agile business processes. [Stoitsev, 07]. The framework enables the modelling, exchange, and reuse of light-

weight task structures defined by the users. In addition to the person-to-person exchange of best-practices, it enables ‘outsourcing’ of dynamic task structures and resources in personal workspaces and organizational units. Thus, they can be managed according to local domain knowledge and made available for reuse in shared repositories. The delegation of tasks generates enterprise process chains that go beyond the user’s personal workspace. The framework facilitates knowledge management and supports proactive tailoring of underspecified business processes by the users.

To facilitate knowledge reuse, the TaskNavigator [Holz, 06] follows a different approach which is so called instance-based task reuse. It makes the use of previously executed tasks as the cases for planning and organizing future similar tasks. This is similar to our task copy approach. However, the two approaches have different focuses. The task copy aims to providing an easier way to task pattern creation and maintains. Moreover, in the task copy process, not only task information is reusable but also the history information captured in task journals is visible to the user. This is valuable to task executors in terms of providing enriched background information of the task execution history.

## **6 Conclusion and Future Work**

This paper described a semantic-enabled task pattern based approach to work experience reuse. The approach brings together a number of interesting concepts, i.e. task copy, task journal, task pattern, and abstraction services. We described these concepts and their roles in the realisation of the proposed approach. By recording the history of past tasks, task journals are used as a means of capturing past work experiences. It is particularly the temporal sequence that makes the proceeding in the task execution more transparent since otherwise in complex tasks the user might be overwhelm by the masses of offered resources. The task copy process is used to transfer these captured experiences to new tasks. Task pattern serves as a knowledge model to represent the structural relations at abstract level of task knowledge, which but can be leveraged to facilitate task similarity comparison. The work presented here lays a solid foundation for task pattern applications.

For the future work, we plan to focus on three aspects. The first one is to extend the Abstractor Services beyond the described implementation. Currently, the described services do not yet consider context information of the current task executor. For example, in a travel task the destination of the user who applies a task pattern should be considered for the provision of travel information. The same holds for suggested experts which might depend on the organizational unit to which the executor belongs. The second one is improving the user interaction for task patterns and task similarity computation for the identification of suitable templates. The third aspect we considering for the future work is algorithm design and development in order to compute similarity between tasks and task patterns with the ultimate purpose of facilitating knowledge reuse for novice users. The general direction of these development can be found in [Schmidt, 09].

## Acknowledgements

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# Toward a New Knowledge Management: Feelings in Action - The Significance of Emotions in Decision Processes

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**Abstract:** According to recent neurobiological and psychological research by A. Damasio respectively G. Gigerenzer it is the aim of this paper to point out the limits of plainly cognitive approaches to decision-making and problem-solving (in economy) and – by showing the significance of emotions and (gut) feelings in decision respectively problem-solving processes to contribute to an essential improvement of Knowledge Management leading to a decisive competitive advantage of enterprises.

**Keywords:** decision-making, problem-solving, rationality, cognitive limits, expertise, emotions  
**Categories:** M.4

## 1 Introduction

In order to create a “feeling” for the necessity to overcome the cognitive limits (of decision-making) in Knowledge Management by taking care of the role of emotions in decision processes – according to recent neurobiological and psychological research by A. Damasio respectively G. Gigerenzer – and thus to be able to create “good” solutions of new/unfamiliar problems [cf. Selten, R., 2001: 17; Gigerenzer, G., 2004: 392-393] (as an essential improvement of Knowledge Management leading to competitive advantage) let us start with a sort of a sophisticated joke:

Two priests from two different world religions – and after unsuccessfully trying to convert each other – eventually had a long quarrel about who has the right approach to God and who is serving Him best. Finally, one of them in a very tolerant mood said to the other: “Let us stop our quarrel! We both serve the same God – you in your way and me in *His*.”

What was the (arrogant) message of the priest? While the other should serve their God as the latter *feels* it to be correct, he himself – on the other hand – will serve God EXACTLY *in the one and only way* (i.e. un-reflected/mechanically), as he *thinks*, that God wants him to do.

We can observe that the point of the joke is not too far away from *real life situations*, especially if one thinks of the way, in which economists respectively

managers really do make their DECISIONS. Watching the way managers “argue” or justify their decisions, one gets the impression that they also serve some God *in the one and only way* and that they *think or believe* their God *wants them to do* (so). Their (anthropomorphic) God is called (homo) OECONOMICUS.

In *economics*, however, decision processes are an immensely important topic, because decisions (e.g. about investments) are thought to explain the economic success of an organisation or an enterprise. As generally known (or accepted), economic decisions rest upon the principle of maximizing utilities (and minimizing costs). Thereby, any decision process should be strictly (i.e. logically) rational – that means by ELIMINATION OF ANY KIND OF EMOTIONS/FEELINGS. Mind you, that this is possible only if no personal relationship toward a real situation exists (as it is in the case of experts).

The average manager obviously takes this theory/principle of decision making in economics based on unbounded/logical rationality [cf. Gigerenzer, 2008: 4; Gigerenzer, 2004: 393] much too literally [cf. “The map is not the territory!”, Bateson, 2000] – just as the priest in the joke –, and therefore forgets about the corrective power of emotions/evaluative feelings within decision processes. This point is argued by A. Damasio, who shows that *emotions and feelings*<sup>1</sup> are indispensable in the coming about of good (and sustainable) decisions [cf. Damasio, 2003: 145]. A. Damasio writes: “[...] as personal experience is accumulated, varied categories of social situation are formed.” On the basis of certain life experiences, we create knowledge concerning the solution of problems in terms of emotion and feeling. “For example, did the immediate outcome of the chosen action bring punishment or reward? In other words, was it accompanied by emotions and feelings of pain or pleasure, sorrow or joy, shame or pride? No less importantly, was the *future outcome* of the actions punishing or rewarding, regardless of how positive or negative the immediate outcome? [...] The emphasis on *future outcomes* calls attention to something quite particular about human behavior. One of the main traits of civilized human behavior is *thinking in terms of the future* [o.e.<sup>2</sup>]” [Damasio, 2003: 145-146]. In this way, we “connect categories of social knowledge [...] with the innate, given apparatus of social emotions [like embarrassment, shame, guilt; contempt, indignation; sympathy/compassion; awe/wonder, elevation, gratitude, pride, cf. Damasio, 2003: 156] and their subsequent feelings.” A. Damasio accords special importance to those emotions/feelings, which are associated “with the future outcome

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[1] According to him [cf. Damasio, 1999] *emotions* are complicated combinations of chemical and neuronal reactions in the brain. They play a regulatory role and have the original biological aim to create favourable circumstances for the survival of the organism. Emotions used the body (guts, muscle-skeleton-system) their theatre, but still have an influence on certain brain functions. Emotions are based upon innate brain functions, which stem from a long evolutionary development. Individual learning processes and cultural influences, however, change emotions in accordance with their trigger and their expression. From these emotional changes of the body and brain functions evolve representations in the brain, which can be perceived in consciousness. For those representations of the emotional changes A. Damasio reserves the concept *feelings*. “They [feelings] translate the ongoing life state in the language of the mind. [...] Feelings are perceptions, and I propose that the most necessary support for their perception occurs in the *brain’s body maps*” [Damasio, 2003: 85].

[2] “o.e.” is the abbreviation of “our emphasis”.

of actions”. They “come to signal a prediction of the future” as an “anticipation of the consequence of actions”. “The revival of the *emotional SIGNAL* [o.e.] accomplishes a number of important tasks. Covertly or overtly, it focuses attention on certain aspects of the problem and thus enhances the quality of reasoning over it. [...] A gut feeling can suggest that you refrain from a choice that, in the past, has led to negative consequences, and it can do so ahead of your own regular reasoning telling you precisely the same “Do not.” The emotional signal can also produce the contrary of an alarm signal, and urge the rapid endorsement of a certain option because, in the system’s history, it has been associated with a positive outcome. In brief, the signal *marks* options and outcomes with a positive or negative signal that *NARROWS* the *decision-making space* and *INCREASES* the *probability* that the action will conform to past experience [o.e.]. Because the signals are, in one way or another, body-related, I began referring to this set of ideas as ‘*the somatic-marker hypothesis*’” [Damasio, 2003: 147]. A good metaphor to illustrate the way in which these emotional signals work is the Word program, which “keeps only recently opened files in memory and ‘forgets’ the rest. This usually *speeds up* finding what one is looking for [o.e.]” [Gigerenzer, 2007: 24].

“The elimination of emotion and feeling from the human picture entails an impoverishment of the subsequent organization of experience. If social emotions and feelings are not properly deployed, and if the relation between social situations and joy and sorrow breaks down, the individual cannot *categorize the experience of events in his AUTOBIOGRAPHICAL MEMORY record according to the emotion/feeling mark* [o.e.] that confers “goodness” or “badness” upon those experiences. That would preclude any subsequent level of construction of the notions of goodness and badness, namely the reasoned cultural construction of what ought to be considered good or bad, given its good or bad effects” [Damasio, 2003: 159].

## 2 Ways of Making Decisions and Solving Problems

The *natural way* of making decisions is based not on un-bounded rationality but on bounded/eco-logical rationality [cf. Simon, 1956: 129-138; Gigerenzer, 2007: 94; Gigerenzer, Todd and the ABC Research Group, 1999; Gigerenzer and Selten, 2001; Simon, 1990: 7; Gigerenzer, 2008: 7-8; Damasio, 2003: 149]. “[The latter] defines the rationality of heuristics independently of optimization and content-blind norms, by the degree to which they are adapted to environments. The study of ecological rationality facilitates understanding a variety of counterintuitive phenomena, including when **ONE REASON IS BETTER THAN MANY**, when **LESS IS MORE**, and when **PARTIAL IGNORANCE PAYS**<sup>3</sup>. *Homo sapiens* has been characterized as a tool-user. There is

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[3] In order to **prevent misunderstandings**, for heuristics in general and the heuristic “partial ignorance pays” especially it is the case that if they are used by laymen with weak background knowledge in a domain of experience (and interests), they will in general lead to bad results resting upon bad decisions. On the other hand, if experts use the same rules/heuristics especially according to their long-time experience they have, (the corrective power of) their (gut) feelings/felt knowledge will guide them to good results because of good decisions [cf. Mérö, 2002: 223-224; Dreyfus and Dreyfus, 1987: 80].



some deeper wisdom in that phrase. The tools that make us smart are not bones and stones, but the heuristics in the adaptive toolbox” [Gigerenzer, 2008: 19].

Ecological rationality expresses itself in the consciousness as a “(gut) feeling”, also sometimes called *intuition*, i.e. it is the foundation of intuitive problem-solving, deciding and acting. Ecological rationality results from an attunement between the structure of environment and the structure of a heuristic/rule of thumb [cf. Gigerenzer, 2007: 48]. The latter makes use of our experiences/expertise, whereby expertise is built upon the evolved capacities of the brain, e.g., recognition memory (which produces categorizations).

But as A. Damasio points out, a gut feeling does not substitute proper reasoning. “It has an auxiliary role, increasing the efficiency of the reasoning process and making it speedier” [Damasio, 2003: 148].

Figure 1 is the graphical representation of two – under normal conditions complementary – paths leading to decision-making respectively problem-solving. A. Damasio [Damasio, 2003: 149] describes it in the following way: “Normal decision-making uses two complementary paths. Confronted with a situation that requires a response, path A prompts images related to the situation, the options for action, and the anticipation of future outcomes. Reasoning strategies can operate on that knowledge to produce a decision. Path B operates in parallel a prompts activation of prior emotional experiences in comparable situations. In turn, the recall of the emotionally related material, be in covert or overt, influences the decision-making process by forcing attention on the representation of future outcomes or interfering with reasoning strategies. On occasion, path B can lead to a decision directly, as when a gut feeling impels an immediate response. The degree to which each path is used alone or in combination depends on a person’s individual development, the nature of the situation, and the circumstances.”

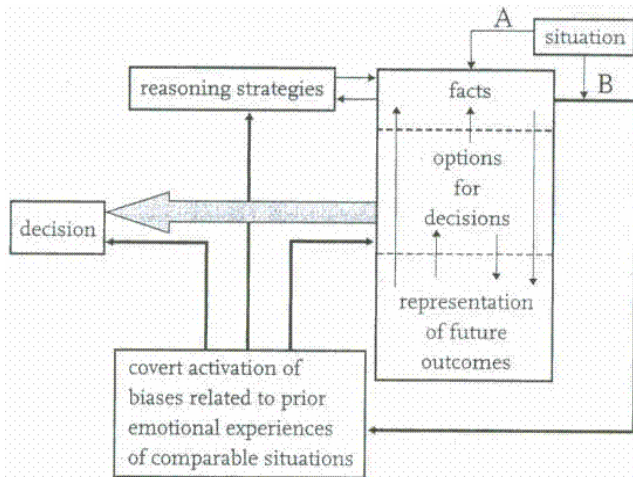


Figure 1: Normal decision-making [Damasio, 2003: 149]

The way, in which both paths – plainly algorithmic and natural/intuitive decision making patterns – bring about decisions, can be illustrated by the following story [Gigerenzer, 2007: 4-5]:

A young man (call him Harry) found himself confronted with the decision between two girlfriends, “both of whom he loved, desired and admired” (and “perhaps” wanted to marry one). Unable to decide, he recalled a letter by Benjamin Franklin from April 8, 1779, who tried to advice his nephew in a similar situation by providing a sort of “balance sheet”:

*“If you doubt, set down all the Reasons, pro and con, in opposite Columns on a Sheet of Paper, and when you have considered them two or three Days, perform an Operation similar to that in some questions of Algebra; observe what Reasons or Motives in each Column are equal in weight, one to one, one to two, two to three, or the like, and when you have struck out from both Sides all the Equalities, you will see in which column remains the Balance. [...]”*

Harry tried to turn this advice into reality. On seeing the result, something unexpected happened: He could not (emotionally) accept the (logically) provided result. But the logic brought to his mind that his heart had already decided – against the calculated result that means in favour of the other girl.

This story tells us that decision processes concerning real life situations (both in every day and in professional life) cannot be reduced to (decision) algorithms (as economic theories seem to suggest in the way they are turned into practice), but that emotions and feelings are really indispensable therefore.

### 3 Lessons from Neurobiology and Psychology

Given the investigations of A. Damasio<sup>4</sup> one can see how the suppression of emotion in the coming about of (economical) decisions may lead to disaster, i.e. if we completely replace intuitive applications of measures to achieve certain aims (e.g., well-done investments) and evaluations of results (acceptability) by algorithms and weak everyday knowledge of use (instead of inform experts’ experiences).

A. Damasio found that people with certain brain deficiencies (either of organic or educational/cultural origin) are still perfectly able to argue and analyse in “laboratory situations”, i.e. disengaged from reality(!). In real life situations, however, they are

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[4] He summarizes his research in the following way: “Decisions made in [...] emotion-impooverished circumstances led to erratic or downright negative results, especially so in terms of future consequences” [Damasio, 2003: 145]. Furthermore, decisions made in emotion-impooverished circumstances do not make us generally happy as relevant research proves: In one study people were asked *how* they decide in everyday situations, e.g. which TV program to watch or what to buy in a department store. Those people, who reported to (consciously) use a decision matrix as basis for an action, were considered as *maximizers*, because they (consciously) tried to get the best from an economical respectively a logically rational point of view. Others, who reported to be engaged in a limited search and to settle quickly with the first (acceptable) alternative as a “good enough” solution, were called *satisficers* [cf. *satisficing*, Simon, 1957], because they tried to become (emotionally) satisfied. The latter were more successful in practice than *maximizers*, who excelled in depression, perfectionism, regret, and self-blame. The *satisficers* on the other hand were more optimistic and had higher self-esteem and life satisfaction [cf. Gigerenzer, 2008: 6-7].

unable to apply their insights to sustainable problem solutions. Cut short, this means that our so called “social knowledge” based on emotions and feelings constrains the set of possible solutions that will be acceptable in the future. If we just concentrate on emotion-impooverished (cognitive) solutions, we will be unable to correct and stick to calculated results solely, which prove threatening in the long run! The usual way is that the calculated results are evaluated and corrected with the help of emotions and feelings.

For a long time scientists were searching in the wrong direction. They thought that it was “a lack of knowledge” that was responsible for the poor decision-making of patients with prefrontal damage in their brain, which cut them off from their emotional experience memory; i.e. their working memory was considered to be inefficient. In the end, however, scientists found out that these patients did have all the necessary information and knew how to navigate such knowledge *logically*. But in reality they were at loss [cf. Damasio, 2003: 143]. In practice, we need knowledge stored in connection with life experiences. We need especially to understand the outcome of a (problem) solution in terms of emotion and feeling. We have to be able to think “in terms of the future”, which sometimes is called an ecological check, i.e. the future must not simply be imagined, it should be felt!

Feelings cannot be reduced to decision matrices, as (many) economists seem to believe – both from a professional point of view as well as according to their personal attitude (“*maximize your utility!*”). In this context G. Gigerenzer writes that he once met a man, an economist, who actually did apply the balance sheet method by Benjamin Franklin, mentioned above, to choose a partner. “*By the way, he is now divorced*” [Gigerenzer, 2007: 55].

If in (economic) decision situations we say (or eventually really believe!) to be compelled to act strictly according to rules predetermined from outside, in this external framework we will cut down the set of possible solutions, that can result from the world of emotions of an internal framework. If emotions are involved in decision processes, we can also recognize the limits of the application of algorithms. Algorithms as such can explain decisions *ex post facto* but not in order to predict an uncertain future.

The discussed topic was supposed to show both sides of bringing about (decisions leading to) “good” solutions of (real) problems – the (plainly neutral) cognitive side and the emotional one. Now, we should be clear about the fact, that besides possible theories or omnipresent action guiding ideas in every day life, we also have to take care of the feelings, which accompany our actions, if we use those theories or advices for making real decisions.

## 4 Conclusion

With respect to Knowledge Management the decisive point is the following: In classical Knowledge Management we start with explicit documentations and knowledge representations and believe that this approach will allow us to grasp the intuitive knowledge of the experts. In contradistinction G. Gigerenzer starts with the idea that the intuitions of the masters/experts can be “reduced” to simple heuristics/rules of thumb. Therefore we will turn round the system and take the heuristics as starting point in order to grasp the experts’ knowledge, such that explicit

documentations of knowledge [given as “complete (full) decision trees/complete problem-solving algorithms”] can be replaced by documentations adapted to the real/practical thinking of human beings [given as “effective (fast and frugal) decision trees/effective problem-solving space”], which correspond to the intuitions of the experts [cf. Gigerenzer, 2007; Gigerenzer, 2008, Gigerenzer, 2002]. The semantics of those decision trees, however, results afterwards, i.e. from the concrete and operative background knowledge of the users. Parallel to this approach, one can still (and definitely has to do it) formulate the theoretical and explanatory knowledge (i.e. the “complete decision trees/complete problem-solving algorithms”) to explain the decisions/problem-solutions *ex post facto* and make it understandable. That means, that we do not start grasping the intuitions of experts respectively their expertise using a complete documentation, but instead we start with the knowledge emerging at a higher level, which has been built up with the help of expertise. Expertise (as a domain-specific problem-solving-competency) together with the identified heuristics can now provide what we originally expected from the (thought to be more or less complete) documentations. In other words: We do not start with pure common sense thinking, but with real personal experiences, which someone has acquired in daily and professional life, knowledge, one had to fight for and which therefore cannot be (re-) produced by applying simple rules under the presupposition of an average layman-knowledge/common sense. This does of course not imply that the latter is considered in a pejorative or devaluating way, in the sense that it is bad or useless. Just the opposite is the case! The intuitions (or “gut feelings”), one can find in daily life, are quite distinct from the artificially constructed average knowledge, one can find in the daily newspapers. This kind of knowledge has to be formulated artificially, such that people are deceived into thinking that everybody can understand everything if the didactic is well chosen and one can follow the argumentation step by step. But that is fiction. Instead we have to “use fiction to talk about fact” and the resolution level of fictions determines the expressive power of our means to convey some message and thus of what we are able to say. Instead we should make use of the plurality, the intuitions and the fine nuances and distinctions available in everyday languages to reach a deeper understanding instead of reducing everything to a constructed mean knowledge. This has also been well known to A. Einstein, who once wrote: “What characterises our time is the perfection of mediocrity and the ‘confusion’ of our AIMS.”

Finally let us summarize the main point of our contribution with a well-known quote from *The Little Prince* [Exupéry, 1991: 68]: *Goodbye,” said the fox. “And now here is my secret, a very simple secret: It is only with the heart that one can see rightly; what is essential is invisible to the eye.”*

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# **Evaluating Success of Knowledge Management Systems – Lessons from the @SK! Case**

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**Abstract:** Evaluating success of knowledge management (KM) is a difficult undertaking, yet without a decent approach to show evidence about its value, KM initiatives might not be sustainable as already evident in many abandoned projects. Although there have been a number of theoretical approaches on evaluating success of KM, so far organizations find it difficult to design an evaluation effort and as a consequence many often only employ the most straightforward approaches such as adding some questions to a general user survey without much reflection as to e.g., who, what, how, why and when they measure and what consequences should be taken upon the results. This paper aids evaluation by providing an interrogative framework for designing evaluation initiatives. Its applicability is shown with the help of a real-world case study evaluating the KM system @sk!.

**Keywords:** case, evaluation, knowledge management system, success

**Categories:** H.4, L.1, M.9

## **1 Introduction**

Knowledge management systems (KMSs) are ICT systems in the sense of application systems, ICT platforms or collections of services arranged for handling of knowledge in the sense of contextualised information throughout the organization or that part of the organization that is targeted by a KM initiative. KMSs can be classified into integrative (codification strategy) and interactive (personalization strategy, [Hansen et al., 1999] ones [Zack, 1999]. The predominant knowledge managed in integrative KMSs might be method, product and process knowledge whereas in interactive KMSs the main knowledge used might be person-oriented knowledge. Determining costs and especially evaluating benefits of KMS are still in their infancy. Whereas the Total Cost of Ownership (TCO) approach as well as approaches building on TCO [David et al., 2002] can at least guide cost accounting and investment strategies of KMS, assessment of the benefit side is much less developed. This is due to the fact that determining the value of the underlying concept, knowledge, just as its sibling,

information, requires at its core a prediction about the value of its future application. Many authors have contributed to description and explanation of the substantial differences between standard economic theory and information economics. Examples are negligible marginal costs or network effects (e.g., [Gersbach, 1991], [Hirshleifer and Riley, 1992]). However, our understanding of the economics of knowledge is even more “primitive” than our understanding of information economics [Teece, 1998], 291. Basically, there are the following alternatives to assess benefits of the application of KMS:

- *Qualitative assessment*: This involves subjective valuations of individuals. Regularly, senior management, the project manager or a sample of participants assess the application of KMS.
- *Quantitative assessment*: Quantitative techniques use precisely defined variables which can be repeatedly measured rendering consistent results.
- *Semi-quantitative assessment*: In this case a person or, more commonly, a group of individuals, assesses the application of KMS on the basis of a structured evaluation process converting subjective judgements into interesting factors using statistical methods, such as factor analysis.

The main research question in this paper thus is how can organizations assess their KMS? They may e.g., use quantitative measures where possible and enrich the results with semi-quantitative and qualitative measures. They may apply the whole repertoire of data collection as can be found in the literature: questionnaire, interviews with participants and selected special roles, such as subject matter specialists as well as measures that can be automatically collected by the KMS, such as access statistics.

This paper presents an interrogative framework for assessing KMS that can guide organisations in designing their assessment procedures (section 2), a description of the KMS system @sk! (section 3) and the results of its application to evaluate it (section 4) before it concludes with the primary lessons learned from this case (section 5).

## 2 Success of Knowledge Management Systems

Approaches to measure an organization’s intangible assets and success of (IT supported) KM initiatives (reviewed e.g., in [Maier, 2007]) lack operationalization. For example ([Probst et al., 1998], 336) simply suggest to measure system use of e.g., an Intranet, as part of the operative assessment of knowledge goals. Other than that, success or failure of a KMS in these frameworks is only assessed at a highly aggregate level, e.g., turnover per employee, share of ICT investments compared to total value added, fluctuation of experts or share of customers improving the organization’s competencies (also [Sveiby, 1998], 263). These measures are influenced by using KMS, but also by a large number of other interventions into an organization’s way of handling knowledge as well as environmental changes.

Success of complex socio-technic systems such as information systems (IS) or a specialisation thereof, KMS, cannot be directly measured. Instead, there has been a large number of factors that are indicators or determinants for success of KMS, such as quality of the system’s functions, quality of its contents, quality of knowledge services, extension of use, user satisfaction as well as impact on the layers of a single

user, a collective of users or the entire organisation [DeLone and McLean, 1992], [Maier and Hädrich, 2001]. As KMS by definition are used in KM initiatives, success of KMS can thus be defined as the extent to which using a KMS positively impacts on the goals of KM initiatives. For AUDI AG, it is important that users accept the system. Thus, user satisfaction and the impact on the user have been taken as indicators for the success of @sk!. Motivated users are more willing to use the software and can be provided with training more effectively. And therefore a company can save costs and optimize the operating of its KMS.

Assessing success of KMS is a complex undertaking itself and there have been numerous approaches aiming to support organisations in designing assessment procedures. These are amalgamated in the form of typical questions organizations have to answer when designing an initiative to evaluate their KMS (see Table 1).

Table 1: Interrogative framework of IS measurement<sup>1</sup>

Questions	Typical answers from IS literature
1. Why measure? (reason)	<p><i>check / assess:</i></p> <ul style="list-style-type: none"> <li>• understand how to achieve IS success; what influences IS success and how? (to improve measurement instruments)</li> <li>• evaluate impact of new information technology</li> <li>• check service level agreements (compliance of contracted IS)</li> <li>• compare (benchmark) our IS with others, certify an IS</li> <li>• legitimate IT expenses / business justification of IS</li> </ul> <p><i>change / adapt:</i></p> <ul style="list-style-type: none"> <li>• improve IS planning</li> <li>• design an IS</li> <li>• adapt (to the needs of the users) and improve an existing IS</li> <li>• reorganize IS services</li> </ul> <p><i>select / allocate:</i></p> <ul style="list-style-type: none"> <li>• select an IS or a service to be implemented / customized</li> <li>• reward IS staff according to performance</li> <li>• prioritize IS projects / investments, align IS to strategy</li> </ul>
2. Measure for whom? (target groups)	<ul style="list-style-type: none"> <li>• users, content administrators, technical administrators, sponsors</li> <li>• IS departments vs. functional department</li> <li>• organization-internal vs. organization-external clients</li> <li>• management vs. operative staff</li> <li>• committee members</li> </ul>
3. Which IS-related elements? (scope, evaluation object)	<ul style="list-style-type: none"> <li>• system, services, staff, function, projects:</li> <li>• centralized vs. decentralized IS</li> <li>• IS, of a certain category, e.g., integrative vs. interactive KMS</li> <li>• IS project, function, department</li> <li>• IS services</li> <li>• IS staff</li> <li>• IS infrastructure</li> </ul>

<sup>1</sup> See also the extensive literature on IS success reviewed by [DeLone and McLean, 1992], [DeLone and McLean, 2003] as well as [Maier and Hädrich, 2001], [Eppler and Maier, 2003], [Kaner and Bond, 2004], [Preißler, 2008].



<p>4. What aspects? (attributes)</p>	<ul style="list-style-type: none"> <li>• IS success, IS quality, information service quality, information quality</li> <li>• perceived usefulness of information, IS (perceived) usefulness, IS usability, ease-of-use, intention to use, IS use / usage, chauffeured use, user behaviour, system acceptance, user satisfaction</li> <li>• perception of strategic value of information systems</li> <li>• IS effectiveness, IS function or IS performance</li> <li>• IT value, net benefits, IT ROI</li> <li>• organisational impact of IS, organisational success, decision quality, decision performance, quality of work life, productivity, user competence</li> <li>• contingent variables, e.g., industry, department size, age and size of the organisation, task characteristics such as uncertainty, complexity, dynamism</li> <li>• user involvement, user participation</li> </ul>
<p>5. How? (methods, scales, instruments, side effects)</p>	<ul style="list-style-type: none"> <li>• data definition/ construct operationalisation supported by survey instruments, user satisfaction surveys, indicators and metrics (quantitative vs. qualitative, individual vs. organizational)</li> <li>• data gathering techniques: observation, interview, questionnaire, focus groups</li> <li>• data gathering tools: traffic analyzers, site analyzers, log file analyzers, Web mining, performance monitoring, simulation software</li> <li>• data analysis: statistical analysis, classification, qualitative evaluation (text analysis)</li> <li>• data visualization / presentation: e.g., portfolio, cob web, alerts</li> </ul>
<p>6. When? (timing, variability)</p>	<ul style="list-style-type: none"> <li>• continuous monitoring vs. periodic surveys vs. one time measurement</li> <li>• during development vs. after roll-out, before vs. after modification / new release</li> </ul>
<p>7. Who? (responsibilities)</p>	<ul style="list-style-type: none"> <li>• external experts, e.g., consultants, certification authority</li> <li>• IS department</li> <li>• users</li> </ul>
<p>8. What next? (follow-up actions)</p>	<p>invest, desinvest, adapt compensation (allocate rewards according to success), adjust planning, change service level agreement,</p>
<p>9. Who takes actions (responsibilities)</p>	<ul style="list-style-type: none"> <li>• users</li> <li>• managers</li> <li>• IS staff</li> <li>• suppliers</li> </ul>
<p>10. What can we learn? (reflection)</p>	<ul style="list-style-type: none"> <li>• increasing validity and reliability of measures</li> <li>• increasing cost-effectiveness of data gathering, improved data presentation</li> <li>• better targeted IS investments</li> </ul>

This framework can be applied by organizations willing to assess their KMS. Questions should be answered in the stated order. Answers to the questions (1-4) result in defining purpose and scope of the assessment. Neglecting these questions which are often only vaguely touched on in practice might lead to assessment results

not acted upon. Answers to the questions (5-7) result in a clear description of the applied assessment procedure and organization. The framework helps here to show alternatives for methods, measures, timing and responsibilities. Answers to the questions (8-10) ensure that the assessment results are translated into actions on the KMS and motivate double-loop learning on the assessment procedure and the methods and measures applied therein. This is the most crucial area of the assessment as it is a means, an instrument, to define actions, not an end in itself. In the following, this framework is used to structure the case of evaluating the KMS @sk!.

### **3 @sk! – the KMS of AUDI AG**

Knowledge management is part of the customer relationship management (CRM) strategy of AUDI AG including lead, campaign, request and complaint management. The increasing complexity of cars and services results in more detailed and specific questions about AUDI AG and its car models. Customer expectations have also increased significantly, especially in the premium automobile market segment.

AUDI AG therefore decided in 2000 to establish a KMS to support customer care agents in answering customer requests. The aim is that each agent has access to the same information source to ensure that each question or request receives the same answer. Customers should therefore receive consistent information and not variable answers depending on the knowledge and experience of the customer care agent.

To provide high quality information, a KM process was established. The heart of this process is the so-called “subject matter expert” responsible for content and administration of the system. Ideally, all agents contact the subject matter expert if they need any information. If the expert is not able to provide support for a request, she contacts experts in the business and specialist departments. The subject matter expert connects the customers’ point of contact (the customer care agents) and the specialists in the business departments. The subject matter expert decides if the information is only relevant to the individual customer’s case and therefore does not need to be communicated further, or if it is relevant for all customer cases.

The supporting system for the KM process is called @sk! which can be seen as an integrative KMS following a codification approach. It helps the subject matter expert to store all relevant information and manage agents’ access to the information contained in the system. @sk! is a Web based system with two interfaces: the user and administration interfaces. After login the user has access to a portal designed like the front page of a newspaper. There are headlines with important new documents, a collection of often used documents and a navigation tree where all documents are stored in a folder hierarchy. The agent has two ways to find information, a navigation tree or sitemap to switch between folders and a full text search engine. The experience of the past seven years shows that navigation and search facilities are used equally. Each agent can contact the subject matter expert by e-mail. If an agent wants to make comments regarding a document he can add public notes to the document.

@sk! provides international markets with a platform only, including database and interfaces, but without local information content. Each market has to establish the KM process and identify its subject matter expert for itself. This precondition must be met before implementation can begin. All details concerning usage of @sk! are described in a service level agreement including an annual user survey the cost of which is

included in the service fee. @sk! is now used in several markets including Italy, France and South Africa for the main brands of the Volkswagen Group. In total, approximately 3,000 users have access to @sk!. Data volume is around 220 GB with more than 1,000,000 documents in several languages.

## **4 Results of Evaluating the @sk! System**

To improve the functionality and usability of @sk! a user survey focused on user perception, satisfaction and the impact that the system had on user tasks had been made. Thus, it concentrated on a user survey which was executed in several locations in Germany in December 2007. Although the survey in South Africa had started in May 2008, the data was combined with the data from Germany. The late start of the survey in South Africa was necessary to ensure that users could get acquainted with the new system sufficiently. In total, 674 people were asked in Germany, Mexico and South Africa. 227 answers were returned which corresponds to a response rate of 33.67%. Most of the answers came from AUDI Germany and Volkswagen Germany. Mexico has been omitted from the analysis presented in the following because of the very few answers.

The amount of questions in the survey depended on location and brand. This is because for example Volkswagen Germany posed questions to the users which were only applicable to their workflow in the call centre. That being the case, AUDI AG asked 15 questions, Volkswagen Germany 19 and Volkswagen South Africa 14 questions.

In this paper the results of AUDI Germany are discussed. That is why the figures represent only a part of the 227 persons mentioned above. Within AUDI AG, 74 persons responded to the questionnaire. Since not all questions were obligatory, to several questions not all 74 persons answered.

While Figure 1 and 2 show the results of AUDI AG, Figure 3 combines the answers from AUDI AG and Volkswagen Germany. That is useful because this way one can get more improvement suggestions.

Referring to the interrogative framework presented in section 2, we can say that the integrative IS @sk! as well as its services and the functions represent the scope of the evaluation or the evaluation object. Since users could be allocated to certain departments and locations, comparisons could be made between them. So, for example, question number 3 of the framework could be answered.

Users were asked to assess certain aspects of question number 4. The majority of questions dealt with IS quality as a whole and information quality. It is also suggested to ask for user satisfaction, usability or the influence of the IS on the daily work. These aspects were also part of the survey.

AUDI AG used the survey as its data gathering technique. The data had been analysed with statistical tests (Mann-Whitney-U Test, Kruskal Wallis T-Test) as suggested in answer 5 of the interrogative framework.

The system @sk! represents an important tool to support daily business of AUDI AG to fulfil customers' needs. @sk! is at least an important tool in daily work for 88.9% (combination of very important / important) of the respondents (Figure 1).

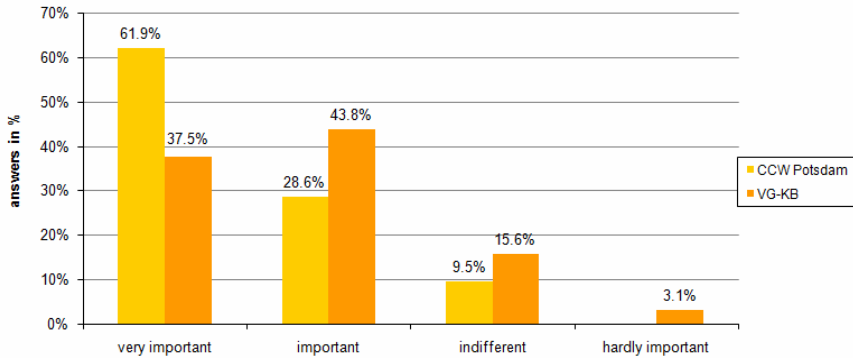


Figure 1: Estimated overall importance - AUDI AG (n=72)

Figure 2 shows the result of AUDI AG in Germany which is similar to the result of Volkswagen in Germany or South Africa. However, there are some parts or functions that have to be improved according to the user survey. In the following some of the proposals, given by the users, will be discussed.

Users were asked to suggest improvements for @sk!. 43 answers (n=104) dealt with usability of the search function. Data structure as well as system performance were criticized by 12 persons. Referring to data structure, users mentioned that new data is not labelled in a way which makes it easier to distinguish between old and new data. Field and type size, colours and layout can be combined to one term, visual presentation. 20 persons suggested improvements there. 10 users reported about problems with the menu navigation as well as the interface structure. Two persons found it useful to implement an easier login, similar to a passthrough authentication.

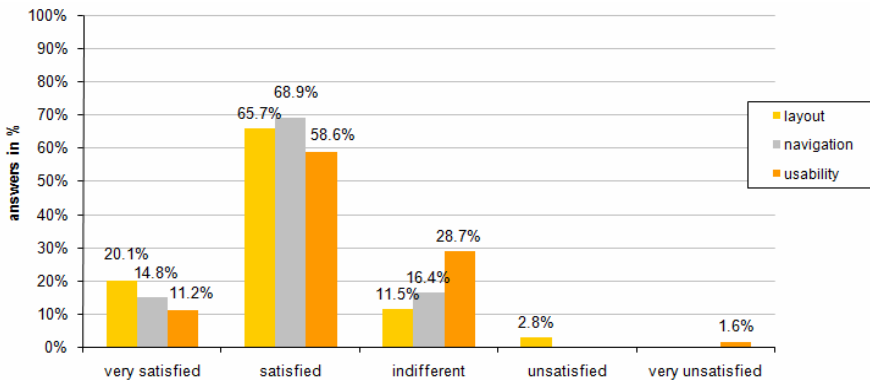


Figure 2: Satisfaction with layout, navigation, usability - AUDI AG (n=74)

Figure 3 gives a comprehensive overview of the suggestions made for the search function. Almost 63% of the answers suggested a thesaurus, more synonyms or cues as well as an auto-complete function, i.e. while entering keywords into the search function, the words could be completed automatically.

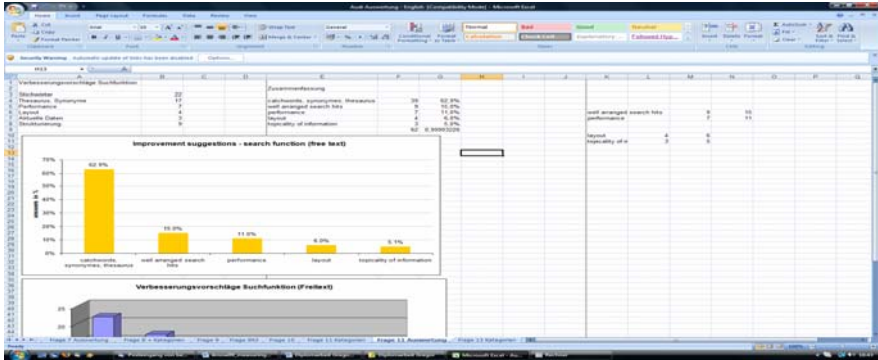


Figure 3: Improvement suggestions search function – AUDI AG/VW Germany (n=62)

15% criticised the complex or confusing output of the hits. 11% said that the search function’s performance is too bad. In terms of visual presentation, 6% mentioned the Internet search engine Google as a reference. Besides, the topicality of the information was criticised as well.

It is conspicuous that 12 users wanted to find more topical information within @sk!. The purpose of this question was to get ideas for additional functions for the system. Topical information should not be mentioned here. It is obvious that the problem of finding information can be traced back to the search function which needs to be improved. Often, users reported that they could only find obsolete information which cannot be communicated to customers.

Additional suggestions were made such as the integration of Web based training, or small additions like satellite pictures to easily find car dealers. Also, it seems that some knowledge in the data base needs to be translated in order for customers to be understood. One user mentioned that often customers ask for the vehicles’ motorizations. Agents in the call centres can only tell customers the KW of each car. For many customers it is much easier to understand the power of the engine if they are told the horse powers. Users also called for more authentic language for certain situations, especially how to deal with articles in newspapers, television or changes in laws. Authentic language is parted in arguments for vehicle techniques (only for technical terms) and more authentic language. Higher performance and improved data structure have already been discussed earlier. What users want to find more is contact information of key users or partners. One person wanted to have information about insurance companies’ rates etc. This request cannot be solved, since there would be too much information for AUDI AG to keep up to date.

## 5 Lessons learned and Conclusion

Summing up, Table gives an overview of the approach taken to evaluate @sk!.

Table 2: Characterization of the @sk! evaluation initiative

Questions	Answers
1. Why measure?	Involvement of users to show that they are part of the system. Get requirements for further development of the system and verification of already known improvement suggestions. Giving feedback to the subject matter experts.
2. Measure for whom?	Subject matter experts and their managers; business department (CRM); IT department (Competence Center CRM)
3. Which IS related elements?	@sk! including all provided functions Integration to KUBA (customer database of the Volkswagen group based on SAP CRM)
4. What aspects?	Usability; Information quality; Overall satisfaction
5. How?	Present: user survey; Future: redesigned user survey with adaptations for each new survey
6. When?	User survey once a year or after major changes in the system (users need some time to get used to the changes).
7. Who?	All departments with customer contact Business Department (CRM)
8. What next?	Present: improve mentioned parts of @sk! in the survey. Future: Subject matter experts have to include figures developed by the data analysis of old surveys into the improvement process.
9. Who should take actions?	Business Department (CRM) - for the system Subject matter experts and their managers – for the content
10. What can we learn?	Providers: find a basis between subject matter experts and users and define which information is necessary or relevant; Users: More user trainings in future; System: redesign data structure, improve search function, insert Feedback tool

The general feedback of the agents about the user survey was very positive. After the 3<sup>rd</sup> survey, it is not an established tool to involve users. Thus, the annual user survey is part of the SLA between AUDI AG and the markets. The survey for 2009 will probably start in July. The results are the basis for the further development, especially the requirements for search improvement. But the survey alone is not sufficient. The personal contact of the agents with the subject matter experts is very important, too.

As for the survey, it would be useful not only to ask users how the system works for them, but also to include a more technical side of the evaluation. A second team could be in charge of that. Tools could be clickstream analysis, log file analysis as well as comparing the results with previously defined key figures. This could work eminently with technical data obtained by the mentioned analysis. A positive side effect of such analysis would be that one would not need the agents to participate in a survey and this data could be obtained whenever needed.

Summing up, the case is made that the interrogative framework can be adequately used to develop meaningful evaluations concerning artefacts of knowledge management, in our case a KMS. Clearly, there is a large heterogeneity in evaluations so that more guidance in designing such instruments is needed.

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## **Improving Topic Exploration in the Blogosphere by Detecting Relevant Segments**

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**Abstract:** With the accelerated growth of the blogosphere, automatically analyzing blogs (specifically extracting information) becomes increasingly important. Here, we focus on the fundamental task of automatically detecting blog topics in order to support users to explore a collection of blogs by focusing on different particular topics according to their interests. We show that topic exploration can be significantly improved (by up to 33%) by using a novel approach to detecting blog page segments that contain relevant information for the blogs' topic.

**Key Words:** Blogs, web page segmentation, segment classification, machine learning, Topic Exploration

**Category:** M.7, H.3.3, M.0

### **1 Introduction**

It is estimated that there are more than 50 million weblogs on the internet and this number is growing daily. They are forming a network —the blogosphere—



by means of comments and trackbacks to other blogs. Usually, blogs' contents reflect (and sometimes even influence) the public opinion [Ulicny 08].

Dealing with the huge amount of content available on the blogosphere requires the ability to filter it based on one's topics of interest. Keyword search, as typically offered by (blog) search engines, merely returns a list of pages containing the keywords. Most of the pages in the result list are not relevant for the user, the user being left alone with the task of manually filtering the list in order to find his topics of interest. The user can be relieved from this burden if appropriate methods for automatic topic detection are used. We show that this is possible by identifying one such approach to topic detection, i.e., finding out topic(s) represented in text fragments —here: blog entries and comments— and applying it to a real application scenario: we query the blogosphere for answers to the question: "Who is responsible for the current financial crisis?".

In particular, we show that our approach to topic exploration is feasible in practice, especially if we filter out irrelevant content by first segmenting the page and then *classifying these segments*. In principle, any web mining application can benefit from the detection and classification of blogs' functional segments. We illustrate our approach and show this can significantly improve automatic topic exploration in blogs in Section 2. Section 3 presents our evaluation method and reports the evaluation's results. A conclusion will be given in Section 4.

## 2 Our Approach

We restrict ourselves to the challenge of recognizing relevant segments in blogs, as they are a widely adopted and used as the most present medium for diffusion of user generated content. We show that this task is feasible and provide a proof-of-concept evaluation by exploring topics in the blogosphere. Weblog authoring software supports different languages, therefore use of language in our scenario is not a discerning feature for filtering of relevant content and should be neglected in favour of a truly language agnostic approach. The task described in our application scenario can be done by analyzing either directly the whole blog page or only relevant segments. The second option is computationally more expensive due to the costs of extracting relevant segments, but we will show that the results are significantly better. These two different options are illustrated in Figure 1.

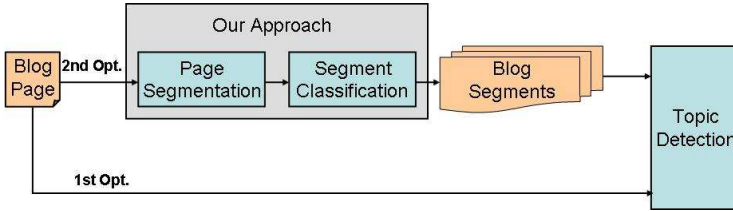


Figure 1: Topic Detection on the whole page (Option 2) vs. only on selected segments (Option 1)

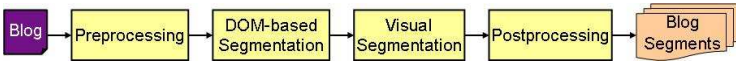
Additionally, Figure 1 shows a process overview of our approach. It consists of two steps that will be explained in this section: segmentation of blogs (Section 2.1) and segment classification using machine learning methods (Section 2.2). Eventually, we explain the applied topic detection approach in Section 2.3.

## 2.1 Web Page Segmentation

Web pages usually consist of several functional building blocks like menus, headers, blog posts or comments. Such block types are called *segment genres*. *Segmentation* of web pages tries to identify these fragments. There are many different approaches for segmenting web pages. Ye and Chua [Ye 04] propose a segmentation based on structural differences between two pages (considering the same page at different times or different pages having similar structure), but this approach needs many samples to work accurately. *Document Object Model* (DOM) based methods as proposed by Debnath et al. [Debnath 05] suggest heuristic rules for dividing a page into blocks that also work in case of absence of tables by also considering other tags. For example, a heuristic that is applied is that header-tags are starts of segments. Ramaswamy et al. [Ramaswamy 04] use the shingling algorithm, which calculates a fingerprint of a block that only changes little if the content of the block changes little. Miloi [Miloi 05] evaluates the Levenshtein distance based on letter alteration operations and a simple distance based on word counts. Yi et al. [Yi 03b] use the internal tag structure of a block and do not consider the textual content. An approach with good results but high computational complexity is proposed in [Cai 03]. Features for this segmentation method are computed based on the visual representation of the page, similar to a human perceiving coherent blocks. A limitation of this approach is the fact that segments tend to be recognized in a very coarse granularity and it is difficult to define appropriate margin thresholds.

As different segmentation approaches have shown to have strengths and weaknesses, a combination of multiple segmentation processes seems to be a promis-

ing approach. Our approach combines ideas from pure DOM-based approaches, visual approaches, detection of re-occurring patterns and common class and ID attributes within a web page. An important goal of the novel approach is to work for a wide variety of web pages. Therefore it cannot depend on a certain design or structure of a web page. Nevertheless, the implementation is flexible enough to add specific algorithms for certain page types. Our approach for segmentation is shown in Figure 2.



**Figure 2:** Segmentation Workflow

It is modularized into several steps with a pre- and a post-processing step wrapping the actual segmentation steps. The preprocessing step itself performs no segmentation, but the HTML source and the CSS source(s) are parsed and the DOM tree is built. In terms of CPU time, this is an expensive step but indispensable for visual segmentation. The DOM-based step uses block-level elements (i.e. elements that denote the start of a new visual block in the rendered HTML, e.g. `div`, `table` and `ul`) as basis and detects patterns in the web page. Repeating fragments in blogs are usually either blog posts or comments. The visual segmentation step uses information like position of an element in the layout or the background colors. The segmentation steps are applied in descending order by their reliability. The advantage of this order is that the latter segmentation steps can access and use the results of the previous steps. The post-processing step is used to remove segments that have been found but that are considered to be superfluous. For example, this is the case when two or more segments are nested and the inner segment group contains the same elements as the outer segment without adding textual content.

## 2.2 Segment Classification

There are numerous different approaches for detecting relevant content in web pages based on segmentation. For example, content-based approaches make use of the fact that noisy fragments usually share a common (tree) structure [Yi 03a]. Other approaches segment a collection of pages in "pagelets" and then try to identify common duplicates [Bar-Yossef 02] or use DOM-based heuristics [Gupta 03].

Our approach adopts methods for *document classification* to achieve our goal. Document classification can be made along different criteria like author or genre

(i.e., kind of document) [Santini 07, Scholl 09]. The goal of document classification is to automatically determine a category for a document using its properties as features. Machine learning algorithms in a supervised approach are a common method to achieve this. For detecting the genre of a segment, the segment is represented by the values of features that are relevant for distinguishing among genres. A classifier learns the characteristics of the different segment genres from a set of pre-classified examples called *training corpus* and guesses the genre of a given segment based on these values.

A web resource most often consists of several building blocks that are determined by its web genre. For example, a blog page has the building blocks *blog post* and *comment*, a forum consists of posts in a thread and an overview of all available topics or threads on the start page. Such blocks are called *segment genres*. Certain segment genres are common in regard to their occurrence in several web genres. For example, nearly all web resources exhibit some form of navigational elements (like menus) in order to access different parts of a web site. Similarly, headers usually impose an identity of the web resource's source onto the page in order to show a surfer where she is, including a logo and some tag phrase. Finally, footers often serve to present a copyright notice and secondary navigation like imprint and contact. These are not our targeted segment genres as they do not convey the content of a page but serve rather administrative and presentational purposes. Based on the works described in [Meyer zu Eissen 04], [Santini 07], and others, we extracted the features that showed to be most promising for our approach. As we are developing a language-agnostic approach for blogs we only considered (syntactical) features that can be extracted from the HTML documents' mark-up and structure. Features that we deemed appropriate were tag frequency, URL depth, punctuation frequencies, document length, ratio of plain text vs. mark-up and link ratios (outgoing vs. intra-site vs. intra-page links). Additionally to these features, we developed new features that we deemed profitable for classification of segments like structural features [Dominguez 08], coverage features (calculation how much of the content of the segment a HTML tag wraps) or URL-similarity features (similarity between all their hyperlink targets) leading to a total number of 215 features for training and testing a machine learning algorithm.

### 2.3 Topic Detection with Probabilistic Models

An emerging approach to topic detection are probabilistic topic models (PTMs), which tend to perform well for large text collections and lead to improvements in text retrieval tasks. PTMs detect topics as patterns of co-occurrences of statistically relevant words at a document collection level. PTMs view documents as a mixture of topics whereas each topic is a probability distribution over words. Therewith a document can be seen as the result of a generative probabilistic

procedure as follows: 1) Choose a distribution over topics; 2) For each word position in the document randomly chooses a topic from the topic distribution and draw a word from that topic. For a compact formal description of PTMs we refer to [Dietz 06].

The strengths of the PTM approach to topic detection that we leverage on for our application scenario of topic exploration are derived by intrinsically accounting for words' context. Natural language ambiguities are implicitly accounted for by the detected patterns of word co-occurrences; for example, different occurrences of a polysem (an ambiguous word) in different text fragments are associated to different topics due to the different words occurring in the same text. The actual meaning of an occurrence is (implicitly) denoted by the corresponding topic. Therewith we are able to fully automatically group blogs dealing with similar topics, without the large costs incurred by other approaches to semantic disambiguation. This facilitates the topic exploration considerably, as confirmed by our application scenario presented in Section 1.

### 3 Evaluation of our Approach

The evaluation of our approach consists of two steps: First, we show that it is feasible to detect relevant segments using machine learning methods and then we use our approach to improve the topic detection.

#### 3.1 Experimental Setting and Results

In order to validate our classification approach, a corpus has been built and manually labelled with the relevant segment genres (*blogpost* and *comment*) and the genre *outliers* representing all other segments. For segment classification we applied J48, a decision tree learner. This machine learning algorithm generates an (un-balanced) binary decision tree based on the most significant feature values from the training data. J48 has shown to be robust, provide good results using few features and very time-efficient, which is especially important because classification is executed for each segment. Our corpus consists of 42 randomly selected blog pages (among those are 17 blog start pages and 25 blog post pages). After segmenting and manually labelling these pages, we obtained 194 blog posts, 46 blog comments and 867 other segments (in total 1107 segments).

blogpost	comment	other	← classified as
166	1	27	blogpost
0	37	9	comment
23	6	838	other
0.87	0.84	0.95	Precision
0.85	0.80	0.96	Recall
0.86	0.82	0.95	F-Measure
94.03%			Accuracy

**Table 1:** Summarized results of testing blog segment corpus

Table 1 shows the result of testing the blog segment corpus using a J48 classifier with 10-fold cross-validation. The overall performance is very good with 94% correctly classified instances. Precision and recall rank about 80%-87% for the blog posts and comments classes. The used features were ranked using Information Gain [Mitchell 97]. Information Gain evaluates the significance of features. The tag frequencies and coverage of div, h3, p, images and hyperlinks were rated best. Additionally, especially the length of the mark-up and the plain text length are deemed significant for the segment genre "blog post". This is because blog posts are usually longer than arbitrary segments. Links to the same domain are meaningful as well for the segment "other", because menus contain a lot of those. A major source of misclassification (nearly all of the incorrectly classified segments) is the differentiation between blog posts and arbitrary segments. The same applies to the comment segments. We think that this is due to several reasons:

1. Blog posts mainly consist of the input of an author and allow nearly all of the HTML element subset that is available. Therefore, they tend to be very heterogeneously structured and written. The other category is pretty heterogeneous in itself, thus segments belonging to that category are easily misclassified. For example, consider a side bar of a blog containing a widget that is providing information about a blog. It will be longer than e.g., a menu and will expose similar properties as a short blog post in regards to length of text and paragraph structure.
2. In general, blogs have two different feedback mechanisms, one being comments. Additionally, most modern blog applications support trackbacks. Trackbacks are incoming references (hyperlinks) from other blog posts and are a way to relate to other blogs. In short, "When someone links to one of my posts, my post links back to them". In our blog segment corpus we labelled trackbacks as being a different class than comments, adding it to

the category “other”. However, in some blog applications trackbacks are displayed in the same way as comments and are thus recognized by the classifier as such.

This confusion between the classes is clearly reflected in precision and recall. Nevertheless, the results are very encouraging and make it possible to apply this blog segment classification to real-world scenarios.

### 3.2 Applying our Approach to Topic Exploration

In this section we show that our approach can significantly improve results of Topic Exploration in blogs. We used automatic topic detection as discussed in Section 2.3 to get an overview of the various particular topics discussed in blogs obtained by retrieving the result pages returned by a popular blog search engine for the keywords “financial crisis” and “blame”. This resulted in a number of 645 documents on which we run the previously mentioned topic detection algorithm. We experimented with different levels of granularity of the topics: we set the number of topics to be detected to 30, respectively 75. In each case, we first run the topic detection on the whole textual content of the HTML files, then re-run them only on the textual content of the blog segments as detected by the algorithm presented in Section 2. For the sake of conciseness we denote each setting by either the word **WPage** or **Segments**, depending on how the textual content has been obtained, followed by the number of topics used.

Four of the topics automatically detected for **WPage\_30** are shown in Figure. 3. Each pie diagram denotes the words that were most frequently assigned to the corresponding topic. We note that (a) is mainly about *Freddie Mac* and *Fannie Mae* while (b) denotes a topic related with the financial crisis that has religious connotations. Other detected topics are less meaningful. For example, the month’s names in (c) are due to taking into consideration blog archive segments, where previous blog entries are listed together with their publishing dates. We will henceforth call this kind of topics and the tokens associated with them *noise*. Another example of a noise segment is denoted by topic (d) which is due to considering segments which are part of the blog infrastructure rather than of the actual content of blog entries, as denoted by words such as *join* or *forum*.

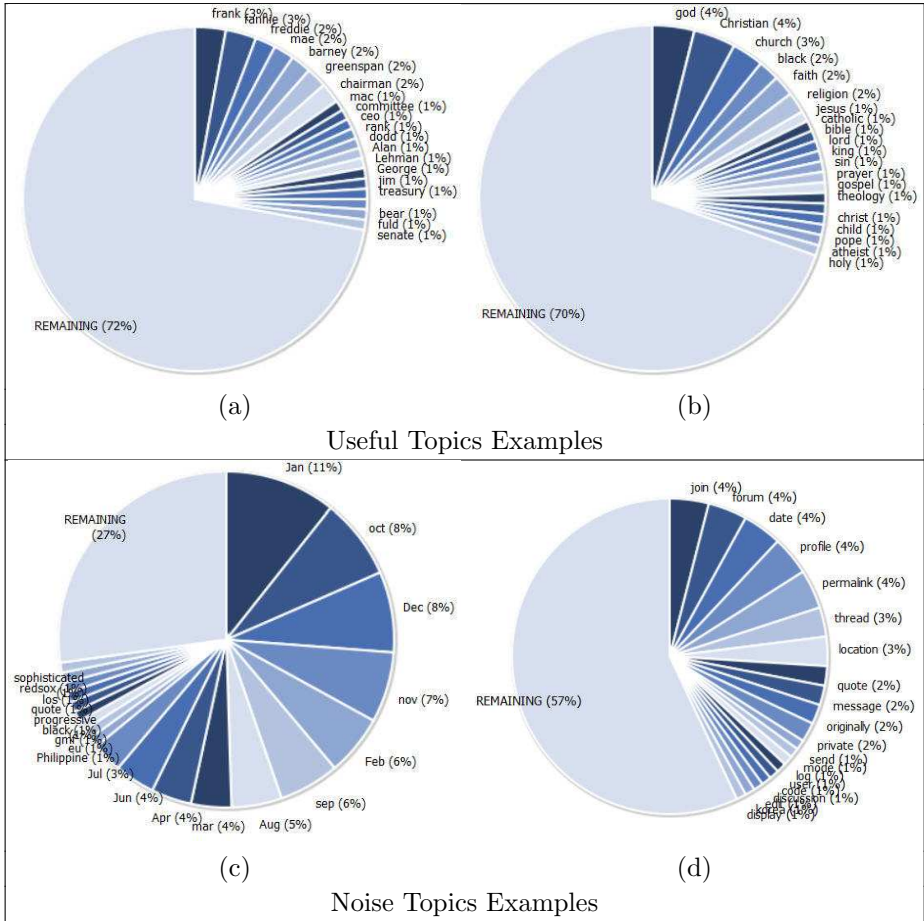


Figure 3: Some topics derived in WPage\_30

The noise topics as defined above are exactly the type of noise information that can be filtered out by page segmentation and segment classification. We indeed found that our segmentation significantly improves the topic detection results as summarized in Table 2. For example, for WPage\_30, we found 9 topics to be noise, whereas for Segments\_30 only 6 out of 30 topics were noise, leading thus to a relative improvement of 33%. Taken at the token level, the number of noise tokens was reduced by more than 37%. The good results are confirmed when considering a different number of topics as can be derived from the second half of Table 2. We obtained similar results using different corpora (searching for "financial crisis" or "Schwarzenegger") and different number of topics (im-



provements between 15% and 40%). Altogether, the results suggest that our segmentation approach leads to a significant improvement independently of the exact setting of the topic detection algorithm used. Generalizing, this validates our hypothesis that our segmentation tailored for blogs can significantly improve information retrieval tasks on the blogosphere.

Corpus	Noise topics(%)	Rel. Impr.(%)	Noise Tokens(%)	Rel. Impr(%)
WPage_30	30.00	n/a	24.40	n/a
Segments_30	20.00	33.33	15.20	37.70
WPage_75	17.33	n/a	17.51	n/a
Segments_75	14.67	15.35	13.45	23.19

**Table 2:** Summary of results

The reason, why still noise topics exist after segment detection is that it is very difficult to eliminate *all* irrelevant content. In particular some limitations of our approach are as follows: 1) An automatic segmentation tool is not perfect. Some segments are too big, others too small. We tuned our algorithm using our training corpus to obtain meaningful segments. 2) Our corpus for segment classification had 1100 segments, but we used only 42 blog pages as source. This is not representative for the diverse types of blogs. Still, we showed that even 1000 training segments can significantly improve Topic Exploration.

## 4 Conclusions and Future Work

In this paper we examined the possibilities of improving blogosphere exploration by filtering out irrelevant content. Therefore, we segment blogs in coherent page fragments and then classify the resulting segments. Our main contributions in this paper consist of developing this approach and providing a proof-of-concept evaluation. We showed that automatically differentiating between these segment genres is feasible and explained the limitations of our approach. Still, there is much space for improvement: segmentation can be enhanced by using heuristics, for example taking into account that each blog post page has exactly one post. Our classification algorithm can be improved by building a more heterogeneous and larger corpus. However, we showed that even a small training corpus can be used to substantially improve a search query.

The research presented here provides a foundation on which further applications and research (e.g., in the field of Community Mining [Berlea 09]) can be based. Generally, our approach enables to handle blogs in a more fine-granular

manner, i.e., separating and targeting the parts of a blog directly. Hence, examination of semantic information in segments (e.g., name of the author or creation date) could be enhanced by restricting the analysis only on the respective segments. In information retrieval, genre-based queries are possible with availability of the segment structure, e.g., “show me all blog posts containing Java Code”, thus filtering all boilerplate template contents that are irrelevant to the actual query.

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## **Monitoring RSS Feeds**

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**Abstract:** The expansion of the World Wide Web has led to a chaotic state where the users of the internet have to face and overcome the major problem of discovering information. For the solution of this problem, many mechanisms were created based on crawlers who are browsing the www and downloading pages. In this paper we describe “advaRSS” crawling mechanism which intends to be the base utility for systems offering collections of news in real time to internet user. In contrast to the common crawling mechanisms our system is focused on fetching the latest news from the major and minor portals worldwide by utilizing their RSS feeds. The news is produced in a random order any time of the day and thus the freshness of the offline collection can be measured even in minutes. This means that the system has to be updated with news every single time they occur. In order to achieve this we utilize the communication channels that exist on the modern architecture of the WWW and more specifically in the architecture of Web 2.0. As the RSS feeds are used by every major and minor portal it is possible to keep our crawler up to date and retain a high freshness of the “offline content” that is maintained in our system’s database.

**Keywords:** focused crawler, RSS, feed monitoring

**Categories:** H.3.3, I.7.1

## **1 Introduction**

Web crawlers are an essential component of all search engines and are increasingly becoming important in data mining and other indexing applications. They are programs which browse the Web in a methodical, automated manner and are used to create a copy of all the visited pages for future use by mechanisms which will index the downloaded pages to provide fast searches and further processing.

Maintaining web archives requires an incremental crawler which is capable of revisiting known URLs independently and adaptively to their estimated rate of publishing new content. The goal is to keep the local repository as up to date as possible. In [Brewington, 00a] and [Brewington, 00b] is denoted that most web pages

in the US are modified during the US working hours a statement that is extremely logical and helpful. In [Cho, 99], Cho and Garcia-Molina show that different domains have very different “page change” rates. An approach that utilizes this fact is a scheduling mechanism which estimates the next update timing of web pages based on their update history using the Poisson process [Tamura, 08]. In [Souza, 07] is proposed an additional feature, which includes the politeness constraint which indicates that we may only probe the source at most  $n$  times and that no two probes may be spaced less than  $\delta$  time units apart. This policy is intended to minimize the required bandwidth and to prevent the crawler from being blocked from the source. Finally, in [Sia, 07] Sia et al. study how the RSS aggregation services should monitor the data sources to retrieve new content quickly using minimal resources and to provide its subscribers with fast news alerts. Their experiments prove that, with proper resource allocation and scheduling, an “RSS aggregator” can provide useful content significantly fast.

Apart from the freshness other issues also occur when creating a distributed crawler, either with use of terminals or multi-threaded. The distribution of resources among the crawlers and the communication between them is a matter of discussion. In [Najork, 01], [Wolf, 02] and [Cho, 98] some specific strategies are introduced for effective crawling and parallel crawling. The basic idea that lies behind parallel crawling is a manager which is assigned with the task of organizing the set of terminals-crawlers that access and download pages. In some cases, the terminals crawlers maintain their own database. This implies that the manager is assigned with the task of getting data from the databases and committing the changes to the central database. Additionally, the manager should read and update accordingly the distributed databases with data collected from every terminal-crawler in order to prevent situations of duplicate entries.

In this paper we describe advaRSS, a crawling mechanism that utilizes the communication channels that exist on the architecture of Web which is nothing more than RSS feeds. The idea is the same as a usual crawler with the starting feed URL being the RSS feed (XML file) and the depth of search set to 1, which means follow only the links found in the first page (feed URL). In contrast to the common crawling mechanisms our system is focused on fetching only news articles from the major and minor portals worldwide (multilingual), in order to deliver personalized content to users. The news is produced in a random order any time of the day and thus the crawling mechanism must periodically poll the sources and check for changes many times per day. To make this resource intensive task more efficient, the system has to learn to predict the rate that an RSS is publishing articles, based both on the static features and the complete posting history.

The rest of the paper is structured as follows. In the following section we describe the architecture of advaRSS while in the third section we display the flow of information. In the fourth section, we discuss the algorithmic aspects of the system and then we describe the experimental procedures that were conducted in order to evaluate the crawling mechanism. This paper finishes with some discussion on the mechanism and we conclude with remarks and future work on the system.

## 2 Architecture

The architecture of the mechanism consists of multiple sub-systems which are assigned with specific roles in order to achieve scalability. The basic parts of the system are (a) the centralized database, (b) the crawler's controller and (c) the terminals that execute the fetching and analysis.

The database is used for storing permanent information such as links to RSS and news articles. Each RSS stored in the database is followed by 24 indicators, one for each hour, which changes dynamically according to the rate that the RSS publishes new articles. Additionally, the database stores information concerning the articles that are fetched utilizing the RSS feeds like the title, the HTML code, the URL, the language, the category and any other information that can be useful by the mechanism that uses this data.

The controller is used in order to organize the whole procedure and is assigned with two major tasks. The first is the direct communication with the database (only the controller can interact with the database) and the second is the job assignment and checking of the terminals. The controller is the part of the mechanism that includes the main procedures and feeds the terminals with URLs from which to download information. In parallel, the controller examines the outputs of the terminals' analysis and stores any information to the database.

The mechanism is utilizing a central MySQL<sup>1</sup> database for permanent storage of data. The system runs every few minutes and the controller is responsible to specify which RSS feeds have to be revisited. This decision is made by estimating the number of new articles that are expected to be published from the last time that the RSS was retrieved. In order to estimate this number, the controller utilizes the hourly posting rates that are stored in the database and the last retrieval time of each source.

Finally, the terminals are used in order to accelerate the crawling procedure. They fetch and analyze the RSS files that the controller has indicated and download every new article that will be found. Thus, the controller will not have to retrieve any RSS feed and communicates only with the terminals that are supposed to send the new articles without any delay. This parallel architecture utilizes the network connections of the terminals to broaden the overall bandwidth of the mechanism. This means that the resource constraints are lowered and the performance of the crawler is increased.

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<sup>1</sup> <http://www.mysql.com> – MySQL DBMS

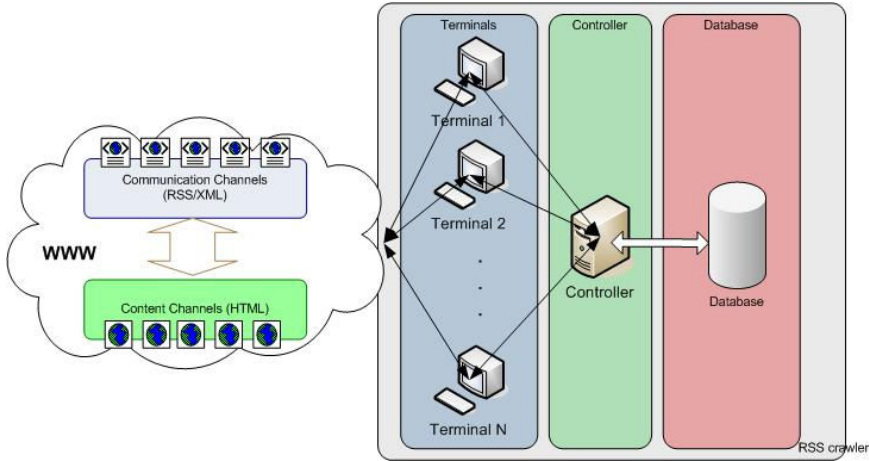


Figure 1: architecture of advaRSS

### 3 Flow of Information

The main procedure of the mechanism can be decomposed into multiple simple tasks. Firstly, the controller gets a list with all the available RSS feeds that are stored in the database. The list will be filtered in order to process only a small amount of feeds each time. The filtering is done by applying the politeness constraint and estimating the expected new articles from each feed. Afterwards, every RSS feed from the aforementioned list will be processed by an available terminal or by the terminal with the lower resource consumption.

The terminals have a local database in which they keep information about the RSS feeds which is their MD5 hash, the last articles that they provided and their last retrieval time. Thus, when a terminal receives a URL to parse, it requests from the corresponding web server to receive the XML file, only if it has been modified since the last date that was fetched. When the web server sends the file, the terminal checks its hash code compared to the hash code that exists to the local database. We consider that the same hash code indicates an unchanged XML file and thus an RSS that is not updated with new articles.

A retrieved RSS file is examined using an XML parser by a terminal, in order to extract the titles and URLs of the articles that are located into the feed. The terminal checks if any of these titles can be found in its local database. We consider that multiple same titles can be found across different RSS feeds but if the same title has been provided by the same RSS at the previous retrieval, then we consider that we already have the article in our repository. For every article that its title does not exist in the database of the terminal, we fetch and send to the controller the following information: title, url, date (of fetching), html and rss identifier from which it is fetched. Finally, the controller stores this information to the central database and updates the posting rate of the RSS that was examined. The tasks are depicted in figure 2.

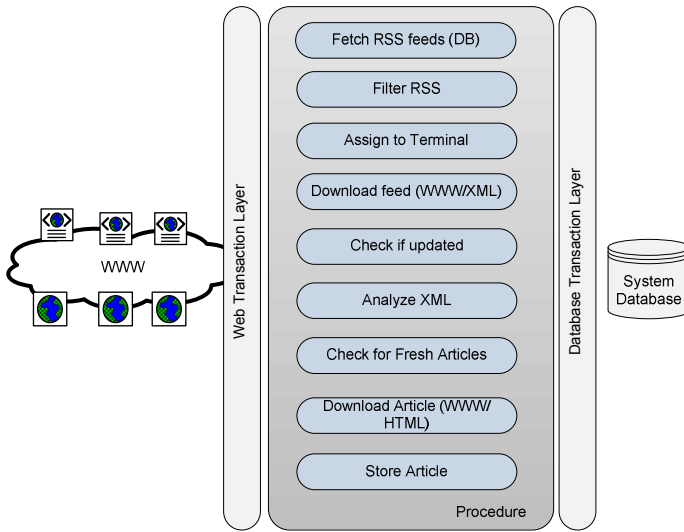


Figure 2: flow of information

## 4 Algorithm description

As already mentioned in the previous paragraphs we intend to create a crawler that will be able to receive the latest updates of news articles of communication channels and store the information into a centralized database so as to be used from every mechanism that supports presentation of news to Internet users. For every RSS in the database, the system maintains an hourly posting rate history and the last retrieval time. The history is used in order to present the posting activity of the source and to predict the rate that the RSS is publishing new articles, based on the fact that an RSS tends to have similar posting rate at a specific hour, each day.

One of the most basic parts of the system is the scheduling mechanism. It is a subsystem of the crawler that, by using the aforementioned posting pattern, manages to schedule the next visit to the RSS feed. During each subsequently visit, the historic information is updated and new predictions are made, leading to a system that is able to adapt on the RSS updating behavior. We concluded to this algorithm by observing how new articles are published by an RSS during the 24 hours of a day. The following diagram shows the average number of articles posted per hour, for a random RSS in our database.



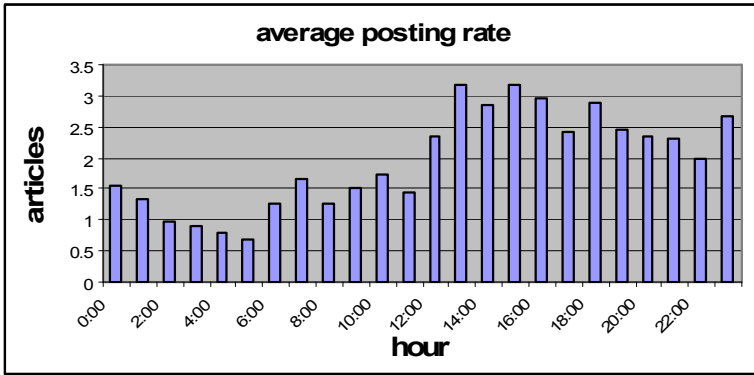


Figure 3: average number of new published articles per hour, for a specific RSS

As it is obvious from Figure 3, the mechanism should schedule more frequent visits at hours with high posting rate. Having the hourly past posting pattern of an RSS and the last time that it was retrieved, we can use the following equation to estimate the expected number of new posted articles since the last retrieval, using the precision of 1 second:

$$articles(t_{now}) = \int_{last}^{t_{now}} \frac{posting\_rate(t_{now} - t)}{3600} dt \tag{1}$$

The above equation utilizes posting rate per second by dividing the hourly rate by the total number of seconds in one hour. It is obvious that we expect a high number of new articles from an RSS feed with high posting rate. Due to resource constraints, the mechanism is able to perform only limited retrievals per time period. Thus, the crawler has to decide which RSS sources to contact in order to fetch as many articles as it can. A simple monitoring algorithm that utilizes the Eq. 1 to schedule a total of k retrievals for each execution should estimate the expected new articles and select the first k with the higher number of articles. Utilizing the fact that the advaRSS crawler can be used as a part of a system offering collections of news in real time to internet users, we can increase its efficiency by including information about the users. The number of subscribers of each feed and their activity on the system can be used in order to modify the above monitoring algorithm. We assume that if a source has more subscribers than others, it should be retrieved with higher priority, in case that all of them have similar posting rates. Putting the above together on a unique ranking metric, we have for an RSS feed f:

$$rank(f, t) = articles_f(t) \cdot (1 + c \cdot subscribers(f)) \tag{2}$$

The parameter c in the above metric can be adjusted to reflect how important the information about the number of subscribers is. In systems that the number of subscribers for each source is unknown, this constant must be set to zero, which means that the ranking metric will not use this information at all. Additionally, the scheduling mechanism that we present, takes into account the politeness constraint, which means that no two subsequent retrievals may be performed in less than x time units apart. We assume that a user can tolerate a delay of 10 minutes for an article,

thus we set the minimum time between two subsequent retrievals to this time period. Finally, the mechanism is able to update the posting pattern for each RSS based on the result of the next retrieval, which is the number of new articles that have been published.

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### Algorithm 1. Monitoring algorithm

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```

feeds[] = Database_Query();
feeds[] = Apply_Politeness_Constraint(feeds[]);
Foreach(feeds[] as feed)
    ranks[feed] = rank(feed, now);
End For
feeds_sorted[] = descending_sort(ranks[]);
To_be_retrieved[] = feeds_sorted[1..k];

Foreach(To_be_retrieved[] as current_feed)
    Assign to terminal {
        XML_Code = fetch_Data(current_feed);
        Extracted_articles[] = Analyze(XML_Code);
        new_articles = find_new_articles(Extracted_articles[]);
    }
    update_DB(current_feed, new_articles);
End For

```

---

The system is initialized using an hourly posting rate that equals to a constant value for each RSS feed. This assures that all feeds will be treated equally for the first day. The updating process of the posting rates, distributes the number of new articles to each hourly rate, making the mechanism able to adapt to each source. However, a source may have not published a new article for a day, which means that its posting pattern and ranking metric will be equal to zero. Thus the above algorithm will not retrieve this source ever again. To overcome this problem, the mechanism uses a minimum value greater than zero for the posting rates.

## 5 Experimental evaluation

In this section, we compare the proposed monitoring algorithm to other retrieval policies. The experiment procedure lasted 90 days and was conducted using RSS feeds from major and minor portals and weblogs.

At the first experiment we put focus on the maximum number of pending articles that a source can have. As pending articles we define the articles that are published but have not been retrieved. The comparison is made using other two monitoring policies. The first is a round-robin policy, which places the RSS feeds in a queue and schedule the retrievals using the FIFO method which means that a source will be revisited after all others have been processed. The second policy uses the posting pattern in order to minimize the total delay of the fetched articles. The delay is defined as the time period between the publishing and the retrieval time.

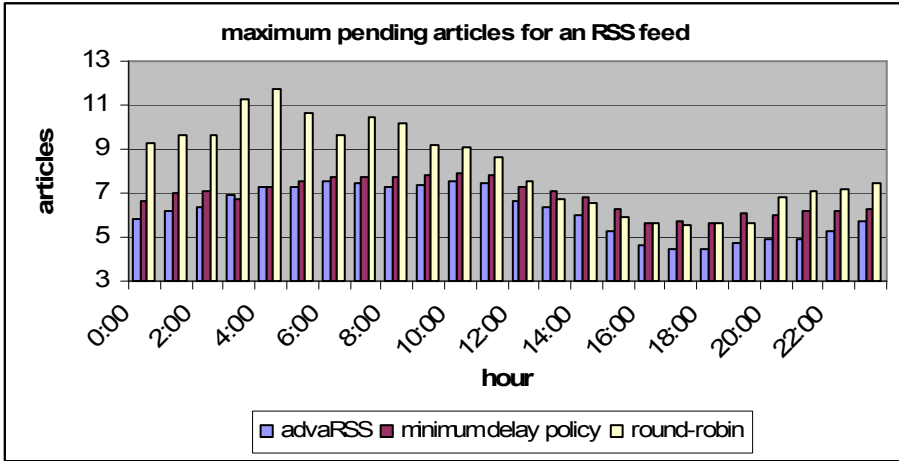


Figure 4: average number of articles, of the RSS with the maximum pending articles.

As it is obvious from Figure 4, the policy that minimizes the total delay increases by 11.2% the maximum pending articles on the source. Using the round-robin policy we notice an increment of 33.4%. The number of articles is an average of the daily measurements. Apart from the above metric, it is interesting to estimate the total pending articles on the system. Thus, the second experiment was conducted using 460 sources and the objective was to calculate the summary of the articles that have not been retrieved yet, for all RSS sources. Both experiments were made by collecting information about these feeds for a period of three months and applying the aforementioned policies.

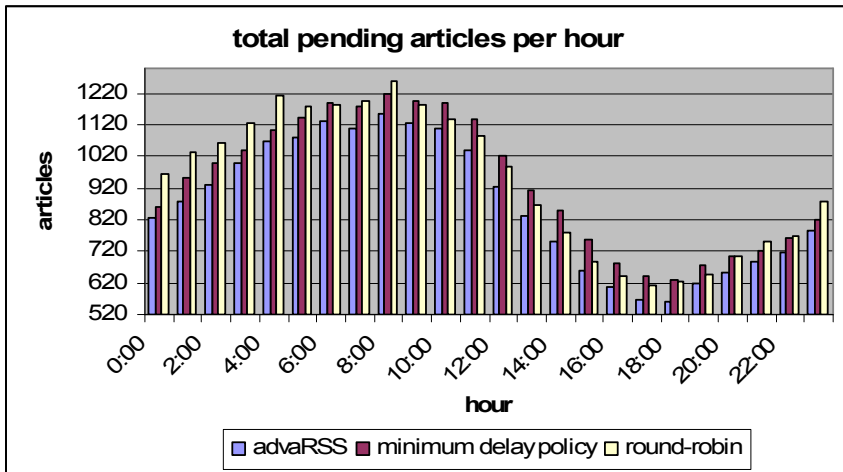


Figure 5: total pending articles on system, per hour.

Figure 5 shows that the pending articles are depending on the posting rate for each hour. We can see that with the “minimum-delay” policy, the total number of pending articles is 7.5% more than the proposed policy. Finally, the result of the round-robin policy is approximately 8.5% more articles. For the experiments, the average retrieval rate is 15% of total feeds per hour.

## 6 Conclusions

In this paper, we described the architecture and implementation details of our crawling system and presented some preliminary experiments. We highlighted the importance of utilizing RSS feeds in order to retrieve useful content from the Web and how this can be efficiently implemented on a system that has limited resources.

In our mechanism the focus is put on the adaptation of the mechanism to each RSS source, as it is obvious that different sources are publishing new content with different rates. In a World Wide Web that has grown enough from the time of its invention, the personalization issue seems to make the difference, and seems to be one of the most important of our era. The advaRSS intends to be the base utility for systems offering collections of news in real time to internet user such as *peRSSonal*<sup>2</sup> [Bouras, 07], [Bouras, 08] which is a single web place that offers, in a unified way, personalized and dynamically created views of news deriving from RSS feeds.

## 7 Future Work

There are obviously many improvements to the system that can be made. A major open issue for future work is a detailed study of how the system could become even more distributed to minimize the resource constraints, retaining though quality of the content of the crawled pages. When a system is distributed, it is possible to use only one of its components or easily add a new one to it. Additionally what we have to do is to compare the results of our crawler with more implementations of other incremental crawlers that selectively chose which pages to crawl.

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# **Successful Initiating of Online Communities An Analysis of Reports, Projects and Expert Interviews**

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**Abstract:** There are several reports, analysis and comments on online communities but just a few meta analyses about successful initiating of online communities. This study focuses on concrete, practical hints and suggestions for practitioners building on literature, analysis of existing online communities and additional expert interviews. Besides a general process description, it gives a more elaborated orientation and decision support for six different application fields.

**Keywords:** virtual community, online community, open innovation, self-help group, learning community, community processes, community lifecycle

**Categories:** L.6.1, K.4

## **1 Introduction**

The need for vibrant communities in a lot of fields, such as the enterprise knowledge management, brand communities, or the usage of new Web 2.0 tools, is enormous. These and many other ventures are unthinkable without active users or without an active community. Their involvement is essential for the success of these Web-related projects. Hence, the question about successful community initiating and building is crucial and gets a lot of attention.

Terms such as “virtual community”, “online community” or “Web community” are used often and similar, too, but without consistent meaning, nor definition. In older definition of the term “community” the geographical proximity and/or familiar relationships play a role [Stocker, 08, 64f]. One, if not the first, approach to define “virtual community” was done by the sociologist Howard Rheingold: “Virtual communities are social aggregations that emerge from the Net when enough people carry on those public discussions long enough, with sufficient human feeling, to form webs of personal relationships in cyberspace.” [Rheingold, 93]. Within our study, we define an online (virtual, Web) community as persons with common interests, using Internet and communication technologies to interchange or develop common contents, developing a strong bond and a feeling of togetherness.

In the following, we will describe the methodology and results of an analysis of practice reports, scientific literature and expert interviews about how the building of an online community will be successful [Schaffert, 09]. The analysis was done within

an ongoing project at the Salzburg NewNewMediaLab (SNML) about online communities and their (also technological) challenges and consequences and is the first within a serial of four project publications.

## **2 Methodological approach of the study**

The purpose of the study was to give an overview about how the building of an online community will be successful from the practical perspective [Schaffert, 09]. After a first review of publications and research we developed the following procedure: Focusing on the publications of the last years in German language we identified (i) theories and explanations of the online community's life cycle, (ii) categorizations of online communities, and (iii) recommendations and examples for their successful initiating. After this we selected six very diverse application areas of the online communities, e.g. non-commercial online self-help groups or enterprise driven internal knowledge management. Now, every recommendation was scrutinized if it can serve as general or as fitting to just one of the application areas. Additionally, we broaden our research for publications, statements, projects and potential interview partners, also to international publications, in the six applications areas. This approach builds on the ideas and concept of Grounded Theory, which describes a systematic theory building from data in the process of research [Glaser, 67]. This procedure resulted in a list of recommendations, short interviews and project description for community initiating in general and within the selected application areas.

## **3 Theoretical approaches concerning the lifecycle of online communities**

There are some theoretical approaches existing, which try to explain the complex incidents of online community development with relatively simple rules or phase descriptions.

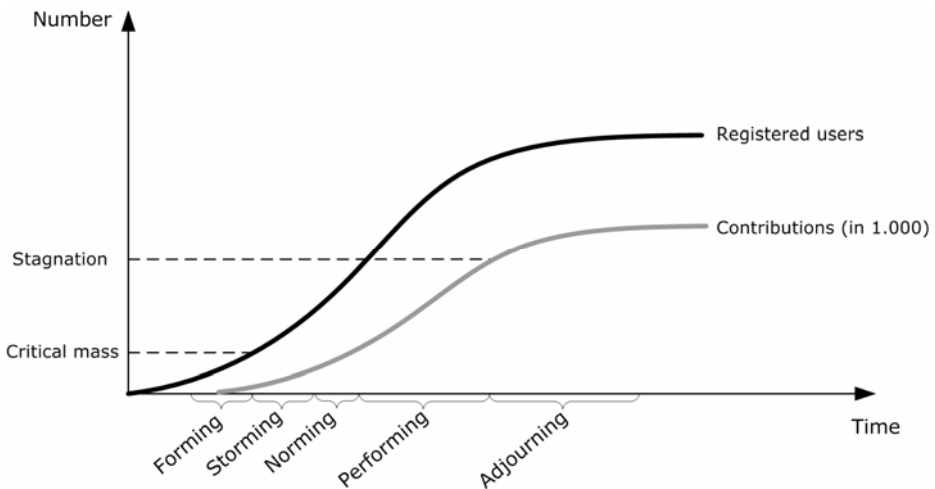
On the one hand, social science approaches are focussing the processes within the community: [Tuckman, 65] developed a four stage model of group development which is easily conferrable to online communities [Swenson, 08]: In the forming phase the group becomes initially known each other, the storming phase is a chaotic phase with a lot of conflicts concerning leadership, roles and tasks. It is typically followed by a norming phase, which reaches an eventually agreement of the group norms; whereas the fourth phase, the performing phase, is the one where the group works effectively.

On the other hand, theoretical approaches are existing that uses variables such as the number of registrants, of contributions as well as time for explanations concerning community development. For example, Reed's and Metcalfe's laws explain that the utility of networks rises with every new node, so it can even scale exponentially with the size of the network. An online community is always a small form of a social network, where every new member means an additional potential contributor and partner for every single existing member. Nevertheless, these simple rules cannot be validated in reality: It does not explain why it needs time until online communities starts to communicate or stop it, even if they have a lot of members. Here the

following explanations help: The theory of critical mass refers to the well known and evident phenomena that it needs a certain amount of registered users before a discussion or collaboration within a platform starts. For German discussion forums, the critical mass of registrants is at about 100 [Beck, 07], other studies ask for at least 20 to 50 needed registrants or interested people to initiate an effectual interaction [Palme, 95].

Furthermore, there exist explanations, why online communities or community platforms cannot have an infinite number of members with an effective communication flow [Beck, 07, 26ff]: The theory of social loafing focus on the idea that people tend to reduce their effort for common, collective tasks compared with individual tasks, which is conferred to online communities [Thorn, 87], [Karau, 01]. Concerning to [Beck, 07] the number of contributions in a discussion forum is not proportional to the number of registrants and that the activity of large groups is below average. In discussion forums with 3.000 or more registrants the number of contributions and also their lengths gets smaller. The theory of information overload is another approach that explains why a rising number of (potential) contributors is not always helpful: Humans can only process a finite number of information. Asynchronous communication such as in discussion forums is generally helpful, but users come upon constraints if the threads are unmanageable. Additionally, mailing lists attracts a lot of people, but a lot of them are lost because of an information overload [Butler01].

We try to bring all these approaches and theories concerning the lifecycle of online communities in one figure, knowing that the measures and scales are vague. As it can be seen in the figure, a critical mass of registered users is needed to kick of communication and collaboration. With a rising communication and collaboration the effect of social loafing and/or information overload can lead to a point of stagnation that means the number of additional contributions declines.



*Figure 1: The life cycle of online communities concerning the number of registrants and active community members as well as the phases of the group processes*



To sum up these theoretical approaches and the empirics and experiences concerning online community initiating, we have a lot of explanations why communities are not going to be successful overnight: In general, a bigger group of interested and potential contributors is needed to arrive at the critical mass point, additionally it always needs some time for the first phase of group phase, where the (potential) members can get some ideas about the communities and other members (e.g. via member profiles).

#### 4 Community building from the initiator's perspective in an overview

Online communities are initiated for a lot of different purposes and also the motives for potential members to participate are diverse. The following figure gives an overview about the community building from the initiator's or manager's perspective. We will give some general descriptions what aspects should be taken into account within this process phase, starting with the general principle for community building: "let it grow". Nevertheless, because of the space limitations, this is just a condensed description without detailed hints or method descriptions.



Figure 2: Community Building from the initiator's perspective in an overview

##### 4.1 The general principle: Let it grow!

Human behaviour cannot be directed and steered as cars. For online communities, no construction manual can be developed; online communities have to be seen as organic beings. The motto has to be "let it grow" as you will use it for plants [Clark, 98]: Plants should be fostered and cultivated, and there are also some existential needs, but nevertheless there will be always a certain degree of uncertainty, of momentum.

Additionally, this principle derives a participation of the community itself in the process of community development as crucial and important.

#### **4.2 Commitment on purpose and goal of the community**

There are a number of persons and organisation that tries to develop an online community for certain motives, for example to make a lot of money with advertisement or to get an important community leader. Such motives cannot easily be transferred to goals which attracts and motivates others. Purpose and goals of a community have to be clearly defined, together with existing community members. This goal could be written down as a declaration of intention [Kim, 01].

#### **4.3 Investigate the needs of the target group**

It is no easy task to investigate the needs of potential community members. Generally, the motives for an active participation at online communities can be distinguished between egoistic and altruistic motives [Kollock, 99]. Egoistic or self centred motives are for example anticipated reciprocity, which means that members expect to get something back from their participation; also bragging rights as well as a sense of efficacy: Some users are just motivated by watching that their activities influences or changes the community. Selfless, altruistic motives follow the idea of helping others or the community itself. For community initiation, these motives of the target group and other typical or expectable interests and background should be investigated. Literature research, but also surveys can be helpful tools to get more information about personal, professional or political interests, demographics, or behaviours.

#### **4.4 Foster communication, collaboration and community**

Visitors are eventually interested in a community: Nevertheless, staying and participating is not a question of this general interest, but of relationships. The feeling of being a part of a community is not developed arbitrarily, it can be supported actively. Fostering of communication, collaboration and community is essential to build a community. From our school time, we probably all remember blackboard duty or rituals as the morning meeting, which are also pedagogical intervention to come to community feeling. From our daily life, we also know a lot of rituals as the greetings or celebration days which unify us with special groups. Such rituals can be translated into online communities: For example, a special greeting ritual for new members could be elaborated.

Additional considerations should be done concerning the roles within communities, especially the roles of leaders. Also private, that means non-public spaces, can be essential for an intimate group feeling. To get some idea about the others, also the member profiles are important. Netiquette, that means, rules of communication and/or moderation should be developed. Last, but not least, a user friendly interface is important.

#### **4.5 Evaluation and Measurement of the Success**

The above mentioned goals and purposes of initiators could serve as evaluation variables of a community's success evaluation. Nevertheless, the motives of the

community initiators are not necessarily identically with the goals of the community itself. As these goals can change about time, it is additionally difficult to answer, if a community is successful. Success can be seen from the community's or the initiator's perspective. Furthermore, it seems to be possible that the success of the community can be seen as independent from the achievement of objectives, for example in the variable of community's healthiness. Positive references, members' loyalty, a small average time until a new member contributes actively, as well as the average time it takes until a member gets an answer, can be seen as variables of healthiness [Spreadloveproject, 08].

## **5 Recommendations for special application areas of community building**

When we started our work on the successful building of online communities we realised that recommendations of concepts of successful community building varies a lot and came to the conclusion that the concrete applications and contexts should be taken into account to give, at least exemplarily, advanced insights into good practice for practitioners. Besides the above mentioned general principle and steps we did a deeper look into the following six applications areas and derived recommendations for these fields: online self-help groups or patient groups, online communities on professional news-sites, communities of learners, customer communities for open innovation, enterprise communities for knowledge management, and communities for open source development. We try to select online communities with and without commercial interest, open and closed communities, enterprise and privately driven ones [Schaffert, 09].

The following table is an overview about target groups, important obstacles and stumbling blocks as well as successful measures of three of this six application areas. We derived it from literature, project analysis and interviews with experts within the fields.

	<b>community of readers on a professional news site</b>	<b>community of learners</b>	<b>community of customers for open innovation</b>
target group	readers such as journalists or contributors	learners	customers
obstacles and stumbling blocks	missing moderation, because news potentially turn out conflicts  the platform is technologically not up to date (e.g. for upload of photos)	the Internet is neither part of daily life and work, nor it is be seen as very attractive by the learners  unfitting composition of groups or partners	research and acquisition of lead users is important  it could be problematic if the public and competitors are able to follow the community's activity
successful measures	attentive moderation and inclusion of users in parts of the platform, activities and competitions	support of cooperative learning with fitting didactical measures and settings, also reputations systems	established instruments of innovation measures, e.g. idea competitions  a member only community  special offers (costs, events, test usage, exclusive content)

*Table 1: Online community building in three application areas*

As this overview illustrates, the requirements of community building in the concrete application areas vary a lot. Whereas privacy in self-help group or patient groups is important to secure the private sphere of the members (they often tend to publish a lot of things there they usually would not tell their neighbours) the same procedure of “member only” spaces is a possibility to rise exclusivity and attractiveness for potential members of customer communities. Additionally, aspects such as user friendliness can be seen as crucial for “another new social networking platform”, but not for an online patient group for seldom diseases.

## 6 Discussion and future work

Our detailed research of successful community building in six applications areas illustrates the ambiguity and limited prevalence of a lot of “general” tips which we have found in Weblog postings and also in literature. Analysing our own approach of structuring and getting more information and recommendations from diverse sources

we see it as fruitful; especially the selection of very diverse application areas. Despite our first impression of confusing information we came to the conclusion that just very little knowledge or clear advice for the first initial steps of community building exist. With our study we hope to give some deeper insights. Nevertheless, the results are just limited to the phase of community initialising and there is still a lack of more research and (meta) analysis of recommendations for community management.

Within our project at the Salzburg NewMediaLab, this was only the first in a serial of studies we will develop for practitioners in the field of online communities and related technologies. The next report in our project will be about meta information of and for online communities: Besides the contributions through content creation or upload, for example photos, text or videos, users are also generating meta information. This meta information is generated, either actively, for instance through tags, or indirectly or subconsciously through user behaviours. This part of the study focuses on new forms of generating meta information and how they can support communities. Realisations will be discussed and research reports will be analysed, dealing for example with tagging behaviour in communities or common usage of tag clouds. Building on a collection of these approaches, we will develop in another report a collection of good practice of recommender systems and its various forms used in communities: An overview of current realisations and experiences with such recommender systems as a service for users and communities will be given. This includes the description of technological concepts and realisations. Last, but not least we will concentrate on systems which indicate engagement within a community or serve as reputation system.

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# An Exploratory Study on the Explicitness of User Intentions in Digital Photo Retrieval

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**Abstract** Search queries are typically interpreted as specification of information need of a user. Typically the search query is either interpreted as is or based on the context of a user, being for instance a user profile, his/her previously undertaken searches or any other background information. The actual intent of the user – the goal s/he wants to achieve with information retrieval – is an important part of a user’s context. In this paper we present the results of an exploratory study on the interplay between the goals of users and their search behavior in multimedia retrieval.

**Key Words:** User intentions, multimedia, information retrieval.

**Category:** H.1.1.2 User/Machine Systems - Human factors, H.2.4 Systems - Multimedia databases

## 1 Introduction

According to the classical model of information retrieval users specify their information need as a query. This query is submitted to an information retrieval system which returns a ranked list of documents containing a subset of its entire document collection containing relevant information. The actual process of issuing a query can be seen in context of the user’s intent. The information need depends on a *goal* a user wants to achieve. To achieve the goal the *information need* is translated to a query [van Rijsbergen, 1979, Broder, 2002]. Therefore, for the rest of the paper we assume that a user has a certain *intention* when formulating a query.

In this paper we deal with the question how users express their intentions in search queries while searching for a particular *multimedia content*, e.g. digital photos on the web. We try to answer the questions whether intentions are expressed in queries in this context and how classes of intentions correlate to the search and browsing behavior of users. The presented results are based on an exploratory study on *Flickr*<sup>1</sup>.

Following the introduction Section 2 gives an overview on related work in the field of intentions in search queries. Section 3 focuses on the case study

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<sup>1</sup> Flickr Photo Sharing – <http://www.flickr.com/>

itself and explains the setup, tasks and analysis of the same. The results, our interpretations and assumptions are presented in Section 4. Section 5 concludes our contribution and gives an outlook on future work.

## 2 Related Work

Jansen et al. [Jansen et al., 2007, Jansen et al., 2008] present an approach for automatically examining user intentions of queries and classification of these queries using a hierarchical classification scheme. This classification consists of three levels: *informational*, *navigational* and *transactional* intentions. Each level shows particular characteristics which are used in the classification process. The intent behind *informational searching* is to locate a specific content to satisfy a particular information need. In *navigational searching* the intent is to locate a web site, the user thinks it may exist. The intent behind the third level, *transactional searching* is to locate a specific web site to obtain some other product. Furthermore, Jansen et al. discovered that most of the queries classified as informational contain question words (e.g. "how to", "what is" etc.), informational terms (e.g. "list", "playlist" etc.), and have a length of greater than two terms. Also the user views multiple result pages. On the other hand, navigational queries mostly contain names of companies, organizations and people, and typically have a length of less than three terms. Moreover, the user views just the first result page which was returned by the search engine. Finally, transactional queries contain terms related to movies, songs, images etc. and furthermore consists of terms like "download", "entertainment", "buy" and "chat".

Broder [Broder, 2002], who presented the original classification scheme used by Jansen et al., deals with the same problem. However, Broder additionally employs a user survey and an analysis of the log files of the AltaVista search engine to evaluate and validate his classification approach.

Also Rose and Levinson [Rose and Levinson, 2004] investigate the problem of identifying intention of users from search queries. They build a more detailed and specific hierarchy which is used during the classification process. They divide the informational level into *directed* (learn something particular about a topic), *undirected* (learn anything about a topic), *advice*, and *list* gradations. Furthermore, they replace the transactional level by the *resource* intention. The classification process itself is based on the interaction of a user and its behavior with the search engine. Though the query itself, the returned results, the viewed results and further searches and query refinements can be taken into account.

Strohmaier et al. [Strohmaier et al., 2007] investigate how users express their goals and introduce a way how these goals can be represented in a semi-formal way using the  $i^*$  notation developed by Eric Yu [Yu, 1996].

In the context of multimedia content, images and *Flickr*, Fan et al. [Fan et al., 2008] developed a hyperbolic visualization based on clusters. A cluster



contains images with similar *Flickr* tags and additionally stores the degree of relationship to other clusters. While searching, a user is "zooming" into a cluster, getting more images of the specified cluster. With this type of visualization, a user may be able to better express his goals and intentions. However, the explicit intentions of users have not been issue of the work of Fan et al.

### 3 Exploratory Study

Related literature indicated that in text search a large percentage of queries contained intentional structures (see [Jansen et al., 2008]). However, this has not been an issue of research for multimedia retrieval. Therefore, the following research questions arise:

1. Are user intentions reflected in multimedia retrieval by search queries and the way the result list is browsed?
2. In how far the explicit intention for multimedia retrieval can be found based on user queries and the click paths?
3. Can user queries and click paths be used for classification of user intentions based on the classification schemes already presented in literature?

As there is currently no extensive data set for multimedia search available we chose to investigate those questions in an exploratory study. We chose to do the study on digital image search. Users were presented a set of ten different information retrieval tasks, which implicitly specified the intentions of search. For the tasks the test users were asked to use *Flickr*, a popular digital photo community web site. The tasks have been classified according to the classification scheme presented in [Jansen et al., 2008] and [Rose and Levinson, 2004]. The following tasks have been presented to the test users (Table 1 gives the intentional classification of the tasks):

1. Imagine you are preparing a motivational talk at your department. Find some pictures and photos which you want to use on your slides in a presentation for expressing *joy*.
2. Imagine you want to travel to *Seattle*, Washington (State), USA the first time. Find some pictures and photos of things which you might be interested in while traveling.
3. Imagine you attended the *Frequency Festival* in Salzburg in the last summer (2008). Find some pictures and photos of this event. Do you find yourself on a photo?
4. Find a picture or photo which expresses *aggression*.

5. Find the best picture or photo showing the *Eiffel Tower*.
6. Find a picture or photo which shows the quality of photos which have been shot at night with a *Canon PowerShot SD990 IS (Digital IXUS 980 IS)* camera.
7. Find out what shape the building *Science World* in Vancouver has.
8. Find out how to *tie a tie*.
9. Find a photo of a person you know personally without using the name as query.
10. Find out the difference in the looks of *Jon Bon Jovi* now and 20 years ago.

Task#	Significant keywords	Intention type	Gradation
1	Motivational talk (Joy)	informational	list
2	Travel to Seattle	informational	undirected
3	Frequency Festival	informational	directed
4	Aggression	informational	list
5	Eiffel Tower	navigational	–
6	Camera quality	transactional	–
7	Science World in Vancouver	informational	directed
8	Tie a tie	informational	advice
9	Photo of a person	navigational	–
10	Jon Bon Jovi	informational	directed

**Table 1:** Intentional classification of the given tasks

The tasks were defined in discussions with Flickr users and researchers. Within this process we found that the classification schemes used in [Jansen et al., 2008] and [Rose and Levinson, 2004] could not be applied easily to digital photo search on Flickr. While it was easy to collect a large number of informational queries, the number of possible navigational and transactional tasks was still very low. With this sample we put focus on informational class (and subclasses), which was the class the interviewed users found most intuitive, while the class of transactional search intentions – the least intuitive one – is only represented by one example.

To track the test users behavior we employed a reverse HTTP proxy logging all user requests. We modified the open source tool *TCPMon*<sup>2</sup> to record the behavior, committed queries and requested resources of each participant. Our analysis is based on the generated log file capturing information of each request:

<sup>2</sup> Apache TCPMon – <http://ws.apache.org/commons/tcpmon/>

- the IP address of a user,
- the HTTP method (GET or POST),
- the date and time,
- the committed query,
- the current page number of the search results on *Flickr*,
- the visited link (page, image, picture etc.), and
- the hops which were taken while surfing.

The click path of test user can be re-constructed based on the IP address and HTTP headers. For the sake of simplicity, our test population was a convenience sample: **persons** of Klagenfurt University. We invited colleagues, students and attendees of a lecture to participate in the case study.

## 4 Results

The analysis of the log file showed that 20 test users attended the issued case study. Eleven of them solved at least one task. Nine apparently just visited the web site without further interaction.

For analysis the generated requests have been grouped by test user (IP) and task. Our first investigation focused on obvious intentional structures. In general, we were not able to find such structures. However, at the second task – "Travel to Seattle" – a test user formulated the query "seattle sightseeing". While this does not follow the common *verb-frame* pattern of a simple intentional query as defined in [Strohmaier et al., 2007], it is still a composition of noun and frame and reflects the intention of the actual search task. Also the recorded requests at the eighth task, which deals with "Tie a tie", contained queries like "how to tie a tie". Also these reflect the intentional nature of the task very well. However, other expected intentional queries as "express joy" or "express aggression" for tasks 1 and 4 have not been issued by the test users. This results in a share of 2.71% of queries explicitly reflecting intentions using a verb-frame like structure, a lot lower than the share found for text search in [Strohmaier et al., 2007]. Due to this we assume that in the context of multimedia data a query just contains keywords which describe the expected and desired content of the image, not the intention itself.

Besides the intentional structures we found in the sample we assume that users might express their intentions on an indirect way through their search behavior. To support this idea we computed the average number of viewed photos (clicked results) for each task and the average duration time needed to solve each task for classification purposes. The results are given in Table 2.

Task#	Significant keywords	Users	Images	Duration
1	Motivational talk (Joy)	9	3.0	2:15
2	Travel to Seattle	6	8.5	4:10
3	Frequency Festival	6	1.8	1:47
4	Aggression	5	3.2	1:55
5	Eiffel Tower	6	3.2	3:23
6	Camera quality	5	3.2	2:35
7	Science World in Vancouver	6	1.2	0:40
8	Tie a tie	6	1.5	1:30
9	Photo of a person	4	3.0	3:52
10	Jon Bon Jovi	5	1.8	1:07

Table 2: Average numbers of viewed images and duration times. *Users* gives the number of users who participated in the task, *Images* gives the average number of viewed images and *Duration* gives the average duration of the task in minutes.

It can be easily seen, that the tasks with a directed informational or advice character (tasks 3, 7, 8 and 10) are rather short ( $duration \leq 2 : 00$ ) and only a small set of images has been visited in result list browsing ( $\#images \leq 2.0$ ). On the other hand, the task based on undirected informational intention (task 2) features the largest duration and number of images viewed for result list browsing with a duration of 4:10 and an average number of viewed images of 8.5. The class of informational intentions with the gradation "list" (tasks 1 and 4) features rather short search times ( $duration \leq 2 : 30$ ) and a rather large number of images viewed ( $3.0 \leq \#images \leq 5.0$ ) compared to the tasks with directed informational or advice character. Navigational tasks (tasks 5 and 9) have a rather large duration ( $3 : 00 \leq duration \leq 4 : 00$ ) and a rather large number of viewed photos (3.0 and 3.2).

## 5 Conclusion and Future Work

In this work we examined the way users express their intentions in digital photo search. In the exploratory study we found that like in related literature only a small part of queries contained explicit intentional artifacts. In fact the share was even smaller than previous work indicated for text search. We further found clues that the user intention class might correlate to the result list browsing behavior in terms of time taken for a whole task and the number of photos viewed. Also we conclude that the taxonomies presented in literature are not sufficient to describe user intent for multimedia search and therefore an adapted model is needed.

While the small size of the test population and the short duration of the study do not represent a significant basis to establish reliable hypotheses we still found interesting clues for further research. We are currently working on a

larger qualitative and quantitative case study which is based on *Squid*<sup>3</sup>, a more stable reverse proxy compared to *TCPMon*. To achieve significant results the tests are organized in a lab with a higher number of test users. Furthermore, we are working on a adapted taxonomy of multimedia search intent and new study tasks. This should provide a solid basis for definition of a model and definition of an algorithm for classification of the user's intent while s/he is searching for multimedia content.

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<sup>3</sup> Squid (Reverse proxy) – <http://www.squid-cache.org/>

## SIVA Producer - A Modular Authoring System for Interactive Videos

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**Abstract:** In this paper a modular authoring system for interactive videos is introduced. The system enables the author to edit the video and add annotations like images, text, hyperlinks to defined scenes or the whole video. It provides a video cutting tool to define scenes, a scene graph to realize non-linear flow of the video and a HTML editor to create text and link annotations. A project can be exported to a XML formatted file with a specific schema and Flash video format (flv) files, which can be interpreted by the project's player. The system is designed to be used intuitively.

**Key Words:** interactive video, interactive learning, authoring system, authoring tool, video annotations

**Category:** H.5.1

### 1 Introduction

Although most people passively watch videos on the Web, different efforts to enhance these videos with interaction features are in progress. One example for enhanced videos are YouTube Annotations. With respect to these trends and the ongoing change in entertainment, our Simple Interactive Video Authoring Suite (SIVA Suite<sup>1</sup>) is introduced to overcome the limits of interactive Web videos. Our system creates videos with several advantages for the viewer, like additional information about objects in a video or the ability of controlling its flow.

Definitions for interactive videos often rely on the definition by Michael K. Stenzler and Richard R. Eckert, namely that “*A video application is interactive if the user affects the flow of the video and that influence, in turn, affects the user's future choices.*” [Stenzler et al. 1996]. This definition only covers the video-part itself. Recent technologies, however, offer more possibilities, like adding additional materials to well defined scenes or linking videos and homepages.

The use of interactive videos is important and can be applied to a lot of areas and scenarios. Examples of possible scenarios for realizing interactivity in videos are introduced next.

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<sup>1</sup> <http://www.siva.uni-passau.de/>

*Usage scenarios*

Possible usage scenarios can be found among others in e-learning and knowledge management.

Many e-learning-applications make use of videos, but allow little interactivity. In many cases, it is only possible to play, stop and pause the video. Thereby it is impossible to offer an explorative and problem-oriented learning environment. Introducing interactivity can dramatically improve the usefulness of an e-learning video. If the video is split in self-defined scenes, the chronology of scenes can be customized to the knowledge of the different spectators. The user may access additional optional information, which may help him/her to understand the presented content. This information can be text, detail screens, manuals or formulas that are shown at particular parts of the video. A learning sequence that will be of interest to experts and beginners can be created. At the same time, the consumer is not put into a passive role. An authoring-system can provide options to design tests to check the learning process as a feedback to teachers and learners.

It is commonly accepted that knowledge management (KM) and knowledge transfer are critical success factors for competing enterprises. Within the discipline of knowledge management great efforts are made to develop software tools in order to support KM activities. An overview of existing tools can be found in [Lehner 2009]. A tool for creating interactive videos can be assigned to several categories used to classify KM tools (e.g. cooperation systems, content oriented systems, e-learning-systems, visualizing systems). A widely accepted and common description of KM activities is the knowledge life cycle. Core activities within the knowledge life cycle are knowledge development and knowledge generation, knowledge search and identification, knowledge diffusion, knowledge representation, knowledge evaluation and the use of knowledge. Most of these activities can be directly supported by intended functions of an authoring tool for interactive videos. For example, the annotation features can be used for cooperative knowledge development. The authoring tool will build an infrastructure and framework to manage, deliver and evolve knowledge across an enterprise with powerful features. The tool can help to make the right knowledge available to employees, partners and customers, to build knowledge capsules for specific deliverables, general product information, examples, links and any other knowledge deemed important. The collection of interactive videos can serve as a personalized knowledge repository [Lehner 2009].

Some features may be important in both scenarios. In many cases, it might be reasonable to show annotations that are related to the whole video. Examples of such annotations are names of the lecturers, the title of the whole video or links to homepages that provide more information. Switches between videos and video sequences, intersections of videos or the selection of a particular sequence

could be required, for example to show content in another perspective.

Several kinds of annotations are needed to fulfill the requirements pointed out in the previous section.

### *Annotations*

Various types of annotations can be used in both scenarios outlined above, as well as in many other scenarios. The most basic type are simple annotations: HTML or text files, images and videos. Interactive annotations are links to websites or buttons to control the progress of the video. Marking relevant or clickable objects and slow motion brings details of video content into focus. Interactive video annotations can also be classified into three validity levels: they can be valid for the whole duration of the video (video annotations), for the period of a sequence (video sequence annotations) or refer to an object in the video (video object annotations).

Each interactive annotation can affect the main-video in different ways. When additional context gets activated, the video may stop or continue, a jump mark may be triggered or a new browser window may be opened and the video stopped. The activation can be triggered by an event or via the interaction of the user: by clicking the controls of the video, by clicking a button or a tagged object in the video or by clicking a label (link, etc.) in the information area.

The remainder of this paper is organized as follows. In section 2, an overview of several similar projects is given and the main differences compared to our proposal are discussed. Section 3 presents the SIVA Producer and section 4 highlights its architecture. A short evaluation of the used frameworks and libraries is also covered by this section. Finally, section 5 concludes the paper with a short summary and future work.

## **2 Related Projects**

This section gives an overview of existing systems for adding annotations, features and interactivity to videos or television broadcast. Some of them provide tools to add text, images, videos and links to scenes or to mark clickable regions. It is possible to add a table of contents to navigate through the video in some systems.

Systems for interactive TV are for instance porTiVity and GMF4iTV. Both systems are inspiration for features in interactive videos but have to fulfill other requirements than these. The goal of the porTiVity-project is to develop a platform to provide Rich Media Interactive TV services with direct interactivity with moving objects [Stoll et al. 2005]. The Generic Media Framework for interactive Television (GMF4iTV) provides interactivity with moving objects and a personalized navigation within additional content [Lopez et al. 2004]. Scene-based interactivity is not possible in these systems.



Several systems for feature extraction, video sequence annotation or video navigation have been developed in the past few years. Such systems aim at finding features of a video neither than enabling an author to add material. Notable systems include M-OntoMat-Annotizer, VideoAnnEx and Vizard amongst others. M-OntoMat-Annotizer is a system for Windows platforms for extraction of visual features and association with domain ontology concepts. It has the problem of allowing no structuring of videos [Petridis et al. 2006]. The VideoAnnEx annotation system allows a simple and consistent annotation of video sequences with MPEG-7 metadata. Every shot of a video can be annotated with predefined descriptions and keywords [Smith et al. 2000]. Vizard is a video annotation system dating back to 2002, which offers content-based image indexing and retrieval and video navigation [Rehatschek et al. 2002].

Anvil is a free video annotation system for text annotations that was developed for gesture research and is suitable for other applications [Kipp 2001]. Anvil provides a graphical user interface for creating textual annotation elements. The system is platform-independent, user friendly and flexible. However images, videos and links can not be added. It is also not possible to split the video into scenes and change the flow of the video.

The academic video search engine YOVISTO<sup>2</sup> was developed to provide online-courses. It offers a timeline, two separate windows, text annotations and an index of the video [Sack et al. 2007]. In contrast to our system, it is neither possible to influence the flow of the video nor to add images or links.

Web-based systems can be found on the Internet. VideoClix<sup>3</sup> allows to add true interactivity to a video object by making it clickable. It provides an easy management and distribution of videos, but like in YOVISTO and Anvil, no influence on the flow of the video is offered. YouTube Video Annotations<sup>4</sup> allows the author to add background information and boxes with text to the video. Clickable areas in a video are easy to add. Adding images and HTML files is as impractical as splitting the video and changing the flow of the video.

ADIVI<sup>5</sup> is a system based on Flash<sup>6</sup> technology that offers the possibility to add additional content (videos, links, images, .doc, .pdf) as well as areas that are tagged with actions [InnoTeams 2009]. No influence on the flow of the video can be exercised.

Virtual Campfire is a framework to create, search, and share multimedia artifacts, not exclusively videos. It offers a collection of tools called Semantic Zapping Services, Collaboration Services and Storytelling Services. The Semantic Zapping Services allow users to search and browse multimedia contents. Collaboration

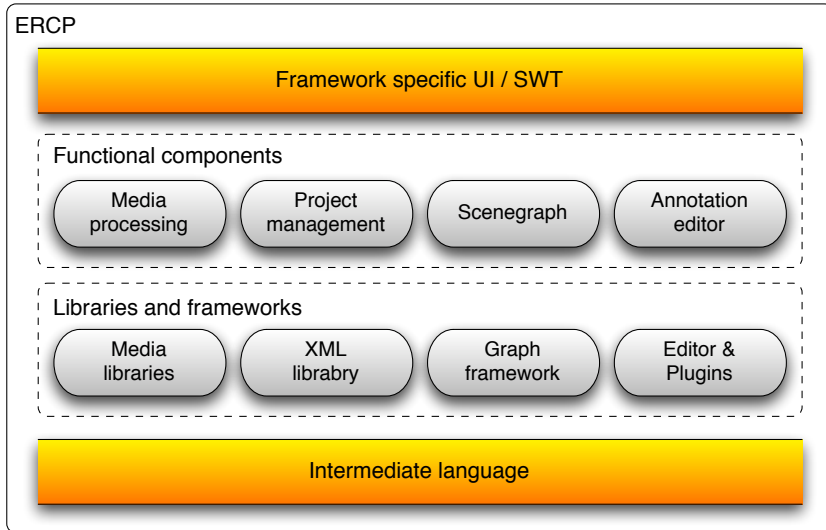
<sup>2</sup> <http://www.yovisto.com/>, 26.02.2009

<sup>3</sup> <http://www.videoclix.tv/>, 26.02.2009

<sup>4</sup> [http://www.youtube.com/t/annotations\\_about](http://www.youtube.com/t/annotations_about), 26.02.2009

<sup>5</sup> [http://www.innoteams.de/P\\_ADIVI.htm](http://www.innoteams.de/P_ADIVI.htm), 26.02.2009

<sup>6</sup> <http://www.adobe.com/de/products/>, 23.02.2009



**Figure 1:** Architecture of the SIVA Suite Producer

Services allow users to annotate, tag and share multimedia contents within a community. Storytelling Services allow re-contextualization of episodic knowledge and with that a non-linearity in a story is possible [Spaniol et al. 2008].

To summarize, these authoring applications only provide a few of the necessary features described at the beginning of this section. The video flow can be rarely manipulated. Organizing the scenes e.g. in a scene graph is impossible in all these systems except Virtual Campfire. SIVA Producer offers all of the required features as well as a tool to define scenes, a scene-graph to manipulate the video flow and a search function.

### 3 SIVA Producer

SIVA Producer offers the functionality for authoring an interactive video. Several application frameworks have been evaluated as a basis for the SIVA Producer. Because of the necessity to achieve a broad support of different platforms, Java based platforms were focused. The most promising platforms were the Netbeans Platform, the Spring Application Framework and the Eclipse Rich Client Platform (ERCP). Finally, ERCP is used mainly due to its sophisticated plugin model, its comprehensive community support and its customizable appearance. To follow the intuition requirements, our system offers its user-interface in an operating system specific look-and-feel, because it is natively rendered by the

operating system. Users of SIVA Producer are able to customize the layout by a drag-and-drop arrangement of most UI components. SIVA Producer consists of four functional components (shown in figure 1).

- **Media processing:** This part of the software offers all functions needed to access, process and watch videos. Our cutting tool offers buttons and sliders for the definition of scenes, enabling an author to split a video into scenes by marking start and end position and naming the scene accordingly. To achieve better usability, a timeline with preview images of the video is used for the scene definition, as shown in Figure 2. An automated scene-detection function is integrated in the cutting tool. Furthermore, a video player with standard features is offered.

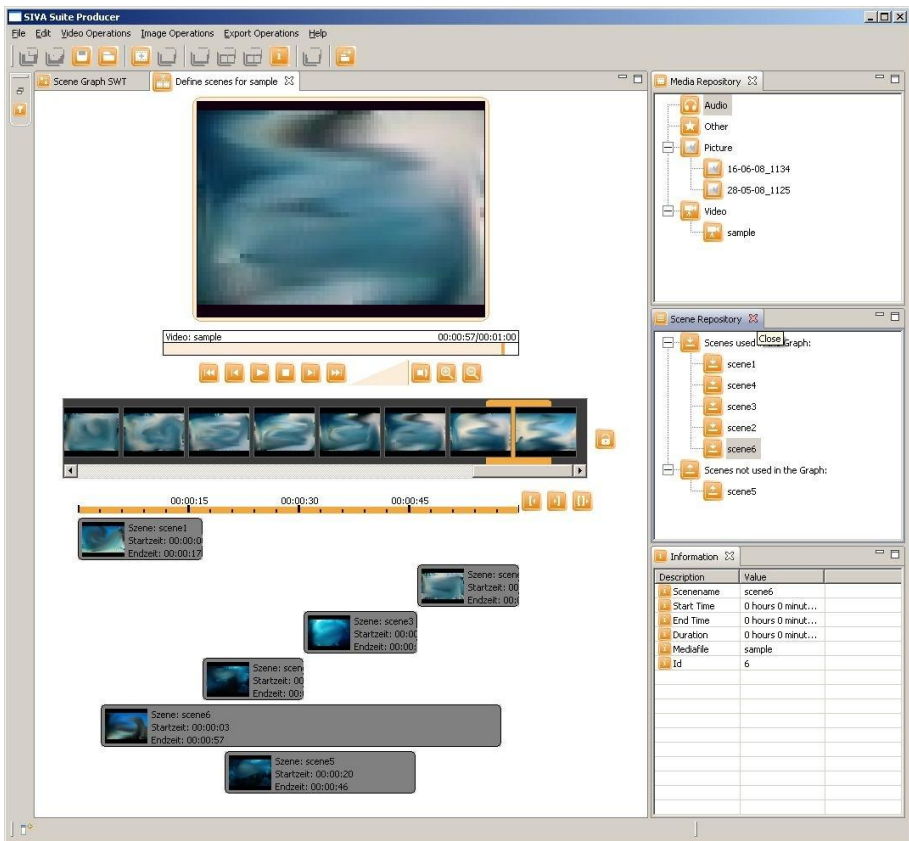


Figure 2: Media processing in SIVA Producer

- **Project management:** This unit offers functionality for organizing project-specific data. It helps keeping track of media files of different types, the scenes and their associated video files and additional content used in a project. E.g. available scenes and media objects are organized in repositories with a detail information area showing information about the currently selected object (see figure 2). Images, videos, HTML-files and other files can be added manually to the media repository. Scenes defined by the author are automatically added to the scene repository. Moreover, a load and save function for projects is available. After the author has finished his/her editing work, the project can be exported. This consists in transcoding all video files of the project to a selected output format (currently flv). The relations between scenes, captured by the scene arrangement in the scene graph, and their annotations are saved in an XML-document. Once the project has been exported, it is ready to be interpreted and played by the SIVA Player.
- **Scene graph editor:** Previously defined scenes are arranged in a scene repository from which they can be added to the scene graph by drag and drop. The scene graph allows the author to arrange the scenes in a graph that represents intersections and a non-linear flow. Scenes in the graph can be annotated with images, videos, links, buttons or HTML-files/rich text. The toolbar of the scene graph editor provides tools to delete and add nodes and edges (see Figure 3).
- **Annotation editor:** Offering an WYSIWYG-HTML editor allows the author to create formatted text with images and links and export the page to a HTML-file, which is added as annotation to a scene. Furthermore, predefined content saved in the media repository can also be added to a scene as an annotation.

Different libraries and frameworks are used to provide functionalities like scene editing and arrangement in the SIVA Producer. The following section describes the selected libraries and frameworks.

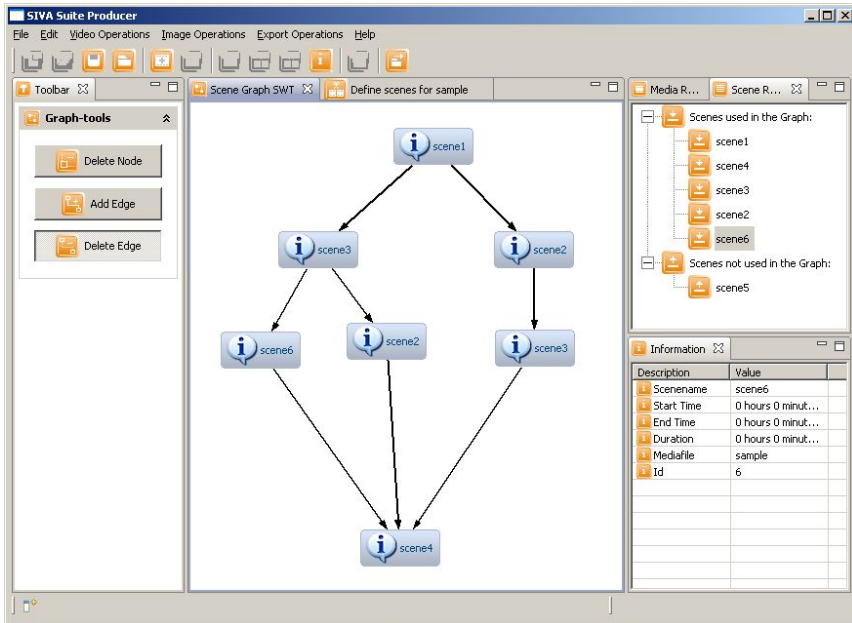
### *Libraries and Frameworks*

Due to the lack of video processing support in the Java SDK and the need for such features in the SIVA Producer, media libraries for Java have been evaluated. The following evaluation criteria were used: platform independence, supported media formats, direct frame access, scene detection, expandability, documentation and support. JMF<sup>7</sup> combined with FOBS4JMF<sup>8</sup> and FFMPEG<sup>9</sup> was chosen as it supports the most media formats.

<sup>7</sup> <http://java.sun.com/javase/technologies/desktop/media/jmf/>, 23.02.2009

<sup>8</sup> <http://fobs.sourceforge.net/>, 23.02.2009

<sup>9</sup> <http://ffmpeg.org/>, 23.02.2009



**Figure 3:** Scene graph editor of SIVA Producer

The library for displaying and editing graphs had to use SWT, due to the Eclipse RCP environment. We have chosen Zest<sup>10</sup> because it is developed by the Eclipse Foundation and uses SWT and Draw2d as GUI library. It provides layout-algorithms for the alignment of nodes. The library is available under the Eclipse Public License v 1.0 and fits perfectly into the Eclipse RCP, having been developed for it.

XML is used in many areas of our system, e.g. project management, project export, etc.. JAXB was selected as XML library for this project due to the good integration into Java, its mature status and its excellent documentation and support.

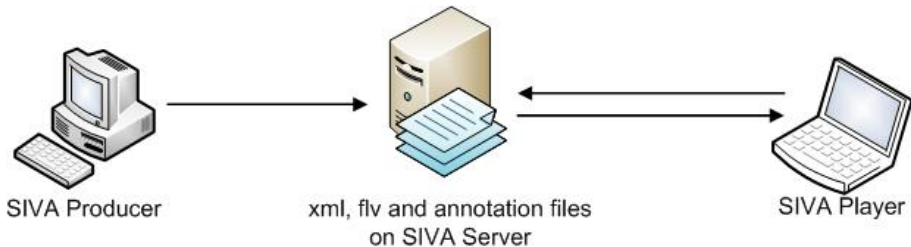
An important feature for evaluating HTML-editors is their implementation as WYSIWYG editor, to make the design of a page with images, text and links easier for amateurs. Another important feature is their availability of the code. According to volume, licensing, completeness and documentation, OnPositive's Rich Text Viewer<sup>11</sup> has been selected for this project. It was deployed for the Eclipse RCP and is available as a plugin. This editor is very extensive, as adaptations of the user interface can be made in the source code.

<sup>10</sup> <http://www.eclipse.org/gef/zest/>, 23.02.2009

<sup>11</sup> <http://onpositive.com/richtext>, 23.02.2009

## 4 SIVA Suite

The whole SIVA Suite consists of three main components - SIVA Producer (described in the previous section), SIVA Player and SIVA Server. The main purpose of SIVA Player is the playback of an interactive video provided by the SIVA Server. Therefore a player with a centered video area and additional annotation areas is offered for integration into a website. The player can be used in window mode, where all annotations are always visible, and in full screen, where annotations have to be activated by clicking a marker. An interactive video is described by an XML-document specifying the interactivity, annotations and the relationships to the main video scenes. Due to the wide-spread and broad support of Adobe Flash, video content is provided in Flash video format (flv). SIVA Player uses Adobe Flex as underlying technology. The three components interact in the following way (see Figure 4): SIVA Producer is used to add annotations and interaction to a video. The whole project is exported as a xml-file, flv-files and additional (annotation) files which are stored in a fixed folder structure. This folder structure is then stored on SIVA Server. When an interactive video is loaded, the xml file is downloaded and interpreted by SIVA Player. According to the settings in the xml file all video fragments and annotation files are retrieved at the right time to be shown in the given part of the player.



**Figure 4:** Scene graph editor of SIVA Producer

## 5 Conclusions and Future Work

The authoring system presented in this paper is designed to enable intuitive handling and to be suitable for beginners. The author can edit the video and add annotations like images, texts, hyperlinks and other videos, which will be shown in the player module. The video can be segmented into scenes by the author or via an automated scene detection. The added information is stored in a XML file for a suited display of the edited video in the player. Basic functions

of the authoring system are creating, loading and saving a project, importing video and media, adding, deleting and playing media. Another basic function is splitting the videos into scenes, which can be named, arranged and annotated in a scene graph. Finally, the whole project can be exported.

A prototype of the system with basic functionality is available. Next work concerns a scene detection. Future tasks are object marking and object tracing and a well developed scene graph with zoom functions and other features that facilitate working with large graphs. An important task in future work is the definition of a reliable and flexible file format to provide seamless cooperation with the SIVA Player.

## Acknowledgments

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# TEAM – a Knowledge Management System for Software Development Process

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**Abstract:** In this paper we present a novel, semantic-based approach for supporting the software development process in a distributed environment. The approach is based on collecting and preserving knowledge used in the software development process in order to support its usage in similar cases later on. One of the main advantages of this approach is possibility to collect required knowledge automatically by observing the behaviour of a software engineer. The approach has been implemented in the TEAM software system and evaluated in three real-world use cases.

**Keywords:** Knowledge Management, Software development process, Semantics, Context Management

**Categories:** M.0, M.2, M.4, M.7

## 1 Introduction

Software development is a collective, complex, and creative effort. It requires the knowledge about the used programming language as well as the right understanding of the problem domain. To deal with complex software processes, it becomes essential to provide computer-based tools to support software developers to perform their tasks. However, the analyses show that standard software has 25 bugs per 1.000 lines of program and that the percentage of failures in software projects is about 70% (source: Standish Group, Chaos Report 2004).

The causes of these failures are different, but most of them can be subsumed under the bad management of the knowledge required in the software development process. Failures in using libraries and repeated errors in compiling code are examples of mistakes that happen very often, are very costly and could be resolved just by better sharing of existing knowledge. Indeed, software development belongs to the very knowledge-intensive processes and current methods for managing knowledge in a software development process are obviously inappropriate ones. Although every software development project is unique in some sense, sharing similar experiences can help developers to perform their activities in a better way. Moreover, reusing

knowledge can prevent the repetition of past failures and guide the solution of recurrent problems.

In this paper we present a new solution for managing knowledge in the software development process. In the nutshell of the approach is the usage of semantic technologies for representing and manipulating this knowledge.

The main advantages of the proposed approach are: (i) exploiting and integrating existing information and collecting new knowledge; (ii) providing easy, rapid access to distributed knowledge; (iii) eliminating time and space constraints in communications through automatic provision of knowledge relevant for a given user context; (iv) stimulating people to share knowledge and to use shared knowledge.

The approach has been developed and implemented in the scope of the EU TEAM project. The evaluation of the system shows clear benefits for the software development process in general.

The paper is organized in the following way: in the second section we present the requirements for the knowledge management (KM) in software engineering (SE) process. In the third section our approach is presented in details. Fourth section presents the implementation and evaluation details, whereas section five contains related work. In section six we give some concluding remarks.

## 2 Requirements for KM in Software development process

As already explained, software development is a knowledge intensive activity and the standard knowledge management approaches can be applied as general frameworks for developing a KM solution in SE. In following we define the requirements for each of these KM phases in the SE domain (adapted from [Probst, 97]):

- **Knowledge goals.** Knowledge goals define the purpose of a KM system. In SE domain it means that we have to define which tasks (problems) should be resolved by the KM system.
- **Knowledge identification.** This phase deals with the identification of structures (models) for representing knowledge. In SE domain it means that all possible knowledge sources (formal and informal) for the software development process must be identified and represented appropriately. The challenge is to represent very complex relations between these sources.
- **Knowledge acquisition.** This phase deals with the gathering of the relevant knowledge from available sources. The challenges in SE domains are related to methods for gathering knowledge from experts in a nonintrusive fashion, i.e. by observing what they are doing.
- **Knowledge development.** It consists of all the management activities intended to produce new internal or external knowledge on both the individual and the collective level. The challenge is SE domain is to develop appropriate visual paradigms for collecting knowledge.
- **Knowledge sharing/distribution.** This phase deals with the efficient allocation of knowledge - i.e. how isolated knowledge can be made fruitful for the overall

organization. Since the software development process can be done in distributed teams, the challenge is the distributed architecture for sharing knowledge.

- **Knowledge preservation.** This is a process of maintaining knowledge important to an organization's mission that stores knowledge/information over time and provides the possibility of recall for the future. Similarly to the previous phase, the challenge is the knowledge preservation in a distributed environment.
- **Knowledge use.** This is the purpose of KM. It is the productive deployment of organizational knowledge in the working process. In SE domain the challenge is the proactive usage of knowledge, i.e. since software engineers are concentrated to some very sophisticated tasks, the better way is to bring the knowledge to them in particular situations (knowledge push) then requesting from them to interrupt the work and search explicitly for relevant knowledge (knowledge pull).
- **Knowledge Measurement.** In this phase the whole KM system is evaluated. In SE domain the challenge is to determine the successfulness of the usage of knowledge artifacts, since due to very complex nature of the knowledge the causalities of the artifacts are quite complex.

In the next section we present our approach for resolving these challenges.

### 3 TEAM System

The main goal of the TEAM system is to support capturing and usage of the knowledge and experience generated during the software development process. The general architecture of the TEAM system is presented in Figure 1. The decomposition is mainly based on functional encapsulation. The TEAM system has a modular, OSGi-based architecture, including different components, which can run separately and deliver different services. The components of the TEAM system are provided as Eclipse plug-ins. Due to Eclipse's foundation in the OSGI Framework, Eclipse plug-ins are also valid OSGI bundles and can reuse OSGi framework services.

The TEAM system consists of four major components:

- The Context System (CS) component observes and interprets the developer's interaction with the developing environment. Additionally, user interaction logs are analyzed by data mining techniques to predict future behaviour.
- The Search and Recommendation (SR) component provides (keyword-based, structured and semantic) search functionality for the knowledge base and recommendations to solve problems the developer encounters.
- The Knowledge Desktop (KD) provides the user interface for accessing the system functionality (e.g. search, recommendation) and also handles all other user interactions (e.g. configuration).
- The Metadata Storage/ P2P (Peer-to-Peer) (MR) serves to store schema information and metadata of the TEAM system and handles the connection and information exchange with other TEAM systems in the TEAM network. The P2P component now included in the MR, because each other TEAM component is only concerned about storing the metadata and has no direct interaction with P2P.

Two components of the TEAM system (i.e. the CS and the KD) fundamentally depend on the Eclipse IDE platform, since the first is used to capture user's interaction in the Eclipse developing environment and the second is embedded in the Eclipse developing environment. Additionally, the CS depends on the Operating System in order to retrieve context information. All other components are independent of developing environment. An additional user interface embedded in other developing environments (e.g. Visual Studio) could access functionality from a TEAM system, which is running as a background application. However, this case is only optional, since the TEAM system is implemented in the Eclipse IDE.

Figure 1 shows the relationships of these modules. The KD is the single entry point to the integrated TEAM system enhancing the software developer's way of working by supplying a user interface to functionalities such as knowledge acquisition (i.e. capturing knowledge), knowledge provision (i.e. creating knowledge items), knowledge usage (e.g. semantic search) etc. Thus it uses functionality provided by all other TEAM components. The KD for example, relies on the SR component in order to query and display search results.

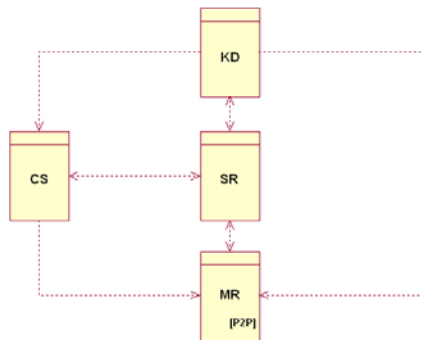


Figure 1: Component model of the TEAM system

The MR is a central TEAM component and thus involved in almost any functionality that deals with the knowledge. It offers a set of services related to the creation/removal/modification/usage/sharing of knowledge items to all other TEAM components.

The CS monitors the developer's activities during software development in order to recognize as soon as possible the need for support or the resolution of a problem. Discovery of a problem/solution is published to other components of the TEAM system that are registered for that. The communication is implemented using subscribe/publish mechanism. Currently, the SR is registered to be informed about discovered problems. To get more information about the discovered problem (e.g. used knowledge artifacts), the SR calls the corresponding services of the CS. Additionally, since a developer must be able to enable and disable at any time the monitoring functionality, the CS provides set of services for the configuration which are used by the KD.

The SR provides to the KD the set of services related to the (keyword, structured and semantic) query construction and refinement. On the other hand, independently

how queries are constructed, they are executed either on the local or on the distributed storage. Regarding recommendation, the SR communicates with the KD in two different ways: a) synchronously, in the case that the recommendation is explicitly required by developers or b) asynchronously, in the case that the recommendation is automatically generated after a problem is discovered. Thus, to support this communication both the direct method calls and the subscribe/publish mechanism are implemented. Finally, the SR provides services for configuration (e.g. setting threshold) that are used by the KD. It supports all activities that comprise a knowledge process and in the rest of this section we discuss how building blocks of general knowledge management system (Section 1) are supported.

### 3.1 Knowledge Goals in TEAM

The goal of the TEAM project is to develop a knowledge management system to support coding phase in the software development process. The TEAM knowledge management system enables better and faster capability of sharing and exploiting knowledge related to the error handling and component reuse in the software development process.

### 3.2 Knowledge Identification in TEAM

In order to increase knowledge transparency the TEAM knowledge management system is built based on TEAM ontologies ([http://www.team-project.eu/documents/D9 TEAM Ontologies.pdf](http://www.team-project.eu/documents/D9%20TEAM%20Ontologies.pdf)) that are shown in Figure 2. They facilitate communication and information exchange, support systematic access to parts of the organizational knowledge base, connect various types of knowledge, infer implicit knowledge out of existing information, improve use of knowledge, etc.

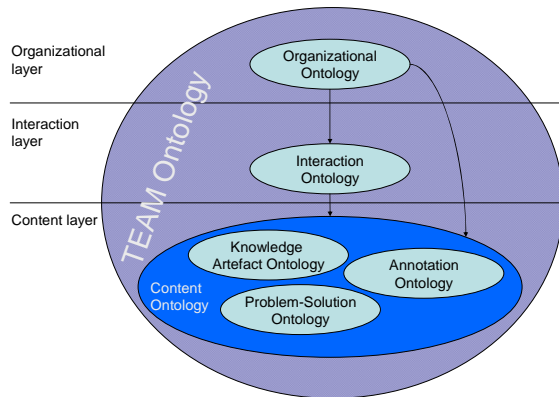


Figure 2: TEAM Ontologies

To provide better support for knowledge sharing and reuse, the TEAM project combines content, interaction and organizational information. Thus, in the TEAM project ontologies are used to describe the structure and content of the knowledge

artefacts, their usage and organisation and to provide a basis for determining how artefacts are related. Different layers model different types of information:

- The content layer enables to determine the structure and content of software objects, related problem reports as well as the solution for problems.
- The interaction layer that builds on the content, as people interact to participate in activities around the code (e.g. software development or problem resolution) describes the structure of interaction.
- The organizational layer describes people, various roles they assume within the organisation, the projects they are involved in, teams performing the tasks, etc.

The content layer consists of several ontologies. The goal of this distribution has been to force modularity in order to use these parts independently:

- the knowledge artefact ontology - describes different types of knowledge artefacts such as the structure of the project source code, the components to be reused, software documentation, knowledge already existing in some tools, etc.;
- the problem/solution ontology - describes the problems that may arise during coding and how they are resolved;
- the annotation ontology - describes general software development terminology as well as the domain specific knowledge.

The main purpose of the interaction layer is to observe user interactions with the system and to infer meaningful context information based on this – e.g. about the current activity of a developer or if the developer needs assistance. This has been modelled using the Interaction ontology.

No knowledge flow can occur outside a shared organizational context, in which the work on artefacts is embedded. If this context is misinterpreted, the meaning that has been understood by a consumer/user and the intended meaning might differ significantly. The organizational context is formed by all organisation aspects including people, infrastructure, projects, etc. The semantics of the organizational layer is captured in the Organisational ontology.

We note here that the TEAM ontologies model formal and informal knowledge related to software development process in a machine understandable form, which enables provision of a qualitatively new level of services, such as gap analysis. Additionally, TEAM does not intend to replace existing artefacts, but to help augmenting and leveraging the existing knowledge. A key enabler for this is the monitoring of developer's interactions inside their working environment, which is essential for realizing context-aware knowledge management system.

### **3.3 Knowledge Acquisition in TEAM**

#### **Role of the SR in knowledge acquisition**

One of the roles of the SR component is to automatically create initial knowledge base by “importing” already existing information into the TEAM system. The TEAM system does not replicate existing information, but rather provides explicit model. Indeed, introducing an ontological representation enables us to “understand” parts of the semantics conveyed by these artefacts and to establish additional traceability links among these artefacts and the software artefacts.

Knowledge acquisition is done by:

- extracting metadata about knowledge artefacts (e.g. method identification) from structured content (e.g. code structure) and from natural language text (e.g. comment in code);
- linking knowledge artefacts - having generated metadata for various kinds of artefacts, it is necessary to relate them semantically. For example, identifying concepts that appear in issue reports is essential for knowledge management support that the TEAM system aims to provide. Certain concepts, such as method names and log messages, are likely to appear in issue/bug reports and provide valuable hints about the code that is involved in producing the bug;
- annotating knowledge artefacts by using a unified vocabulary, i.e. the Annotation ontology (see Figure 2) that ensures unambiguous communication.

In this way the TEAM system is able to automatically acquire existing knowledge that could be useful for the TEAM most important tasks (e.g. error handling). The proposed solution does not require human processing/understanding, and more importantly provides support for integration.

### **Role of the CS in knowledge acquisition**

The CS component addresses knowledge acquisition task by providing the TEAM system with powerful concepts for self-management [Kephart, 03]. It:

- collects data about users' interaction with IDE and enriches this data with semantics based on underlying ontologies;
- analyses the semantically-enriched data using data mining methods;
- creates a plan of action in a form of rules that are results of data mining methods;
- executes these rules in order to discover whether a developer needs support, wants to share knowledge, etc.

Knowledge acquisition is done in two modes:

- on-line acquisition of problem/solution knowledge through interpretation of an aggregated sequence of interaction data to a higher context (e.g. discovery of a problem) based on (i) developer's interaction with IDE and (ii) the application of learned rules;
- off-line acquisition of learning rules that help in detecting problems encountered by developers.

In that way, the TEAM knowledge management system tends to be a user-friendly platform that captures information from the work process and automatically interprets it without extra effort for developers. By capturing interaction data, we avoid asking the developers explicitly since they tend to be reluctant to provide the feedback via filling questionnaires or forms. Additionally, the CS component integrates the results from the analysis of the usage data with the methods that guide the process of knowledge acquisition, which means that a kind of a "usage loop" is created.

### 3.4 Knowledge Development in TEAM

The TEAM system supports individual knowledge development as well as collective knowledge development. The KD component of the TEAM system provides a powerful user interface for developing knowledge.

The KD focuses on interacting with the basic objects of the knowledge base, i.e. individuals and their relations (both data and object properties). The metadata development needs guidance from the ontologies. In order to allow for sharing of knowledge, newly created metadata must be consistent with the TEAM ontologies. Several modes of putting knowledge into knowledge base are supported:

- manual metadata development: the TEAM ontologies are used in order to guide developers towards creating relational metadata. The KD component supports manual metadata development by dynamically creating dialogs whose content is generated based on an entity from the TEAM ontologies;
- dynamic metadata development based on user behavior: Some metadata is set automatically based on the user's contribution in creating knowledge base. For example, based on the number of positively assessed solutions defined by a user or frequency of the usage of his/her solutions, the value for the expertise level for this user property will be set.
- implicit metadata development based on the application of rules: One of main advantages of using ontologies is reasoning, which enables creation of new, implicit information. An example is that, a user who wrote a frequently-used and positively assessed solution for a problem about a SE artifact is an expert for that artifact.
- ontology extension: Besides of creating metadata, the developers are able to extend the Annotation ontology. Thus, ontology extension is also supported.

### 3.5 Knowledge Distribution in TEAM

The TEAM system fosters knowledge sharing. It occurs within communities of practice and interests (represented as P2P network), which can help speed up the learning curve. From a technological point of view peer-to-peer solutions are particularly well suited for knowledge sharing, because they make it possible for different participants (organizations, developers, or departments) to maintain their own knowledge structure while exchanging information. The P2P TEAM network is shown in Figure 3.

From the functional point of view, the TEAM system supports three types of knowledge sharing:

- knowledge pull: making local knowledge accessible to others who might be interested in it. The MR component is able to publish knowledge artefact stored in a private (local) storage into the public (distributed) store and to revoke it. Knowledge stored in the distributed part of the MR is available over the network by using the P2P services.
- knowledge push: generating recommendation for resolving a problem discovered by the CS. This is done in an automatic way based on the solutions for that kind of problem or similar problems whose solution already exist in the repository.



- inverse search: suggesting peers to share knowledge that other peer asked for. The SR component of the TEAM system recommends developers to share certain private information. Thus, developers receive actual information on the benefit of their effort.

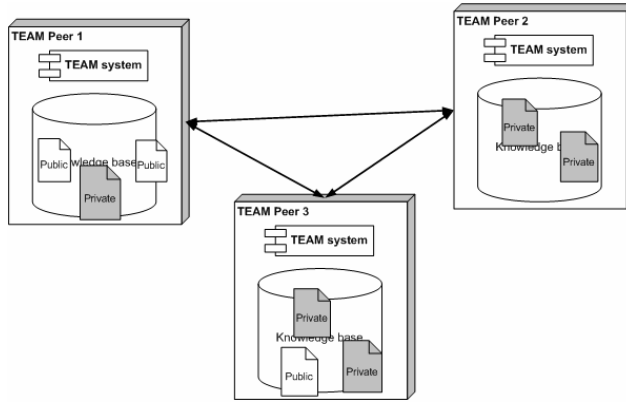


Figure 3: Peers in a TEAM network with local (private) and public knowledge base

### 3.6 Knowledge Use in TEAM

To gain developer acceptance, the TEAM system is integrated into the software development organization's process, allowing collecting and storing relevant knowledge as they are generated in the work. The main advantage of integrating knowledge management into an IDE is that knowledge management is put into software engineers' workflow, since software development activities occur inside the computational environment rather than in the external world. Consequently, the TEAM system, i.e. the KD component that is the user interface for the TEAM system, is also integrated to the existing work environment. While TEAM develops a general framework for KM in IDEs, its prototype implementation is done for the Eclipse IDE. However, other environments can be used. The crucial part of the KD is the wiki. Its purpose is to provide assistance to software developers in accomplishing their tasks in a more flexible fashion and shorten their total effort in terms of time. In order to achieve this goal, the KD approaches software development documentation and related problem solving by combining lightweight yet powerful wiki technologies with semantic web standards. We chose wikis for their significant support in knowledge articulation by providing lightweight and flexible mechanisms as well as semantics in order to add structured formulation to the wiki contents. This combination gives software developers the opportunity to capture their knowledge related with a software development artefact exploiting a structured formalism. This knowledge will be then reusable, more easily shared and retrieved in the future by the semantic wiki's resilient user interface.

### 3.7 Knowledge Preservation in TEAM

As shown in Figure 4, in the TEAM project we distinguish between local (private) knowledge, which is not available to others and public (distributed) knowledge which is available to others via the TEAM P2P network. The MR component addresses the issues of storing all knowledge. Whereas it ensures central control, standardization, high capacity, and robustness, the P2P part of it is viewed as a way of enabling distributed control, differentiation, customization, and redundancy. Regarding the local knowledge, the MR provides a consistent and reliable means of access to local knowledge. The local store consists of: a) T-Box, i.e. TEAM ontologies that represent schema (terminology) for representing knowledge; b) A-Box, i.e. metadata that represent instantiations of the entities defined in the TEAM ontology and c) Rules, i.e. axioms and general rules (e.g. for discovering a problem that a developer has during coding).

## 4 Evaluation - Knowledge Measurement in TEAM

We have performed two types of evaluation of the usability of the TEAM system. The formative takes into account the easiness to capture, develop, use, share and preserve knowledge artifacts. On the other hand, the summative evaluation focuses on the importance of knowledge artifacts and how they fit with the company's goals. Since we are lacking of space, we will present only the highlights from the formative evaluation that are directly related to the advantages of the system we mentioned in the introduction.

We consider the scenario-based evaluation in which a scenario describes sequences of actions taken by a user with a specific goal in mind. To maximize the benefits of this method, we prepared questionnaires that end users had to fill out in order to reflect on their experience with TEAM system. The process was performed in a 2 hours online session (in total 3 sessions took place) using an electronic collaborative platform (CENTRA) where representatives three software companies with the guidance of the technical TEAM people used the TEAM system to complete certain tasks as described in predefined scenarios, i.e. how to find software components that should be reused, how to annotate code, etc. Users are, in general, very satisfied with the system. Remarks are, as usual in the case of new technologies, related to usability issues. We present here the results from the evaluation of the scenario "Resolve an error", which is related to the resolution of an error in a coding scenario that is based on the usage of a (rather complicated) class library. The system' provided benefits in this scenario are: 1) proactively avoiding errors by suggesting the user the best practice in using that library (in a non-intrusive way), 2) support in finding the root-causes of the error and its repair and 3) extending the knowledge base automatically after the error has been resolved. We measured the effectiveness of each of them, expressed in terms of: a) percentage of accepted suggestions (objective measure), b) percentage of useful, but accepted, suggestions (subjective measure: yes - no) and c) ease of usage (subjective measure, scale 1-10). For the subjective measure users were asked to provide an answer. The results are presented in Table 1.

<b>Objective:</b>	<b>Metrics:</b>	accepted suggestions (%)	useful suggestions (%)	ease of usage(average)
<i>Avoid errors</i>		66%	85%	8.4
<i>Repair errors</i>		86%	78%	5.2
<i>Extend knowledge base</i>		91%	85%	8.3

*Table 1: Evaluation results*

Discussion: The percentage of accepted suggestions is quite high, except for the “Avoid errors”: an explanation is that our system is too sensitive and provides suggestions for information about classes when it is not necessary. On the other side, the ease of usage is quite high. The usefulness of accepted suggestions is high for all three cases. The ease of usage in “Repair errors” is rather low since it performs a kind of root-cause analysis which for an un-experienced could be difficult to understand.

## 5 Related work

There are several approaches for managing knowledge in SE. In this section we give a short overview of some of them.

The Knowledge Dust to Pearls approach [Basili, 01] combines and makes use of benefits both from the AnswerGarden (which represents Knowledge Dust) and the Experience Factory (which represents Knowledge Pearls). It captures the knowledge dust that employees use and exchange on a daily basis and immediately, with minimal modifications, makes it available throughout the organisation. This process is accomplished by creating a system that supports peer-to-peer activities; i.e. the employees of the organisation help each other and fulfill the short-term return goals of a knowledge capturing and sharing approach.

The Knowledge Dust to Pearls approach is influenced by the ideas of the Quality Improvement Paradigm (QIP) which provides a model for process improvement in software organisations. QIP uses the notions of continuous improvement and iterations as the main vehicle for planning, executing, evaluating, and improving processes. The backbone of the Knowledge Dust to Pearls approach is the Experience Factory which establishes a learning organisation. The Experience Factory is, however, a sophisticated approach that satisfies an organisation’s long-term needs of sharing experience.

The Experience Factory [Basili, 94] is a framework for the implementation of the Quality Improvement Paradigm. The Experience Factory enables organisational learning and professes the need of existence of a separate support organisation. The role of the support organisation is to support the project organisation in order to manage and learn from its own experience.

A complementary approach that satisfies the short-term needs of an organisation is the AnswerGarden approach [Ackermann, 90].

Holz presents in [Holz, 03] a detailed life-cycle model for POKM (Process-Oriented Knowledge Management) that is specific to software development

processes. This life-cycle model for Software Engineering Process-Oriented KM (SE-POKM) is integrated into the life-cycle model performed by the organisation's Process Group and becomes an essential part of a continuous organisational learning process.

The main advantage of our approach is the usage of ontologies for the formalization of the SE knowledge and the context-awareness in order to personalize the delivery and usage of knowledge.

## 6 Conclusion

In this paper we presented TEAM knowledge management system which supports developers during the software development process to produce better quality software. Although benefits can be derived from individual tools addressing separate software development activities, the real power of the TEAM system lies in supporting the whole knowledge management process. Indeed, TEAM can be considered as integrated collections of services that facilitate software development activities by applying knowledge management paradigm in capturing, storing, disseminating, and reusing knowledge created during software process as well as in integrating existing sources.

The backbone of the system are TEAM ontologies which define the shared vocabulary that is used to facilitate communication, search, storage, and representation. The ontology-background of the TEAM system enables to move from a document-oriented view of knowledge management to a content-oriented view, where knowledge artefacts are interlinked, combined, and used. Furthermore, the TEAM ontologies constitute the glue that binds the TEAM components together. Since all knowledge handled have a formal meaning (semantics) associated, it is accessible not only to human developers, but also to automated components/tools.

The future work will be oriented toward expanding the collaboration between knowledge distributed between peers by using distributed complex event processing

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## Framework for Analyzing and Clustering Short Message Database of Ideas

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**Abstract:** We introduce a framework for a new idea tool NOTE, which gathers, fosters and manages innovative ideas. NOTE supports the development of organizational memory and is connected to the practices of organizational innovativeness. The tool utilizes text mining methods in idea processing, management and visualization and is thus a new approach in idea management software. The tool is under development.

**Key Words:** idea tool, innovation, text mining, practice, organizational memory

**Category:** H.2.8, H.3.3, H.4, H.5.2, H.5.3

### 1 Introduction

Business organizations collect a lot of knowledge, including huge databases about products, customers, competitors, markets, etc., gathered throughout the years. Organizations have also personal knowledge on employee's personal work space, such as text and data files, books, and e-mails, and as an enormous source of information, employee's wide tacit knowledge about their own field and tasks [Nonaka and Takeuchi, 1995], but also hobbyist knowing about many other relevant matters for the organization, outside their own responsibilities [Kotro, 2005]. New ideas and innovations are fundamental in product development of business organizations. Innovations are often based on creativity, but they also arise from the knowledge in an organization. Business organizations have a lot of tacit knowledge, but currently the whole variety of it cannot be used in the innovation process. Furthermore, part of the organizational memory about old ideas disappears every time someone leaves the company.

Innovations are often facilitated with innovation tools but present tools are not good enough to support all the innovativeness and creativity organizations have. One of the reasons is that knowledge is much more diverse than what innovation tools support. There is a need for tools that facilitate communality and common organizational memory evolution in an organization. [Kotro and Paukkeri, 2009]

The innovation process in business organizations can be divided into a number of different stages, including e.g. scenario and portfolio management, business intelligence, idea collection and generation, idea management and evaluation, and project planning [Kohn and Hüsigg, 2006]. In this article, we focus on idea collection, generation, and management.

New ideas occur in the practice of everyday life in organizations and mostly outside the organizational boundaries [Kotro, 2005]. To be able to bring back the ideas occurred outside the working place people tend to write down their ideas and inventions in notebooks, post-it notes and other pieces of paper, or store them to the depths of the file systems of their laptops and mobile phones. Later, it is often impossible to find the note that is needed, or create an overview of all the ideas, not to mention the numerous lost pieces of paper. If this kind of information was collected to an easy-usage electronic notebook it would give a new way to process tacit knowledge in organizations.

Product development team members play with ideas and come up with new ones. An interesting characteristic in revealing ideas to the colleagues is whether the identity of the author is somehow attached to the idea or not. In many situations people tend to be more willing to enter their ideas to an idea collection if they get the praise of having their own name behind the idea. On the other hand, sometimes people prefer to filter their wild ideas if they have to reveal them with their own name. They might feel that they are not experts of the area and do not know all the consequences, and thus the idea might be totally foolish. Also organizational structure might prevent people from mentioning something that is contradictory with other people at a higher position in the hierarchy.

To really support creativity and innovations in organizations, there should exist software tools that collect and remember ideas, manage them, and are easy to use. Such a tool should provide a simple way to enter notes and easy access to the variety of different ideas that are produced by anyone in the organization.

## **2 Note Tool**

NOTE innovation tool helps with the problems of vanishing organizational memory, disappearing or badly accessible notes, and wide range of ideas that are hard to be organized. NOTE is a shared electronic noteboard where the employees of a company write down their observations, ideas and questions. The ideas can be entered whenever they spring into mind, through a mobile phone or a web browser. The underlying data processing system processes the notes and links similar or related ideas together. While contemplating the NOTE database, the arisen idea clusters are visualized in an intuitive way. NOTE may also link external information to the ideas from the databases of the organization or from public databases.

## 2.1 Use Case

We give an illustrative working example of the NOTE tool from the publishing sector.

A project manager of a company enters a note 'Three of my neighbours have recently bought Kindle' on NOTE. The day after, a product developer adds notes 'People still buy books if they want to read' and 'iPod is used for reading but not for reading entire books'. The NOTE engine links all the related notes to these, generating clusters of books and iPods. The result is visualized as a cloud of notes. The product developer is able to see other related ideas and thus enrich one's own view of the state of the publishing sector (see [Fig. 1]).



**Figure 1:** Clustering of notes related to books.

In the afternoon, there is a meeting discussing a possible upgrade from traditional books to e-books. All the ideas relating to e-books in NOTE public database are visualized on the screen. Although lots of notes about electronic books have been added recently, NOTE finds also ten years old notes in the database that suggest paper free offices within a year. That makes people think that the e-book boom might be just momentary hyping as the disappearance of paper was earlier, and they decide not to go out of traditional books.



On the way from a meeting to another, a salesperson writes down the ideas occurred when visiting a customer and submits them to NOTE by SMS. The salesperson checks also the personal NOTE space containing notes about customer companies and their needs. The salesperson creates some additional links between the notes about two companies with similar interests.

## 2.2 Note Engine

The uniqueness of the NOTE tool is the use of an autonomous engine that processes all the ideas entered to the system. When the number of notes and ideas in the idea collection increases a lot, it starts to be impractical to read through all of them. By using advanced text mining methods, the NOTE engine is able to process a huge amount of data and find semantic connections between the notes. Besides providing the customary lists of ideas, sorted by date, author and category, NOTE provides the user with similar or related ideas that were stored earlier to the idea database of the company. The NOTE engine groups and clusters ideas according to the semantic similarity of the texts. NOTE remembers older ideas and picks up the relevant ones from the large idea collection. The tool visualizes ideas in a way that a clear view of the entirety of the needs, innovations under process and targets of development in the company can be established.

NOTE adds a date stamp and either user name or anonymous tag to each note entered to the system. Thus temporal changes can be tracked and statistics given about the emergence of innovations. Users may create and delete links and see clusters according to their own preferences. In addition to the public workspace, each user has a private workspace where they can develop and collect their individual ideas. In a later version, NOTE will link customer data, visualizations and other relevant external information to the notes.

## 2.3 Text Mining Methods

The NOTE engine uses statistical text mining methods for processing notes. Short notes, about 1–20 words each, may be written in any language for which there is also textual background material available. The background material is used as a sample of 'general language' for the clustering methods. In the first version of the NOTE engine, first and second order term-document matrices are used together with *tf.idf* score [Salton and Buckley, 1988] to create a semantic vector space of the idea texts. The clustering is conducted in the vector space by *k-means* algorithm [MacQueen, 1967] with cosine distance measure.

Language is redundant with synonyms and ambiguity and thus semantically similar short notes share the same vocabulary very rarely. Therefore, the second version of the NOTE engine will use a bias corpus: the bias corpus is a collection

of text documents in the used language and on the area of the business (for example, from the company's own databases or publicly available data). The bias corpus will be used for expanding the short notes, to be able to calculate the similarities between notes more accurately.

The NOTE text mining methods are statistical, as the opposite to rule-based systems with fixed vocabulary and restricted sentence structure, and they follow the unsupervised machine learning paradigm. Due to the statistical approach, NOTE is able to process new, not-predefined words and phrases by simply running the unsupervised clustering again. NOTE text mining methods are also language independent, that is, basically the system needs only reference corpus in the used language [Paukkeri et al., 2008] and is thus easily modified to a new language. Anyway, to obtain more smooth performance, some small, easily replaceable language-specific components must be added. Text mining algorithms will be discussed in more detail in a forthcoming publication.

## 2.4 Visualization

The clustering of NOTE may be local, linking just the most relevant notes to the idea at hand, or global, organizing all the notes in the databases into clusters. The unsupervised clustering is visualized according to the preferences of the user:

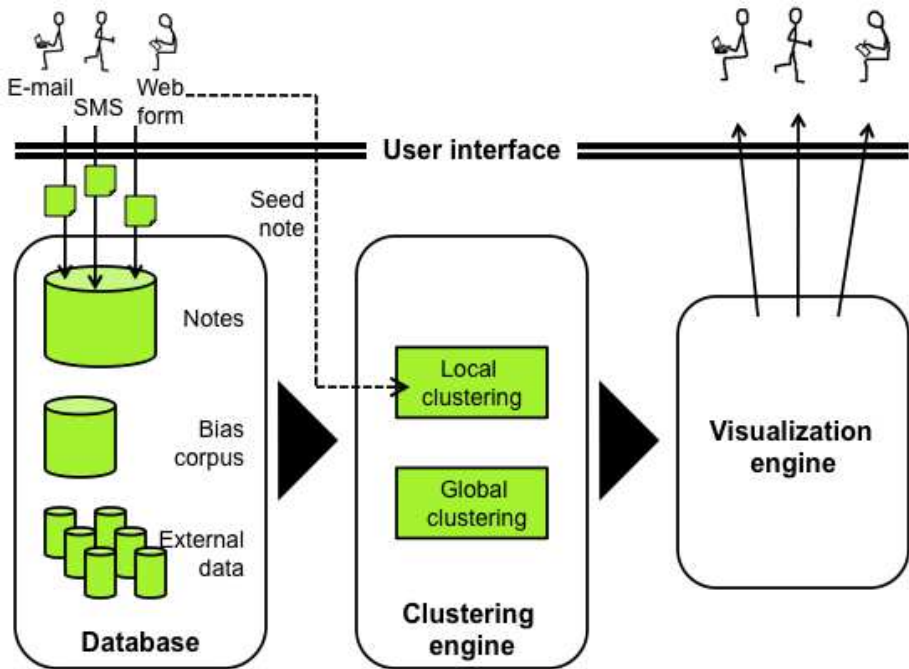
- In **General overview**, all the publicly available notes in the database are clustered and arranged according to the semantic similarity. The general view helps in tracking the emphasis of ideas in the company and the changes over time.
- **Notes on one's personal space** can be clustered separately or combined to the public notes.
- **Notes related to certain note or topic** can be linked to build a local cluster.
- **Classification** according to a predefined list of product names or keywords, or automatically extracted keyphrases from an external set of documents [Paukkeri et al., 2008].

The user may facilitate the cluster to have the emphasis on:

- **Recent notes**; notes with a recent time stamp get more weight.
- Notes by certain **author**.
- According to **votes** given to notes.

The visualization is based on the resulting clusters of notes and the cosine distance between notes in the term-document vector space. The growing database does not cause trouble to the visualization, since links to the most relevant notes only are visualized in the local clusters. An important part of the visualization is to select appropriate labels for the clusters and sub-clusters in the global clustering [Lagus and Kaski, 1999].

The framework of NOTE tool is visualized in [Fig. 2]. The system contains a large database of notes, a bias corpus and external information. The clustering engine performs local and global clustering for the notes and gives the output to the visualization engine. The users may use NOTE freely by mobile phone or through Internet.



**Figure 2:** The NOTE idea tool framework.

### 3 Related Work

This work is multidisciplinary work and has connections to several fields, ranging from organizational theory research through knowledge management to text

mining. Organizational theory, and especially innovation as a decentralized activity in organizations, forms an important background for the key ideas of the NOTE tool [Kotro, 2005, Kotro, 2007, Kotro and Paukkeri, 2009]. Text mining discussion will come as future work.

There are lots of idea generation and management tools available on the market. Many of the tools are based on mind maps or trees and their visualization. The user is able to write their own mapping and scan through the previous visualizations. Usually there are some functionalities to process the created map structures. The nodes of the maps contain usually few words. Some examples are *Decision Explorer* (Banxia Software Ltd.)<sup>1</sup>, *Idea processor* (Axon Research)<sup>2</sup>, and *MindView 3* (MatchWare)<sup>3</sup>. These systems are easy and effective to use but they are just electronic versions of the pencil-and-paper mind maps and do not involve any processing of the texts or comparisons between maps.

*Goldfire* (Invention Machine)<sup>4</sup> is innovation software that supports several innovation tasks and tools. It uses semantic indexing technology to extract relevant concepts from internal and external databases, like corporate documents, content repositories and technical websites. Concepts are collected to knowledge bases to allow *Goldfire* to generate dynamic taxonomies of query results and create summaries of documents. *Goldfire* processes English, French, German and Japanese text and also supports translations between these languages. The system analyzes documents with computational linguistics methods but does not directly utilize those methods in innovation refining.

Some approaches for clustering and visualizing document collections have been proposed. *WEBSOM* [Honkela et al., 2004, Kohonen et al., 2000] organizes vast document collections to a two-dimensional plane using statistical representations of the vocabulary used in the documents. The clustering method is *Self-Organizing Map (SOM)*, an artificial neural network method that uses unsupervised learning paradigm. *WEBSOM* is used to analyze e.g. patent abstracts. *eClassifier* [Cody et al., 2002] categorizes automatically large collections of text documents. It has many different visualization techniques and also extraction techniques to provide concept summarizations for each category. *SWAPit* analyzes and visualizes document collections using ontologies as the basis of clustering [Seeling and Becks, 2004]. It uses a multiple views paradigm to enable user to simultaneously explore documents on content level, conceptual level and based on associations to structured data records. The reviewed visualization methods use article abstracts or whole articles as their data. For shorter texts, such as notes, different methods are needed. Methods to analyze shorter contexts are discussed in [Pedersen, 2008].

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<sup>1</sup> <http://www.banxia.com/dexplore/index.html>

<sup>2</sup> <http://web.singnet.com.sg/~axon2000/>

<sup>3</sup> <http://www.matchware.com/en/products/mindview/default.htm>

<sup>4</sup> <http://www.invention-machine.com/ProductsServices.aspx?id=50>

## 4 Conclusions and Future Work

We introduced an idea of a tool that facilitates innovativeness in a business organization. The NOTE tool is used to create and update the collective memory of a company. The tool combines statistical text mining methods with the daily practices of an organization in a novel way.

NOTE combines different sources of information and brings unofficial and practical information into a part of product development process and decision-making. It emphasizes creative brainwork, supports virtual communities and face-to-face teamwork, and helps product managers to innovate. NOTE lowers the hierarchy in an organization by collecting innovations from every level of the hierarchy, according to the value of the idea, not the status of the employee.

A demonstration version of the system has been implemented with most of the functionalities: web page and e-mail submission of notes, the first version of clustering and most of the visualization features. The future of the NOTE framework includes the development of a working application with the second version of the NOTE engine that utilizes bias corpora. Furthermore, qualitative research of the usage of NOTE in business organizations will be conducted. Further technical steps after the second version of the NOTE engine are adding some extra functionality, e.g. machine translation that would be useful in international organizations.

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# Modelling and Automatic Extracting of Contextual Semantic Annotations

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**Abstract:** In order to reach the semantic Web, approaches to automatically extract semantic annotations from textual documents have been proposed. In this paper we propose an approach to automatically extract annotations by taking into account context in order to obtain a better representation of the document content. Our context is modelled by contextual relations built up from both the structure and the semantics of the text. Our approach requires text documents and a domain ontology as input. It automatically generates a set of contextual semantic annotations represented in RDF.

**Keywords:** semantic annotation, annotation extraction, rhetorical relation, context, ontology

**Categories:** I.2.7, M.0, M.1, M.4

## 1 Introduction

These last years, many works have been performed to semi-automatically extract annotations from web resources in order to reach the semantic Web. In the field of textual semantic extraction, an important step forward has been realised through the availability of automatic natural language processing (NLP) tools. These tools are generally based on linguistic methods such as morpho-syntactic patterns matching [Aussenac-Gilles, 06] or on statistical methods such as frequency of terms co-occurrences. The approaches used so far are generally based on term extraction. Some of them enable also the extraction of relations between these terms. But in most cases, the context where these terms appear is ignored. This observed limitation of term extraction approaches was our main motivation to propose a new approach of modelling and extracting annotations, which takes into account the context in order to give a better representation of the document content. In this article, *semantics* is considered as *the representation of a linguistic unit (of text) in a knowledge representation formalism which allows inferring on this semantics*. From our particular point of view, the *semantic annotation (SA)* of a document is considered as *a snapshot of its content done by an annotator (human or program)*. This SA must be *machine readable*. Our work was carried out in the framework of the SEVENPRO<sup>1</sup> European project whose objective was to develop a virtual environment annotated semantically to design products, in order to assist engineers in their new products

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<sup>1</sup> <http://www.sevenpro.org/>

design and to allow the exploitation of both textual document semantics and 3D representations.

This paper is organised as follows. First of all, in *section 2*, we present a brief overview of related work on textual annotation. Then in *section 3*, we propose a model of context and contextual relations. In *section 4*, we detail the contextual semantic annotations extraction approach and we give a case study showing how the annotations are extracted. In *section 5*, we expose score results of the approach experiments. In *section 6*, our conclusions are presented.

## 2 Semantic annotation

This section focuses especially on both approaches, automatic and semi-automatic, for generating annotations taking into account the notion of context. However, more details are provided in [Uren, 06] for a more thorough understanding of semantic annotation and a state of the art of the current generation of semantic annotation systems and platforms. There are two ways to extract annotations. The first one relies on the content of the document itself and the second one relies on external information sources (context of redaction, external hyperlink...). For the first one, there are two techniques to annotate documents by their contents. The classical one usually consists in associating a set of keywords to each document. The second one, called semantic, annotation assigns to each document an annotation based on *concepts* defined in an ontology and possibly their relations [Guarino, 99][Khelif, 07]. In [Desmontils, 02], the author proposes a supervised approach to index Web resources. In [Vargas-Vera, 01], the author describes a semantic annotation tool for extraction of knowledge structures from web pages through the use of simple user-defined knowledge extraction patterns. Other extraction methods are dedicated to specific areas such as genomics [Nédellec, 04] for example. For the second way, the basic idea proposed by [Njmogue, 04] is that the indexation of a document depends on the activities of the organisation and not on the keywords present in the document. In [Abrouk, 06], the author proposes a semi-automatic annotation approach based on the references cited in a document and without prior knowledge of its content. The authors [Naing, 03] propose an ontology based method to automatically extract hyperlink information about relation instances from a web site.

The challenge is to propose an approach which models the context for the two ways of annotations extraction. In addition, the approach must give a concrete process to extract annotations for one of these ways.

## 3 Contextual semantic annotation modelling

We are interested in extracting contextual semantic annotations from texts. Therefore, the objects handled are of textual type. A "*textual object (TO)*" is defined as a text element (*word, sentence, title, text between bracket, paragraph, section, part of a sentence...*) which conveys semantics. A semantic conveyed by a TO is called *semantic annotation*. The SA is represented in RDF formalism and it can be *class(s)*, *triple(s)* and *named graph(s)*. The use of any semantics is indeed tightly depending on the context it is located in.



McCarthy [McCarthy, 93] defines the context as the generalisation of a collection of assumptions. Contexts are thus represented as first order formal objects. McCarthy assumes that a proposition  $p$  is true in a context  $c$ , where  $c$  is supposed to capture everything that is not explicit in  $p$  but that is required to make  $p$  a significant statement, for what it is supposed to represent. Such a basic relation (between the proposition  $p$  and its context) is always given in another context. In [Brézillon, 03], the author proposes the following definition: “*The context is the information that characterises the interactions between humans, applications, and environments.*”

With regards to textual document processing, we define the context as (Fig. 1):

” *The context of a given TO is a tuple of sets  $\langle TOs, RCs \rangle$  where: the TOs are the textual objects interacting with it and the RCs are the contextual relations (structural, temporal and others) implied in the different interactions*”.

” *The context of a given SA is a tuple of sets  $\langle SAs, RCs \rangle$  where: the SAs are the semantic annotations interacting with it and the RCs are the contextual relations (spatial, temporal and others) implied in the different interactions*”.

Consequently, “*the contextual SA is this SA with its context*”.

In contrast to the relations between *concepts* which have been proposed to represent knowledge, the contextual relations, proposed here represent the relations between TO and between SA.

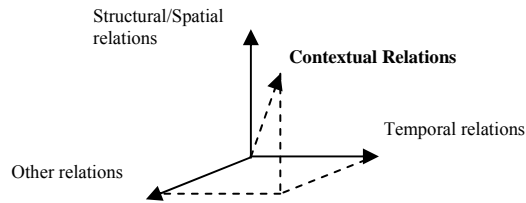


Figure 1 : Three dimension representation to allow modelling context

In addition, the notion of granularity allows us to reinforce our vision on the fact that contexts are nested within each other. The context notion exists at any granularity level. Therefore, it is possible to study the contextual relations not only between the TOs on the same detail level, but also between TOs belonging to different levels. Moreover, when the handled TOs are the documents themselves, we can regard relation among documents as contextual relations such as *cited references, hyperlink, etc.* In this paper, we focus on existing contextual relations within documents.

A *temporal CR* is a relation expressing the time notion among TOs (resp. SAs) within the same granularity level or not. For instance, with regards to SAs (*before, during...*) and with regards to TOs, we also consider verb tenses (*present, future...*).

A *structural (resp. spatial) CR* is a relation expressing the relative position of TO (resp. SA) among them within the same granularity level or not. With regards to TOs, examples of structural relations are *succession, belonging...* With regards to SAs, spatial discourse markers express a rank (*front, after...*) or location (*in, on, under...*).

*Other CR*, that is neither spatial/structural nor temporal, is a relation expressing a semantic notion among TOs (resp. SAs) within the same granularity level or not. With regards to TOs, an example of CR is the degree of importance between a paragraph and its title. With regards to SA, any discourse marker expressing either an addition

(*moreover, in fact...*) or an illustration (*such as...*) for example is considered as a CR. We will detail the use of *discourse relations* in the next section.

So far, the context notion and contextual SAs are modelled. It remains to expose how it is possible to identify the TOs, the CRs and how to generate SAs of TOs?

#### 4 Extraction of contextual semantic annotations

As said above, several levels of granularity exist with regards to SAs, depending on the TOs chosen (sentence, paragraph...). The difficulty is to choose the best granularity to produce the best SA. The proposed approach focuses on a particular level of granularity that is deemed semantically rich. The TOs handled at this level are delimited by "*discourse relations*". *Discourse relations* [Taboada, 06] in Rhetorical Structure Theory (RST) domain are also called coherence relations, conjunctive relations or rhetorical relations. Some works have already been done to identify these discourse relations in the text [Marcu, 02][Teufel, 00][Saito, 06]. Another approach is proposed by [Desclés, 06] to automatically annotate documents by using the "semantics of speech". This method relies on a rule engine enabling to identify the text segments that contain a *definition*, a *cause*... In our approach, we focus on the identification of rhetorical relations explicitly marked. In the example: [Jack failed the exam] *because* [he was lazy], the first argument in brackets is the *fact*, the second argument is the *cause* and *because* the explicit marker. Explicit markers existing between *arguments* (sentences or parts of text) represent the three dimensions of contextual relations: temporal, spatial/structural or semantic.

##### 4.1 Contextual semantic annotation extraction process

Two main stages constitute our process: "*textual handling*" stages followed by the "*semantic handling*" stages (see Figure 2).

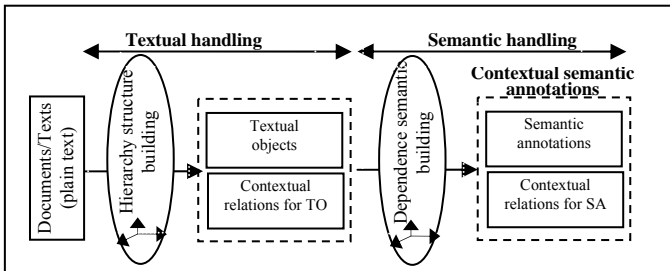


Figure 2: Contextual semantic annotation extraction process

```

3 Description of the mill internal elements
3.1 Inlet Headliners
This new design is composed of 3 thicker bolted rings, compared to
the original design of 2 rings. The liners have a thickness of XXmm.
except for the area of most wear (R/2-R/2+R/3), where the thickness
is YYmm.

```

Figure 3: Text excerpt

Figure 3 shows an excerpt of document provided. It describes the components of an industrial machine (engineering mill), and the assembling procedure.

#### 4.1.1 Text handling stage

The aim of this stage of our exploitation process is to identify the *textual objects* and the *contextual relations* between them.

**The textual objects identification step** consists in identifying *titles, phrases, discourse markers, words...* as well as the *arguments* of each discourse markers in the text. The engineering GATE platform [Cunningham, 02] has been used to identify TOs. It is based on successive application (pipeline) of transducers<sup>2</sup> to the texts. A library of contextual relations is collected from both the *discourse markers* and other *spatial, temporal and semantic contextual relations*. For each contextual relation of this library, a JAPE<sup>3</sup> rule is generated automatically to obtain their positions in the text. Other heuristics are considered and manually transformed into JAPE rules. For instance, a JAPE rule (Figure 4) allows identifying the *numerical indicators* preceding some sentences (titles) such as “7.5.3.”.

```

Rule:TitleNumber
({Token.kind == number}({SpaceToken.kind == control}
({SpaceToken.kind == space})*)|
({Token.lemma == "."}{Token.kind == number}))+
{SpaceToken.kind == control} ({Token.lemma == "-"})*
({SpaceToken.kind == space}*))
:TitleNumber --> :TitleNumber.TitleNumber = {kind =
"titleNumber", rule=TitleNumber}

```

Figure 4: The JAPE rule to identify the numerical indicators

The JAPE rules are applied as transducers in the GATE pipeline. In addition, indications of position such as *start* and *end* in the text of *sentences, discourse markers...* are used to identify the *discourse markers arguments* in the text.

**The contextual relations identification step** requires to build the text hierarchical structure: (a) First, titles are identified by using *numerical indicators* preceding sentences and heuristics such as "GATE transducer identifies titles as paragraphs. If a

<sup>2</sup> A transducer is a finite state machine which enables to produce for each visited state, one or several information.

<sup>3</sup> JAPE (Java Annotation Patterns Engine) is the language for expressing grammars offered by the platform GATE (an example is given in 4.2.3 section).

paragraph contains a single sentence which starts by a numerical indicator, then this sentence is a title". It has to be noted that the default transducer provided by GATE to identify titles is not very accurate; (b) then the scope of the detected titles and in their hierarchy (i.e. a paragraph or a subtitle belongs to a title) are deduced; (c) finally, the nesting between paragraphs, sentences and arguments is built by using position indicators in the text. Once the hierarchical structure of the text is built, contextual relations are deduced. For example, the sentence 's1' belongs to the paragraph "p1".

#### 4.1.2 Semantic handling stage

This stage aims at identifying SAs and contextual semantic relations.

*The semantic annotations generation step* aims at representing the semantics of TOs within a knowledge representation formalism. The chosen formalism is RDF(S). RDF is based upon the notion of triples (*resource, property, value*). To associate RDF triples to TOs by referring to the ontology, we propose to identify *resources* (or *concepts* or *classes*) and *properties* in the text. Therefore, we propose to build automatically a set of JAPE rules. Indeed, the main idea is to use the value of the "rdfs:label" property in a RDFS schema to build JAPE rules.

The *ClassesJapeRulesBuilding algorithm* explains how associated JAPE rules to "classes" are generated:

<pre> <b>ClassJapeRulesBuilding Algorithm</b> {   Classes ← ListOfClass(ontology); Rules ← "";   // ListOfClass request ontology by using SPARQL<sup>4</sup>   // query to get the Class list and their Labels from   // ontology   For each Class ∈ Classes do {     HeadRule ← <b>HeadRuleBuilding</b>(GetNameOf(Class));     EndRule ← <b>EndRuleBuilding</b>(GetNameOf(Class));     BodyRule ← "";     For each label ∈ GetLabelsFrom(Class) do {       BodyRule ← BodyRule       + <b>BodyRuleBuilding</b>(Label)+" ";       If (ExistNextLabel) then {BodyRule ←       BodyRule + "   ";       //in Jape language " " is the operator "or"       } //endFor       Rules ← Rules + HeadRule + BodyRule + EndRule;     } //endFor   } //End of ClassJapeRulesBuilding_Algorithm </pre>	<pre> String <b>HeadRuleBuilding</b>(nameOfRule){   Return "Rule: JRule"+ nameOfRule ; }  String <b>EndRuleBuilding</b>(nameOfRule){   Return "):nameOfRule--   &gt;:nameOfRule.Class={kind=   rule=JRULEnameOfRule }"; }  String <b>BodyRuleBuilding</b>(label){   Body ← ""; Words ← GetWordsOf(label);   For each w ∈ Words do {     wlemma ← lemmaOf(w);     Body ← Body + "{Token.lemma=="wlemma"     (/SpaceToken)}?";   } //endFor   Return Body; } </pre>
--	---

For each class, *head rule* and *end rule* are built by *HeadRuleBuilding* and *EndRuleBuilding* functions. The body rule of class is built by using *BodyRuleBuilding* function with lemmatised words of labels. If there are more than one label for class the operator "|" is added among parts of body rules.

The algorithm of properties rules building is the same as for classes. In this case, the SPARQL query returns properties list and their labels.

<sup>4</sup> <http://www.w3.org/TR/rdf-sparql-query/>

<pre> &lt;rdfs:Class rdf:ID="RingOfDiaphragmMill"&gt; &lt;rdfs:subClassOf rdf:resource="#Item"/&gt; &lt;rdfs:label xml:lang="en"&gt;Ring of mill diaphragm &lt;/rdfs:label&gt; &lt;rdfs:label xml:lang="en"&gt;Ring of diaphragm &lt;/rdfs:label&gt; &lt;rdfs:label xml:lang="en"&gt;Ring&lt;/rdfs:label&gt; &lt;rdfs:comment xml:lang="en"&gt;denotes a part of a diaphragm mill (i.e.ring). &lt;/rdfs:comment&gt; &lt;/rdfs:Class&gt; </pre>	<pre> Rule:JRuleRingOfDiaphragmMill ( ({Token.lemma=="Ring"}({SpaceToken})? {Token.lemma=="of"}({SpaceToken})? {Token.lemma=="mill"}({SpaceToken})? {Token.lemma=="diaphragm"}({SpaceToken}) ? )   ({Token.lemma=="Ring"}({SpaceToken})?{To ken.lemma=="of"}({SpaceToken})?{Token.lemma=="diaphragm"}({SpaceToken})?) ) :RingOfDiaphragmMill--&gt;: RingOfDiaphragmMill.Class={kind="RingOfDi aphragmMill", rule=JRuleRingOfDiaphragmMill } </pre>
--	--

Figure 5: Domain ontology excerpt and its associated JAPE rules automatically generated

Figure 5 shows an example of RDFS description of the class "RingOfDiaphragmMill" in the domain ontology. It also shows the associated "JAPE rule". The "Token.lemma" refers to all the possible variants for a word. Afterwards, JAPE rules are built to detect *candidate values* of properties such as numbers in the text. Thereafter, all JAPE rules are introduced in the *pipeline* to locate *instances* of classes, *properties* and *candidate values* of properties in the text. Then it is possible to build RDF triples. However, ambiguity issues may arise. Indeed, different *classes*, *properties* or *values* may be detected in a same TO. To solve this problem, we check the *range* and the *domain* constraints in order to associate the right class to each property. However, the opposed problem may arise, i.e. no existing class to associate to properties of TO. To solve this issue, the granularity level is increased. These solutions are implemented in the *semantic annotations generation algorithm*:

#### Semantic annotations generation algorithm

TO: *textual object* (argument) deduced from hierarchical structure; TOs : set of TO;  
TO\_max: The biggest TO considered (for example: all of the document, section, paragraph,...);  
**INPUT** : TOs, TO\_max;  
SA: semantic annotation that we want to associate to TO;  
**For each** TO ∈ TOs do {  
TO' ← TO; P ← set\_of\_properties\_in(TO');  
SA ← Null;  
**While** ((TO' ≤ TO\_max) and (P ≠ ∅)) {  
**For each** pj ∈ P do {  
RDFTriplesGenerating Algorithm  
(pj, TO', SA);  
**If** (used\_for\_RDF\_generation(pj)) **then** {P ← P - {pj}};  
} //endFor  
**If** (P ≠ ∅) **then** {TO' ← TO'.IncreaseContext()  
// Increase the granularity level: from the argument,  
// to the sentence, to the //paragraph, then add the  
// scope of subtitle, then add the scope of title...  
} //endIf  
} //endWhile  
**If** (notNull(SA)) **then** {AssociateObjects(TO, SA)}  
} //endFor

#### RDFTriplesGenerating Algorithm(p, TO, SA) {

C ← set\_of\_classes\_in(TO) // set of classes in TO  
c1 ∈ C(domain(p)) // c1 is a class which verifies the  
// domain constraint of the property "p" and if  
// several classes exist, then select in the ontology  
// the class which is the most specific class and  
// which has the shortest distance with "p" in  
// the text  
c2 ∈ C; I ← set\_of\_values\_in(TO)  
inst ∈ I // Select from values inst which has the  
// shortest distance with "p" in the text and  
// preferably after "p"  
**If** (notNull(c1)) **then** {  
**If** (range(p)=="literal") **then** {  
SA ← SA + GenRDFtriples(c1, p, GetLabelInText(p));  
// The label corresponds to the 'string' value of the  
// properties found in the text  
}  
**If** (range(p)=="float") and (notNull(inst)) **then** {  
SA ← SA + GenRDFtriples(c1, p, inst)}  
**If** (range(p)=c2) **then** {  
SA ← SA + GenRDFValueOfClass(c2, GetStringInText(c2));  
SA ← SA + GenRDFtriples(c1, p,  
GetStringInText(c2));  
}  
} //end\_of\_RDFTriplesGenerating\_Algorithm

This algorithm takes as input the TO extracted at the lowest granularity level considered (*argument*). For each TO, it identifies properties occurring in the text, and subsequently, an attempt is made to match each property with the class it is a property of and its value. If for some properties in the text, the algorithm fails to create the triple, a larger context is sought. Figure 6 shows generated contextual SAs corresponding to the underlined sentence in the text excerpt of figure 3.

The SAs are represented in RDF (XML syntax). In addition, figure 6 shows the contextual relation “*compareTo*” identified between the two SAs.

**The contextual semantic relations identification step** of the semantic handling stage of our extraction process aims at assigning semantic roles to the discourse markers already detected. In [Marcu, 02][Sporleder, 06], authors propose to automatically identify these roles (*contrast, continuation, explanations...*). However, some problems persist in complex ambiguous "discourse markers". In addition, no automatic tool to identify semantic role exists in "RST" domain. The scope of this work is limited to the identification of discourse markers locations in the text.



Figure 6: Contextual relations dependency between semantic annotations

## 5 Experiment result

Experiments have been carried out on texts written in English. The proposed approach has been experimented on a corpus of 313 sentences (3768 words and 1862 other linguistic units such as: numbers, commas, brackets...) written by the industrial partners of the European project SEVENPRO. 114 rules are thus automatically

generated corresponding to 64 classes and 50 properties in the domain ontology and 80 other rules to identify discourse markers.

	Identifications		Total existing	Precision (%)	Recall (%)
	Right	Wrong			
Titles and hierarchy	26	0	26	-	-
Sentences/ Paragraphs	285/ 205	101/0	313/ 205	-	-
Arguments	497	-	-	-	-
Discourse markers	113	16	127	87,59	88,87
Properties	174	30	195	85,29	89,23
Classes	436	126	458	77,58	95,19
Candidate values properties	413	15	413	-	-

Table 1: Evaluation of the extraction

Table 1 lists the score results of all elements extracted from the text. The validation (right/wrong) of all elements extracted is verified manually. Two parameters are computed to identify the quality of the generated SAs: the precision and the recall. Getting the best scores, involves a trade-off between these two parameters. All titles and their hierarchy are identified correctly. The *sentences* and *paragraphs* are identified by default transducer of GATE. The score of identification *argument* relies on *sentences* identification score. The wrong scores (see Table 1) of *discourse markers*, *properties* and *classes* identifications is due to duplicate identification of the same words. For instance, the rhetorical relation “*as well as*” is identified as three rhetorical relations: two “*as*” and “*as well as*”.

Furthermore, the proposed approach has been experimented on large corpus of 2422 sentences. The “Table 2” compares the RDF triples extraction result within various levels of granularity. The granularity is an important factor. Indeed, it impacts greatly the generated SAs. The existing classes within a sentence of title are used to generate RDF triples in TOs to get better result. We observe that the precision of generated RDF triples is satisfactory when TO\_max is an *argument*. On the other side, the recall is unsatisfactory. When the TO\_max is increased, the precision decreases a little and the recall increases. When the TO\_max is increased to section, the precision has a significant decrease. Indeed, the precision of generated triple relies on the proximity among property, class and value. The trade-off between precision and recall gives the best RDF triples score when the TO\_max is paragraph.

		Identifications		Total existing	Precision (%)	Recall (%)
		Right	Wrong			
Generated RDF triples when TO_max is :	Argument without title phrase	191	29	756	86,82	25,26
	Argument + title sentence	539	113	756	82,67	71,30
	Sentence + title sentence	546	118	756	82,23	72,22
	Paragraph + title sentence	593	130	756	82,02	78,44
	Section + title sentence	641	208	756	75,50	84,79

Table 2: Evaluation of semantic annotations generation algorithm: generated RDF triples

## 6 Conclusions

In this paper, we proposed an approach to model and to extract semantic annotation by taking into account the context of textual sources. The main steps of the proposed approach are summarised as follows: *i*) identification of textual objects; *ii*) identification of contextual relations corresponding to TOs; *iii*) generation of semantics annotations represented by RDF triples; *iv*) identification of contextual semantic relations. All proposed steps are automated, and a prototype is implemented to assess the various steps of this contextual extraction approach. The evaluation results are very satisfactory. This approach of extraction and use of contextual semantic annotations offers promising results in the domain of knowledge extraction from texts. However, two challenges remain to be overcome:

The first one is the exploitation of inference on semantic discourse relations by using semantic Web technologies. Therefore, we propose on one hand to represent discourse relations semantics with inference rules and on the other hand to use the proposals discussed about *Source Declaration*<sup>5</sup> to assign a IRI (Internationalized Resource Identifiers) to a set of triples (named graph) and [Corby, 07] to represent interweaving between *semantic annotations* by related named graphs.

The second challenge deals with the difficulty of inferring on spatial and temporal contextual relations. Therefore, we draw inspiration from *Geographic Information Systems* works. More specifically, we are looking at Allen relations [Allen, 84] to specify temporal contextual relations and Egenhofer relations [Egenhofer, 91] to specify spatial contextual relations.

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<sup>5</sup> <http://www.w3.org/Submission/rdfsource/>



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# **Integrating Motivational Aspects into the Design of Informal Learning Support in Organizations**

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**Abstract:** Motivational aspects in knowledge management have so far largely been considered from the perspective of designing and implementing incentives that influence the extrinsic motivation of employees to participate, contribute, share etc. This is increasingly considered problematic so that this contribution takes a more holistic viewpoint by analyzing and systematizing barriers that have an impact on the motivation to engage in knowledge maturing activities. Based on a collaborative ethnographically informed study and targeted semi-structured interviews, a model is presented that decomposes the motivational aspects. Furthermore, it is presented how motivational aspect can be incorporated into the design of learning support systems.

**Keywords:** motivation, barriers, workplace learning, informal learning, knowledge maturing

**Categories:** L.3.6, D.2.1

## **1 Introduction**

While the motivation of employees has been recognized as a major factor for successful implementation of knowledge management systems, most measures to influence motivation have concentrated on incentives, both in terms of monetary rewards and other extrinsically motivation schemes which are designed as top-down instruments (for case studies see, e.g., Wenger 2002). Research has shown that these can work under certain circumstances, but usually (particularly in genuine knowledge worker environments) are problematic, often short-term in their effects and sometimes even counter-productive (see, e.g., Krönig 2001, Lin 2007, Wenger 2002). Web 2.0 has shown that under certain circumstances people are highly motivated to contribute and to share knowledge, a phenomenon which has stimulated further investigation into the subject like experiments on knowledge sharing behaviour from a psychological perspective (e.g., [Riss 06], [Cress 06]).

Motivational design (a term coined by [Keller 88] for educational settings) of software systems is a growing interdisciplinary field which has the goal of integrating motivational aspects into the design process of software tools. Keller developed the ARCS model, identifying Attention, Relevance, Confidence, and Satisfaction as motivational factors. This model (as well as others in the same spirit) is focused on learning and instructional design as the target of their design activities.

Little investigation has taken place for workplace settings where informal learning and the integration of learning and working are dominating elements: which barriers do we have to take into account there? How should supporting tools be designed for a workplace context?

In this paper, we want to present an approach to designing informal learning support, which has been developed as part of the European Integrating Project MATURE (<http://mature-ip.eu>) and is based on (a) an ethnographically founded methodology and (b) an extensive literature analysis in the fields of psychology, human resources management, and CSCW (Computer Supported Cooperative Work). In section 2 we will present the ethnographically informed methodology before explaining the model in section 3. In section 4 we will propose a development methodology that can integrate motivational aspects into the software development before concluding in section 5.

## 2 Ethnographically informed model building

From a theory point of view, there are plenty of models and theories to describe the fuzzy concept of human motivation, e.g., from psychology, game theory, power theory, or activity theory. However, these models are useful for analyzing a given situation, but are frequently of little help for translating the findings to concrete design measures. The main cause for this is that human motivation is a generic phenomenon, but it can only be addressed in a context-specific way. It should be obvious that motivation of students in a formal educational setting, motivation of learners in an online course, and motivation of employees for work-integrated informal learning & interaction with others share the same psychological foundations, but are very different to approach when it comes to concrete measures.

### 2.1 Ethnographically informed study

What is needed is a deepened understanding about contexts that share key characteristics. To that end, a team of ethnographers of the MATURE project have immersed into six different organizations (ICT companies, career guidance services, hospital training center) with knowledge workers and observed their daily practices [Barnes 09]. One focus of that collaborative ethnographically informed study was the identification of motivational barriers for knowledge maturing activities, where knowledge maturing is understood as the advancement of knowledge (i.e., learning) on a collective level, which encompasses teams, communities, or organizations [Maier & Schmidt 07]. Such activities largely consist of informal learning activities, but focus more the collective benefit than on the individual one.

Ethnographers annotated their scripts with codes that identify motivational phenomena (either explicitly reflected or implicitly observed). By the frequency of those codes, the most important observations were

- *on the positive side (motivators)*: curiosity and personal interest, membership in a community, money, personal standards, status and power

- *on the negative side (barriers)*: usability (of software systems), regulations (by the organization), workload and lack of resources, geographical barriers, lack of help, lack of money, personal attitude, competition, team culture

Apart from these results, the most important effect of the ethnographic studies was the deepened understanding of workplace realities of knowledge workers, which allowed for setting up a suitable model (presented in the next section). One could argue that these results are highly subjective and depend on the ethnographers and their sites, but the comparison within interactive workshops between the ethnographers of the different sites has shown hardly any fundamental differences.

## 2.2 Validation with semi-structured interviews

To check whether the developed model helps in the organizational reality and reflects the situation found there, we have conducted two additional semi-structured interviews, one big German energy company, and a big German software company. The interviewed persons were asked about problems in the main areas of the models and the organizational measures and experiences with interventions. This has shown that those areas are useful distinctions for analyzing practical cases and for discussing interventions.

## 3 Model of motivational barriers and intervention areas

As motivation is a wide and open field, the ethnographic studies have shown that it is more valuable to describe and address motivational barriers, rather than trying to decompose determinants of motivation as such. Those determinants rarely occur in isolation; real-world phenomena are complex mixtures so that the decomposition does not yield much added value. Barriers, however, and their systematizations allow for identification of different fields of intervention.

Our research is further more focused on knowledge maturing activities, i.e., activities that contribute to the advancement of knowledge on a collective level [Maier & Schmidt 07]. This is a particular perspective for which the basic model of workplace behaviour by [Comelli 03] had to be extended, identifying three main aspects (see fig. 1): individual, work context, and (additionally) interpersonal context.

### 3.1 Individual context

This aspect refers to factors that originate directly in the personality and personal characteristics of the individual. Two basic families of factors can be identified:

- **Capability** describes factors that affect whether an individual can engage in knowledge maturing activities. This comprises cognitive abilities to understand the issues at hand, and competencies to cooperate, or to explain to others.
- **Interests, values and needs** affect whether an individual wants to engage in knowledge maturing activities. These interests can be rational goals (e.g., for one's own career), but also comprise personal values (e.g., personal quality

standards) and needs (e.g., for appreciation). Here many psychological theories exist. One of the most promising in the field of knowledge workers is the self-determination theory by [Ryan 00], which identifies three basic needs for intrinsic motivation: Experiencing autonomy, Experiencing Competence, and Experiencing relatedness.

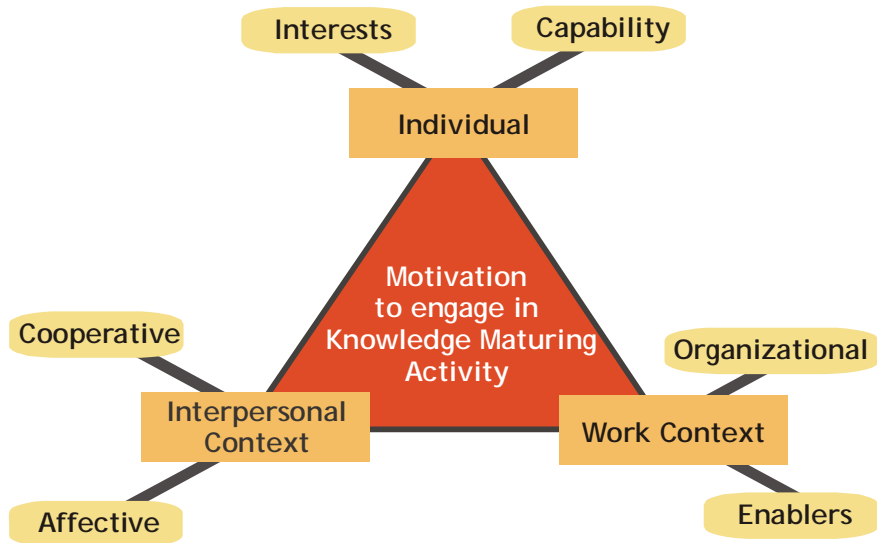


Figure 1: Motivational aspects to engage in knowledge maturing activities

### 3.2 Work context

The work context consists of organizational prerequisites for engagement in informal learning activities:

#### 3.2.1 Organizational factors

Organizational factors affect whether the individual is allowed to or even supposed to engage in concrete maturing activities, i.e., it comprises authorization, legitimation, commitment, rewarding, among others. The most important aspects here are:

- **Organizational culture** represents the social framework for acceptable and desired behaviour in a company [Schein 95]. Such a culture is constituted by unwritten rules, shared values, and a feeling of identity and comprises communication culture, culture of trust (openness and transparency vs. control), and culture of innovation, among others.
- **Organizational structure** can promote or prevent knowledge flow to happen. Deep hierarchies and fine-grained organizational divisions affect the maturing activities [Rosenstiel 03]: *Compulsory coordination* with superior institution increases the costs of non-standard activities and cooperation across structural entities. *Centralization and restricted information channels*

allow for efficient coordination of a large organization in the short run, but discourage self-initiated activities and thus also reduce the freedom of action.

- **Corporate rules and regulations.** Extensive corporate rules and regulations limit the freedom of action for the actors in the organization, thus reducing the experience of autonomy.
- **Management practices** are important, for informal feedback on behaviour. Appreciation fosters the motivation of the individual.

### 3.2.2 Enabling factors

Enabling factors refer to the technical and non-technical facilities offered or tolerated by the organization to engage in knowledge maturing activities. This comprises technical systems like document and knowledge management systems, email, instant messaging, but also coffee machines and water coolers as possibilities social interaction. Frequently, not only the facilities as such, but also the implicit and explicit regulations for its usage form an important part. Based on [Riege 05] and the observations within the ethnographic studies, barriers in this area include usability barriers, mismatch between individuals' needs, requirements and integrated IT systems and processes, lack of integration of IT systems, lack of compatibility between diverse IT systems and processes, lack of training regarding employee familiarization of new IT systems and processes, lack of communication and demonstration of all advantages of any new system over existing ones, lack of technical support (internal and external) and immediate maintenance of integrated IT systems, and transparency and control over tools.

### 3.3 Interpersonal context

The **interpersonal context** is equally important as most knowledge maturing activities involve interpersonal communication and cooperation.

- **Cooperative** factors refer to cooperation as such and its inherent conflicts of interest from a more rational point of view. As cooperation in a single activity is frequently asymmetric, mismatches of interest occur so that win-win situations do not form. In this area we need to consider phenomena like the prisoners' dilemma (where expectancy of reciprocity and immediate benefit can help to overcome) and power theory to understand the effect of knowledge sharing in terms of losing power. Experimental findings suggest [Cress 06] that lowering contribution costs, making transparent the benefits to others and the identifiability of one's own contributions have a positive effect on knowledge sharing activities.
- **Affective** factors refer to the emotional side of social relationships and how the involved individuals view the quality of these relationships. This includes factors like trust, or "personal chemistry".

### 3.4 Intervention

Such a model is only of use if we can not only diagnose problems, but derive also interventions, i.e., what can we do to remove or lower barriers. Interventions can

follow two different philosophies: (1) to directly “motivate” by providing incentives, better solutions to a specific target group etc. or (2) to indirectly change the environment through organizational & team development (e.g., for changing culture).

Such interventions can be technical, sometimes socio-technical, but also completely non-technical. Examples for such interventions in the different intervention areas are listed in the following table:

<b>Individual Context</b>	
<b>Interests</b>	allow for pursuit of individual interests and account for individual needs (e.g., curiosity) experiencing competence experiencing autonomy personal sense of perfectionism
<b>Capability</b>	human resource development, e.g., training, job enrichment, mentoring etc.
<b>Interpersonal Context</b>	
<b>Cooperative</b>	improving the economies of cooperation create and exploit social dynamics establish team culture overcome geographical distance awarenesss
<b>Affective</b>	team building promoting communication and empathy limit competition
<b>Work Context</b>	
<b>Enablers</b>	appropriateness of tool support ensuring usability ensuring smooth transitions between different systems ensuring reliability
<b>Organizational</b>	changing organizational structure (e.g., more permissive) changing regulations appreciation, valuing of creativity, new ideas incentive systems

It is clear that these factors cannot be clearly separated, and also have at least long-term interdependencies:

- Capabilities of the individual can be improved by organizational measures (giving more responsibilities). This in turn can result in a shift of interest as self-esteem has risen. A change in interest changes the fundamentals of cooperation with others.
- Or the organization introduces technologies that promote transparency and participation. This can conflict with or transform the corporate culture, which in turn influences the foundations of cooperation, e.g., changes the value of competition vs. cooperation

## 4 Towards a motivational design methodology

The model allows for a systematic approach to motivational barriers and separates different aspects. But how to move on from here towards a systematic integration into the design process? One important lesson of the MATURE project was that it was highly beneficial to have software developers as (a part of) the ethnographers. While the original purpose of the ethnographic studies has been in the first run primarily to inform the concept development, it has turned out that taking part in those studies, i.e., immersing into a team of people at their workplaces, creates a very deep understanding of problems, needs, barriers etc. (in short: the target users' reality). This has created a fundamentally different level of shared understanding between technical developers and application partners.

Based on those experiences, we propose the following methodology, which is evaluated as part of current project activities:

- **Immersion of technical developers in the workplace reality** as part of rapid ethnographically informed studies with a focus on motivational aspects and guided by the model as presented in the previous section
- **Derivation of personas**, i.e. a precise description of a user's characteristics and what he/she wants to accomplish [Cooper 99] as a real world person with an explicit consideration of the three aspects of the model (i.e., what is the individual/interpersonal/organizational context of the persona that influences her motivational structure)
- **Development of use case descriptions** for those personas in direct interaction of developments and users (or their representatives), with an explicit section on interventions targeted to motivational aspects or context conditions
- **Deriving functional and non-functional requirements** from those descriptions
- **Formative evaluation of early prototypes** with end users in which – if possible – different motivational measures are compared to each other in order select the most effective one.

As an illustration of the role of persona descriptions, here is an excerpt of a persona description that includes motivational aspects:

*"Silke has high personal standards and aims at continuously learning to improve her work practice. To that end, she regularly reflects about how tasks were carried out and what could have been done better or worse. Based on those insights, she updates templates and process descriptions. Where possible, she discusses her experiences with others. She also regularly visits the operational departments in order to learn about the current situation, problems, and developments. She has very high personal standards and is committed to improving her work practice in all aspects. She is very open and interested, also in topic not directly related to her current work situation. She tries to make sense of new trends. Her sense of perfection also applies to her everyday task management. She plans her tasks and appointment each day meticulously, and prepares each meeting with elaborate notes. She always uses paper*



*and pencil for that, and she needs the feeling of satisfaction of ticking off completed items. She often has problems with the usability of computer software. Particularly, labels, buttons, and icons should be uniform across different applications and should not change with software updates. Clear structures within the applications are crucial as she lacks deep knowledge about computers.”*

## 5 Conclusions

Motivational design of informal learning support is an important step for ensuring sustainability and user acceptance of solutions. This paper has presented a model that systematizes motivational barriers into three areas: individual, interpersonal, and work context aspects. The model is based on a series of ethnographically informed studies and a small-scale validation as part of interview with representatives of large German companies. This model helps to systematically consider motivational aspects in the requirements engineering process of informal learning support, e.g., by including them in persona and use case descriptions.

The first application of the methodology has shown that it enriches the understanding of the software development about the target user and thus forms the basis of an improved dialogue. Further research will investigate the effectiveness of concrete design measures in experiments that are targeted at improving certain motivational aspects in the context of informal learning and collaboration, e.g., transparency about user activities, reputation scores, promoting sense of ownership, feedback on usefulness. This will help to evolve the motivational model into a design framework from which software designers can choose.

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# Why not Empower Knowledge Workers and Lifelong Learners to Develop their own Environments?

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**Abstract:** In industrial and educational practice, learning environments are designed and implemented by experts from many different fields, reaching from traditional software development and product management to pedagogy and didactics. Workplace and lifelong learning, however, implicate that learners are more self-motivated, capable, and self-confident in achieving their goals and, consequently, tempt to consider that certain development tasks can be shifted to end-users in order to facilitate a more flexible, open, and responsive learning environment. With respect to streams like end-user development and opportunistic design, this paper elaborates a methodology for user-driven environment design for action-based activities. Based on a former research approach named ‘Mash-Up Personal Learning Environments’ (MUPPLE) we demonstrate how workplace and lifelong learners can be empowered to develop their own environment for collaborating in learner networks and which prerequisites and support facilities are necessary for this methodology.

**Keywords:** User-Driven Environment Design, End-User Development, Semantic Interoperability, Workplace Learning, Lifelong Learning

**Categories:** D2.1, D2.2, L3.1, L3.6

## 1 Introduction

In our everyday life we experience a lot of environments and tools that were designed by others; houses are constructed for different usages by different building enterprises, cars have been developed for more than one century to what we know nowadays, computers are built and assembled by many vendors, and software is realised by developers and teams, usually according to their mental models and design expertise – just to name a few examples. However, when it comes to regular usage of these environments and tools people tend to customise them in their specific way: they furnish each room of their houses, they decorate their cars and (must) adjust the mirrors to their needs, and they adapt the operating system and install their preferred programs.

Nowadays, the development of learning technology is driven by companies and open-source communities, whereby software solutions for knowledge workers and lifelong learners have to fulfil many requirements and sophisticated mechanisms of socio-technical systems, as shown with the multi-activity distributed participators design process for work-integrated learning systems in [Jones & Lindstaedt, 08] or the

concept of learner networks in [Koper et al., 05; Wild, 09]. In this scope, knowledge management aims at supporting the designers (domain experts and software developers) through various business- and technology-driven models, like the SECI model [Nonaka & Takeuchi, 95]. Again, such approaches put the organisation central stage prescribing how knowledge transfer ought to work and, at the same time, ignoring idiosyncrasies of learners and communities.

Due to the complexity and dynamics of such socio-technical systems, expert-driven software engineering is not sufficient any more, and alternatives are considered to be useful or even urgently required for workplace and lifelong learning. In this paper, we sketch the paradigm shift from traditional software engineering to new streams like opportunistic design and end-user development and, furthermore, describe a methodological approach to user-driven environment design applicable for knowledge workers and lifelong learners. In the end, we summarise our experiences gained with that software development method so far and argue for the potential of this approach.

## 2 Moving from Traditional Software Engineering to User-Driven Development

Looking back on the history of **software engineering**, development methods have developed from rather static and product-centric process like the V model or the spiral model to more dynamical methodologies taking into account the ever shorter software life cycles with fast changing requirements as well as issues of socio-technical systems, i.e. networks of humans and machines and their interrelationship and interaction [Trist, 81; Geels, 04]. Recently, many application areas require iterative processes interweaving design and prototyping phases in combination with extreme programming [Beck & Andres, 00] and agile software development [Cockburn, 02].

On the other hand, user-centred design dating back at least to the 1970s has a long tradition in the field of **human-computer interaction**. [Preece et al., 98] state that user-centred design dedicates extensive attention to the user for all steps of the design process. Therefore, [Maguire, 01] proposes various user-centred design methods for each phase of the software development process, beginning with the planning and usage context (e.g. stakeholder identification, user observations, task analysis, etc.) up to designing and evaluating software (parallel design, prototyping, usability inspection and testing, questionnaires, and the forth).

However, expert-driven software engineering and human-computer interaction still lack the ideas of recent streams, like community platforms and related **Web 2.0** concepts. Placing the focus on a more active participation of users and interactions with others has led to dealing with requirements engineering of socio-technical systems and, furthermore, to methodologies like the RESCUE process by [Jones & Lindstaedt, 08].

Additionally, the dynamics and complexity of socio-technical systems require development processes going beyond the methods depicted so far. [Hartmann et al., 06] come up with the idea of **opportunistic design** which considers users to hack, mash and glue software (and hardware!) artefacts to achieve their goals. According to these authors, mashing up existing and own code pieces provides more functionality

up front, although the ‘last mile’ (finalising the full application) may be slow (but not always necessary). For their approach they are using AppleScript for enabling (experienced) users to realise their solutions on the basis of existing and own source code.

Similarly, **end-user development** aims at empowering users to design their software environments for their purposes, whereas this development process ranges from customising user interfaces over visually assembling applications up to real programming tasks [Fischer et al., 04]. [Lieberman et al., 06] state that end-user development changes systems from being “*easy to use*” to being “*easy to develop*” in order to increase their responsiveness towards the diversity of users, i.e. people with different skills, knowledge, cultural background, etc., as well as towards the dynamics of work and learning practices. Lieberman and his colleagues differentiate between (a) parameterisation/customisation and (b) program creation/modification. Moreover, they highlight typical activities, like parameterisation of software components, annotations, programming by examples, incremental programming, model-based development, and so forth.

According to [Fischer et al., 04], it is necessary to motivate users to practice the hand-on skills required for an end-user development approach, e.g. by giving examples or demonstrators. Beyond that, opportunistic design of a learning environment requires even more **competences of end-users**. According to the classification by [Stahl, 08], these competencies comprise technical ones, like basic computer and internet skills, methodological ones, for instance being capable to know and utilise a specific tool for a certain purpose, personal ones, i.e. self-motivation, self-confidence or self-efficacy in working and learning with online tools, as well as social ones, such as the capacity to collaborate with others, communicate ideas and information, or to connect to learner networks.

Overall, [Kraus, 05] introduces the idea of the ‘**long tail of software development**’ and sees the opportunity to satisfy the needs of many if (experienced and capable) end-users are willing to create opportunistic assets and share them with others. Specifically for higher education, [Wild, 09] states that end-user development is more powerful than instructional design or personalised adaptive e-learning as it does not take away important learning experiences from learners, e.g. by calculating the optimal path through a course, but supports them in constructing knowledge within their activities, e.g. through recommendations or good practice sharing [Mödritscher & Wild, 09].

### 3 A User-Driven Methodology for Environment Design and Learner Interactions

The end-user development method described in this section is built on a former conceptual approach called ‘Mash-Up Personal Learning Environment’ (MUPPLE) and developed within the scope of higher education [Wild, 09]. Without going into details of this approach, some preliminaries have to be stated at this point:

- MUPPLE is based on a **web application mashup infrastructure** which allows learners to integrate arbitrary web-based learning tools into a single

user experience (see also Fig. 3). This mashup paradigm is one possible front-end and might be realised in other ways.

- Requirements for integrating learning tools into MUPPLE comprise a certain degree of **widgetisation and semantic interoperability**. Widgetisation means that a web application can generate web-based output (widgets) for certain functionality through RESTful requests, i.e. a Uniform Resource Locator (URL) address. Semantic interoperability deals with the possibility to plug one system to another one so that an exchange of data and its processing in a meaningful way is achievable. Such a mechanism can be regarded as a powerful approach for enabling users to create new functionality. For instance, a PLE including 10 interoperable widgets does not only have 10 basic functions for learning (e.g. bookmarking, searching, browsing, creating artefacts, etc.) but also  $(n - 1) \times \frac{n}{2} = 45$  possibilities to combine two different widgets (e.g. bookmarking results from the search widget). Most of these combinations might not make sense but it should lie with the users to play around and identify a new, valuable functionality. Aiming at a generic solution for web tools, we build on RSS feeds (distributed feed networks) to achieve semantic interoperability [Wild & Sigurdarson, 08].
- Similarly to the Activity Theory introduced by [Engeström, 87], the usage context of MUPPLE is structured through a very **simple model of a learning activity** which consists of a set of user interactions, each interaction being formalised as a triple of (a) an action, (b) an outcome, and (c) at least one tool. The actor is the user in front of the screen (user-centred approach), while the action labels the user interaction and the outcome describes a real or an abstract achievement (e.g. an artefact or a user goal). The tool (including a URL) is necessary to formalise how a user can achieve the outcome. Examples for such generic user interactions are ‘find paper using Google Scholar’ (with the URL <http://scholar.google.com>), ‘publish self-description using VideoWiki’ (with the URL <http://distance.ktu.lt/videowiki/addvideo>) or, to describe an everyday situation, ‘sign contract using pen’.

Based on these preliminaries, we differentiate between functional and non-functional requirements. On the one hand, we consider **functional requirements** of the learning environment to be the features which are directly related to the learning process, typically involving a specific tool. Such requirements are materialised with action-outcome-tool triples which include RESTful requests to a widget or even a tool combination if semantic interoperability is fulfilled for the web applications involved. The set of functional requirements is open, so that users can define their own interactions and bring in their own tools. In the context of traditional software engineering, the model of a learning activity would be equal to the concept of a *class* having the user interaction statements as its *methods*. Normally, creating a new activity would instantiate an empty activity-*object*, whereas users can add new methods (*mix-ins*) and each user-given functional requirement would stand for one ‘interaction method’ (with the parameters action, outcome, tool, and URL). As part of

our practice sharing strategy, it is also possible to derive activities from a so-called activity pattern which can be seen as a class pre-initialised with abstract or real methods by another user (cf. [Mödritscher & Wild, 09]).

On the other hand, **non-functional requirements** address the end-user development framework, in our case the MUPPLE prototype, which includes all facilities enabling and supporting users in creating web application mashups for their activities and interacting with the tools. These non-functional requirements have to be (iteratively) gathered and realised by the provider of the end-user development framework; they are highly dependent on the presentation layer of a solution and the characteristics of the tools involved, like semantic interoperability or widgetisation issues. [Wild, 09] derives these requirements from different research perspectives, like learning design, semantic interoperability, social networking, practice sharing or personalised learning, and summarises them for our first MUPPLE prototype.

Fig. 1 visualises our **methodology for end-user development of personal learning environments**. The top left corner indicates the user interaction scheme which can be used to instantiate a learner interaction either by specifying the action-outcome-tool triple manually, by taking advantage of the recommendation service, or by reusing them from a pre-defined activity pattern. The start of the actions of one activity leads to the web application mashup, as shown in the centre of the figure.

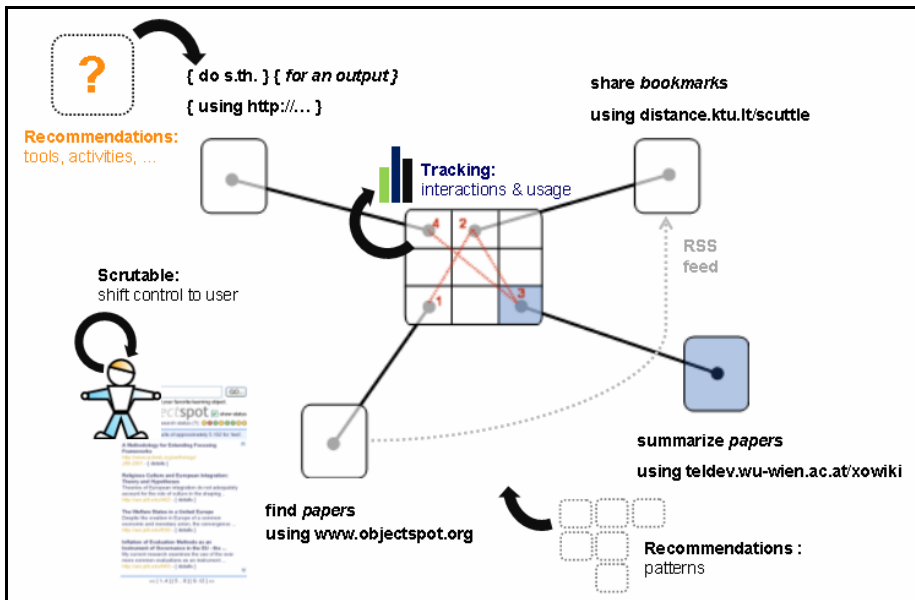


Figure 1: User-driven methodology for environment design and learner interactions

Now, the user has the control over the user interface, is able to work with the tools in any specific order, fully rewrite the activity, complete or resume actions, and export new patterns from this activity. Certainly, users can bring in new tools if they require them for successfully finishing an activity. These new user interactions with the environment are subject to automated generation of recommendations or to user-

driven good practice sharing through the activity patterns (top left and bottom right). Fig. 1 also gives an example for applying a tool combination, for example the interaction ‘find papers using <http://www.objectspot.org>’ enables users to send selected search results to their preferred bookmarking tool and share these bookmarks afterwards (cf. interaction ‘share bookmarks using <http://distance.ktu.lt/scuttle>’).

Specifically, the MUPPLE approach has been developed within the scope of higher education, assuming that learners are self-motivated enough to design their environments to collaborate in meaningful PLE-based activities. Such approaches to self-directed learning are also observable in the fields of workplace and lifelong learning [Ulbrich et al., 06; Koper & Specht, 06]. More likely, the user-driven methodology for environment design is not only applicable for these two areas but for any action-oriented activity, even beyond the context of learning. The non-functional part of MUPPLE, however, is dependent on the technological solution and usage context and, therefore, not transferable to other domains.

## 4 Implementation of and Experiences with User-Driven Environment Design

In this section we use our first MUPPLE prototype to explain how end-user development of and interactions with these environments can be supported. As a first step towards implementing environment design we have designed a domain-specific language, namely the ‘Learner Interaction Scripting Language’ (LISL), to be able to materialise how learners design and use their environments [Mödritscher et al., 08].

Fig. 2 gives an example of a LISL script which describes a MUPPLE activity consisting of three actions (lines 1-3: compose, browse and bookmark), each one bound to a specific outcome (lines 4-6: self-descriptions, peers and selected descriptions) and displaying a windowed widget with a specific RESTful request to the VideoWiki application (lines 10-12). The lines 7 to 9 define two tools (VideoWiki and Scuttle) and the channel between these tools, which is set up by the connect statement and requires a certain degree of semantic interoperability.

```

1> define action compose with url http://[...]?action=create
2> define action browse with url http://[...]/%%peers%%
3> define action bookmark
4> define object 'self-description'
5> define object 'peers' with value 'group_a'
6> define object 'selected descriptions'
7> define tool VideoWiki with url http://videowiki.icamp.eu
8> define tool Scuttle with url http://scuttle.icamp.eu
9> connect tool VideoWiki with tool Scuttle
10> compose object 'self-description' using tool VideoWiki
11> browse object 'peers' using tool VideoWiki
12> bookmark object 'selected descriptions' using tool VideoWiki
13> drag tool VideoWiki to column 1

```

Figure 2: Example LISL script for activity ‘getting to know each other’



As mentioned before, we differentiate between a functional and a non-functional view on learning environments. On the one hand, the action statements (lines 1-8 and 10-12) refer to the functional requirements of the learning environments and comprise the learning tools required and defined by the learners for their specific situation (activity). Connecting two or more tools, furthermore, leads to new functionality (e.g. bookmarking VideoWiki entries in the Scuttle tool) and increases the powerfulness of this approach so that learners can reuse and mix functionality for more sophisticated (real-life) situations.

On the other hand, non-functional requirements cover the learner interactions with the environment and are therefore dependent on the overall environment, the single tools, and the learner interactions with it. Such statements are hard-coded for specific integrative frontends, like Yahoo Pipes, iGoogle, or our web application mashup solution. For instance, line 13 indicates that learners can drag and drop windowed tools from one to another position along a grid-based mashup space on the screen. Further statements are about connecting, minimising, maximising or closing tools, and so forth.

The screenshot shows the MUPPLE editor interface. At the top, it displays "Activity Pattern" and "Getting To Know Each Other". Below this, there are tabs for "activity space", "preview", "code", and "log". The "code" tab is active, showing a LISP script with the following content:

```

lisl 1> define action Compose with url
http://distance.ktu.it/videowiki/addvideo?namespace=gtkoa
lisl 2> define action Browse
lisl 3> define action Browse a second time (error)
lisl 4> define action Bookmark with url
http://distance.ktu.it/scuttle/bookmarks.php/foedrit?action=add&tags=gtkoa
lisl 5> define object 'self-description'
lisl 6> define object 'self-descriptions of peers' with url
http://distance.ktu.it/videowiki/list/index?namespace=gtkoa
lisl 7> define object 'selected self-descriptions'
lisl 8> define tool VideoWiki with url http://distance.ktu.it/videowiki
lisl 9> define tool Scuttle with url http://distance.ktu.it/scuttle
lisl 11> Browse object 'self-descriptions of peers' using tool VideoWiki
lisl 12> Bookmark object 'selected self-descriptions' using tool VideoWiki
lisl 13> Browse
lisl 14> drag tool 'VideoWiki' to column 1 and row 0

```

The "preview" tab shows a grid of video thumbnails. The first thumbnail is titled "Self-description of Felix" and shows a man. Below it, the author is listed as "Felix Moedritscher" with a date of "2008-06-04 15:45". To the right, there is a form titled "Browse self-descriptions of peers using VideoWiki" with fields for "Title" (containing "getting to know each other"), "Author name" (containing "Felix"), and "Description". There is also an "Add video" button.

Figure 3: MUPPLE page for the LISP script in Fig. 2

Using this scripting language, it is possible to capture ('externalise') environment design capabilities and learner interactions with MUPPLE and, more importantly, to exploit these scripts in some way, e.g. for automated generation of recommendations or user-driven practice sharing. Within our first prototype, the result of such a LISL script is a so-called MUPPLE page, as shown in Fig. 3. Learners, in fact, do not need to create these pages by manually writing LISL code but can use web-based widgets, which materialises their interactions by appending commands to the LISL script.

The header of a MUPPLE page, as shown on top of Fig. 3, displays the type (activity or pattern) and the title of the learning situation (activity). On the right-hand side, users can navigate through their activity space, create new activities from blank or from the given patterns, and add new action-outcome-tool triples to the opened activity, either by specifying them manually or by making use of the recommendations. Opening one activity executes the LISL script of this page within a web-based interpreter which reconstructs the last state of the MUPPLE page. Thereafter, the user can choose between three possible viewing modes of the page: (a) the tab 'preview' displays the tool mashup (bottom right of Fig. 3); (b) the tab 'code' shows an in-line editor for the whole LISL code of the page; (c) the tab 'log' visualises the result of the web-based interpreter, i.e. also warnings and errors in connection with the current LISL script (in the centre of Fig. 3).

Within our prototype, starting a new action within one activity is equivalent to having a learner to 'implement' one functional requirement. In this context, the end-user can manually specify the details of the interaction (action-outcome-tool triple) or use recommendations provided by our prototype. Therefore, MUPPLE empowers learners to design their environment. The non-functional requirements are more or less realised by functions of the whole platform, comprise the learner interactions with their mash-up personal learning environments and are subject to being adapted or extended by us, the PLE developers. So far, the non-functional part of MUPPLE monitors how learners use the environment which is materialised by adding additional LISL code to the current page (like the statement in line 13 of Fig. 2).

In a preliminary evaluation study, we observed that new MUPPLE users who are not at all experienced in environment design prefer working only with the web-based widgets and extensively use the recommendations provided by the system. Those users being familiar with MUPPLE having programming skills or having to prepare a lot of exemplary scenarios (facilitators) slowly proceed to script the functional requirements of their environment. Adding the LISL code for learner interactions, however, is always left to the widget-based wrappers of the platform.

## 5 Conclusions and Outlook

In this paper, we have sketched a methodology for end-user development of personal learning or working environments and demonstrated how it can be set into practice. Furthermore, we argued for the need to support learners in designing their environment. Overall, user-driven environment design seems to be a promising approach for both knowledge workers and lifelong learners, particularly if they are self-motivated enough. In this context, [Alvesson, 04] argues for specific competencies necessary for knowledge workers (e.g. social competencies or capabilities to orchestrate the interaction process), which we tried to consider with

different features of our MUPPLE platform, like a recommendation service. In terms of important usability components, learnability and efficiency, the required hand-on skills need to be trained by inexperienced users which we tried to realise through emergent behaviour of our PLE solution and help facilities.

However, this first prototype needs to be extended and improved, e.g. with regulation and reflection facilities for collaboration in learning networks or good practice sharing functions. Moreover, the whole MUPPLE approach as well as our methodology for user-driven environment design is based on specific technical requirements, like widgetisation and semantic interoperability of tools, which are often not fulfilled. Although a lot of research and development still needs to be undertaken, user-driven environment design offers a great potential for knowledge workers and lifelong learners if this approach centres the learners and their specific needs and not organisational requirements. Finally, the organisation also might benefit from this learner-centred approach, as the materialisation of environment design and learner interactions is more or less the externalisation of implicit knowledge. From this perspective, the concept of a mash-up personal learning environment can be seen as an enabler for action-oriented, community-driven knowledge management.

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## Knowledge Management Issues in Teaching Extreme Programming

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**Abstract:** Extreme Programming focuses on spreading knowledge through many collaborative practices like pair programming, planning game, and retrospectives. The basic idea behind these practices is to share the work specific knowledge across the development teams as well as the management quarters. This knowledge sharing is said to have an accelerated effect when it is combined with the retrospectives analysis of the knowledge gained and the process performed. This inherent property of Knowledge Management (KM) facilitated by retrospective analysis is being used to teach Extreme Programming (XP) methodology as a graduate level Software Engineering (SE) course and is showing a notable effect on the learning process. The paper describes the KM issues in XP practices and how these issues are being managed for the students to present them with a profound learning experience.

**Key Words:** Knowledge Management, Agile Software Development, Extreme Programming, Software Engineering Education, Learning Experience

**Category:** L.1.0, L.1.1, L.3.4, M.0, M.1, M.4, M.8, M.9

### 1 Educational Perspective of Knowledge Management Requirements in Software Engineering

Agile methodologies like XP rely heavily upon sharing knowledge and information across the whole development organization. This knowledge sharing model exists among developers themselves for sharing any technical knowledge, and also among developers, management, and customers for development related feedback; among developers and customers regarding new and upcoming market demands and change in user requirements; and among customers and management regarding long term development goals, competitors, and market situation. This knowledge sharing is important across the whole organization, and inability of organizations to share such type of knowledge has resulted in many failed software projects.

New approaches to KM have given new dimensions to SE education. SE education is changed from conventional student-teacher interaction in a class room to a wider spectrum which covers not only coaching of classical concepts

in class room but also provides an insight into practical experiences of people with real life software development through computer-based knowledge sharing and collaboration.

XP methodology defines team work as a necessity for software development. Promoted through the use of its practices, XP provides a unique form of KM which is embedded in the routine process of software development. In conventional SE education setup the learning process is not as profound as would be ideal. The main reason for this is that while teaching traditional software development methodologies, it is not very easy to simulate the real life situations due to the prolonged processes in the methods life cycle and also due to completeness requirements at all stages of development. Due to the light weight process of XP methodology [XPatUniv] it is possible to make students visualize all stages of software development by simulating a rather close-to-real situation.

The main objective of this paper is to describe some of the experiences in teaching an XP course to a combined class of graduate and undergraduate students. The authors are directly involved in organizing that course. The focus of this paper is to identify knowledge management issues and requirements associated with XP practices and to review how these issues are being handled in this academic context. This will help to identify what more is required to give the students a profound and thorough learning experience.

The rest of this paper is organized as follows. Section 2 defines the importance of KM in team work. Section 3 explains the need for KM in the educational context of XP as an SE course. Section 4 gives a review of XP practices implemented so far in the course and their respective team work, KM and educational issues. Section 5 gives a brief introduction to the said XP course wiki which is used as student teacher collaboration and knowledge management platform. Section 6 concludes the paper by taking a review of what is done and what still needs to be done.

## **2 Importance of Knowledge Management in Team work**

Software development is a team oriented and collaborative process which demands effort from all participants to bring together technical and process oriented skills in order to develop a working system. XP is human-oriented practices-based methodology which requires team-work in every phase of the process. Starting with planning the project and going through all coding and testing phases up to the release of the software, all team, including developers, managers, and customers, are involved from start to end.

XP teams are cross functional teams [chau03] which promote direct communication among all members having different functional roles such as developers, customers, and managers. This reduces the risk of miscommunication which

arises in traditional role-based teams working along the long chains of communication [chau04]. The direct communication in XP helps in sharing and externalization of the technical and process related knowledge which is considered to be as important an asset for the organization as human, money and material resources. The key in KM is to manage knowledge just as all other organizational resources are managed so that it can be reused as and when required [teamkm1996]. A general KM process goes through the following steps in the form of a loop:

- Discovering Knowledge
- Generating Knowledge
- Evaluating Knowledge
- Sharing Knowledge
- Leveraging Knowledge

In XP this process is to be managed by the whole team. Self organizing XP teams generate a vast amount of knowledge simply by following the XP practices. For example, during pair programming sessions both pair partners discuss, evaluate and solve the problem by sharing their experience and knowledge. Likewise, a lot of knowledge is generated during planning sessions, retrospective meetings and even during short stand-up meetings. All XP practices, through their inherent structure, promote this whole process of KM.

### **3 Need for Knowledge Management in XP Course**

The paper is based on the experiences gathered in teaching XP as a graduate level course. The course is conducted for eight blocked hours per week for a whole semester and it is divided into two parts. The first part of the course introduces the theoretical concepts about the XP and the second part of the course is based on software development project, applying the process learned in the first part of the course. Examinations are conducted at the end of both parts of the course. More than 100 students register for the course. The students are divided into 10 teams during the first part of the course, so that the students are well acquainted with their team members before they actually start software development in the second part of the course.

Along with all the issues of KM that are defined in the previous sections there is a more pressing need for a profound KM in managing this course, which is explained in the following lines:

**Diverse Technical Base** The students registered in this course have different technical background because they come from many different academic faculties. Due to this reason there is also a difference in the courses that they have completed so far.

**Diverse Technical Background** The students registering for the course are in different semesters of their study programs, that is why they also have different technical backgrounds. Also, many students work professionally as software engineers before or during their courses, some have several years of experience. This is very helpful in KM when students work in teams, as great care is taken to distribute experienced students evenly over the teams.

**Different level of Education** The course is offered to both graduate and undergraduate students. The participants are of different age groups, with difference in their technical knowledge base, as well as in practical experience with software development.

According to the format of the course, and for better and diverse knowledge experience on behalf of the students, there is a need to distribute students among teams with these diverse technical skills and backgrounds. It is also taken care of that female students are equally distributed although they constitute on average around 15 percent of the whole class.

## 4 XP in Knowledge Management and Educational Context

This section briefly defines some of the team practices of the XP that have been applied, to date, in the context of this course, their KM issues and the educational context in which these are applied.

### 4.1 Pair Programming

Pair programming defines an interactive coding session among two developers sitting together in front of the same computer and sharing a keyboard and a mouse. Both developers work on the same piece of code at the same time. They act as a driver and navigator. The driver is the developer who controls the keyboard and the mouse at a time and the other partner acting as a navigator guiding through design and test process. According to the format of the practice the driver and navigator swap their role very frequently thus both get opportunity to code [XPEExplainedBeck04].

#### 4.1.1 Knowledge Management Factor

This practice involves very informal and spontaneous communication but generates a lot of knowledge as both developers, pairing together, share their technical



knowledge and experience regarding design, coding and testing [chau04]. This practice is characterized as providing a great learning experience as it gives an opportunity to the pair partners to learn from the experience of each other and at the same time apply their own knowledge in the domain. To make sure that the knowledge generated and shared by the pairs is also distributed to the whole team the pair partners are switched very frequently, and this also helps the whole team to come together [chau04] [XPExplainedBeck04]. This practice embodies a social process as it allows not only to share technical and situational knowledge but also lets the developers to know better about each others' strengths and weaknesses.

#### **4.1.2 Educational Context**

In the context of said course the students are asked to work on different coding and non-coding assignments. In the first part of the course the students have done many non-coding process-related assignments. It has been a good experience to ask the students to work in pairs on writing assignments, and on tasks like designing paper mock-ups. This has been done in order to teach them designing and coding related tasks as well as the pair-working practice before they actually start pair programming. This practice is of great importance in the context of this course as it is defined that there is a mix of students with different skill levels and educational background. This practice greatly helps in providing almost the same knowledge level among the whole class. Also, the pair learning concept is introduced using this practice.

### **4.2 Retrospectives**

In XP, project retrospectives allow continuous learning by having a flash-back on what has been done in a previous development cycle [XPExplainedBeck04]. These are postmortem reviews, taken by the whole team together, which allow to learn from what is done and then refine the process if required. These retrospectives are performed on a regular basis during a software development process and hence allow to refine the knowledge and apply it in the same project.

#### **4.2.1 Knowledge Management Factor**

The practice of retrospective makes it possible to identify obstacles that have hindered the process or the development one way or the other. The team also discusses the success factors in order to make sure that that the whole team understands how things work better. The team may also raise points of concern regarding any technical or management related issues. In this way it provides a platform for communicating one's own voice to all concerned people [chau04].

### **4.2.2 Educational Context**

In the first part of the course, this practice is used to get feedback from students about their learning experience. In every lecture the students are given exercises about XP practices. As an after-class assignment the students are asked to write a brief review report on what they did in the exercise, how well they managed it, and also about their experience - did they like it the way it was conducted or did they have problems. These reviews done by students are allowing them to speak their thoughts and convey their problems to their course organizer in a very informal but organized way. This also reveals how well they are understanding the concepts of XP. Also, as these reviews are published on the course wiki site and are visible to all course participants, this has resulted in easy sharing and distributing knowledge among the whole class.

## **4.3 Planning Game**

XP process divides the whole development process in releases and iterations. Each release consists of more than one iterations. Before each release and iteration the planning meetings are conducted to discuss and settle system requirements as well as business requirements. These planning meetings are attended by the whole team including all developers, managers and customers [XPEExplainedBeck04].

### **4.3.1 Knowledge Management Factor**

The planning is always done with the whole team. This makes the whole process visible to everyone. Each team member knows what is going to be done the next development cycle (release or iteration). Any change in the previous plan also becomes visible to everyone. This transparent process removes any danger of miscommunication among developers, customers and managers.

### **4.3.2 Educational Context**

The students attending this course are greatly encouraged to make use of this practice. They were encouraged to do a small planning exercise while they were starting to prepare for their exam. According to feedback given by the students it was a new experience for them to properly plan how they were going to prepare for the exam and it was very time efficient, it helped them to be more organized and to do more in less time.

## **4.4 On-Site Customer**

XP requires a customer with the development team to allow direct communication among the customer and the developers when needed. This helps the customer, who is investing lots of his money into the project, to make sure that the development is done according to the specified requirements [XPExplainedBeck04].

### **4.4.1 Knowledge Management Factor**

Direct communication among the customer and the development team is very important. In conventional software engineering process the flow of information from customer to developers, and vice versa, is through the management. This results in late delivery of information to the customer and developer parties and even, sometimes, in loss of important information. The inclusion of a customer in the XP team removes these problems and provides quick customer feedback to the developers which makes their task easier. On the other hand, being with the development team all the time makes it convenient for the customer to introduce new requirements at the earliest.

### **4.4.2 Educational Context**

The students are divided into teams during first part of the course and are assigned customer, manager, coach, and developer roles. The students taking the role of customer get a good training in acting as the customer of the product that his/her team develops. Although the real customer tasks come in the second part of the course but they also they also get to play their role in the first part of the course in a couple of non-programming exercises, and even in exam preparation. They learn how to formulate their requirements in a form that developers can understand, and to specify the acceptance criteria to understand the success or failure of a task at the end.

## **4.5 Story Cards**

In XP, customers write the requirements of the system to be developed in the form of a narrative which is called a story. These stories are usually written on paper cards and are displayed in the room where the development team works.

### **4.5.1 Knowledge Management Factor**

The story cards are usually displayed on a wall or at a prominent place in the XP work room. This makes the development plan visible and transparent to every one in the team. All developers know what their colleagues are working at, and for the managers and the customers it provides an efficient way of looking at the status of the project.

### **4.5.2 Educational Context**

In many different exercises during the course the students playing the customer role in each team write stories for the developers specifying the tasks to be done. In this way they learn how to specify their requirements in a form that the other members of their team are able to understand. The customers are encouraged to discuss the stories first with their managers and then they ask one of the developers to help them in formulating the stories. The story cards help the developers to organize their work and to visualize at what stage they are working.

## **4.6 Stand-Up Meetings**

A stand-up meeting is a short and efficient means of communication among the whole XP team. Theoretically, a stand-up meeting is called every morning before starting to work. It is also attended by all team members. Every one tells very briefly what he/she did the day before and what they expect to do that day. It is called a stand-up meeting as it is kept very short by forcing everyone to stand, not involving any detail question and answering. If there are any points of discussion then these are discussed outside the scope of stand-up meetings [XPEExplainedBeck04].

### **4.6.1 Knowledge Management Factor**

As defined above, it is a very quick means of sharing important knowledge with the whole team. Everyone gets a very quick review of the progress since the last stand-up meeting and also about who is doing what during the rest of the day. It provides enough knowledge to everyone to organize themselves.

### **4.6.2 Educational Context**

It has become customary in the course to start every lecture with a stand-up meeting. This practice was initially adopted to give the students a practical experience about stand-up meetings in an XP way. But now that this has been practiced many times it is accepted as a good way of sharing some very important knowledge at the beginning of the lecture. In the start of the course the organizer encouraged every one to speak. Now that student groups are created and roles are defined, the teams managers are asked to represent their teams in stand-up meetings.

## **5 Examination as a KM Tool**

The students are required to take examination at the end of each part of the course. The examination preparation is also introduced as an XP process where the customer is asked to make planning of what to prepare for the examination. The customer writes the preparation tasks in the form of stories. The whole team works with the customer in defining the stories for the exam preparation. The stories are worked on in pairs, hence performing pair learning. To further enhance the learning process the examination is also taken in pairs. Two students sit together, discuss the questions and write answers which are according to the combined knowledge of the pair. This way of examination spreads knowledge and let the students learn from each other.

## **6 Wiki as a Source of Knowledge Management in Classroom XP**

Since the start of the course, a wiki [wikiperth04] has been set up to facilitate collaboration among all course participants. The course's initial format was based on individual students, which was then defined for pairs and then for teams. The students have been given different assignments which they have worked on individually, in pairs and in teams. To further promote learning and sharing knowledge which they gather in lectures and in exercises the students upload their assignments on the wiki. This has allowed to make work assignments, and reviews of class exercises done by the students, visible to every one and also it is helping the course organizer to review and understand how the course is working out. The course wiki is providing the following modes of knowledge management:

### **6.1 Support for Personal Portals**

Each student has been encouraged to use his/her personal wiki page to put every kind of information which could be useful for others as well as for the course. In the very first class all participants of the course are advised to put their contact information on the wiki-page. They are also encouraged to mention their knowledge and skill of programming tools and methodologies, their technical likes and expertise and also what they intend to gain from the course. The students are also advised to personalize their wiki pages so that the class as well as the course organizer is able to have a better and fast acquaintance with the students. The XP exercises review assignments which they are asked to put on their wiki pages also serve as a good way of knowledge sharing and this has helped the course organizer to understand how students are following the course and what aspects of the course need to be refined.

## **6.2 Team Portals**

As the students start working in teams, each team is given a team portal which is used by all team members to put information about their team organization, their meetings, team assignments and all other team related activities. Each team portal shows the team members, their roles, and their expertise and skills. This externalization of knowledge on team level portrays a specific KM model which is required from the general educational aspect as well as from the point of view of teaching XP.

## **6.3 The Scrapbook: Role-based Experience and Feedback**

Each team wiki portal manages a scrap book for all roles, for example, developers, customer, etc., in the team. Each role enters its review of the practice and exercise at the end of each work day. Thus, this scrap book works as an on-line retrospective of the course.

## **7 Conclusion and Future Work**

XP practices promote knowledge management in an educational setup. XP facilitates team work which further enhances the sharing and externalization of knowledge to support the learning process. Teaching XP by simulating student teams to real software development teams, and simulating the conditions that prevail in software development organizations, has provided a good learning experience to the students. The opportunity to work in cross functional teams, with all XP roles visible, has been an experience for the students which they can not get before actually joining the industry. It has also been an opportunity for the course organizers to introduce all role types in software development teams instead of only developers, which is the case in usual software development courses. This has been possible due to the specific setup of the course. The informal feedback gathered from the course participants shows that they are having a good experience in learning software development practices as well as the social and organizational concepts. The course organizers have arranged to conduct surveys from the participants at different stages of the course to make an empirical analysis of the whole course organization and the XP process. The survey results will be published after the end of the course. It will provide a formal analysis of the whole XP teaching course.

The course has entered into the second phase during which the students will work on a software development project and will apply all XP practices. This will allow to look into the knowledge management aspects of those practices which are not experienced yet in the context of the first part of the course and hence not described in this paper.

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## **A Placement Web-Service for Lifelong Learners**

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**Abstract:** This contribution introduces a placement web-service which has been developed in the context of the TENCompetence Integrated Project. The web-service uses Latent Semantic Analysis (LSA) to calculate similarity between documents in learner portfolios and content in the current learning network of the learner. In the first part of the paper the placement problem in learning networks is introduced. Next we discuss the architecture of the current web-service prototype and describe our evaluation approach. Several limitations and future developments are discussed at the end of the paper.

**Keywords:** Latent Semantic Analysis, Placement, Web-Service, TENCompetence

**Categories:** L.1.0, L.2.2, L.3.0, L.6.0, L.3.6

### **1 Introduction**

Aside from traditional educational offerings by institutional providers of technology-enhanced learning more and more focus is given to learning scenarios outside these institutions. Especially in professional education the importance of learning networks [Koper, Sloep and Rusman 05] for non-formal education is rising [Kamtsiou et al. 08]. This is, besides other factors, also provoked through the use of social software for self-directed learning and competence development [Klamma et al. 07]. In these learning networks people get together who share one or more competence



development goals. Several providers can contribute learning activities to this network. Based on these contributed resources, learning activities and the behaviour of the participants emerging effects can be used as the basis for several service offers.

In the TENCompetence project one focus is the development of models and tools which help to bridge the worlds of formal education and non-formal approaches all subsumed under the concept of competence development programmes [Koper & Specht 08]. In the TENCompetence Integrated Project two independent but intertwined Web services have been developed to provide learners with orientation and feedback in learning networks. The placement Web service provides learners with a starting position in learning networks while the navigation web-service [Kalz et al. 08a] leads the learners through the learning network based on the position provided by the placement service. These services have been integrated in one recommender system for learning resources which can use and reason with information from several sources and backgrounds. While data from formal providers of competence development programs can most of the time offer well structured information about the programmes and e.g. dependencies between learning activities in non-formal learning scenarios this can not be assumed.

For this purpose the hybrid personalizer has been developed [Herder & Kärger 08]. The hybrid personalizer tries to overcome the problems of both learning contexts (formal & non-formal) through a collection of “top-down” and “bottom-up” Web Services which contribute to a recommendation of learning activities. The recommendation is computed based on information available about the learner, the learning activities, and the behaviour of other (successful) learners. The recommendation provided by the system is two-fold: on the one hand, it ranks learning activities based on how close they are to the learner’s current knowledge level; that is, learning activities that are still too advanced are scheduled at a later point in the initial recommended visualization of the curriculum (or rather, competence development program).

On the other hand, as a second dimension, the system ranks learning activities based on to what extent they match the learners’ preferences—as explicitly indicated in their profiles and as estimated from the behaviour of similar users. The placement service was used here mainly to compute the similarity between the content of the learner’s portfolio and the content attached to the learning activities from non-formal sources without an extensive set of metadata. To test the reliability and performance of the placement web-service we have conducted a technical evaluation for further development.

In this paper we focus on the placement web-service for lifelong learning. Based on the discussion of learners needs in non-formal professional learning we introduce the problem of placement in learning networks. The architecture of the placement web-service is discussed and a first technical evaluation and empirical results are presented. Several limitations are discussed and a research and development outlook is provided.

## **2 The Placement Problem in Learning Networks**

### **2.1 Learner needs in non-formal professional technology enhanced learning**

Lifelong learners which make use of Technology-Enhanced-Learning have different needs and different expectations of technology-support for learning than learners in formal educational settings. Both learners share the wish to get personalized educational offers which fit to their prior knowledge and their learning goal. Most approaches from the traditional Adaptive Hypermedia (AH) literature assume for this problem the existence of a top-down-design for learning and a clear structure with pre-requisites defined and adaptation based on these predefined structures. In research on adaptive sequencing of learning resources for example a domain expert is assumed that models the learning goals and the domain concept ontology [Karampiperis & Sampson 05].

In non-formal education these assumptions often do not hold, because the sources and routes through the learning networks are not clearly defined and structured. This is also recognized in recent literature from adaptive hypermedia and referred to as the “open corpus problem” [Brusilovsky and Henze 07].

While these traditional models calculate the prior knowledge of learners only internal in their systems through a logic which is based on which pages a learner has visited inside the system and which pages contain similar content, for learning networks for non-formal professional development other techniques to take into account prior knowledge of learners are needed due to the open and dynamic structure of these networks. One approach to solve this problem is to ask contributors of learning networks to define the related learning goals to every learning activity added to the network and retrieve goal-related learning activities [Lindstaedt et al. 2008]. While this approach may work well in more hierarchically organized learning and working environments its success depends to a very large extent on the willingness and ability of contributors to add these information.

In learning networks other techniques have to be applied which can handle the dynamic nature of the learner profiles and the learning content in the network as well. Because of this dynamic nature we have chosen an approach which takes the similarity between the content in the learning network and the content in the learner portfolio as a proxy for prior knowledge analysis [Kalz et al. 08b]. This is what we refer to as the “placement problem” in learning networks which we discuss in the next section in detail.

### **2.2 The placement problem in learning networks**

In a nutshell the placement problem boils down to the question which learning activities a learner should take in the learning network and which can be omitted taking into account his prior knowledge. In traditional formal education this problem is mirrored in a process called Accreditation of Prior Learning (APL). In this process learners apply with their portfolio for a study programme. Domain experts study these portfolios and decide based on the submitted material which parts of the study programme can be exempted and which personalized curriculum the learner gets. This process is time-consuming and expensive so a need is to support this process with technology.

In the UK this process has been recently covered in a JISC funded project which focused on the development of services for students and assessor in this procedure. An “estimator” service should serve in the pre-entry phase of the APL process to estimate the “importance” of a specific part of the learner portfolio for a potential claim [Haldane et al. 07]. In the context of the TENCompetence project we have evaluated and developed a solution for the same purpose which is based on the extensive use of Language Technology. In the next part we describe the architectural design of this application and present the context in which this service is embedded.

### **3 Placement Web-Service Prototype**

#### **3.1 Latent Semantic Analysis**

The core technology of the Placement Web Service Prototype (PWSP) is Latent Semantic Analysis (LSA) [Landauer 2008]. LSA is a method for extracting and representing the contextual-usage meaning of words by statistical computations. The whole process of this analysis consists of several steps like the pre-processing of the text involving weighting and normalizing mechanisms, the construction of a term-document matrix, a mathematical function called singular-value decomposition (SVD) similar to factor-analysis, the rank reduction of the Term Document matrix and finally the projection of a query vector into the latent semantic space. In this latent semantic space the main concepts of the input are represented as vectors. Concepts or documents containing these concepts in this space are similar if their vector representations are close together in the space which provides a measurement for the similarity of text and concepts. The power of LSA in comparison to classical keyword techniques is the ability to match similarity even if documents do not contain any joint terms. LSA has been applied in several fields like medicine, psychology or computer science and it has shown good performance in essay scoring [Foltz, Laham, & Landauer 99] and tutoring systems [Graesser, Chipman, Haynes, & Olney 05].

Based on these experiences we have evaluated the use of LSA for approximating prior knowledge of learners based on their writings and results of this evaluation are promising. For the TENCompetence project a web-service prototype has been developed whose architecture is explained next.

#### **3.2 Architecture of the PWSP**

The Web-Service is built on top of an LSA implementation in PHP. The PHP implementation offers compiled methods for all basic LSA steps from importing documents, through cleaning up, building the Term-Document-Matrix (TDM) matrix, decomposing and reducing it and performing queries. This significantly reduces the code complexity without removing the option to implement custom scripted steps in between. It is possible to switch between a built-in and (two) external decomposition applications: As built in method we have used the ALGLIB library [Bochkanov and Bystritsky 08], while users can use General Text Parser [Giles, Wo and Berry 03] or SvdLibC [Rohde 05] as well if they request them from the developers. No matter which engine is used, the output is always formatted in Harwell-Boeing format, making it easy to compare the various engines and to switch between them. The PHP

implementation also allows various locations for input documents like ftp, (local) disk and nntp (usenet). Other document sources can be implemented easily. It also has a wide range of textual cleaning functions built-in. The implementation can work directly with documents in txt-format or Word, PowerPoint and PDF. It also allows these type of documents as query. Because it saves all intermediate output in an easy readable non compressed format if the matrices are small enough, the implementation is suitable for research purposes. Figure 1 shows a high level overview about the web-service prototype.

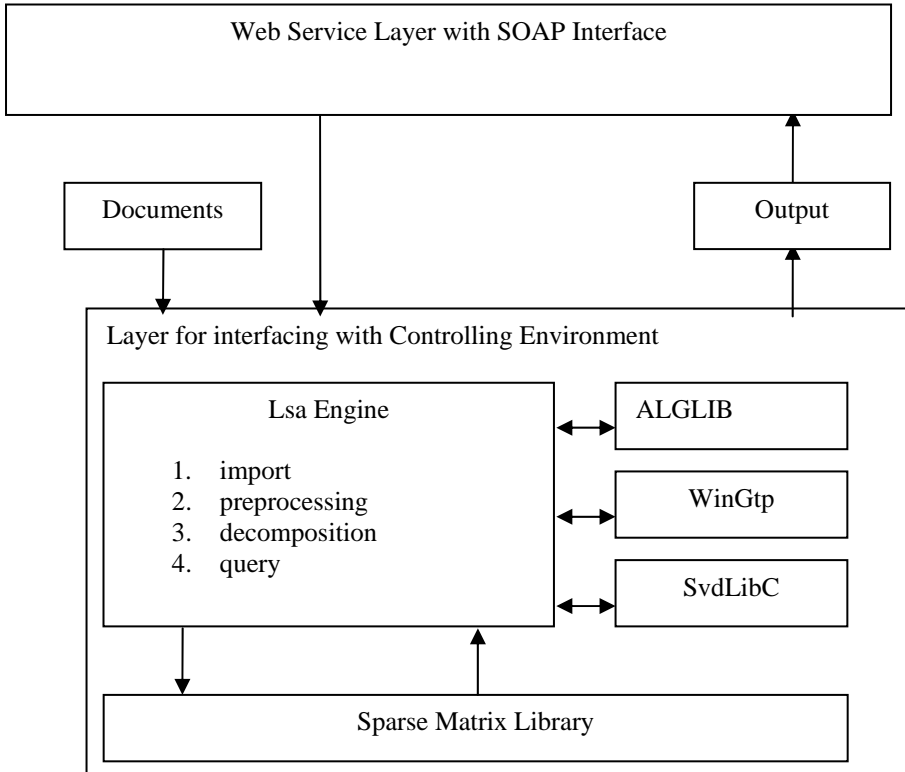


Figure 1: Architecture of the PWSP

On top of the Sparse Matrix Library the Lsa engine is built that performs the various actions necessary for Latent Semantic Analysis. These steps are:

1. importing documents
2. extraction of plain text from text files, Microsoft Word, Microsoft PowerPoint and Adobe Acrobat documents
3. pre-processing the imported text
4. constructing the Term x Document matrix (TDM)
5. performing the singular values decomposition and transforming the output of the decomposition

6. reducing the rank of the Term x Document matrix (TDM)
7. building a query vector
8. projecting a query vector onto the reduced Term x Document matrix
9. performing the query by calculating distances, dot products and cosines between the query vector and the reduced Term x Document space
10. allow retrieval of results

The Web-Service layer on top of the implementation offers a SOAP interface which can be called from external applications. As a result the web-service delivers a list of annotated documents with their similarity scores attached. Table 1 shows an overview of the API of the placement web-service prototype.

Placement Web-Service Interface (API)				
Name	Method	Description	Input	Output
getPositionValues	Get	Return a list of UoL annotated with cosine values	lduser=xx	2-dimensional array of floats. Each UoL with its calculated cosine values.
Frequency		DATA Fields		Format
On request.	EventType	lduser = Integer Learninggoal = Array (Strings)		

Table 1: Placement Web-Service Interface (API)

In the next part of the paper we discuss the evaluation of the web-service prototype.

## 4 Evaluation

### 4.1 Performance Evaluation

In two prior studies we have evaluated the performance of using LSA for prior knowledge approximation. Since LSA was used in the past on the basis of large corpora from information retrieval we first had to evaluate its applicability on much smaller corpora which we expect to be available in learning networks. In this first study we could show the importance of applying stopwords and we have proposed a method to estimate the number of factors to be retained in LSA for small corpora [Kalz et al. 09a].

In a second empirical study we have collected real data from students and compared LSA results with results from two domain experts who analyzed the documents according to semantic similarity and prior knowledge of students [Kalz et al 09b]. In this study we could show that we can optimize the LSA procedure by applying the stopword and dimensionality method from the former study and we could reach a false negative and false positive rate under 10%. In this regard the correctness of the web-service results was satisfactory.

## 4.2 Technical Evaluation

There are several approaches how to evaluate semantic web-services and frameworks from a technical perspective. While we cannot discuss here extensively the several approaches for evaluation of semantic web-services we would like to present only the categories in which these web-services and their frameworks are evaluated. [Küster et al. 08] present the following aspects for such an evaluation: Performance & Scalability, Usability & Effort, Correctness, Decoupling and Scope & Automation. In Table 2 we show the evaluation results from a first evaluation of the PSWP.

Category	Result
Performance & Scalability	30 seconds for a dataset of around 800 documents (total size 7 MB).
Usability & Effort	Usability is high. Currently low effort, but might increase in future versions.
Correctness	Has been evaluated in an empirical study, but we expect that a “training phase” is needed for every implementation.
Decoupling	Not tested/Does not apply
Scope & Automation	Not tested/Does not apply

*Table 2: First Evaluation Results of the PWSP*

We have tested the performance and stability of the web-service with the same dataset which we have used for the empirical evaluation of LSA for placement purposes. For the dataset which had a size of 7MB in total the service needed around 30 seconds to respond and deliver the annotated list of learning activities (Core 2 Duo T7200 (2 GHz) PC with 1 GB of RAM). All documents used in the evaluation were text files so that no conversion into text format was needed. Scalability has been tested with datasets of different size and the time needed to get the result list increased on the one hand with the number of documents that have to be converted into textformat and on the other hand with the number and size of documents.

The usability of the current prototype is high, since we have coupled it with a WAMP (Windows, Apache, MySQL, PHP) package and so the setup time for the web-service is low. We could not test the aspects of decoupling and scope/automation since these aspect fit better to large frameworks than to a single web-service. In the next part of the paper we discuss the results of the evaluation and provide a perspective for further development of the web-service.

## 5 Conclusions and Outlook

In this contribution we have introduced a placement web-service which has been developed in the context of the TENCompetence Integrated project. While we think that the work presented here is an important contribution for formal and non-formal contexts in technology-enhanced learning, there are several limitations of our

approach. Since the services focuses on word usage in texts it can only work in domains where textual expression is important. Another limitation of using LSA for placement support is the inability to recognize more structured information like metadata. For this purpose other techniques have to be applied to allow for a matching like e.g. case-based reasoning approaches. The result of the first technical evaluation was that the web service performance was not suited for a productive system. This result was mainly due to scalability and effort issues. Response times higher than 30 seconds could be observed. Although this long reaction time depends to a large extent on the hardware of the Web Service machine we also analyzed improvements of this response time in the architecture. An important architectural aspect which leads to these response times was the combination of updating the Term-Document-Matrix (TDM) and singular value decomposition every time before a query is executed. Since an update of the matrix is only needed when sufficient new content has been added to the learning network or the portfolio of the learner this process does not have to be executed before every query. For further development of the web-service we will work on the performance issues and we will split the process of updating the TDM and execution of the query. This is a well know problem in LSA research [Zha & Simon 99] and several solutions for this problem have been proposed which will be explored in the future.

Another important aspect of future work is related to the effort to set up the web-service to work correctly. Although we could evaluate a method to improve the web-service results sufficiently on a data set from psychology studies a new “training phase” will be needed for implementations in other context. For the further development of the web-service a rating system should be introduced that aligns the behaviour to the ratings of web-service users. For this purpose an adjustment layer should be implemented that can “learn” from the ratings of the results by users.

While we have focused in this project only on the application of Latent Semantic Analysis for prior knowledge approximation we combined text and data mining approaches in another recent project. The Semantic Weblog Monitoring Framework (SWeMoF) will enable users to conduct similarity analysis, classification and clustering experiments on corpora generated via RSS-feeds from weblogs [Kalz et al 09c]. With this framework we will be able to improve the construction of test corpora on the one hand and we will extend our approach on other methods and approaches that go beyond the application of Latent Semantic Analysis alone.

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# **Perspective and Contrast, Design Principles for Supporting Self-directed and Incidental Learning**

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**Abstract:** This paper reports on a meta-analysis of two qualitative studies that use visualisations of user interactions in Web2.0 systems in order to support self-directed and incidental learning. This analysis focuses on the identification of design principles for supporting learning beyond the well structured conditions of educational institutions. The studies applied a reference architecture for context-aware systems together with a contextual framework that is based on the theory of situated learning. Although combining these concepts lead to satisfactory results, it appeared that the design of visualisations for supporting self-directed learning requires further constraints. The given meta analysis identified the two design principles “perspective” and “contrast”. This paper discusses how these principles were present in both prior studies.

**Keywords:** learner support, Web2.0, self-directed learning, design principles, HCI, information visualisation

**Categories:** L.1.0, L.2.1, L.2.2, L.2.4, L.3.1, L.3.4, L.6.0, K.3.m

## **1 Introduction**

Recently a new type of software tools has become popular on the Internet. These applications mark the advent of the Web2.0 [O'Reilly, 2005]. The Web2.0 stands for web-based services that allow their users to create and manipulate resources. Another aspect of the Web2.0 is that services are no longer considered to be standalone, but that they can be integrated into higher level services. The ability of connecting services into new applications attracts also the educational technology community. One track in the related discourse is related to personal learning environments (PLEs). PLEs are learner centred mash-ups of the learners' Web2.0 services [Wilson, 2006]. The idea of PLEs as integrated Web2.0 services is directly connected to the constructivist concepts of emergence and self-organisation [Von Glasersfeld, 1995]. This holds potential for supporting communities of practice and self-directed lifelong learning.

This paper is on a meta-analysis of two qualitative studies that use visualisations of user interactions in Web2.0 systems in order to support self-directed and incidental learning. The next section outlines the background and motivation of this study. It is followed by the research questions that are addressed by this paper and a brief description of the two studies that are analysed. The fifth section reports on the key results of the studies. It is followed by the analyses. The following section analyses the two studies in order to identify design principles that can be applied for designing technological support for self-directed and incidental learning. This paper concludes with an outline of the practical constraints of applying the identified design principles.

## 2 Background

Self-directed learning is a key factor in the knowledge economy. The so called “knowledge worker” is by definition in a continuous learning process [Steward, 1997]. For knowledge workers and practitioners within weakly structured or emerging professional environments, the process of “self-directed learning” cannot be separated from practice. This type of development in practice is for many knowledge workers the prime context of learning, because traditional forms of formal and even non-formal education cannot meet their advanced and highly specialised learning needs. However, the connectedness of learning and practice holds the danger that the learning processes are no longer recognized [Bjørnåvold, 2000].

Self-directed or incidental learning depends on a person’s ability to take initiative and to reflect on her or his learning actions [Knowles, 1975; Marsick, 2001]. Therefore, reflection is a factor for learning of professionals [Schön, 1983; Schön, 1987; Ertmer, 1996], where three types of reflection were distinguished: “reflection in action”, “reflection on action”, [Schön, 1983] and “reflection for action” [Ertmer, 1996]. For the autonomous learners, two aspects for supporting learning can be identified from the existing literature. Firstly, participation in a community of practice is relevant for sharing knowledge and developing ideas, concepts, and solutions [Lave, 1991]. Secondly, reflection is a meta-cognitive activity that is crucial for the personal learning process. Feedback is required to stimulate and support reflection [Butler, 1995; Ley, 2001; Ertmer, 1996]. However, even in communities of practice, feedback on the individual learning process is not guaranteed.

The theory of situated learning [Lave, 1991] states that learning is always situated in a context. While prior research in the domain of mobile and ubiquitous learning emphasises situated learning in terms of localised learning, the discourse on situated learning [Lave, 1993; Wenger, 1998] suggests a greater complexity [Glahn, 2009]. By analysing the work related to this theory, 6 contextual dimensions [Lave, 1993] and 12 context factors [Wenger, 1998] were identified (Table 1). The mapping of these dimensions and factors provides a conceptual framework for designing visualisation for providing contextualised feedback on situated learning, because it allows identifying the types of possible interpretations of the learning processes that can be expected for each context dimension. For example if the participation dimension is focused as the primary context dimension, it can be expected that learners relate meaningful learning experiences to the following factors: *presence*, *interaction*, *involvement*, *personal identity*, *communal identity*, *boundaries*, and *community building*.

Internet technologies hold great potential for supporting self-directed and incidental learning of individuals and communities [Wenger, 1998]. [Wenger, 2005] argue that Web2.0 services play an increasing role for facilitating communication and information organisation between the peers of a community of practice. This suggests that PLEs can provide suitable frameworks to connect individual learners and communities into learning networks for lifelong competence development [Koper, 2005]. However, this potential depends on the ability of a PLE to provide appropriate feedback for emphasizing the learning progress.

Lave, 1993 →	Processes	Peers	Event	Participation	Concept	World
Wenger, 1998 ↓						
Presence		X	X	X		
Rhythm	X		X			
Interaction		X		X		
Involvement				X		
Value		X			X	X
Connections		X			X	X
Personal Identity				X		
Communal Identity		X		X		
Relations		X				
Boundaries		X		X		X
Integration	X	X				
Community building	X	X		X		

Table 1: Contextual dimensions and contextual factor alignment

### 3 Questions of research

One of the key problems with technological support for self-directed and incidental learning is that the knowledge domain, the personal learning objectives, and the competence levels of the learners are not explicitly expressed and sometimes not even conscious to the learner. Under these conditions is information visualisation of learner actions is one approach to provide feedback on learning activities. Selecting and arranging relevant information of such feedback is not trivial. Therefore, the present study addresses the question about the generalisable design principles for providing contextualised and personal feedback in situated learning.

This has been motivated by the following research questions [Glahn, 2008a].

- What is the effect of different aggregators, strategies and indicators on the learning process and how can they get effectively combined and applied for supporting the learning process?
- How can a system collect data and aggregate contextual information in a way that it can provide meaningful information at the different stages of a learning process?

- What contextual information is relevant to support the learning process and does this information change throughout the individual learning process?

## 4 Method

This study analyses the findings of two earlier qualitative studies, in which visualisations were used to provide feedback on the participants' activity. The first study used embedded bar chart visualisations [Glahn, 2007]. This study used the team.sSpace platform and analysed two types of bar chart visualisations of the participants' activities in relation to their engagement collaborating [Glahn, 2009]. One visualisation is a personal "activity counter"; the other is a "performance chart". The two visualisations were embedded in a peer information portal and linked to more detailed information and enable the participants to scrutinise the details about what is shown in the graphics. Figure 1 shows that the "performance chart" relates a learner's actions to the actions of the group, while the "activity counter" visualises a learner's actions without additional context. The only difference between the visualisation was the arrangement and presentation of information, while the underlying data was the same.

Furthermore, the explicit and implicit tagging of the team.sSpace participants was analysed [Glahn, 2008b]. This second analysis focused on the differences among the participants in using the available information.

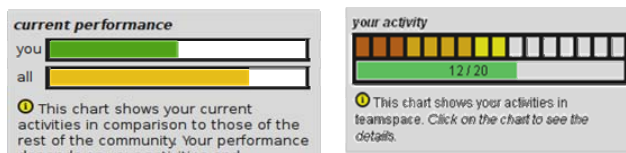


Figure 1: team.sSpace indicators; performance chart (left), activity counter (right)

The second study analysed if a tag cloud can stimulate reflection on tagging online resources [Glahn, 2008c]. For this study used the ReScope tag cloud, which visualises the global tag usage is represented in the font size and the recent tag usage is displayed in different colours (see Figure 2). The selected data sources are related to the context dimensions 'concept' and 'process'. Given to the conceptual framework presented earlier it was expected that the tag cloud stimulates equally reflections related to the three related context factors 'rhythm', 'value', and 'connection'. Furthermore, it was anticipated that the visualisation has no particular affinity to one type of reflection. In addition to the tag cloud the participants were encouraged to take notes about their reflections on the tag cloud. These notes were associated to the visible tag cloud in a way that the participants were able to revisit and reassess previous states of their tag cloud.

Both systems implemented the four layered architecture for context aware systems that has been proposed by [Zimmermann, 2005]. This architecture abstracts the information processing of context-aware systems into a sensor layer that covers the data capturing, a semantic layer that models the aggregation of the captured data,

a control layer that covers the processes of contextualisation, and an indicator layer that models the ways of how a context aware system responds to a user.

The systems were evaluated based on the user interactions with each system over a period of nine weeks in case of team.sPace and three months in case of ReScope. For both studies the participation was voluntary and none of the participants contributed to both studies.

The screenshot displays the ReScope user interface. On the left, a tag cloud titled "ReScope Tags" contains numerous tags in various colors and sizes, such as "ajax", "blog", "coding", "design", "education", "linux", "opensource", "research", "software", "tools", and "web2.0". A "[help]" link is visible in the top right of the tag cloud area. On the right, a sidebar shows the user's profile "Christian Glahn" and a section titled "How are you reading your tag cloud? [help]" with a count of "140". Below this is a "Reset To Current Tag Cloud" button and a "Previous notes" section. The notes section lists several entries with timestamps, including "A note while demonstrating to wim" (12.12.2008 14:19:04), "fresh bookmarks make quite some changes with my cloud - #blogs are more important now." (02.10.2008 09:58:19), and "This is the #tag #cloud at the start of the #experiment !" (24.09.2008 01:35:42).

Figure 2: User interface of ReScope

## 5 Key findings

The team.sPace study focused on two aspects. The first aspect is the different perception of two activity visualisations among the participants. The second aspect concerned the differences in tagging and the usage of tagged resources. The results indicate that the performance chart was more engaging than the action counter for contributing participants. For non-contributing participants this visualisation appeared to be discouraging. The action counter appeared to be ignored by the participants. The results of the tagging activity suggest that the active tagging and the use of tagged resources refer to different aspects of interest, but cannot be related to the level of participation. While the perception of the provided differed among the participants working with different indicators [Glahn, 2009], the use of the available resources on the portal did not vary in the same extend [Glahn, 2008b].

In the ReScope study the participants in the study were encouraged to use the provided note keeping function to record their reasoning on their tag cloud. The notes provided by the participants were categorised regarding the three types of reflection of [Schön, 1983] and [Ertmer, 1996], and to the contextual factors that were suggested by the contextual framework. After cleaning notes without meaningful

content, all notes could be associated to the three types of reflections and to the expected context factors. The distribution of the notes that is shown in Table 2 indicates that the reflection notes show neither affinity to a particular type of reflection nor to a context factor. The results indicate that the dually encoded tag cloud stimulated reflection on the tagging activity of a learner. Using the highlighted tagging information supports the learners to evaluate and monitor the semantic structure of the resources that are found on the web. Because the participants' notes could be associated only to the predefined context factors it can be suggested that the concepts of situated learning can be applied for guiding the development of technological learning support.

	<i>rhythm</i>	<i>value</i>	<i>connection</i>	<i>Total</i>
<i>Reflection on action</i>	8%	18%	13%	39%
<i>Reflection for action</i>	5%	13%	8%	26%
<i>Reflection in action</i>	11%	8%	16%	34%
<i>Total</i>	24%	39%	37%	100%

Table 2: Association of notes to context factors and reflection types of the ReScope study (variations of totals due to rounding)

## 6 Discussion

The two studies analysed different visualisations of learning activities as a form of feedback. The team.sSpace study focused on the visualisation of the quantities of learner activities in an information sharing environment. The ReScope study analysed a visualisation of personal concepts. The present study seeks for the common aspects of the two visualisations in order to infer initial design principles from these results. For this purpose the results of the studies were analysed if and to what extent they help to answer the overarching research questions.

Regarding the first question on the effects of visualisations and aggregators and their arrangement, the team.sSpace study indicated that the same underlying sensor information influenced the participants' perception of the collaborative activities, and that more complex design principles for activity indicators are required. The insights of this study were partially used for designing ReScope, which reflected the context dimensions "concept" and "process". The findings of the second study were in line with the expectations according to the framework.

The second question concerns data collection and aggregation for providing meaningful information to self-directed learners. The analysis of team.sSpace suggests that contextual factors are not relevant at the sensor level, because both visualisations were based on the same activity data. The differences were at the level of aggregation and of visualisation. This is in line with the analysis of the tagging habits that suggests only differences between active and passive tagging, but not between the participation level of the participants.

The final question on the relevant contextual information cannot be answered by the two studies, because the studies did not cover all contextual dimensions and factors that are suggested by the theory on situated learning. Despite the limitations and the differences of the studies, two design principles can be identified for contextual learning support. These principles can be named as *perspective* and *contrast*. Although both principles were identified in the context of information visualisation, they refer to educational and cognitive aspects of the personal learning processes as it is described in the following sections.

### **6.1 The design principles and the architecture for context-aware systems**

This section puts the two design principles in relation to the system architecture for context aware systems. This helps to make more targeted design decisions while implementing tools for supporting self-directed learning.

The perspective principle can be reflected at the level of aggregators and controllers. In the first design study the concept of perspective was only implicitly reflected in the design, but the findings suggest that the perspective principle corresponds to aggregators and to their arrangement in an adaptation strategy. This insight has been applied in the design of the ReScope tag cloud of the second design study.

The contrast principle can be associated to indicators and the arrangement of aggregators in an adaptation strategy. This suggests two types of contrast. The first type can be described as visual contrast. This type reflects the presentation mode of the information at the level of an indicator and allows a learner to compare and relate different aspects of contextual information. The second type can be described as information contrast. This contrast type is related to the arrangement of aggregators and depends on the type of information that is provided by the contrasting aggregators.

While contrast at the level of indicators mainly addresses the visualisation of information in terms of usability, is contrast at the level of controllers focused on the arrangement of potentially meaningful information. At this level the aspects of perspective and contrast are tightly coupled in the design decisions. The designs studies covered in this paper were based on the contextual framework that was developed from the literature on situated learning. This framework defines relations between contextual dimensions and context factors and has been used a guide for defining, selecting, and arranging aggregators for supporting self-directed learning processes.

### **6.2 Design principles in team.sPace**

team.sPace can be considered as a group information system, because it displays the resources of a group portal. Therefore, the general perspective of team.sPace is a community perspective, i.e., the participants use the system to share information with their peers.

The activity visualisations provide two different perspectives of learner activity. The action counter visualisation indicates provides a personal perspective on the participant's actions. The visualisation shows only a participant's actions. In this



visualisation the contrast principle is not reflected, because it relies only on a single aggregator. Thus it can be considered to show a personal perspective.

The performance chart provides a community perspective on the participants' actions, because it shows the personal actions as a percentage of the actions that were performed by the most active participant and in relation to the group's average activities. This information contrasts the personal information and contextualises it to the group. To achieve this contrast, the chart relies on two aggregators. One to compute the personal performance and one to compute the group's average performance.

The different perception of the two indicators in the team.sPace study can now be explained as following. The performance chart was more engaging for the contributing participants of the group, because it fitted to the perspective of their use of the system while contrasting their effort with the group's average. The personal perspective of the activity counter could not meet the perspective of the other participant's primary use of team.sPace: the personal perspective on the actions did not provide meaningful information for the participation in the group.

### **6.3 Design principles in ReScope**

ReScope provides a tag cloud that shows the global and the recent use of tags of a participant with the delicious.com social bookmarking system. The system offers no form of collaboration with other users. Therefore, the primary perspective of using ReScope is considered as personal.

The tag cloud combines two concepts in the visualisation. The first concept is the general focus of the tags that are related to web resources that the participant has assigned to the personal bookmarks. The second concept is the process, in which the temporal interests of the user change. These concepts encoded differently into the tag cloud. The general focus of a tag is encoded in the font size of a tag. The temporal interests are encoded by the colour intensity of a tag in the tag cloud. This co-presence of information contrasts the temporal interests with the general interests of a participant.

At the level of the arrangement of the aggregators, the information shown in ReScope is selected from two information feeds that offer pre-aggregations of a delicious user. These feeds are provided through the delicious.com feed API. As both perspectives use similar information, namely the number of tags over a defined time period, they can be used to highlight different aspects of tagging web resources to the participants.

The reflections that were documented by the participants of the ReScope study suggest that contrasting two types of personal information supported the participants for reflecting their tagging behaviour.

## **7 Conclusions**

The findings that are presented in this paper provide only initial answers on the three research questions. However, the findings show despite all their limitations that the concepts of situated learning can be applied for developing technological support for self-directed learners. By focussing at the context factors that were identified for

situated and collaborative learning it is possible to provide targeted solutions for supporting self-directed learning. This implies that situated learning can be technologically supported beyond providing and arranging tools for learners and communities. With the help of indicators it becomes possible to provide PLEs as tools for self-directed learning. .

Activity indicators can provide valuable information that allows learners to create meaningful relations between their actions, their knowledge, and their environment. This meta-analysis of our previous studies on the application of indicators for supporting self-directed and incidental learning extracted two design principles that appear to be relevant if visualisations of user activities should provide feedback on learning processes in loosely structured environments. The first principle is perspective. This principle suggests that this type of feedback has to provide a meaningful view on past actions that integrates the prime context of the learner. The second principle is contrast. This principle suggests that information is perceived as relevant if it is presented in relation to similar information of a different perspective. In this paper illustrates how these principles were applied in two different systems that integrate Web2.0 services for collaborative and for personal use.

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# Modeling Personal Knowledge Networks to Support Resource Based Learning

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**Abstract:** In resource based learning settings learners have to cope with a multitude of resources. One big challenge for learners is managing the knowledge contained in these resources appropriately. We discuss some existing knowledge modeling methods and related tools with regard to learning scenarios. This paper focuses on presenting a knowledge modeling approach based on personal knowledge networks. Aggregation and mapping of these personal networks can form a community network supporting exchange of knowledge. Furthermore a proof-of-concept is described.

**Keywords:** Resource based learning, Knowledge networks, Knowledge representation

**Categories:** L.1.0, L.3.0, M.4, M.5

## 1 Introduction

For introducing resource based learning, we would like to start off with a typical personal learning scenario: Anne has to prepare a talk about the weather phenomenon wind. She doesn't know anybody to ask for help. Therefore she searches the web for information. She finds many web pages about this topic which can be relevant for her talk: news pages about catastrophes, scientific articles, weblogs with eye-witness accounts, reviews of books and many more. With one author of a paper she is familiar because she met him on a workshop in Berlin recently. He is an expert on this field and has published numerous articles about storm cycles. During her research she finds references to different kinds of wind like hurricane, blizzard and tornado and how they emerge. Besides the URL of these different web pages she wants to note a short summary and a hint about the reliability of the sources.

This small scenario is a typical informal learning scenario in resource based learning settings. Usually, this kind of learning is a self-directed learning process where learners have to cope with a multitude of information autonomously. We focus on supporting resource based learning on the web because the web is becoming more and more an important source for information as it provides easy access to up-to-date information. In the following parts, we subsume all web contents that can be accessed via web browser under the term *resource*. Challenges for learners are that all information on the web is widely dispersed and resources are not intended primarily for learning purposes. So, learners often suffer from conceptual and structural disorientation because of the huge amount of resources and the lack of structure between the resources. Moreover, resource management is an additional cognitive load. In this paper we focus on three goals:

One main goal of our work is the support of personal knowledge management: Resources shall be organized in a form which supports efficient and effective retrieval of resources even after a long time. Often people forget the exact title or the author of a resource. But they can remember context information, for example the fact that the author is an expert of a special field or that the resource was found during a particular task. Therefore learners should be enabled to save not only the resource but also specific information which has only indirect relations to the resource but is important for the learners. This means that learners should be supported to externalize their knowledge into an information system based on their own needs.

A second main goal is the integration of knowledge in the own knowledge structure: Learning is efficient especially when the learners are active [Meier, 06]. The classification of new resources in the own knowledge structure is such an active process. While saving new resources, associations between already saved resources and topics have to be analyzed by the learners. Thus, new knowledge is connected to existing knowledge. At the start of a research, learners search for resources about a broad overview of a topic if they are novices in this topic. Later they are able to identify subtopics and more specific terminology and thus can search for resources in a more systematic way. They will find new connections between known topics. By modeling these links, an interlaced knowledge structure is created. As interconnecting knowledge, topics and information in such a way, islands of knowledge are avoided.

The third goal is supporting communication of knowledge. Learning is a social process [Cross, 06]. Most learning takes place through communication and during community activities like collaborative work on a project. Building networks between people and content is important especially in the unstructured processes of informal learning. Therefore we develop an approach that enables learners to model their knowledge individually, but still with the possibility to share their knowledge and to profit from other learners.

Some approaches to model knowledge structures and related tools are discussed in the next chapter. In [chapter 3], the modeling of the proposed personal knowledge networks is described. A prototype as proof-of-concept is shown in [chapter 4]. Finally, this paper concludes with a summary and further steps in [chapter 5].

## **2 Related Work**

Representations of knowledge can be modeled using knowledge modeling techniques. They aim to represent knowledge in information systems based on concepts and relations. Knowledge is coded into a form that is interpretable by a computer for processing the modeled knowledge and reasoning with it [Stock, 08]. However, the resource-based learning scenario has special requirements because learners are no experts in knowledge modeling. Therefore, an adequate knowledge modeling technique has to be individual, flexible and easy to use. In the following sections, three knowledge modeling methods (ontologies, topic maps and semantic networks) and respective example systems are described and evaluated with regard to their possible use in resource based learning. Further, we discuss the tagging concept and social tagging systems, although it is arguable if they can be categorized in one of the knowledge representation methods.

## 2.1 Ontologies

[Studer, 98] defines ontology “as a formal, explicit specification of a shared conceptualization“. This is a definition from information science that extends the familiar definition of [Gruber, 93]. Building and designing ontologies is a formal process with a focus on collaboratively classifying concepts and creating associations (e.g. subtopic relations). This usually involves intensive discussions about concept definitions. Axioms and logical rules can be defined in ontologies. Axioms are declarations that are always true and are neither contained in the ontology nor can be reasoned with it.

*Semantic Desktops* are systems that build individual knowledge representations based on (personal) information management ontologies. These applications aim to support users in organizing, finding, creating and communicating knowledge [Sauer mann, 09]. Therefore they model resources like e-mails, calendar dates, address information, locations, desktop files, web artifacts, etc. that are typically present in information management scenarios and append (automatically extracted) metadata to these resources. Nepomuk [1] is one relevant example for Semantic Desktop applications that aims to exchange information over boundaries of applications and desktops. Further, it provides collaborative content production tools like a semantic wiki to enable users to communicate knowledge over a network of people.

Semantic Desktops use ontologies with fixed rules. Thus, extending and adapting personal ontologies to new contexts requires a high level of expertise in modeling ontologies. Finally, Semantic Desktops are not designed for learning contexts but for personal information management of rather structured information.

## 2.2 Topic Maps

Topic Maps (an ISO standard) consist in essence of topics, scopes, associations and occurrences which link topics with external information resources.

*Digital Mapping Tools* like Ontopia Knowledge Suite [2] serve as knowledge repositories and as navigational tools for digital environments modeled as Topic Maps. They represent conceptual knowledge, content knowledge and related information [Tergan, 05]. Because of their visualization, they give a good overview of content structures and can show relations between concepts or knowledge gaps, as well.

Although digital mapping tools are applicable for knowledge communication, they do not support social collaboration for building communities. Big maps without an added explanation are difficult to understand for other learners because they become crowded and/or complex if much content is included.

## 2.3 Semantic Networks

[Sowa, 92] defines semantic networks as “graphical notation for representing knowledge in patterns of interconnected nodes and arcs“. This idea goes back to [Quillian, 68], who strived for a more comprehensive representation of meanings of words in thesauri. He distinguished between *types* and *tokens*. In his terminology,

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[1] <http://nepomuk.semanticdesktop.org/xwiki/bin/view/Main1/> Online: 2009/03/03

[2] <http://www.ontopia.net> Online: 2009/03/04

types are classes of concepts and tokens are instances of types, e.g. Anne is a token of the type *person*. This distinction is not necessarily required because the differences between types and tokens can also be modeled with specific attributes [Huijsen, 04]. Usually, in semantic networks nodes are interpreted as concepts, edges as relations, and both may be labeled for specifying their types.

The *Semantic Web* [Berners-Lee, 01] is not a single application but it subsumes knowledge technologies that aim to provide background and context information to web resources so that computers are able to process and infer over their actual content. They add a semantic layer to web contents in order to bridge the knowledge gap between human beings and computer machines.

By adding descriptions of content, context and structure to web resources a flexible and personalized access can be provided so that resources, which were not intended for learning purposes, could become learning materials. For example, a teacher could add additional information like covered topics, required previous knowledge, target group, etc. with which students can be guided. A disadvantage of semantic web technologies is that modeling a semantic network is often as complex as building an ontology.

## 2.4 Tagging

Tagging is a paradigm by which users add arbitrary keywords to items, be it websites, books or friends. As web 2.0 applications are emerging, tagging becomes more and more important as a simple means for users to organize their items in without the constraints imposed by strict hierarchical organization (e.g. having to choose a unique category for items). By aggregating the tags of all users, folksonomic structures emerge that all users can profit from. Either the tags are predefined in a vocabulary or they can be chosen freely.

There are several web-based annotation systems with social-network features. Delicious [1] - a free *social tagging application* - enables users to save, annotate, manage and share web pages. It is described here exemplarily with regard to tagging features because tagging can lead to a knowledge structure. On saving a resource, the system suggests tags, e.g. on the basis of a combination of tags of the user and of the folksonomic structure. The own resource collection or the web pages of other users can be browsed via tags. It is possible to build up networks with other users and to share the collection with them.

Tagging is a very easy and flexible way to organize knowledge, but in existing tagging tools only relations between resources and tags are possible. Linking and structuring tags in an explicit way has not yet been realized, except features like the trivial "bundling" of tags as used in Delicious.

## 2.5 Conclusion

The different forms of knowledge representation mentioned above are often used synonymously in scientific works, e.g. sometimes ontologies are defined as a special case of semantic networks or vice versa. All structures can be represented graphically as a network consisting of nodes and edges. For end users, differences between the

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[1] <http://www.del.icio.us> Online: 2009/03/03

forms of knowledge representation are insignificant [Steinacker, 02]. The different forms can be transformed into each other, but some meaning can be lost due to the different strengths of modeling methods.

### 3 Modeling Knowledge Networks

In our scenario of resource based learning, users model their knowledge structure individually. These users are novices in knowledge modeling, thus the task of creating knowledge representations via formal modeling methods is too complex and takes too much time to learn. Therefore we propose an approach based on a combination of semantic networks and the tagging concept. We use the term *knowledge network* in this paper to distinguish from formal modeling methods.

In the following, some terms are explained for a better understanding of the next sections in this chapter. We differentiate between *concepts* and *individuals*. In analogy to object oriented software engineering, *concepts* correspond to *classes* and *individuals* to *instances*. Concepts define possible attributes of an individual e.g. URL is such an attribute for an individual like a resource in our scenario. The attribute definitions as a whole are called attribute schemas. User defined attribute schemas are named *extensions* (as – again analogue to object oriented programming – the concepts themselves are extended to provide additional attributes). Links between resources and concepts and among each other are called *relations*.

In essence, personal knowledge networks in our scenario consist of resources, tags and relations between them. Resources and tags are nodes in the network with predefined attributes, e.g. all individuals have an internal id, a name, a date of creation and a date of last update. The *resource concept* defines the attribute schema for all *resource individuals*. In our model, a resource can have the additional attributes *URL*, *description* and *screenshot*.

Tags are only identified by an id and a name. They are comparable to tags in other tagging systems as they represent a simple plain-text token and have no further attributes. Besides simple tags there are further special tag types: *topic*, *person*, *goal*, *event*, *location* and *miscellaneous*. Users can model their own attribute schemas as extensions for these specialized tags. As these definitions are abstract, an example based on the scenario of the [1 Introduction] in the next section will clarify this.

#### 3.1 Focusing on Modeling Personal Knowledge Networks

Anne, the learner in the scenario of the [1 Introduction], wants to manage resources she found together with additional information in her personal knowledge network. Therefore she saves the resources with their properties *URL*, *name* and *a description of the web page*. How we support this process of saving resources in our software will be described in [chapter 4].

In the knowledge network all resources are saved as individuals of the *resource type* and the properties are saved as the individuals' attributes. Anne has found all the resources in this scenario in the context of her goal preparing a *talk for the seminar climatology* dealing with the topic *wind*. This goal is an important possibility for Anne to structure and to organize her found resources. Later she is able to retrieve these resources via this goal if she links all resources with this goal. The linking can



be done easily by tagging with the name of the goal *talk for the seminar climatology* when saving the resource. When tagging, Anne can assign a specified tag type to this keyword. If she specifies *talk for the seminar climatology* as goal, this tag is created as individual of the *goal type* and the relation between resource and goal is drawn automatically. If the tag has already existed in her knowledge network, only the relation is created. Anne saves also the association between the goal *talk for the seminar climatology* and the topic *wind*. Therefore Anne tags the goal with *wind* and specifies it as *topic type*. Similarly, Anne creates a relation between a resource and *Prof. Meier* (person type) who is related to a *workshop* (event type) which is again linked with *Berlin* (location type). The information *eye-witness account* is important for Anne because therewith she can vitalize her rather theory-centric talk. She tags the corresponding resources with the keyword *eye-witness account* without assigning a specified tag type. If required, Anne will catch up on specifying it later.

The predefined types and attributes in the basic model are not sufficient for Anne to be able to model all desired information in her knowledge structure. The resources, which Anne collects during her research, represent different information types. Therefore she creates a new *scientific article type* which extends the existing *resource type*. For individuals of the scientific article type she defines an attribute *year of publication*. She does this with the extension *book type* in the same way. For individuals of *book type* she can save the ISBN now. Thus, Anne can sort her resources e.g. with regard to the information type, for example if she only wants to get all scientific articles. This example shows that a flexible and easy, yet exact, modeling of an own knowledge structure is possible by using tags and specifying extensions. Especially the possibility of specifying the tag type due to personal preferences is useful for modeling the network, as users will find it easier to retrieve the information later as stated in our first main goal: Users may save resources with relevant additional information in order to externalize their knowledge structure similarly to the knowledge structure in their mind, having the possibility to extend the existing structure if required.

### 3.2 The Aspect of an Aggregated Community Knowledge Network

All personal knowledge networks are managed in the same data base, thus all knowledge networks can be accessed centrally. All individuals, extensions and relations that are modeled by each user are linked to the respective user automatically in order to ensure the separation of the user's and the other users' networks. This makes building a community knowledge network by aggregating and mapping of all available personal knowledge networks possible. For example, identical tag names or URLs of resources allow automatic conclusions that there are similarities or overlaps between different personal knowledge networks. Thus, automatic mappings enable users to share their knowledge structures without prohibiting to model their structures individually. Further, users can be made aware of each other and profit from resources of other users, which can be recommended for the current research.

Still, mapping of knowledge networks poses several challenges like usage of different names for the same things and vice versa. In future work, we will improve existing algorithms for identifying similarities and differences between knowledge structures and adopt them to personal knowledge networks.

## 4 Prototype

We implemented a prototype (see [Fig. 1]) as a proof-of-concept that is composed of three parts: a backend for storing and managing the knowledge networks, a client that represents the GUI to the user and a web service that handles the exchange of data between backend and client. The backend is based on K-Infinity [1] to which the web service provides a thin layer; both are not a focus of this paper.

The client is embedded as a sidebar into the web browser Firefox. When importing a web page into the knowledge network, the client extracts URL, title and marked text of the imported web page and creates a screenshot for visual orientation and quick re-finding. Users may alter this automatically extracted information and additionally tag the resource. The prototype shows already existing tags via auto-completion and tag clouds. Tags that exist in the community network but not in the user's one are marked. Assigning specific tag types is simply done by entering the tag name into a text field corresponding to the respective type. For extending the predefined types there is a form where users can type the name of the new extension and define its attributes.

While searching for new information on the web, the client presents additional information when a new web page is opened in the browser. For example, users are notified if the current web page has already been saved in their own knowledge network. If this is the case, resources with similar tags to the current page are shown, so that users can get a quick overview of the resource's context in the knowledge network. Similarly, users are notified if another user has saved this web page and further probably relevant resources are listed. The shown resources in the sidebar are potential starting points for further browsing the knowledge network.

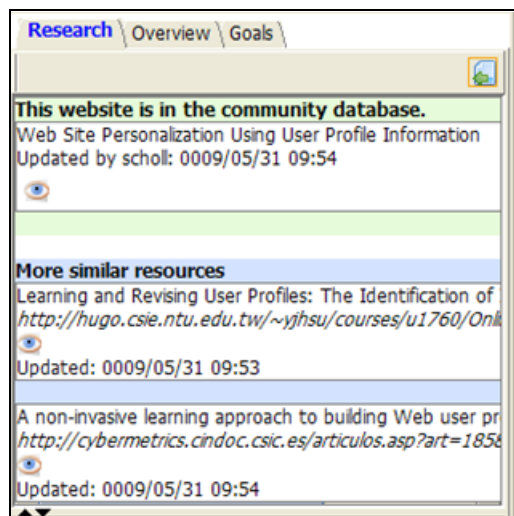


Figure 1: Similarly tagged resources to the current page in the Firefox client

[1] <http://i-views.de/> Online: 2009/03/03

## 5 Summary and Next Steps

This paper describes a knowledge modeling approach based on personal knowledge networks to support knowledge management in resource based learning. It combines the advantages of tagging and semantic networks (by the concept of specifying tags) and allows knowledge management that matches the users' way of thinking by using tags from any type and the possibility to define own extensions. A first short-time evaluation shows that the particularities of resource based learning are accounted for. At the moment, we are evaluating this prototype in a complex user study with a group of PhD students over a period of four weeks to get feedback on how to improve our concept. In future work, we will address mapping algorithms in order to improve collaboration of users and recommendation of similar relevant resources.

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# **Inter-Organisational Knowledge Transfer in Small-World Networks**

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**Abstract:** Small-world networks represent a decentralised network topology in which several actors are strongly connected with each other. A high clustering coefficient and a high number of short paths within a social network characterise such a network. Particularly in the context of inter-organisational knowledge transfer among R&D organisations, the structure of small-world networks appears significant for effective knowledge transfer. This paper reports on an investigation into the nature of inter-organisational knowledge transfer among R&D organisations. The topology of a social network is explored using UCINET social network analysis software. From these findings, implications are drawn for ICT support at an inter-organisational level.

**Keywords:** knowledge transfer, inter-organisational, R&D, social network, small-world network, ICT, decentralised, peer-to-peer, KMS

**Categories:** J.4., H.4.2, H.4.3

## **1 Introduction**

Inter-organisational knowledge transfer is the exchange of knowledge among diverse organisations with the aim to expand and leverage their capabilities and resources [Grant and Baden-Fuller 1995]. Although there can be various emphases, in the context of this research, it refers to the movement of knowledge between two or more organisations in a knowledge-intensive environment, such as the Research and Development (R&D) sector. The aim of inter-organisational knowledge transfer is to reuse existing knowledge and also facilitate innovation. Although the larger part of research into knowledge transfer has been undertaken at the organisational level, more recent studies have investigated the benefits of knowledge transfer in inter-organisational environments including strategic alliances, business clusters, value

chains and informal networks and communities of practice [Cranefield and Yoong 2005]. Research into the inter-organisational transfer of knowledge, particularly in informal networks in the R&D sector, appears to be relatively rare [Allen et al. 2007]. There is also a lack of research in elucidating Information and Communication Technology (ICT) support for the transfer of knowledge in social relationships in this environment.

This paper reports results of a case study that investigated knowledge transfer in an inter-organisational social network in the New Zealand (NZ) environmental Research and Development (R&D) sector. This study was guided by two research goals. The first aim was to elicit key knowledge transfer structures, such as the network topology, among R&D organisations. The second aim was to draw implications regarding ICT support. This paper specifically focuses on the identification of the network topology which is a major indicator for knowledge transfer and ICT support [Kwon et al. 2007].

## **2 A small-world network topology: A Social Network Perspective on Knowledge Transfer**

### *Social networks and knowledge transfer*

A social network consists of a set of social entities, such as individuals, groups or organisations that are linked to each other in order to exchange information [Haythornthwaite 1999]. Social network research focuses on relationships between these entities, which can be represented by communications among members of a group [Wasserman and Faust 1994] and informal, interpersonal relations in social systems [Scott 2000]. The transfer of knowledge in social networks can be facilitated by different means that may include various ICT's, especially in the case of people working in distributed locations. Like other types of media, ICT may enhance the accessibility of a person's knowledge to other people in the network. This accessibility is a statistically significant relational characteristic of knowledge seeking behavior in a network [Borgatti and Cross 2003].

### *The network topology*

In terms of network topology, social network structures can show diverse levels of centrality, which is a major indicator for knowledge transfer in the network. Centralised structures include Barabasi or Moderate Scale Free network structures, whereas more decentralised structures are presented by random or small-world networks [Kwon et al. 2007]. Small-world networks in particular are characterised by a more decentralised structure than completely random networks. A small-world network structure includes some degree of centralisation in the form of local clusters and can therefore be differentiated from a pure random network [Kwon et al. 2007] [Watts and Strogatz 1998]. Local clustering in small-world networks facilitates reliable accessibility and links between local clusters can provide easy access in the network [White and Houseman 2003].

In terms of social network analysis, small-world networks can be identified by two main characteristics: firstly, a high number of short paths (small average path

length) between any two members in the network: and secondly, a high clustering coefficient that indicates the existence of a certain degree of centralisation in an overall decentralised network. In general, a path in a network is a linkage between at least two network members and is illustrated by lines in a visualised network. However, no connection is repeated and no network member is visited twice [Borgatti 2005]. The length of a path is represented by the number of nodes (network members) it contains [Borgatti et al. 2002]. A short path directly links two members in a network [Kwon et al. 2007] whereas a long path also includes linkages to other members. Such direct linkage, as provided by a short path, allows for direct communication and therefore quick transfer of knowledge - particularly if the contact frequency is high, too. The other typical characteristic for small-world networks is a high clustering coefficient which represents the average of an high neighborhood connectivity per network member [Kwon et al. 2007]. Watts and Strogatz [Watts and Strogatz 1998] introduced the clustering coefficient measure in 1998. In particular, they determined that the neighborhood connectivity in small-world networks is higher than in comparable random networks [Watts and Strogatz 1998]. These two characteristics were applied to the empirical data of this study.

### 3 Results AND Analysis

The social network in this case study was identified as a small-world network. Sixty-seven study participants took part in data collection. Key groups of participating organisations were local and central government agencies, Crown Research Institutes (CRIs), private businesses and universities. Results are based on study participants' contact frequencies for advice giving and seeking activities in the workplace.

#### *Small-world network characteristics – high clustering coefficient*

The network's clustering coefficient was significantly higher with 0.79 than the clustering coefficient in a comparable same-sized random network with 0.42 as shown in the following table. In addition, Table 1 illustrates the clustering coefficients in relation to the network's overall density. The measures were conducted by using UCINET software<sup>1</sup> [Borgatti et al. 2002].

<b>Clustering coefficient</b>	<b>Clustering coefficient for a comparable random network</b>	<b>Overall network density</b>
0.79	0.42	0.62

*Table 1: Clustering coefficients and network density*

The figures in Table 1 confirm that, due to their considerably dense local neighborhoods, this network shows a higher clustering coefficient compared to a random network of the same size. In order to avoid an 'over-interpretation' of high clustering coefficients, [Hanneman 2005] recommends a comparison of the clustering coefficient to the overall density of the network. The density is the total number of

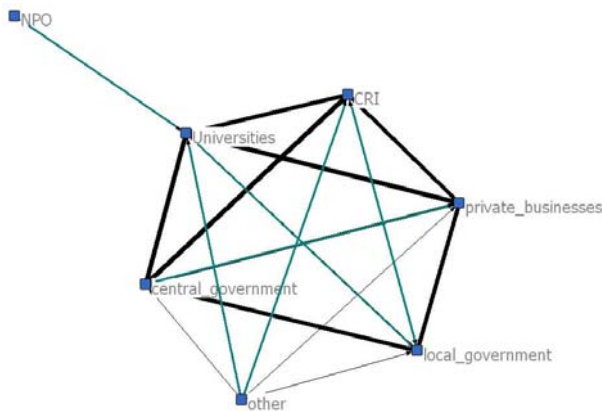
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<sup>1</sup> UCINET 6.188

ties divided by the total number of possible ties [Borgatti et al. 2002] and therefore represents the average connectivity in the whole network. The density of the entire network was also high (0.62) as shown in Table 1. In addition to the high clustering coefficient, this finding reveals a high network connectivity, which represents overall good opportunities for knowledge transfer. However, as the density result was high, the clustering coefficient value did not reflect an equally high value, as it would have in a network with a lower density. This means the opportunities for knowledge transfer within the local clusters were only slightly higher than in the whole network.

#### *A high number of short paths*

The shortest paths in this case include, for example, the path connecting private businesses and universities or CRIs and central government (see Figure 1). As this study's small-world network represented an advice network, in which people most often knew whom they wanted to contact for seeking or giving knowledge, a considerable number of short paths was present.



*Figure 1: Small-world network*

The identification of a small-world network presents some promising aspects for inter-organisational knowledge transfer. Due to the high clustering coefficient and the high number of short paths, study participants shared the advantage of having a relatively easy access to inter-organisational knowledge sources. Apart from inhibitors such as remote locations or competition issues, this small-world network topology provides a reasonably well structured opportunity for inter-organisational knowledge transfer.

## **4 Practical Implications for ICT support**

In small-world networks, ICT can efficiently support information processing [Kwon et al. 2007]. ICT allows for connections across different organisations, and these connections help encourage collaboration and knowledge transfer among network

members. A high degree of local clustering and a high number of short paths in the small-world networks allow for a facilitation of routine communications among people by ICT [Kwon et al. 2007].

Due to this network's decentralised structure, decentralised ICT and particularly decentralised a KM system may be the best support solution at the inter-organisational level, as knowledge processes often cross organisational boundaries [Maier and Hädrich 2006]. A decentralised KM solution (such as Groove) is based on a peer-to-peer architecture. In line with this study's identified small-world network topology, a peer-to-peer KM system seems appropriate. Such a decentralised system allows several powerful groups of organisation which are strongly connected to use peer-to-peer connections efficiently. Weak and intermediate connections may use the peer-to-peer connections less often, but as a decentralised KM system is less costly in maintenance than a centralised system, it even seems more appropriate to support knowledge transfer among weak ties. Moreover, peer-to-peer systems typically reduce the barriers of knowledge transfer at the individual level. Individual knowledge workers are more motivated to participate in a peer-to-peer KMS and share the benefits [Maier and Hädrich 2006]. As the presented results are based on data of individuals' advice giving and seeking activities, a decentralised KMS may thus also provide support at the individual level.

## 5 Outlook

Further research could investigate specific services such as infrastructure services and knowledge services of a decentralised KMS [Maier and Hädrich 2006] in regard to additional study results, including the types of knowledge transferred and ICT security standards in the inter-organisational networks. These investigations could help develop further recommendations for ICT support.

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# **Knowledge Service Governance - Guiding Lightweight Composition of Knowledge Services**

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**Abstract:** With the advent of more light-weight technologies for connecting contents and functions provided by diverse application systems, called mashups, also individuals with their personal knowledge environments can benefit from arranging services flexibly to help them fulfil their knowledge needs. These personal, collaborative initiatives are often associated with trial-and-error, grass-roots level approaches which need an organizational and technical infrastructure to guide them without losing the momentum created in these fragmented knowledge management activities performed by individuals, communities or in projects in an organization. Based on a discussion of these issues, this paper outlines the foundations for a knowledge service governance model to guide these activities.

**Keywords:** knowledge management, maturity, process, service, service-oriented architecture

**Categories:** H.4.2 - Types of Systems, M.2 – Knowledge life cycles

## **1 Introduction**

After human-, technology- and process-oriented KM, recently a fourth KM phase has reached businesses backed by the hype keywords Web 2.0 and social software: collaboration-oriented KM. While in many organizations knowledge workers are busy trying out new alternatives for production of contents, for networking and for self-directed learning, questions arise how these activities can be coordinated so that they are in line with organizational goals and processes. This is even more challenging as more and more of these new KM activities are crossing organisational boundaries extensively using wider community network effects. Thus, a large number of fragmented KM instruments have been tried out in organizations which claim to solve particular knowledge-related problems, but are not connected or integrated. Introducing a service-oriented KM infrastructure seems to be a promising approach for bundling these manifold fragmented KM instruments and tools into KM services [Woitsch and Karagiannis 02] and supporting knowledge-intensive business processes. This concept not only allows for a flexible (re-) configuration of internal KM services, but also for configuration of new services called from outside the borders of organisations and support on-demand KM concepts.

However, as implementing these concepts is a costly, complex and often arguable undertaking, many KM projects have been abandoned leaving knowledge workers

with the insight that KM is important, yet unsupported by corporate initiatives. With the advent of more light-weight technologies such as tagging, RSS and mashups, also individuals with their personal knowledge environments can benefit from arranging services flexibly to help them fulfil their knowledge needs. These personal, collaborative KM initiatives, often associated with trial-and-error, grass-roots level approaches, need to be guided with the design of an organizational and technical infrastructure without loosing the momentum created in KM activities performed by individuals, communities or in projects. This paper outlines a knowledge service governance model suggested to guide activities taking advantage of the mechanisms for light-weight composition of services for handling of knowledge while preserving the (quality) advantages of a controlled service-oriented infrastructure.

## **2 KM Services and mashups**

More light-weight technologies termed mashups have been largely driven by the consumer market and appear to have also large potential for businesses. Mashups can best be described as lightweight applications where end-users themselves arrange contents and functions into new services which can be shared, recombined into other services etc. Mashups access content from a set of data sources, e.g., feeds, spreadsheets, screen-scraped content or HTML pages. Additionally, mashups may access functions (or services) using application programming interfaces (APIs). An API is a collection of functions offered in a provider-dependent form, e.g., as JavaScript library or in a standardized way, e.g., as Web service.

IT companies such as IBM, SAP and Microsoft currently examine using mashups for business applications [Cherbakov et al. 07]. So-called enterprise mashups are Web-based resources that combine content, data or application functionality from more than one resource in enterprise environments by empowering end-users to create and adapt individual information-centric and situational applications [Hoyer and Fischer 08]. The emphasis is on using mashups within the business context by linking them with concepts of service-oriented computing. Enterprise knowledge mashups are a subset of mashups focusing on supporting core KM activities, such as knowledge creation, search, refinement, sharing and use for handling knowledge within, about and from business processes. They can also be characterised as a specific type of knowledge artefact which can be managed with similar KM concepts. For example, the building blocks offered for knowledge mashups will reflect some higher-level concepts representing the core KM activities.

Integrating the concept of these lightweight applications, or so-called situated applications, into robust, scalable, enterprise-wide SOAs has benefits, but also bears problems [Cherbakov et al. 07]. Looking at benefits accompanied with mashups from a knowledge workers perspective, mashups encourage innovation at departmental and individual level. They also improve business solutions by creating applications that fit better with user's requirements, satisfy short-term knowledge workers needs, address niche markets and fill in gaps in the overall IT portfolio. Mashups are developed by non-professional programmers, often in a non-formal, iterative, and collaborative way in order to shorten the development process of design, implement, compile, test and run. In addition, available information and knowledge are enriched by new mashup resources and due to accessing wider Internet communities, information might get

richer as well as more quality assured. Altogether these effects are directly related to improve the use of knowledge in business processes.

Certainly, introducing enterprise mashups also creates some new challenges [Cherbakov et al. 07]. The IT department views these new applications as controlled chaos. There is no formal budget, users are involved as co-developers, applications are developed spontaneously and applications are in perpetual beta. There is little attention on scalability, availability and maintainability and best practices of adoption are non existent. Another area of concern is related to control, security, privacy and integrity, such as how to deal with data ownership, opening up enterprise data resources, the connection of external and internal services and the sharing of these services on a global scale.

### 3 Integrating knowledge mashups into a service infrastructure

A KM service infrastructure adopts the SOA concept by utilizing knowledge services to develop an integrated, process-oriented KM [Maier and Remus 08]. It also provides the backbone for mashups of services depicted in figure 1.

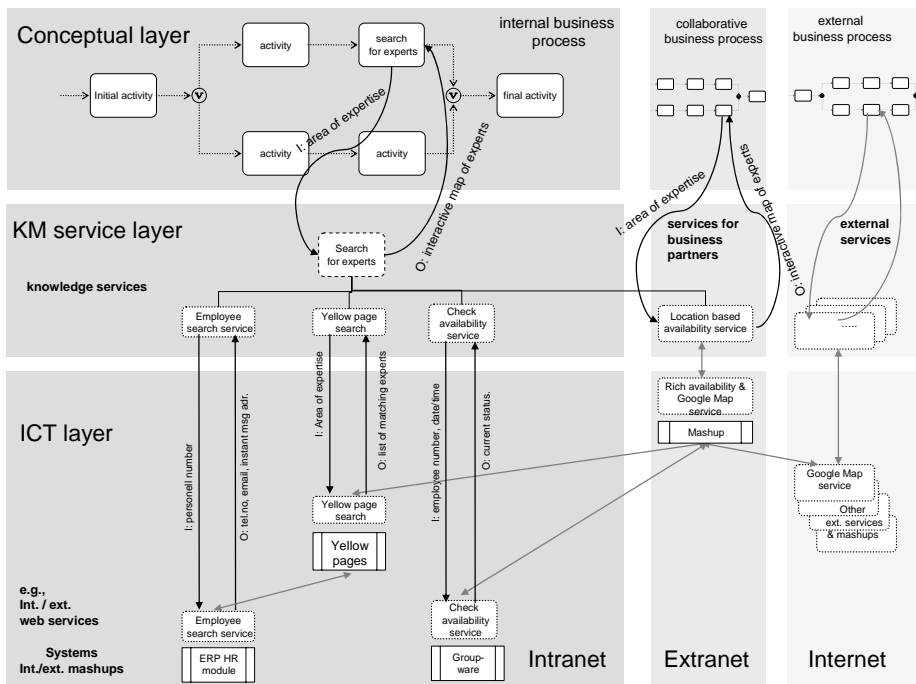


Figure 1: KM service infrastructure

Based on process descriptions, the *conceptual layer* defines which services are required in which core business processes, which services are offered by what service processes, who is responsible for them and what resources are allocated to fulfil them.

The *KM service layer* is introduced to bridge the gap between conceptual and ICT layer. It also defines service levels which are specific to KM and assumes a collection of services available in or accessible for the organization which can be used as building blocks for mashups or for compositions deemed interesting from a knowledge perspective. The *ICT layer* comprises various knowledge services dispersed over heterogeneous systems. In addition, a variety of mashup technologies can be applied to systems internal and external to the organization.

Let us assume a knowledge-intensive business process for allocating field staff, undertaking maintenance work. One of the tasks is to find field workers with the right expertise and allocate them to ad-hoc teams. Following the old process, the allocation manager had to manually search the internal yellow page system by area of expertise, look up the personnel number and then check their availability via the Groupware system. One of the problems was to manually coordinate field workers according to their actual location, and optimize the time to get to the site. Being Internet savvy, she thought of using mashup tools to combine the internal search and availability check with a map which shows the current location of each field worker. She would then be able to use this information to flexibly assemble teams according to their geographic proximity. The first step was to talk to the IT department in order to open up the Web service for allowing internal searches through the yellow page system. The service retrieves data from the employee search service which itself interfaces to the ERP's HR module. The next step was to combine both, the internal yellow pages search service and the check availability service together with the external Google Map Web API into a new enterprise mashup. As the mashup was incorporated into the process, the manager just needs to enter areas of expertise and she can easily browse through a Google map showing actual locations of corresponding field workers.

After having successfully used this mashup for a couple of weeks, a lot of interest emerged to use this service and/or recombine it into other more complex services. Next to some suggestions for improvement, one idea was to open it up for wider internal use, but also expose it to external business partners. The IT department also realized that opening the yellow pages search service triggered a large number of similar requests to have access to existing or create new useful services. In many cases, however, numerous redundant or slightly different services were created in parallel. For example, there is a choice to be made with respect to the internal knowledge service "search for experts". It can be realized with the help of the three composed services "employee search service", "yellow page search" and "check availability service" or by the mashup service "location based availability service". One might assume that quality checks (correctness/availability) in the former case are approved according to a set of organizational standards while the latter is not checked.

This small scenario already shows the need for additional governance, which is currently not covered by common (service) governance models.

## **4 Towards knowledge mashup governance**

Governance is generally a term that has come into wide use recently. From an organizational perspective, many relevant management functions such as finance, HR or business relationships can set up their individual governance mechanisms [Weill and Ross 04]. This is also true for the IT function. IT governance specifies the

decision rights and accountability framework to encourage desirable behavior in using IT [Weill and Ross 04]. It is about determining who systematically makes and contributes to those decisions, about encouraging and leveraging the ingenuity of the enterprise's people in IT usage and ensuring compliance with the enterprise's overall vision and values and about meta planning, thus there is a need to develop, implement and continuously improve a planning system for describing IT objects, structures and processes. Consequently, the idea of governance can be further detailed to frame only a portion of IT decisions, here the handling of knowledge mashups. Many decisions have to be framed here, e.g., who decides on what types of mashups can be developed by users in what way observing which rules and adhering to what standards.

The concept of knowledge maturing [Maier and Schmidt 07] can be applied to describe how using mashups matures in organizations. Thus, similar to SOA governance models, where governance is structured according to the SOA lifecycle, the maturing model can be used to frame a service governance model, specifically adapted to the challenges and needs of knowledge mashups. It would see knowledge services and mashups as a complex eco-system of collaborating providers and consumers of distributed services. Figure 2 shows an exemplary list of steps in the development of using mashups in an organization. At each of these steps, certain rules and policies have to be defined, communicated, enforced, maintained and adapted.

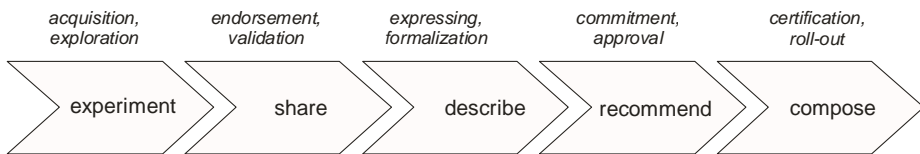


Figure 2: Maturing of mashups

- *experiment*: New ideas for mashups are developed by individuals either in highly informal discussions or by browsing the knowledge spaces available inside the organization and beyond, e.g., in the Web. This step is driven by curiosity and creativity. The mashups are subjectively valuable and deeply embedded in the context of the originator. The main activities that are performed in this step are exploration and acquisition of data and services available to the individual employee.
- *share*: This step is driven by social motives and the benefits that individuals typically attribute to sharing knowledge. These are, among others, belonging to a preferred social group, thus increasing probability of getting back other valuable mashups from the community when one needs them. From the perspective of semantics, this accomplishes an important maturing step, i.e. the endorsement of mashups by community members which results in a validation of their usefulness for the community.
- *describe*: Mashups created in the preceding two steps are often inherently unstructured and still highly subjective and embedded in the context of the community. In this phase, purpose-driven structured descriptions of the mashups are created, e.g., by expressing purpose, sources, procedure and outcome of mashups and thus formalize their deployment.

- *recommend*: Prerequisite for this step is that mashups are tested, found valuable and described well resulting in quality assured patterns of mashups that can be recommended or even prescribed to be used in certain defined situations in an organization. This is based on commitment by a group of users or legitimation by supervisors of an organizational unit.
- *compose*: Finally, in case the mashups have proven so useful and their contents so mature that they can be made a part of the managed set of services composed in a SOA with its promise to comply to regulations. This allows organization-wide roll-out of the composed services and certification in order to increase trust in their quality, validity and security.

## 5 Conclusion and Outlook

Based on the discussion above, it became evident that integrating knowledge mashups into a robust, scalable, enterprise-wide SOA would need a particular governance structure – a knowledge service governance – which is strong enough to guide the design of an organizational and technical infrastructure without losing the momentum of these grass-roots level approaches. Being particularly useful for dealing with evolutionary, collaborative approaches, the knowledge maturing model was proposed to structure possible rules and policies within a wider knowledge service governance model. It hereby addresses governance problems which are typical for these personal, collaborative KM initiatives. The next step would be to further develop this governance framework by detailing rules and policies according to the core KM dimensions, such as people, strategy, organisation and processes, knowledge base, culture and systems.

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# **Will Personal Learning Environments Become Ubiquitous through the Use of Widgets?**

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**Abstract:** Nowadays Personal Learning Environments (PLEs) are described as the use of different social software tools for learning and teaching. The use of common web browsers often is a precondition to fulfil the requirements of social software tools. In this publication a new perspective as well as a couple of prototypes is presented to allow a more independent solution in this context. Using the new JavaFX technology so called widgets are implemented which can be used on different devices as well as different operating systems. Furthermore also the web browser can be replaced by a browser instance. It can be summarized that through the use of widgets the learning environment of the future can be more individualized and personalized.

**Keywords:** uLearning, Personal Learning Environment, Widget, learning

**Categories:** H.3.5, K.3.1, L.3.0, L.3.6

## **1 Introduction**

Web 2.0, first announced by Tim O'Reilly [Reilly, 05], changed the way humans are dealing with the Web. So called social software is widely used to connect people of same interest and helps to exchange thoughts, opinions by sharing and collecting.

Bearing in mind these new possibilities for communication and collaboration also learning and teaching is changing radically. Stephen Downes described it as e-Learning 2.0 [Downes, 05] and pointed out that a future learning environment “becomes, not an institutional or corporate application, but a personal learning center, where content is reused and remixed according to the student's own needs and interests. It becomes, indeed, not a single application, but a collection of interoperating applications—an environment rather than a system”. In the same way Wilson [Wilson, 05] is talking about a user-centred Personal Learning Environment



(PLE). As follow up numerous publications are dealing with the idea of a highly individualized system. Harmelen [Harmelen, 06] expressed that Virtual Learning Systems (VLE) and Learning Management Systems (LMS) are not dealing well with the needs of the learners. Without any doubt from a teacher and learner perspective, the personalization of educational environment will enhance the learning and teaching behaviour. But there are still some problems we have to overcome.

Introducing PLEs by using common social software as mentioned by some research works [Attwell, 07a] [Attwell, 07b] [Schaffert, 08] is maybe not satisfying due to the fact of different restrictions: On the one side the use of different web applications often implicates problems of service stability, accessibility and data protection. On the other side, the implementation of own systems needs high effort and technical support [Green, 06] [Pearson, 08]. A very interesting approach seems to be the use of Mash-Up technology for PLEs as described by Wild [Wild, 08]. But even this approach narrows the user down to a web browser. Due to the fact that ubiquitous learning (u-Learning) is defined as [Zhan, 05]

u-Learning = {u-Environment, u-content, u-Behaviour, u-Interface, u-Service}

interoperability will be one of the major components of personalisation.

In this publication we describe the use of standardized widgets technology and a first idea of how JavaFX (see section 2.3) can be used successfully for a future device-independent PLE.

## 2 Widgets

Widgets (in some applications also known as gadgets) are small client side applications than run on desktop or a web page. In other words widgets are a portable chunk of code that can be installed and executed on any html based webpage or on a desktop. The code is hosted on the client side. It can be a simple JavaScript code or a java applet or an Adobe Flash code for embedding media players. This code usually is embedded in the <body>-tag of an html document on the client side. In this way it provides the graphical user interface of the widget and also its functionality. Widgets enable a very simple distributed knowledge transfer and diffusion. The code that implements the widget can be on any server that is accessible through the WWW. As a result many different distributed services can be provided client-sided such as a CMS or a LMS without any further technical efforts. Widgets are also very often used in personalized homepages, personal desktops or in the PLEs where users are supported to aggregate and create their own configuration of widgets. iGoogle<sup>1</sup>, Netvibes<sup>2</sup>, Protopage<sup>3</sup> and Pageflakes<sup>4</sup> are some examples of such personalized desktops. The following are some projects, which provide end users with many various widgets. Konfabulator of yahoo widgets, Dashboard of apple project, Desktop widgets of Opera and Google gadgets are the most famous projects which also provide developers with some tools to implement the widgets. The only characteristic that these projects have in common is the lack of interoperability for desktop widgets.

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<sup>1</sup> <http://www.google.com/ig> [last visited: 09.03.2009]

<sup>2</sup> <http://www.netvibes.com/> [last visited: 09.03.2009]

<sup>3</sup> <http://www.protopage.com/> [last visited: 09.03.2009]

<sup>4</sup> <http://www.pageflakes.com/> [last visited: 09.03.2009]

They do not follow any open standard development infrastructure. Therefore for each project a corresponding widget engine must be installed at first to be able to run widgets on desktop.

In order to overcome this lack of interoperability a standard has been recommended by W3C as widgets 1.0 family of specifications which will be discussed in the following chapter.

## 2.1 The W3C Widgets 1.0 Family of Specifications

According to Widgets 1.0 Packaging and Configuration [Widgets 1.0 PC, 08], the W3C defines a widget as follows: “*Widgets* are full-fledged client-side applications that are authored using Web standards. They are typically downloaded and installed on a client machine or device where they typically run as stand-alone applications outside of a Web browser. Examples range from simple clocks, stock tickers and news casters to complex applications that pull data from multiple sources to be “mashed-up” and presented to a user in some interesting and useful way.” The specifications [Widgets 1.0 PC, 08] standardize a zip packaging format, an xml based configuration file and a series of steps which developers should follow while they implement widgets. The packaging format acts as a container for files used by a widget. The xml-configuration file declares some metadata and configuration parameters for widgets. Furthermore the expected behaviour and means of error handling for widget user agents are specified.

## 2.2 IST PALETTE and TenCompetence

IST PALETTE [Palette, 08] and TenCompetence<sup>5</sup> are two projects of the European Union which have already implemented the draft W3C widgets 1.0 specification (both packaging and API). Both projects also focus on educational applications. Wookie [Wookie, 08] is a standalone widget engine which was developed as a part of the TenCompetence project, in order to enable learning activities to coordinate the usage of different external tools. It can be integrated into any web application by using the wookie widget factory API. It has the task to instantiate the widgets within the platform and renders them to the user interface of the corresponding web applications. To simplify this integration for existing applications the TenCompetence has developed plug-ins for some famous web applications such as Wordpress, Moodle and Elgg. Unlike Wookie, the widget engine in IST PALETTE [Palette, 08] is implemented as a part of the Palette web portal which means that the integration of widgets in other applications cannot be performed by plug-ins. IST PALETTE [Palette, 08] has extended the widget manifest of the W3C [Widgets 1.0 PC, 08] and added additional default user preference values. Although this extension is advantageous for e-learning systems where widgets can be configured and customized according to their preferences, the TenCompetence’s Wookie widget engine cannot handle these widgets as their manifest file contains extended elements not described in W3C standards [Widgets 1.0 PC, 08]. Both projects have extended the W3C standards [Widgets 1.0 API, 09] in order to enable intercommunications within the

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<sup>5</sup> <http://www.tencompetence.org/> [last visited: 09.03.2009]

application in the background or through drag and drop between the widgets. Events can be fired between the widgets in the application.

### **2.3 JavaFX and widgets**

“JavaFX<sup>6</sup> is a rich client platform for building cross-device applications and content. Designed to enable easy creation and deployment of rich internet applications (RIAs) with immersive media and content, the JavaFX platform ensures that RIAs look and behave consistently across diverse form factors and devices.” [Castillo, 09] It was announced by Sun Microsystems<sup>7</sup> in 2008 and supports the development of PLEs. Widgets can be implemented and integrated in PLEs and users are able to personalize their specific needs through widgets. The next chapter describes FeedBoard and AtomWidget, two widget prototypes developed using JavaFX Platform.

## **3 FeedBoard and AtomWidget**

### **3.1 Introduction**

The implementations of FeedBoard and AtomWidget are both aimed to run on different platforms and devices. The user interface of both applications is designed to be embedded in a browser window, on a desktop as well as on a mobile device. The ability of being platform and device independent enables developers to develop one application and run it on different infrastructure.

#### **FeedBoard**

The goal of FeedBoard is to monitor different feeds embedded in a PLE. FeedBoard is able to run in a web browser, a mobile device, a desktop computer and in future releases even on a television. The current prototype is developed to run embedded in a web based PLE and a mobile device using JavaFX and JavaFX Mobile technology support.

The first prototype just downloads a specified RSS feed, parses it and displays the results on different views. FeedBoard updates the feeds in a specified time interval. FeedBoard notifies the users about the updated feeds if new feed entries are available. Because of the use of JavaFX technology FeedBoard has a big advantage compared to current feed readers. This advantage of FeedBoard is called “Drag-to-Install”. FeedBoard's difference to other widgets is the ability to be dragged-out of the browser window and being “installed” on the operating system by dropping it onto the operating system's desktop. The term “installed” means here that a shortcut is created on the desktop and that the widget (in our case FeedBoard) is added to the list of installed software on the current operating system.

The “Drag-To-Install” feature was introduced by Sun Microsystems's launch of JavaFX Platform. Users are able to select a widget of choice in the web browser, drag-and-drop it out of the browser window onto the desktop of the current operating system. The widget can be started using the automatically created shortcut placed on

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<sup>6</sup> <http://www.sun.com/software/javafx/> [last visited: 09.03.2009]

<sup>7</sup> <http://www.sun.com> [last visited: 09.03.2009]

the desktop even if the browser window has been closed. The browser window doesn't have to be started in order to make use of the widget.

### 3.2 AtomWidget

AtomWidget is the second prototype developed by TU Graz Department of Social Learning and demonstrates the use of a RESTful architecture [Fielding, 00] through a JavaFX application. AtomWidget implements HTTP methods such like GET, POST, PUT and DELETE in order to communicate with a java server called Simple Atom Server. The server of choice for the prototype implementation is called Simple Atom Server and was developed through Jersey<sup>8</sup> a JAX-RS (JSR 311)<sup>9</sup> Reference Implementation for building RESTful Web services. Simple atom server retrieves HTTP requests and returns data in ATOM<sup>10</sup> publishing protocol format. Resources can be added using the POST method, resources can be deleted using the DELETE method. In order to update a resource AtomWidget uses the HTTP PUT method and to retrieve a list or a specific entry AtomWidget uses HTTP GET request method. The communication between AtomWidget on the client side and the simple atom server is being managed over the HTTP protocol and the ATOM publishing protocol. AtomWidget was developed using JavaFX technology and can be integrated into PLEs. Through the "Drag-To-Install" feature of JavaFX users are able to start AtomWidget without a web browser by clicking on the shortcut placed on the operating systems' desktop.

## 4 Conclusions

The W3C specifications are a standard that can be a basis for all PLEs and e-learning systems. Thereby the problem of interoperability is solved. Distributed services can be easily diffused and mashed up in a PLE. As the implemented prototype demonstrates, u-learning can be easily realised by using ubiquitous services independent of the platform or device of learners. Another positive aspect is the user centred model. As [Harmelen, 06] describes, in a PLE the learn objects should be under the control of the learners themselves. The learners can personalize their learning environment by adding ubiquitous widgets relevant to their interests in a PLE in ubiquitous environments, while they are on the way (mobile) or sitting in front of PC. As software systems should always be easy to extend and flexible to changes, the implemented widget prototype meets this requirement by implementing and using a RESTful architecture.

## 5 Future Work

As described in section 3, it is possible in near future to run JavaFX applications on televisions. Another future work is the integration of external services and social

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<sup>8</sup> <https://jersey.dev.java.net/> [last visited: 09.03.2009]

<sup>9</sup> <https://jsr311.dev.java.net/nonav/releases/1.0/index.html> [last visited: 09.03.2009]

<sup>10</sup> <http://atomenabled.org/> [last visited: 09.03.2009]

networks such as twitter, facebook, etc. It is also planned to offer specific university services through widgets. It can be summarized that the use of widgets will enhance the personal learning behaviour towards individuality and independency.

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# A Novel User Interface Approach for Personal and Semantic Knowledge Management

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**Abstract:** We present iMapping, a diagrammatic zooming and nesting based approach for visually structuring information objects on the desktop with a special focus on personal knowledge management. It was designed based on a set of requirements gathered from the analysis of existing knowledge mapping techniques from a cognitive science point of view. We also briefly introduce a prototypical implementation.

**Key Words:** personal knowledge management, knowledge maps, semantic desktop

**Category:** H.5.2, H.4.1, I.2.1

## 1 Motivation

Many knowledge management systems, especially those who rely on highly structured information and meta data being entered and maintained by the users, fail because users do not make this additional effort if they do not have to. This may be one of the reasons why semantic technologies have not found widespread use so far, although semantic meta data would undoubtedly improve findability, interoperability and, in general, automated processing of information and knowledge items. For these technologies to be widely used, they have to provide immediate benefit to the user and it is crucial that they are very easy to use and do not constrain the user in her daily work. This immediate benefit is more likely to be experienced when users manage their everyday knowledge resources like personal notes, files, bookmarks etc. like in the setting of a semantic desktop environment (cp. [SKSB09]).

When semantically formalised knowledge structures are used, content is typically fine grained and highly structured. Such content structures are typically more complex than plain text or classical hypertext structures. Even with the relatively simple structures in classical hypermedia, where we just have inter-linked information objects on the granularity level of whole pages or documents, hypertext research has shown that users often get “lost in hyperspace” when browsing without additional navigational help [Ter02]. This stresses the need for user interfaces that facilitate navigation and authoring of such structures without losing orientation. Using graphical environments for structuring externalized knowledge enables the user to use his highly efficient sense of spatial orientation in his *knowledge space*.

Allowing users to spatially arrange information items may enhance the link between their mental and external models because it enables the use of diagrammatic depictions whose obvious structure corresponds more closely to the structure of the content. This helps the user to intuitively grasp an overview of the subject matter. Unlike text, diagrammatic knowledge representations carry a structural analogy to the content they represent [Sch02].

Research in cognitive and instructional psychology has shown that visual mapping techniques provide easy ways to rather intuitively structure fine-grained information objects—for an overview see [Hal03]. Based on this analysis, related literature, and some user-studies, we derived a set of requirements described in [HA09]. Based on these, iMapping was designed as a new visual mapping approach that tries to unite the strengths of established mapping techniques. It combines these strengths with modern IT approaches like deep zooming and semantic technologies.

iMapping supports the whole range from easy informal note-taking to formalized knowledge engineering in the same powerful, yet easy-to-use environment. The basic metaphor of an iMap is a large pin-board where information items can be spatially arranged, enabling users to gain a visual overview over collections of items at once. These items can represent bits of text as well as (in the near future) any kind of external resources like files, web pages, pictures or other maps. They can also be nested into each other and interlinked in various ways. Besides browsing by links, users can navigate an iMap by zooming through it.

## 2 iMapping Design and Functionalities

The iMapping design is based on the requirements described in [HA09] (in this volume). It combines functionalities from several of the related tool categories sketched in Sec. 4, none of which cover all of these functionalities themselves. These are in particular: (i) visual knowledge representations with structural analogy to content; (ii) easy hierarchical overall topology; (iii) providing overview by integrating context and detail through zooming; (iv) facility for graph-based relation mapping; (v) allowing constructive ambiguity; (vi) support for formal semantic statements and (vii) and querying these semantic structures at the various levels of formality they have (mainly through the QuiKey extension mentioned below). To be more concrete, here are the basic functionalities of iMapping:

**Basic Hierarchy of Information Items.** The basis of iMapping is a large two-dimensional surface where items can be freely placed. Usually (e.g., for personal note-taking or idea management), these items will be short text passages. The size can vary from just a keyword to a short note or whole paragraphs including rich text marked up by using a wiki syntax provided by the CDS back end. These items can contain other items such that one can use microcontent rather than long, unstructured text passages. Longer texts are then a sub-map containing a sequence of smaller text-items. The iMap hierarchy goes down into deeply nested nodes which can be zoomed into (see Fig. 1). There can be multiple visual instances of one and the same information object, because it may be relevant in different contexts.

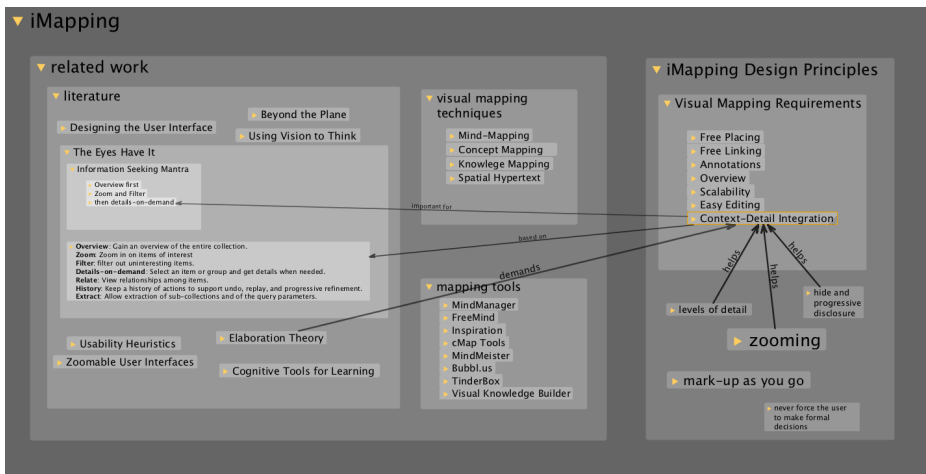
**Adding and Creating Content.** Adding content to an iMap is done by clicking anywhere in the map and typing some text. It is always possible to add vague and unstructured content. Although allowing for semantic knowledge management, it has been a fundamental design decision, to never force the user to specify any semantics. Content can later be refined and formalised incrementally.



**Levels of Detail.** Some information objects—especially text—are rather hard to recognise when they are scaled down to thumbnail size. So, composite items have two possible states: open and closed (expanded/collapsed).

**Establishing Link Structures.** There are three different ways of interrelating items in an iMap: (a) *linking* on an item level (stating a relation between two objects). Each of these can be mere navigational links or carry formal semantics, if specified. (b) *nesting items* into another (c) relating them by short semantic statements with QuiKey

To avoid the confusing “spaghetti syndrome”, links (arrows) are not shown by default, but only made visible on demand, depending on user settings—e.g. on mouse-over (see Fig. 1). Explicitly drawn links stay visible permanently. In the same way, items can be semantically interrelated by drawing links between them which can then be typed. If this is done using auto-completion, reuse of existing relation types is fostered.



**Figure 1:** Sample iMap with link-structure of one item made visible.

### 3 iMapping Implementation

The current prototypical implementation of iMapping is based on java and makes use of the zooming user interface framework piccolo (See Sec. 4). It is complemented by QuiKey<sup>1</sup>, a kind of smart semantic command-line that focuses on highest interaction-efficiency to browse, query and author semantic knowledge bases in a step-by-step manner. The data model and back-end used by both iMapping and QuiKey is called “Conceptual Data Structures” (CDS):

<sup>1</sup> For further information on QuiKey see <http://quikey.info/>.

### 3.1 Conceptual Data Structures

CDS is a lightweight top-level ontology about relations that naturally occur in common knowledge artefacts. It is designed to bridge the gap between unstructured content like informal notes and formal semantics like ontologies by allowing the use of vague semantics and by subsuming arbitrary relation types under more general ones. By that it is suitable for representing knowledge in various degrees of formalisation in a uniform fashion, allowing gradual elaboration. CDS serves two purposes here:

First, as a flexible semantic data model providing a set of crucial structural primitives that can be extended by the user. The core top-level relations in CDS e.g. are *order* (before, after, etc.), *hierarchy* (corresponding to item nesting in iMapping and subsuming semantic relations like *is\_a* and *part\_of*), *linking* (subsuming hyperlinks as well as any other freely specified relation carrying formal semantics or not) and *annotation* (subsuming free-form notes as well as tags and types).

Second, the java-based CDS-API serves as a back-end for both iMapping and QuiKey, providing basic querying and reasoning functionality. Furthermore, like that the data entered in either of these tools can also be accessed and edited by other CDS-based tools like the browser-based CDS workbench HKW<sup>2</sup>.

For more information about CDS see [VH06].

## 4 Related Work

As a rather novel GUI approach for personal and semantic knowledge management, iMapping has a unique position and there is no directly comparable approach known to the authors. But, of course, there are many related fields of work which contributed ideas to the design and realization of iMapping:

**Visual Mapping Techniques:** are methods to graphically represent knowledge structures. Most of them were developed as paper-based techniques for outlining, brainstorming, learning facilitation or for eliciting knowledge structures. Most of these techniques are related to one of the following basic approaches:

*Mind-Maps* [BB96] provide an easy-to-understand, tree-like structure for outlining a topic or for sorting items. But they are not suitable for relational structures between items because they are constrained to hierarchical models.

*Concept Maps* [NG84], on the contrary, have a graph-based structure which emphasizes these relations. But they are not as easy to handle because explicitly specifying all these relations is too laborious e.g. for simple note taking or brainstorming.

*Spatial Hypertext* is for viewing a self-contained hypertext from an overview perspective, by spatially arranging single pages. However, the Spatial Hypertext paradigm expressly abandons the concept of explicitly stating relations between objects and uses spatial positioning as the basic structure. To fuzzily relate two objects, they are simply placed near to each other, but maybe not quite as near as to a third object. This allows for so-called “constructive ambiguity” [SM99] and is an intuitive way to deal with vague relations and orders. While Spatial

<sup>2</sup> <http://semanticweb.org/wiki/HKW>

Hypertext in its pure form is not suitable to author formal knowledge structures needed for semantic knowledge management, the general approach may well be used as a User Interface basis. For an overview over visual mapping approaches and the cognitive psychology underlying them, see [Hal03].

**Zooming User Interfaces:** Pad and its successor Pad++, both developed in Maryland<sup>3</sup>, were the seminal developments in this area. It has been used in various applications and also as a web browser capable of showing the viewed web pages and their link-structure from a bird eye's view. The work on Pad++ finally led to "Piccolo"<sup>4</sup>, a toolkit in Java and .Net that supports the development of 2D structured graphics programs, in general, and, in particular, Zoomable User Interfaces like iMapping, whose current implementation is based on it.

**Semantic Desktops** DeepaMehta [RVH05] was one of the first semantic desktop systems. It lets the user freely specify semantic relations between typed information items on a topic maps basis. It provides a graph-based UI in a thin client. Once an item (or relation) has been specified (in a topic map), DeepaMehta keeps it in a background repository on the server, independent from whether they are still part of an actual topic map. This separation between the structural model and visual model is also adopted in iMapping: it allows multiple (visual) instances of an item to be used in different contexts or locations—much like hard links in a Unix file system. Also, through the use of CDS, the same structured data can be used in different tools.

Several iMapping Prototypes and also most of the current implementation has been developed as part of the *Social Semantic Desktop* project "nepomuk"<sup>5</sup>. For more information on semantic desktop systems in general, see<sup>6</sup>.

## 5 Discussion and Future Work

We have used repeated formative evaluation [Scr91] to guide our design decisions. Further evaluations are being carried out. First evaluation results where an iMapping prototype has been tested against the market leading mind-mapping application "MindManager", seem to encourage the iMapping design, as interaction speeds did not differ significantly while users preferred the iMapping application. The exact results of this study are still in the publication process and can be obtained soon from the website mentioned below.

Limitations of the current iMapping implementation that are subject to ongoing and future work include the following: Currently, there are only text-items. In the future, it should be possible use external content in iMaps, such as pictures, documents and web pages. The layout of items in a map could be parsed to extract implicit structures, like sequence, and proximity. Formal semantic refinements of content structures could be unobtrusively proposed during informal interaction ("mark-up as you go").

Semantic knowledge management technologies might in the future be able to significantly increase interoperability. However, if knowledge management does

<sup>3</sup> <http://www.cs.umd.edu/hcil/pad++/>

<sup>4</sup> <http://www.cs.umd.edu/hcil/piccolo/>

<sup>5</sup> <http://nepomuk.semanticdesktop.org>

<sup>6</sup> <http://semanticdesktop.org>

not start on a personal level, providing immediate benefit to the single knowledge worker, it is questionable whether semantic knowledge management systems will ever spread very far. Focusing on user interaction and cognitive ergonomics will be an important point there, especially because in knowledge-intensive tasks, a user can barely afford to sacrifice much of his limited cognitive capacity [Mil56] to dealing with the tool instead with the content itself. iMapping-based user interfaces could be a step to make highly structured knowledge management in different levels of formalisation easy and intuitive.

For more information on iMapping and to download the latest implementation, see <http://imapping.info/>.

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## **SkiBaserl – Knowledge Management in High-Performance Sports**

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**Abstract:** Bringing together knowledge bearers is a crucial factor for innovation in high-performance sports. Since the capabilities of a growing amount of nations are converging, every detail counts to win a competition. To harness the competence, experience and knowledge of various stakeholders, the Innovation Network Alpine Skiing has developed a custom-designed knowledge and idea management system. Having adapted Web 2.0 technologies to the requirements of innovation in the special environment of high-performance sports, the knowledge workers are enabled to easily contribute to the innovation process. The Wiki-based solution called “SkiBaserl”<sup>1</sup> is successfully used in several development projects within the German Skiing Association. This article delivers an outline of the development process, the implementation and an evaluation of the tool.

**Keywords:** social software, wiki, high-performance sports, knowledge management

**Categories:** M.0, M.8

### **1 Introduction: Web 2.0 goes High-Performance Sports**

The Internet has experienced an enormous evolution. Users have developed from pure consumers to contributors who not only read content but also provide, edit, evaluate and comment. The keyword is “participation”. The willing and active involvement of many users, independent of organisational constraints, processes, technologies or certain platforms, represents the main characteristic of Web 2.0 [O’Reilly 2005].

The straightforward possibility for everyone to contribute to the big picture can enrich many approaches to knowledge management.

This is exactly what companies try to benefit from within their intranets. Since the knowledge, know-how and qualification of employees is a crucial resource, it bares enormous potential to facilitate their contribution. Thus, for business purposes the expression Enterprise 2.0 has been introduced by [McAfee 2006]. Immanent in this term is the question about the deployment potential of Social Software in companies. Compared to the private use of these tools, they have to master different and company-specific intranets challenges. When designing a socio-technical tool the

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<sup>1</sup> The term “SkiBaserl“ consists of Ski (German for skiing) and the Bavarian diminutive for database, “Baserl”.

integration of organisational structures and processes has to be taken into account. Having adapted Web 2.0 solutions to the enterprise environment, these tools offer powerful opportunities to distribute tacit knowledge and best practices companywide.

For in-company operation, these tools are adjusted to company context and additionally enriched by experiences with existing intra-company tools. E.g. the online-encyclopaedia Wikipedia or the social networking platform Facebook have already served as role-model for the prototypes of several companies [Back et al. 2008; Buhse and Stammer 2008; Coleman and Levine 2008; Cook 2008; Koch and Richter 2008].

The success story of Web 2.0 based tools inspired the task force within the Innovation Network Alpine Skiing to follow the example. Hence, one main challenge of the SkiBaserl Project was to select and adapt Social Software to the again different requirements of innovation in high-performance sports in general and the environment of the German Skiing Association in particular.

Within the scope of this article, the “high-performance sports 2.0 scenario” is presented from the project team’s point of view. In the next chapter the method applied during the development is introduced. Moreover the special requirements of a knowledge management tool that is used in high-performance sports are summarized. In chapter three the solution itself – the SkiBaserl – is briefly presented. In chapter four several lessons learned from the development and from the introduction are presented. Chapter five gives a brief outlook for the future of the SkiBaserl.

## **2 Background and Methods**

What separates the high-performance sports environment most from a classic Web 2.0 setting are the special stakeholders and the use scenarios. The Innovation Network Alpine Skiing cooperates on a scientific level with a heterogeneous network of different experts (kinetics and training science, sport technology, medicines, software technology, innovation management, etc.).

These involved persons participate in organized, complex (knowledge-intensive) projects. Among them are knowledge bearers and idea suppliers who are only to a small extent bound to their desk. There are also those, who are equipped with interesting information and experiences from their expertise of work, which usually are not available for other actors. Consequently, prior knowledge management was done decentralised on the participant’s laptops (and in their heads). The vision of all partners was to create an all-time accessible knowledge base. It should allow easy contribution and retrieval access to increase the number of idea suppliers in the sense of an open innovation process [Reichwald and Piller 2006]. Especially insights and experiences about the many, potentially innovation-relevant fields should be made easier to document, comment and be sustainably accessible.

Based on these, deliberately abstract needs and wishes, a Wiki was chosen as technological base. This Wiki was integrated as far as possible into the work environment and processes of the participating actors. Due to the not too IT-affine users and their motivation to contribute, focus was laid on embedding the technical solution in a social context and a joyful work environment.

To reflect on and evaluate the development of the SkiBaserl the action research method was applied. The special characteristic of action research is that the researcher

takes an active role in the development process. Thus, the combination of theory and practice is the basis for a better understanding of complex problems in specific situations and contexts.

According to [Baskerville and Wood-Harper 1996] the five prerequisites of action research are

- the existence of an accepted theoretical model: in our case innovatorics for high-performance sports [Moritz 2006].
- the active involvement of the researchers in the five phases of the action research process. [Susman 1983] entitles the phases that incorporate an iterative, cyclical process as follows: Diagnosing, action planning, action taking, evaluation and specific learning. The authors were involved in all five phases.
- the structural and continuous recording of the findings. Therefore detailed interviews and surveys of the development team were conducted on a regular basis. In addition the handling of the prototypes and wiki were observed.
- the possible instantaneous appliance of the findings for both sides.
- the iterative and durable connection of theory and practice.

These five prerequisites of action research were considered during the whole project.

### 3 The solution: Skibaserl

The Wiki-based *SkiBaserl* enables users to store, organise and obtain information and knowledge by a web-based password-protected interface. The integrated WYSIWYG-editor acts as an enormous simplification for new and meta-text illiterate users. In addition, users were given the option to send contents or whole pages per mail to the “*SkiBaserl*”. When necessary, those were adjusted by one of the two “Wiki gardeners”. These are employed as administrators to keep a uniform structure in the Wiki. Thus, they monitor the distribution of tags and adjust them where necessary. Concerning the tags’ structure, three categories emerged as being helpful. Tags were distributed to certain subjects (e.g. “aerodynamic”, “gliding” or “technique”), content description (e.g. “experience”, “technological know-how” or “innovation”) and finally individual project titles. (e.g. “orthotic”).

To support the innovation work, the methodology [Moritz 2006 and 2009] is integrated in the Wiki and illustrated with earlier projects of the Network Alpine Skiing.

Great relevance was given to the term “joyful use”. It unites all means that promote the Wiki above the level of user-friendliness and towards a system one loves to use. For example the terms in the *SkiBaserl* were kept as simple and colloquial as possible. The site map is entitled “What’s new?” and the button for site-creation is labelled “I know something”. Furthermore, emphasis was put on presentation and assembly to support browsing (keyword: “serendipity”).

### 4 Lessons Learned

The lessons learned are structured into two phases. Firstly, the experiences during the development phase (in collaboration with the users) are described and, secondly, the

impressions of the development team according to the introduction into productive work are explained.

#### **4.1 Development**

Below, some measures are listed and described which supported the development process and helped to adapt the Wiki to the needs of the users and its periphery. Great importance was placed on cooperative and open interaction, to avoid ‘gaps’ between experts, athletes and technicians and to communicate among each other on the same level. Straight away the initial meeting was held “in snow” on a hut in Garmisch-Partenkirchen and had a positive impact on the motivation of the task force. After the primary phase of mainly theoretic work the first working prototype was like a catalyser for the project. By using and testing the technical implementation a lot of valuable information was gathered that helped to improve the system in a further iteration loop.

Regular presence-meetings to discuss the development progress of “SkiBaserl” had a positive influence on the atmosphere in the team and galvanised (especially) the (partly inactive) users into action. The integration into ongoing projects (e.g. creation of many contents of as many diverse users as possible) was necessary to identify potential usage capabilities. In this context, it became clear that the identification of usage scenarios did not take place disconnected from the system. Instead, it went hand in hand with the usage of an early prototype.

It was known from the beginning, that a majority of users is not very IT-affine. Therefore, the simplification of the platform (slimming) had priority as well as measures to increase motivation and simplification of usage, especially those of the WYSIWIG-editor. Editing Wiki-pages played a central role. Sadly, neither open-source-plugin-ins nor commercial tools are very well-engineered at the moment. Especially problematic were the users’ expectations to find functions comparable to office solutions like MS Word. Finally, as a solution to this, a strongly adapted version of the editor TinyMCE was employed, as well as active work on the users’ expectations. Unexpectedly, the Wiki’s property of being a web-based platform emerged as a great usage motivation. The users emphasised that, beside data security (“once entered, forever accessible”), the Wiki encouraged to revise document content and to restructure it compared to a text document.

As expected, awareness functions like “latest changes” were employed by the users with increasing favour. It appeared, that the highest barriers (and consequently, strongly de-motivating factors) were non-transparent functions or reactions of the system like little bugs in the editor. Here, a fast reaction and clarification by the administrators were necessary and helpful.

#### **4.2 Change Management**

In the course of the Wiki’s adaptation, it became clear that openness to change requests is an important factor of success. True to the motto of ‘trial and error’, the users were animated to experiment. Accordingly, in the beginning numerous features were provided and the ones that turned out to be redundant were deactivated over time.



During operation in a pilot development project, it became clear that various navigation tools are necessary, since user groups, intentions, and projects tend to differ considerably. Now it's possible to navigate through SkiBaserl with the help of tags, a file structure, or the search function.

At the beginning, it was also uncertain how access authorisation to individual, confidential pages should be handled. To avoid additional barriers and to create an innovation friendly climate, it was decided to keep all pages accessible for every user. For individual cases, it was decreed that highly confidential contents should not be saved in SkiBaserl. This case has not yet occurred.

### 4.3 Summary and Discussion

Summing up the lessons learned the most important experiences of the socio-technical solution, the development process and the introduction period are outlined.

Simplicity and joy of use were identified as the main success drivers of the technical solution. Furthermore the consideration of and support for different use scenarios and user groups played an important role. During the development process the adaption of the wiki was in the centre of attention. Therefore the integration of several auxiliary plug-ins, regular face-to-face-meetings and the teambuilding event as well as the fast reaction to bugs turned out to be very relevant. In the introduction period the most important factors for success and acceptance were openness to users' change requests and thus the adaption to use scenarios, not having been taken in account so far.

As a matter of course the results are closely related to the development and introduction of a knowledge management tool into the specific context of innovation in high-performance sports. For this reason one has to be aware of two constraints regarding the usefulness and transferability of the results to similar projects. The conducted action research cannot deliver information about long term reliability and return on investment of the SkiBaserl and a different area of application might have different needs and requirements. Nevertheless our results can serve as suggestion for the introduction of a wiki in similar environments.

## 5 Future Prospects

By now, the SkiBaserl has been deployed in several cooperation projects. According to the users, the cooperation in innovation projects can be considerably improved. Not least because the different knowledge bearers have a central contact point where to provide and retrieve information. The crucial detail deciding about success or defeat in a competition might be in there.

However, work on SkiBaserl is continued. Up to now, it is adapted for information and knowledge management in the Innovation Network Alpine Skiing. Notwithstanding it provides potential for interpersonal communication to foster the informal communication and motivation. Therefore in another step, a blog and a chat shall be integrated. Further on, focus will be placed on "joyful usage".

The integrated music-player of an user plays in the background: Wolfgang Ambros sings enthusiastically: "Skiiii foan!"

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## **Study: The Web 2.0 – a High Capacity Research Landscape for Professional Translators?**

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**Abstract:** Professional translation services are often perceived as quite expensive and people tend to go for the lowest price possible when commissioning a translation. To stay capable of competing with lay translators, professional translators have to continuously increase the efficiency of their work process. Researching information consumes a considerable part of the time needed for producing a high-quality translation. This work evaluates whether Web 2.0 applications with their social and collaborative characteristics have the potential to support the professional translator in his daily work. Here the main focus of attention is on a possible increase in efficiency of search and knowledge management processes. In phase one of the study we conducted a survey to determine the translator's preferred search tactics, knowledge resources, and communication channels. Secondly, we conducted user tests on a Web 2.0 social media sharing platform followed by open interviews to find further evidence for the potential of Web 2.0-based collaborative applications in the professional translator's business.

**Keywords:** professional translation, search actions, Web 2.0, knowledge management, expert networks

**Categories:** M.0, M.3, M.7, M.8

### **1 Introduction**

The demand for professional translation services has increased significantly over the past years. Nevertheless professional translators still have to justify the prices for the services they provide. Business clients tend to consider translation services as costs rather than as investments. And there is still the wide-spread belief that anyone who can speak a foreign language and has a dictionary at hand makes a good translator [Nord, 2002]. Professional translation is a communicative action embedded into a specific situation and requires various language and intercultural mediation competencies [Risku, 2006]. Translating, as writing texts, is a creative process.

Therefore, machine translation results do not comply with the requirements of a high-quality translation product [Beste, 2006].

Up to 75% of the time a professional translator needs to prepare a high-quality translation is spent for searching for relevant information and terminology [Austermühl, 2001]. The use of Computer Aided Translation (CAT-) tools enabling the re-use of vocabulary for new translations is very common in the translation industry [Keller, 2006]. However, the search for context information (e.g., Which are the devices of an espresso machine?), domain-specific terminology (e.g., Is it called *foaming*, *frothing*, or *steaming* milk?), the management of the translators' knowledge resources [Budin, 2002] and the continuous enhancement of their competencies still remain a day-to-day challenge.

Many professional translators work remotely or in small translation companies and their interactions for knowledge exchange or collaboration among each other are quite limited. Online communities dealing with foreign languages and translating like [www.leo.org](http://www.leo.org), [www.translationdirectory.com](http://www.translationdirectory.com), or [www.aquarius.net](http://www.aquarius.net) exist. However, these platforms mainly provide discussion forums and acquisition tools.

Could Web 2.0 with its collaborative bookmarking, community building, communication, and data preparation functionalities be a remedy to the situation explained above? Which Web 2.0 applications can actually support the translators' search and knowledge management processes? How could a search or knowledge transfer scenario in a translators' expert network look like?

This paper provides an informative basis on how Web 2.0 applications could be used to support professional translators in their daily work. After a short introduction of the topic in Section 1, Section 2 provides an overview of related work done in the past. Section 3 presents the results of the survey conducted in phase one of the study. The scenario test performed on the social media sharing platform ALOE [Memmel, 2008] and its results are presented in Section 4, followed by a summary and conclusions in Section 5. Section 6 provides an outlook on future research in this area.

## 2 Related Work

Results of a previous study by Britta Nord [Nord, 2002] show that the average translator uses knowledge resources 17 times per hour while addressing six different resources per query. The reason for any research action is a cognitive deficit which occurs anytime the translator has a question on a source text unit. Nord focused on traditional, non-web-based knowledge resources like print dictionaries and reference material. Her findings don't give any evidence on how relevant digital or even web-based resources are for the professional translator. The lack of empirical data on user patterns of web-based collaborative applications among professional translators made it necessary to conduct a new study. Therefore, we conducted a survey asking for professional translators' search and communication behavior. Additionally, we prepared a closed experiment with a Web 2.0 social media sharing platform to learn more about translators' affinity towards Web 2.0.

### **3 Survey on Translators' Search and Communication Behavior**

In this study, 70 professional translators who are members of the German Translators Association BDÜ<sup>1</sup> were randomly contacted and asked to complete a questionnaire asking for their affinity for various knowledge resources, communication channels and online communities. Fifteen of the questionnaires returned were filled out completely and thus could be considered for the analysis. The participants' average age is 36.3 years, they have 10.3 years of work experience and 87% are freelancers. 87% of the participants are female. They dedicate 19% of their overall working time to search actions. The majority of the participants describes the research process as an essential part of their daily work (93%) and perceives it as quite time-consuming (53%). However, 87% of the group state that the Internet facilitates the search process significantly compared to former times.

#### **3.1 Resources used most frequently**

The participants state that in the majority of cases, they would address their queries to search engines, online dictionaries, and Wikipedia.org, followed by print dictionaries. Typical web-based collaborative applications and Web 2.0 technologies like wikis (excl. Wikipedia.org), weblogs, discussion forums, podcasts etc. [Gehrke/Gräber, 07] are seldom used. The majority of Web 2.0 applications are not well-known or even completely unknown in the group.

#### **3.2 Communication channels used most frequently**

The majority of the persons interviewed (60%) communicate with other professional translators on a regular basis. Traditional communication channels such as e-mail (used in 33% of cases) and phone calls (used in 27% of cases) are used most frequently among the survey participants. Considered quite helpful are face-to-face conversations (helpful in 50% of cases) and their online equivalents discussion forums (helpful in 34% of cases) or instant messaging (helpful in 23% of cases). However, all three communication channels are not used frequently. These results indicate that online communication channels are considered valuable but have not been adopted by professional translators for business use.

#### **3.3 Online communities and collaboration**

53% are members of an online community for professional translators. 47% use a community for order acquisition purposes. No one of the participants shares their knowledge resources online with other translators. This indicates that professional translators expect from an online community to benefit in terms of order acquisition rather than having the chance to enhance collaboration and knowledge exchange.

One third of the group state they would only share their knowledge resources with other professional translators in a closed community. A reason for Web 2.0 applications not being used to their full potential among professional translators could

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<sup>1</sup> <http://www.bdue.de>

be the fear of “losing knowledge” to lay-translators in open communities and thus losing competitive advantages.

### **3.4 Conclusion**

The results of the survey conducted in phase one of this study indicate that Web 2.0 applications are still not well-known among professional translators and have therefore not yet been adopted. Professional translators seem to rather keep their knowledge to themselves instead of sharing it with a large community so they would keep ahead of competition. Nevertheless, web-based communication channels are considered more helpful as their frequency of usage among the participants might suggest. This could be an indication for the potential of Web 2.0 applications that support communications and knowledge exchange in the translation business.

In Section 4, we describe how a search scenario for professional translation purposes could look like when using Web 2.0 applications and how we conducted user tests based on this scenario. Additionally, we discuss the main findings of an open interview conducted with the test users after the test.

## **4 Scenario tests**

The scenario test was realized on the social media sharing platform ALOE of the German Research Center for Artificial Intelligence (DFKI) Kaiserslautern. Based on collaborative actions and collective intelligence strategies, ALOE enables end users to systematically organize and share knowledge resources. All kinds of resources can be easily saved directly on the platform or, in case of external resources, bookmarked. Collaborative tagging, ranking, and commenting ensure a clear description of the content and facilitate the retrieval of the resources on the platform. Registered users can also be found based on the metadata they assigned to resources. This enables the formation of expert communities [Mommel, 2008].

### **4.1 Theoretical scenario**

The theoretical scenario outlines a search process in the environment of an expert community which uses Web 2.0 applications: A professional translator faces a cognitive deficit during the translation process. In this situation, there are at least two possible ways Web 2.0 applications could support them in finding the answer to their question. Either they know that their professional or social network includes an expert in the particular field and they contact this expert immediately using a web-based communication or collaboration tool (if, e.g., the expert needs to have a look at the source text). Or they are member of an online community dealing with the particular field and therefore able to use the other experts' knowledge resources saved on a platform and easily accessible through, e.g., collaborative ranking and tagging tools. Long and inefficient search actions could thereby be eliminated.

### **4.2 Scenario-based user test**

The scenario-based user test was conducted with three graduate professional translators. It simulated the core translation work flow with special regards to research

actions on the web-based collaborative platform ALOE. Apart from ALOE and the internet, the test users did not have any other knowledge resources available to ensure that they would direct their queries to web-based applications only.

In order to assure that the test persons would not only use the ALOE platform as a simple information resource collection but simulate an expert network, we decided to assign fictitious expert identities to the test users and allocate corresponding knowledge resources, which had already been prepared in the run-up, to their ALOE user profiles. The topics of the texts to be translated by the test persons during the scenario correlated with their fictitious expert identities while overlapping in topics. It was not possible to track all user actions on the platform due to the limited resources available. Therefore, an open interview was conducted after the scenario test to obtain qualitative user feedback as described in the following section.

### **4.3 Qualitative user feedback**

The participants were asked for feedback regarding their experiences while working with ALOE. All test persons stated that ALOE's functionalities like the tagging and rating of resources facilitate finding relevant information and managing knowledge resources. Especially the possibility of finding domain experts and contacting them instantly or using their knowledge resources was considered to be of great help when facing a cognitive deficit. In such case, all test persons prefer to ask an expert directly rather than searching for information in digital or hard-copy resources. All participants would share knowledge resources on a web-based translators' community platform, preferring a closed community for professional translators only. However, they all agree that mutual support among translators might increase the efficiency of the research process as well as the quality of the translation product.

## **5 Summary and Conclusion**

Based on the idea of ensuring efficiency and quality in search actions as part of the core translation process, in phase one of this study a survey was conducted to find out how Web 2.0 applications are used among professional translators today. In a second phase, a scenario-based user test was conducted on the social media sharing platform ALOE in order to investigate whether professional translators have an affinity for Web 2.0 applications. In the survey, 87% emphasize that the Internet facilitates their search actions significantly. However, collaborative Web 2.0 applications have scarcely been adopted by the professional translators' community so far. The user tests outlined possible scenarios of how web-based collaboration could increase the efficiency of translators' search actions. Especially the fact that experts and their knowledge resources were easily accessible was regarded as a strong advantage by the test users as they stated in the open interview after the tests.

## **6 Future Work**

To find out how Web 2.0 applications could make a high capacity research landscape for professional translators and enable knowledge exchange, translators' individual

expert networks are to be investigated using the method of social network analysis. In a second step, Web 2.0 applications which support exactly the relationships identified will be bundled on a platform. Scenario tests are supposed to give evidence on whether Web 2.0 applications can increase the efficiency of the professional translators' search process making use of collective intelligence, division of labor, and specialization in the professional translators' expert community. Preparation of this study has already started and first results are expected by March 2010.

### **Acknowledgements**

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## Usage Metadata Based Support for Learning Activity Reflection

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**Abstract:** An important activity for the learner while learning is the reflection on the learning path and strategy. So far, not many tools provide an automatic support for the reflection on the learning activities. Here, we describe our approach to enable reflection with the help of usage and contextual metadata. We describe how we capture usage information and provide algorithms like the identification of similar users, contents and tools for reflection like a learner Zeitgeist application or the elicitation of learning paths.

**Key Words:** usage metadata, learning path, learning reflection, learner zeitgeist

**Category:** H.4, M.6, J.5, L.2

### 1 Introduction

Today, an increasing amount of educational activities is carried out online. Many courses offer supplemental learning material needed to pass. Teachers provide access to their learning resources, include students within the respective learning management system that is used to manage learning resources, assignments and learning outcomes. Students use the web to find learning resources using respective learning management systems, search engines like Google or specialized portals like MACE<sup>1</sup>. Furthermore, students use the web to collaborate on their learning assignments using respective tools like ALOE<sup>2</sup> or just simple email, chat and file sharing tools.

Reflection on the learning path is one of the key principles to improve the learning process [Moo99]. So far, the tools used by students and teachers provide only little support for the reflection on the learning path and behavior. Instead, tools provide access to formal results of learning activities like the grades obtained on an assignment. Or, if students are asked to continuously publish their

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<sup>1</sup> <http://www.mace-project.eu>

<sup>2</sup> <http://aloe-project.de>

work progress, teachers use the opportunity to give direct feedback to the student work. Furthermore, ePortfolios are used to collect the works and results of students and thereby represent the student's achievements. Consequently, reflection is provided only at the end of the learning activity.

We strive to provide the learner with reflection on her learning path even during the learning activity. In other words, we aim to be able to continuously provide feedback on the various learning steps taken. In addition, we enable students to review their activities in the light of the achieved results. Note that if the used learning system provides access to the learning results, the correlation of learning activities and achieved results can be done automatically to some extent to improve learning strategies. Such an example is described in [WMD07].

From our perspective, a learning path is a simple time-sequence of activities of a user within a certain environment geared towards achieving a learning goal. The activities are represented as observations on the application level, therefore unifying observations from all applications. In general, the observations can be captured locally on a user's computer by observing her interaction with applications. Additionally, the observations can be captured remotely by observing the interaction of a user with a server or over a network. Both sources – local applications and network servers – can be exploited at the same time. Here, we focus on one learning environment that encompasses a number of servers.

In this paper, we describe the necessary technology that enables us to provide feedback on the learning path taken. Specifically, we describe how the observations about student activities with the combination of the specialized thematic portal MACE and the social community hub ALOE enable learning path feedback. The MACE-ALOE system provides the environment in which the observations about the user are captured. We therefore concentrate on the server-side collection and exploitation of observations.

The combination of MACE and ALOE is described in Chapter 2. Chapter 3 discusses the MACE Zeitgeist application while Chapter 4 presents steps towards the derivation of learning resource profiles and learning paths. Chapter 5 concludes the paper.

## 2 Metadata in the MACE and ALOE systems

The MACE system [SVC<sup>+</sup>07] provides a specialized thematic portal that makes architectural learning resources available across repositories. Thereby, we provide access to digital learning resources that are distributed in various world-wide repositories. In order to facilitate access, various types of metadata about the learning resources and the user activities are employed. The learning resources are described utilizing an extension of the Learning Object Metadata (LOM) standard, thus forming an application profile [DHSW02] of LOM for the use

within the MACE system. The learning resource descriptions are stored centrally in the MACE store whose mechanism is described in [PTdJ<sup>+</sup>07]

In addition, we capture the usage of the learning resources through and within the MACE system. The observations, represented in the contextualized attention metadata (CAM) format [WNVD07], are stored in the usage metadata store of the MACE system.

The MACE system is intertwined with the ALOE system. ALOE is a web-based social media sharing platform that allows to contribute, share and access arbitrary types of digital resources such as text documents, music or video files. Users are able to either upload resources (using the system as a repository) or by referencing a URL (using the system as a referatory; called bookmarking). Users can tag, rate, and comment on resources, they can create collections of resources, join and initiate groups etc. Furthermore, arbitrary additional metadata can be associated with resources.

The ALOE system provides observations of user activities related to the MACE system. These observations are also stored in the MACE usage metadata store. See [MS07] for more information about ALOE and the underlying system architecture.

### 3 Zeitgeist as means of reflection

Here, we briefly describe the Zeitgeist application as an analytical statistic tool for learner reflection that is based on CAM. It provides a simple time-based overview of activities in the MACE system as a first step towards a reflection on the learning path of a user. The learner is able to analyze which learning resources she accessed when, how she found them and which topics have been relevant to her and when. These reflective information can then be used to make learning paths more explicit, e.g. to modify and control them to make learning activities better targeted to the respective learning goals.

Figure 1 shows the Zeitgeist dashboard that we use to confront the user with her history of activities within the MACE system. In the figure, the "Usage Summary" (top grey box) shows the user activities for January 2009 when she viewed the metadata ("Viewed") of 136, downloaded 84, bookmarked 60 and tagged 34 learning resources, thus describing the behavior of the learner within the MACE system. Detailed information are provided through the link called *Details*. The middle grey box titled "Usage History" shows the activities of the user per week indicating when she viewed metadata, downloaded learning resources or tagged or bookmarked them. With this statistic, a learner can determine when she was looking for learning resources and when she found suitable ones. For example, in the given graph, the learner searched for contents in the beginning of the week and started downloading learning resources only in

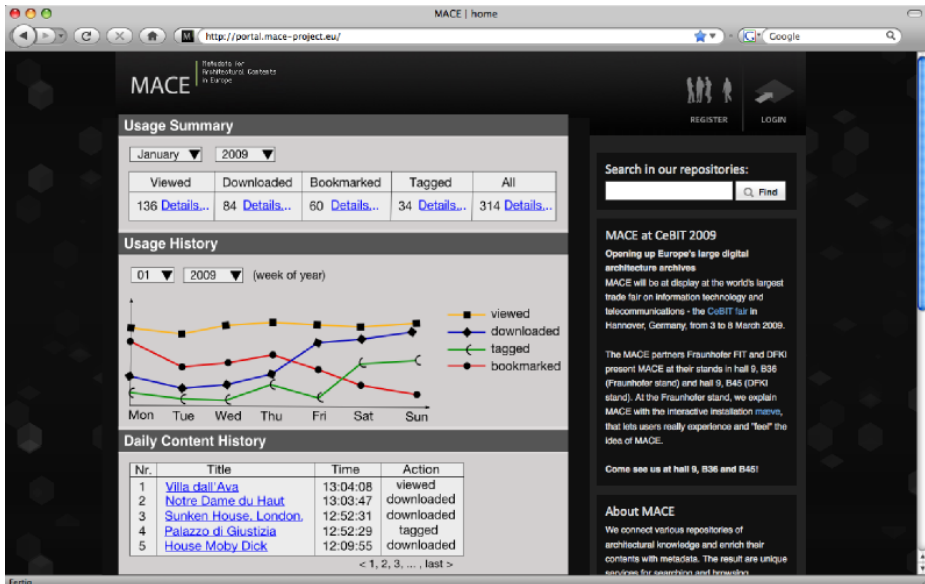


Figure 1: MACE Zeitgeist dashboard

the second half of the week. The continuously high "viewed" line indicates the search and later on the download while the "downloaded" line shows the number of downloads per day. The download line correlates with the "bookmarked" line that continuously decreases towards the end of the week. The grey box at the bottom titled "Daily Content History" shows the most recent learning resources that the user viewed and when, including the respective action. For example, the learner viewed the metadata of "Villa dall'Ava" at 13:04:08 and downloaded the learning resource "Notre Dame du Haut" at 13:03:47. For quick access, the title links to the respective learning resource.

The Zeitgeist dashboard provides hints on the learning trend, e.g. by showing an overview of which learning resources and topics have been relevant to the learner and when. Complementary to conventional user profiles, the trend reveals when the learner carried out which activities and with which learning resources and thus serves as the bases for an insight into learning paths and strategies.

The CAM based statistics provide a first step towards supporting the learner in reflecting on her learning activities. The confrontation of the user with her activities within the portal helps her to understand her steps towards the respective learning goal [Moo99].

## 4 Learning paths and contexts

As described before, the MACE usage metadata store entails learning paths through the MACE system usage. Here, we describe some highly conceptual approach to elicitate the context of usage for learning resources. We pick up intuitions from discourse and text processing according to which the context of a discourse act is (partly) defined by the discourse acts that have been carried out before (see [KR93]). That is, for an action  $a$  that occurs within a sequence of actions  $b_1 \dots b_n a c_1 \dots c_m$  we define  $a$ 's pre-context as the sequence of actions that occurred right before  $a$  ( $b_1 \dots b_n$ ), and we define  $a$ 's post-context as the sequence of actions that occurred right after  $a$  ( $c_1 \dots c_m$ ). The lengths of these sequences are subject of further experiments. In two further steps we simplify context representations. First, for all actions that are related to a learning resource, we reduce the actions and their contexts to learning resources and learning resource sequences. That is, we define the contexts of a learning object  $o$  as the sequences of learning resources used right before and right after  $o$  was used. Secondly, we reduce learning resource sequences to bags or even sets of objects. The representation of contexts as bags or sets of objects allow us to apply a very simple and straightforward similarity measure. The similarity of two context is related to the number of learning resources they have in common; it is defined as the fraction of the number of joint elements and the number of all context elements.

Similarity measures can be extended when learning resource profiles rather than concrete learning resources are taken into consideration. One can then evaluate and compare contexts not only regarding the learning resources they contain but also regarding the *types* of learning resources they contain: two contexts that contain different objects can be similar because they contain different objects of the same types.

Again picking up intuitions from language processing (especially from the notion of a paradigmatic relation, see [Sau66], [Hqw06]), we assume that context similarities give rise to content similarities. That is, comparing the use contexts of objects provides us with insights into their semantic relations.

We intend to use the similarity and closeness information of contexts and learning resources in combination with Zeitgeist analysis like trends for the provision of suitable learning paths, suggestions of modifications to learning paths and generally for learner guidance in responsive learning environments.

## 5 Conclusions and Future Work

The reflection on the learning path and activities enables the learner to significantly improve her learning. Nevertheless, supportive tools are missing so that reflection is often only possible after concluding a learning activity or through

evaluation measures (test, etc.) In order to enable reflective information for the learner within the learning process, we provide simple Zeitgeist-like statistics that show which activities the user carried out on which resources at which time. Furthermore, we provide the basis, e.g. identification of similar users and contents, to elicitate the learning path followed by a learner. The actual learning path can then be used to identify errors and take corrective measures. While we describe the conceptual approach here, apart from its evaluation, future work includes the derivation of the learning path using similarity measures for users, learning resources and their correlations. Experiments have to show that the derived learning paths actually show the real learning paths.

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## Domain-specific Knowledge Management in a Semantic Desktop

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**Abstract:** Semantic Desktops hold provide intelligent information-management environments that respond to users' needs. An important requirement for developing such environments is that the underlying ontology reflects the users' work context. For specialized work domains, where people deal with rich information sources in a context-specific manner, there may be a significant amount of domain-specific information available in text documents, emails and other domain-dependent data sources. Our goal is to support knowledge management by to using this information in a Semantic Desktop. We have extended an existing semantic desktop by introducing content- and structure-based information extraction, domain-specific ontological extensions as well as visualization of semantic entities. These extensions address needs in strategic decision making, where domain-specific, well-structured knowledge is available but scattered in documents and communications. The goal for this type of domain-aware semantic desktop is to assist decision makers, such as military commanders, in sense making.

**Key Words:** knowledge management, semantic desktops, domain-specific ontology

**Category:** H.5.3, H.5.4

### 1 Introduction

Inconsistent or improper use of information is a major cause of concern in environments where the correct, timely, joint assessment of a situation is paramount to success. As part of knowledge management at the strategic level of a large organisation, documents are communicated within as well as between different levels of management, using both general desktop applications as well as specialized systems. Correctly assessing the information contained in such documents as well as in supporting information systems is critical to success. For efficient information management, Semantic Desktops [Karger et al. (2005), Sauermann et al. (2006)] have introduced Semantic Web technologies to desktop environments. The aim is to provide users with a unified knowledge-management platform that integrates several application-specific information sources.

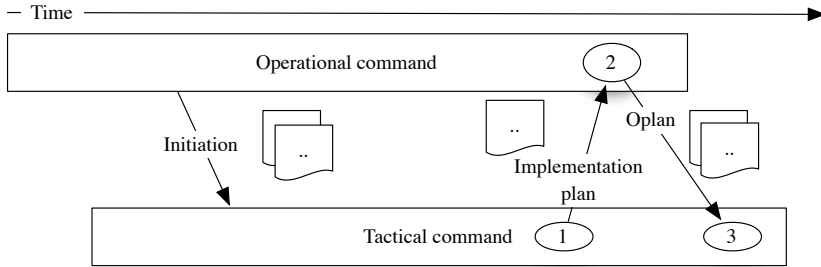


Figure 1: The document flow between the operational and tactical levels of staff during the decision-making process.

To be effective in supporting strategic decision-making, however, semantic desktop ontologies must accommodate the specific context of work to provide useful reasoning services [Leifler and Eriksson (2008)]. In this paper, we (1) discuss how ontology-based *information management* in current semantic desktops can be extended with domain-specific features, and (2) describe an implementation of such extensions in a semantic desktop environment that can provide significant benefits to *knowledge management* for command and control.

## 2 Background: The command-and-control domain

In strategic decision-making environments, which we exemplify with military command and control, correct sense-making is critical to success [Brehmer (2007)]. As an example of the knowledge-management process in command and control, consider Figure 1, where two levels of command communicate by sending documents to one another. Although research on intelligent systems for automating strategic decision making has yielded important results [Smith et al. (2005), Hayes et al. (2005), Becker and Smith (2000)], and recent work has attempted to bridge the gap between automated systems and conventional tools [Leifler (2008)], mission plans are still crafted as a set of structured textual documents. These documents describe separate planning aspects, such as the task organization, rules of engagement, available time frames, force composition, and relevant intelligence information.

## 3 The IRIS semantic desktop

The IRIS semantic desktop [Cheyer et al. (2006)] is a modular, service-based semantic desktop project that features an integration with external applications via plus ins. In IRIS, the standard tools are general in the sense that they are



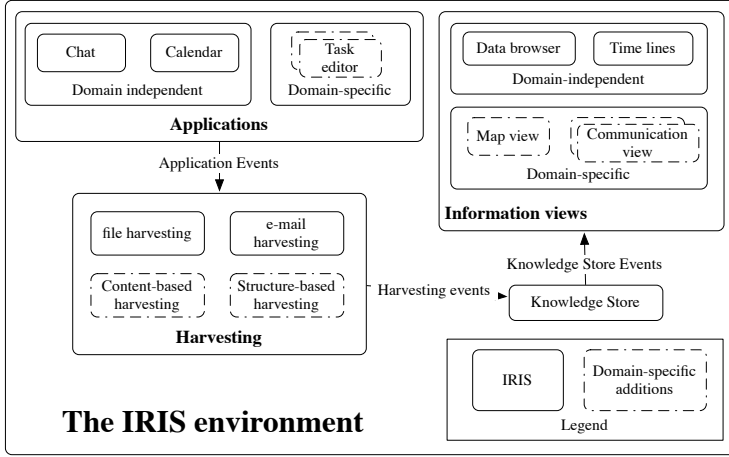


Figure 2: The IRIS semantic desktop enhanced with domain-specific additions.

not specific to a particular work context. To create domain-specific support in information-intensive work domains, however, we need for more powerful mechanisms for handling the semantic entities in the documents. Supporting commanders in document-based decision making [Fig. 1] requires features that are beyond what is provided by current semantic desktops: (1) the ability to *classify domain-specific words and phrases* by their semantic class, and (2) the ability to *recognize domain-specific structures* of work-related documents. As a response to these specific challenges, we have extended the IRIS semantic desktop with *named entity recognition* and *document structure analysis* [Fig. 2]. In addition, we have extended the IRIS ontology to accommodate our specific domain.

#### 4 Domain-specific extensions to IRIS

Current IRIS functionality for harvesting information from files and populating the ontology database relies on the use of the SEMEX [Cai et al. (2005)] information management framework. To extract semantics pertaining to the work context, we have deployed natural language processing components from the GATE framework [Cunningham et al. (2002)] in IRIS to recognize semantic objects by their linguistic features. Some semantic objects are written in a particular format, such as force descriptions, directions and locations in military documents. These references can be found by searching for noun phrases that have a domain-specific signature.

We extract information from the domain-specific document structure of files containing *synchronization matrices*. This addition to the IRIS harvesting envi-

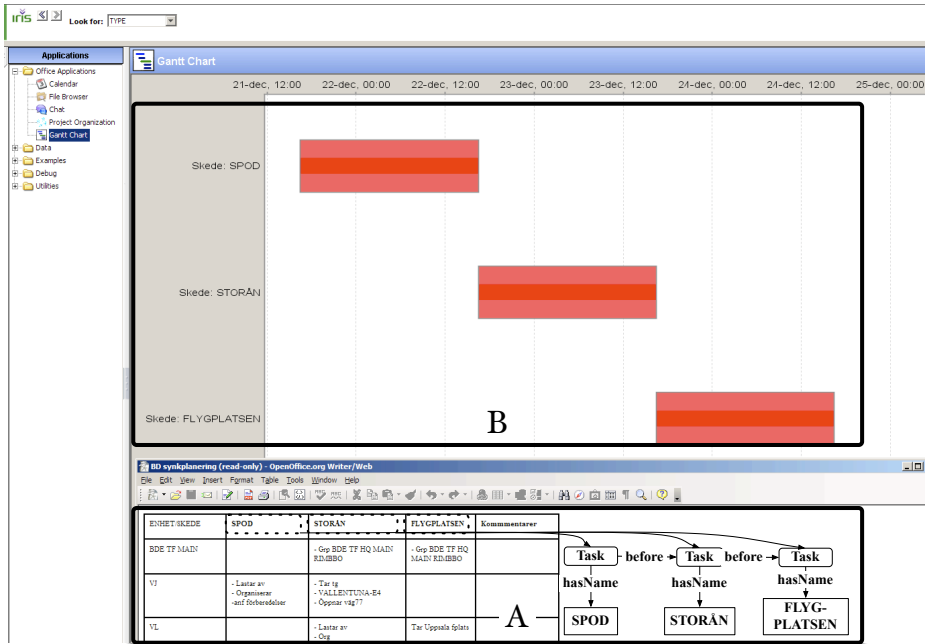
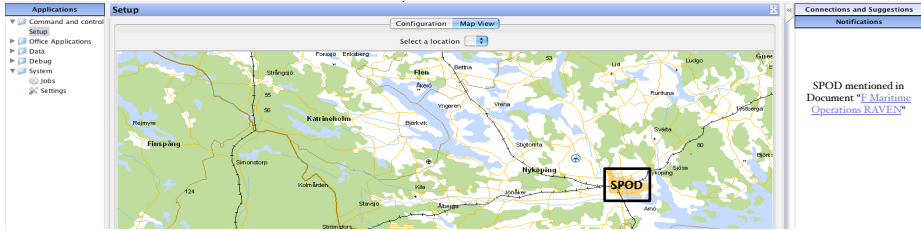


Figure 3: The IRIS environment contains a graphical component to show tasks in a time line. By automatically harvesting synchronization matrices (lower section, A), we can populate the time line with tasks that correspond to those being planned for (upper section, B).

ronment was created using XPath-based document structure filtering of OpenDocument files. Figure 3 (lower section, A) shows how specific parts of a synchronization matrix are used to create semantic objects denoting stages of an operation. The information from named entity analysis and document structure analysis is harvested from documents automatically in IRIS, and is used for navigating domain-specific ontology information more efficiently using special information views. The current IRIS ontology is written in OWL-DL and contains concepts related both to the activities performed by applications in a desktop environment, such as opening files, launching applications and reading e-mail, as well as to what users reason about in the environment, such as people, tasks, and places.

Once domain-specific harvesting has been set up by coupling named-entity recognition to ontology classes in IRIS, and by recognizing structure-dependent semantic entities and their relations in office documents, this information is processed by IRIS in an event-driven manner. In Figure 3, a time line visualizes



**Figure 4:** Map view showing a geographic reference linked to a document.

the stages of an operation, as harvested from a synchronization matrix. Another example of how domain-specific, event-driven information can be used to assess the current situation is shown in Figure 4 where the Secure Point of Debarkation is marked on a map. When documents are manipulated, the set of geographical references is updated by using GATE for harvesting location references.

## 5 Related Work

Reeve and Han surveyed extraction of semantic information from documents using automated methods [Reeve and Han (2005)]. In other projects aimed at defining the semantics of documents, researchers have integrated ontology-editing capabilities within document-processing environments to support semantic annotations when writing documents [Groza et al. (2007), Eriksson, 2007]. Franz, Staab and Arndt [Franz et al. (2007)] have demonstrated integration of several application-specific information sources in a semantic-desktop framework.

## 6 Summary and Conclusions

We have described a model for enhancing semantic desktops with domain-specific ontologies for supporting strategic decision making. The model includes the use of natural-language processing and document-structure analysis, and has been implemented on top of an existing semantic desktop (IRIS). Our results show that using domain-specific extensions, a semantic desktop can provide directed support for richer environments and at a higher level than otherwise possible. By domain-specific extensions to the ontology and harvesting mechanism, rich and custom-tailored support mechanisms can be developed with only minor additions to the semantic desktop.

## Acknowledgements

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## Informative Common Subsumers for Diseases Diagnosis

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**Abstract:** This paper proposes an approach for automatically extracting symptoms associated to a given disease from semantic-based descriptions of health records of patients affected by an investigated pathology. The proposal implements non-standard reasoning services developed in Description Logics for the individuation of informative commonalities in concept collections and can make significantly easier the diagnosis process of rare and unknown diseases.

**Key Words:** Common Subsumers, Healthcare, Description Logics.

**Category:** M.4, M.7, H.3.3

### 1 Introduction

Healthcare is one of the knowledge domains in which semantic technologies have been traditionally most widely employed in literature. Such a domain is in fact characterized by a large amount of available information whose sharing is crucial in several circumstances.

Of course a multitude of information systems exist at local level to manage available data, with a consequent heterogeneity in data representation, which makes hard the integration process. By adopting ontological structures conveying a shared interpretation on the meaning surrounding the available data, a partial integration may be reached.

Most ontologies developed for healthcare domain aim at modeling human anatomy and known pathologies. GALEN [Rector et al., 1994] is probably the most known general ontology developed to provide a common terminology in

the medical domain. UMLS [Bodenreider, 2004] and SNOMED<sup>1</sup> represent further examples of ontologies working as vocabularies for healthcare. Several other approaches are focused on the proposal of semantic annotation schemes for clinical texts and health records ([Bodenreider, 2004], [Sheth et al., 2006]), in order to provide interoperability and information sharing. Nevertheless, only a few approaches cope with the issue of relating diseases with their symptoms in order to support diagnosis([Hadzic and Chang, 2005], [Minchin et al., 2006]). It is also noteworthy that the new HL7<sup>2</sup> version has been somehow designed with an ontological formalization.

In this paper we present a semantic-based approach for the automated individuation of factors commonly related to a known disease. The approach exploits non-standard inference services [Colucci et al., 2008] proposed in Description Logics [Baader et al., 2003] to automatically extract shared characteristics in a set of concept descriptions. In particular, the approach uses patients health records modeled according to an ontology describing possible symptoms, treatments or behavioral factors affecting patients health. Such records represent the knowledge base to be investigated for discovering factors common to patients sharing a diagnosis. In other words health records of patients affected by the same disease work as training set for learning how to diagnose known pathologies. Obviously, the more the disease is rare and difficult to diagnose, the more our approach is helpful in suggesting affecting factors both explicitly recorded in health records and implied by elicited information.

The validity of the approach has been tested with real data collected in the Pediatric Surgery ward of the Policlinico general hospital in Bari, Italy. At the first stage of analysis, the health records selected to validate the approach are related to patients affected by appendicitis.

The paper is organized as follows: in the next section we shortly provide the background of the semantic-based approach we propose here. Section 3 shows instead how to implement the proposed approach for supporting diagnosis in a real data framework. Finally, conclusions close the paper.

## 2 Formalism and Inferences

The proposed approach models information in patients health records according to Description Logics (DLs) formalism, in order to take advantage from useful non-standard reasoning services specifically developed for the extraction of commonalities in collections of concept descriptions in DL. Due to the lack of space, we do not delve into details about DL formalism and standard reasoning (the interested reader may find them in [Baader et al., 2003]), but we shortly recall

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<sup>1</sup> <http://www.snomed.org>

<sup>2</sup> <http://www.hl7.org/>

only non-standard services fundamental in our approach. In particular, Least Common Subsumer (LCS) was defined [Cohen and Hirsh, 1994] to find features shared by *all* of the elements of a given collection.

In order to deal with the problem of extracting commonalities in a *portion* of elements in a set, in [Colucci et al., 2008] four different common subsumers were proposed:

- ***k*-Common Subsumers**(*k*-CSs) formally represent characteristics shared by *k* concepts in a collection of *n* elements (with  $k < n$ );
- **Informative *k*-Common Subsumer** (IkCS) are defined as *k*-CSs adding informative content to the LCS computation, given that LCSs are also *k*-CSs, for every  $k < n$ ;
- **Best Common Subsumers** (BCSs) represent features shared by the maximum number of elements in a collection, and makes sense when such a maximum is less than *n* (*i.e.*, when the LCS is equivalent to the universal concept);
- **Best Informative Common Subsumers** (BICS) are defined as BCSs adding informative content to the LCS computation, given that, when the LCS is not equivalent to the universal concept, it is of course the BCS of a collection.

### 3 Illustrative Example

In this section we show how to exploit inference services proposed in Section 2 to automatically extract commonalities in health records of patients sharing a final diagnosis. In particular we employed anonymous health records belonging to a sample of 100 patients affected by appendicitis hospitalized in the Pediatric Surgery ward of the general hospital in Bari, Italy. In order to show how the proposed approach works, we provide the data related to three patients in the sample, whose clinical status is introduced in the following:

**Patient 1:** Female, 12 years old, feeling abdominal algia to right iliac fossa, constipation, lower right limb neuralgia, asthenia, temperature and dysuria;

**Patient 2:** Female, 7 years old, feeling abdominal algia to right iliac fossa, alternate phenomena of constipation and diarrhea, vomit and temperature;

**Patient 3:** Male, 5 years old, feeling abdominal algia to right iliac fossa, stranguria, lack of appetite, constipation, headache, limb tingling and temperature.

We notice that the three patients have not behavioral factors and do not take treatments affecting health because of their young age, but w.l.o.g. we considered also such affecting elements in our modeling. In order to provide the vocabulary for health records description, we developed an ontology in the DL  $\mathcal{AL}\mathcal{E}\mathcal{N}$  [Baader et al., 2003]; an excerpt of the main hierarchy is shown in Figure 1(a), together with the hierarchy of a specific class, **Anatomy**, in Figure 1(b). The ontology axioms involved in the representation of the three patients taken as case study are instead listed below:

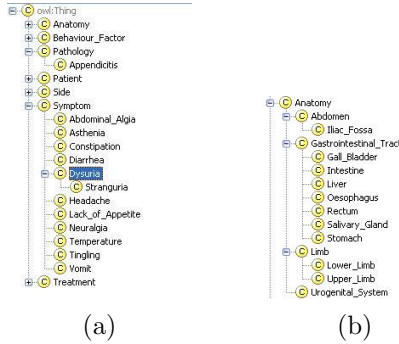


Figure 1: (a) Ontology Main Hierarchy (b)Anatomy Class Hierarchy



Figure 2: Patients Health Record Descriptions

Abdominal\_Algia  $\sqsubseteq$  Symptom  $\sqcap \forall$ affects.Iliac\_Fossa  
 Constipation  $\sqsubseteq$  Symptom  $\sqcap \forall$ affects.Gastrointestinal\_Tract  
 Vomit  $\sqsubseteq$  Symptom  $\sqcap \forall$ affects.Gastrointestinal\_Tract  
 Diarrhea  $\sqsubseteq$  Symptom  $\sqcap \forall$ affects.Gastrointestinal\_Tract  
 Dysuria  $\sqsubseteq$  Symptom  $\sqcap \forall$ affects.Urogenital\_System  
 Stranguria  $\sqsubseteq$  Dysuria  $\sqcap \exists$ causesPain.

Figure 2 shows the modeling of the three patients health records according to the proposed ontology.

In order to automatically individuate symptoms usually shared by patients affected by appendicitis, we employ a general approach originally proposed in [Colucci et al., 2008] for extracting commonalities in concept collections.

Of course, we are not only interested in “obvious” symptoms, but the effort in modeling knowledge related to patients health records should be exploited to discover unknown associations between symptoms and pathologies. In other



words, our approach aims at finding symptoms that are non necessarily felt by *all* of the patients affected by a given pathology, but also by a *relevant* number of patients.

Notice that the concept descriptions representing health records use the full expressiveness of  $\mathcal{AL}\mathcal{E}\mathcal{N}$ . In [Colucci et al., 2008] we proposed an algorithm for computing partial common subsumers in  $\mathcal{EL}\mathcal{HN}$ , showing also its extensibility to  $\mathcal{AL}\mathcal{E}\mathcal{N}$ . The algorithm relies on the computation of the LCS proposed in [Küstners and Molitor, 2005]. In this paper we instead adopt the novel tableaux-based method for LCS computation proposed in [Donini et al., 2009], which extends to the full  $\mathcal{AL}\mathcal{E}\mathcal{H}\mathcal{LN}_{R^+}$ . In the following we show the results of common subsumers computation on the collection of concept descriptions  $S = \{\mathbf{Patient\ 1, Patient\ 2, Patient\ 3}\}$ , commenting on their impact on disease diagnosis. First of all, we compute the LCS of the collection, representing the portion of health records common to all of the three patients:

$$L = LCS(S) = \exists\text{hasPathology.Appendicitis} \sqcap \exists\text{hasSymptom.}(\text{Abdominal\_Algia} \sqcap \exists\text{affectsSide.Right}) \sqcap \exists\text{hasSymptom.Constipation} \sqcap \exists\text{hasSymptom.Temperature}$$

Of course, LCS represents symptoms which are well known for appendicitis but we are interested in less common symptoms, frequently associated to appendicitis; to this aim we search for portions of health records shared by at least two patients out of the three in the collection and start computing the set  $\underline{CS}_2$  of 2-CSs of the collection.

$$\underline{CS}_2 = \{L, L \sqcap \text{Female}, L \sqcap \exists\text{hasSymptom.}(\exists\text{affects.Limb}) \sqcap \exists\text{hasSymptom.Dysuria}\}$$

Among the three retrieved 2-CS, we are particularly interested in the ones adding informative content to the LCS, which we called I2CS. The set  $\underline{ICS}_2$  of such concepts is given in the following:

$$\underline{ICS}_2 = \{L \sqcap \text{Female}, L \sqcap \exists\text{hasSymptom.}(\exists\text{affects.Limb}) \sqcap \exists\text{hasSymptom.Dysuria}\}$$

Given that the LCS of the collection is not equivalent to the universal concept, computing the set of BCSs makes no sense (see Section 2). The set of BICSSs (see Section 2) is instead equivalent to  $\underline{ICS}_2$ : if one more patient is added to the set of those sharing features expressed by I2CS, the latter necessarily reverts to the LCS of the collection.

The proposed tiny case study shows how, thanks to the computation of Informative Common Subsumers, we discover that two patients out of three are affected by some symptoms to the limbs and dysuria. We also found out that two patients are female. Even though introduced here in a limited set of three health records for the sake of simplicity, our approach has been evaluated with reference to a sample of 100 patients. Produced results confirm *e.g.*, that dysuria and symptoms to limbs affect a significant portion of patients affected by appendicitis. On the contrary, the prevalence of female patients has not been retrieved in results from the general sample (intuitively, such a not significant result is due to the very limited arity of the case study set and to the binary

nature of patients sex information).

## 4 Conclusions

We have presented an approach supporting diagnosis through a semantic-based individuation of symptoms shared by a significant portion of patients affected by the disease to diagnose using informative common subsumers. We implemented our approach in a case study employing real data related to patients affected by appendicitis and the results have been validated by pediatric surgeons working in the general hospital of Bari. Even though appendicitis is a very frequent disease, apparently not needing support to diagnosis, we chose it to test our approach, in order for the evaluation to be free from interpretation faults. Nevertheless, our proposal is designed to make easier the diagnosis of rare and not well known diseases: initial difficulties in recognizing such pathologies may be overcome through a backward investigation on health records of affected patients and this is the objective of ongoing investigations.

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## **A Comparative Study on the Use of Web 2.0 in Enterprises**

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**Abstract:** An increasing amount of companies are interested in using the innovative potential of Web 2.0 technologies. This paper describes the main results of a comparative analysis of several quantitative empirical studies on the use of Web 2.0 in enterprises. This includes findings about diffusion, possibilities of application, benefits, barriers, and factors of success for the use of Web 2.0 in enterprises. The findings of this comparative study show effective and reasonable ways of using Web 2.0 in enterprises.

**Keywords:** Web 2.0, Enterprise 2.0, empirical study, survey, potential, benefit, barrier

**Categories:** A.1, H.4.2, H.4.3

### **1 Introduction**

During the last years, the term “Web 2.0” [O’Reilly 05] has found its way into businesses. Web 2.0 is best described as a combination of new technologies (like web services, AJAX, RSS, mashups), new types of applications (i.e. social software, like wikis, blogs, social networking), new patterns of interaction, and new principles of organisation (e.g. participation, wisdom of crowds) as well as new business models (such as long tail, webtop, etc.). Likewise, the term “Enterprise 2.0” [McAfee 06] has emerged for the use of Web 2.0 applications and technologies in enterprises including the organisational change in enterprises, which accompanies the technical innovation. Due to the high potential of using Web 2.0 applications and technologies in enterprises, much research on their usage in enterprises has been done recently. Usually, relevant case studies (e.g. [Back 08]) or quantitative empirical research (e.g. [Alpar 08]) covering a wide range of objectives, problems, and perspectives constitute the empirical basis for this research work.

This paper offers a comparative analysis of suchlike studies on the use of Web 2.0 in enterprises. Thus, it summarises the current findings of the existing studies on this subject. In addition, it draws some conclusions for the practical application of Web 2.0 technologies in enterprises as well as points to areas for future research. Such a comparison of different studies provides a synopsis of the findings and gives a good orientation about the state of knowledge. In addition, the data for the respective studies, which form the basis for this paper, were collected at different dates, thus making it possible to identify general tendencies about the development and specific fields of use of Web 2.0 in enterprises. Furthermore, the synopsis of many quantitative data gives a greater coverage, thereby offering better possibilities for orientation than a single study. This paper locates differences between the studies compared, thus offering hints to possible areas of further research.

In Section 2, the methodological approach to the analysis of the studies is described in some detail. The findings of the comparative study are presented in Section 3, whereas Section 4 discusses them, draws some tentative conclusions from the findings, and gives a forecast on future research.

## 2 Methodological approach

The comparative analysis of different studies on the use of Web 2.0 in enterprises will clearly state what is currently known on the subject, especially on the challenges and perspectives. On this basis, deductions can be drawn about necessary further steps for realising the full potential of Web 2.0 in enterprises. Altogether, ten studies were examined in this comparative analysis: [Bughin 07], [Bughin 08], [ClientVela 08], [CoreMedia 07], [Döbler 07], [Herrmann 07], [IBM 08], [Leibhammer 08], [Trommsdorff 07], and [Wittmann 08]. Only studies including data from Germany were selected. Hence, studies only based on data from other countries were not considered. In order to assure the comparability of the studies, they were selected according to the following principles: The studies were to be predicated on quantitative empirical data. In addition, each study should take multiple Web 2.0 applications into its focus. Thus, mere case studies (e.g. [Back 08]) as well as studies focussing on just one single application type (e.g. [Euroblog 07]) were excluded a priori. To assure a high relevance, only studies dating back less than two years were included in the comparative analysis.

To compare the studies an analytical framework was developed. Key aspects were: conceptualisation of the term Web 2.0, diffusion of Web 2.0 in the enterprises, range of application in the enterprises, benefits, barriers, and critical success factors. These are the main aspects the studies are dealing with, the only exception being the conceptualisation of Web 2.0, which is hardly considered by the analysed studies at all. The data was evaluated by using the method of content structuring. That is to say, the material of the studies was partitioned according to the respective aspects of the chosen analytical framework. In the ensuing detailed analysis, typical features were identified by searching for similarities and differences between the studies. This task was accomplished with the aid of the software Atlas.ti 5.5.4. The next section presents the respective findings in an aggregated and concentrated form, abstracting from the details pointed out by the studies.

## 3 Findings

This section highlights some aspects distilled from the many findings of the comparative study, namely the conceptualisation of Web 2.0, the diffusion, range of application, benefits, and barriers of the use of Web 2.0 in enterprises.

### 3.1 Conceptualisation of the term Web 2.0

Neither does any of the studies bother to give a precise definition of the term Web 2.0 as used in the context of the respective study nor are the respective interview partners queried as to their understanding of this term. Most of the studies mix up diverse

technologies, application types, principles of organisation as well as business models and juxtapose them in an undifferentiated way (e.g. [Bughin 07]). Implicitly, most of the studies lay particular stress on the technical aspects. This becomes obvious when looking at the possible answers given to the question whether the companies are using Web 2.0. In most cases, certain technologies and application types are enumerated. Only one study [IBM 08] is based on a non-technical definition of the term Web 2.0.

### **3.2 Diffusion in the enterprises**

Generally, the term Web 2.0 is well-known in business by now. As to individual application types, the picture is somewhat more differentiated: While some of the studies report that application types like wikis, blogs, and social networking are known by more than 90% of the companies, the degree of popularity for the types RSS, tagging and bookmarking is significantly lower in the range of 70-80%.

According to the studies based on a technical definition of Web 2.0, over 30% of the companies surveyed make use of Web 2.0 technologies and applications. However, the one study [IBM 08] employing a socio-technical definition of Web 2.0 states that a far smaller share of companies uses Web 2.0 (under 10%).

Undisputedly, wikis are the most widespread Web 2.0 application in enterprises. Similarly, instant messaging and forums are well-established in practical use. Other well-known applications like blogs and social networks, however, are to a significant degree less frequently used. As a rule, the rate of usage of Web 2.0 in enterprises depends heavily on the business sector the company is engaged in as well as on the size of the company. A differentiation between business sectors yields the result that the use of Web 2.0 is very high in the information industry, the reason being that a strong affinity to information and communication technology exists in this branch (e.g. [Leibhammer 08]). In contrast, the industry and the service sector have adopted Web 2.0 less often. In particular, the finance sector shows a comparatively low use of Web 2.0 (e.g. [Wittman 08]). A differentiation according to the size of the enterprise lends some support to the suggestion that the use of Web 2.0 increases with the size of a company. For example, large companies employing more than 5000 persons use some of the application types nearly twice as often as the average.

### **3.3 Range of application**

With respect to the range of application of Web 2.0 in enterprises, one has to distinguish between organisational function and organisational level of use. As to the former category, Web 2.0 is most extensively used in After Sales Service (e.g. [Bughin 07]), Marketing, as well as in Research and Development ([e.g. [Herrmann 07]). Some potential is also seen in Logistics (e.g. [BITKOM 07]). However, Web 2.0 doesn't seem to be particularly suited for Human Resource: According to one study [CoreMedia 07], HR managers are twice as likely to consider Web 2.0 as not suited to be employed in their area as the average manager.

With a view to the organisational level, the most popular area of use for Web 2.0 is the project team. According to the studies surveyed, more than 50% of the Web 2.0 users use Web 2.0 technologies and applications on this organisational level (e.g. [Leibhammer 08]). With 45%, the company-wide use is the second important area. Again, this is more common in larger companies with more than 500 employees (cf.

[CoreMedia 07]). A cross-company use (i.e. collaboration with suppliers, partners, and customers) is also more frequently observed in larger enterprises (e.g. [Bughin 07]), most often a unidirectional distribution of information prevails (e.g. via blogs).

### 3.4 Benefits

The studies show that the use of Web 2.0 in enterprises has its biggest impact on knowledge work, innovation processes and cooperation. All of these areas will benefit by the improvement and speeding up of processes that an adoption of Web 2.0 technologies and applications entails. Knowledge work is expected to benefit primarily by an improvement of the search for experts and contact persons (e.g. [CoreMedia 07]). Furthermore, a well-directed as well as faster and easier exchange of information should result from adopting Web 2.0 technologies and applications. Besides, the use of external and internal knowledge as well as internal communication processes on the whole are expected to be improved (e.g. [Leibhammer 08]). At the same time and by the same reason, innovation processes are expected to benefit from the use of Web 2.0 technologies and applications as the integration of both external and internal knowledge is improved and the collective intelligence of employees and customers is utilised. In addition, the possibility to use Web 2.0 applications in order to improve cooperation with customers will both raise the quality of service on the one hand and have positive effects on the acquisition of new clients on the other hand, amongst others because the companies get a good means to keep a closer eye on the – possibly changing – customers' needs (e.g. [ClientVela 08]). Internally, companies expect an increased cooperation of employees over and beyond departmental barriers and a better integration of the employees in general (e.g. [Leibhammer 08]). In other areas, like cooperation with partners and suppliers as well as improving the decision processes in general, companies expect the magnitude of benefits due to the adoption of Web 2.0 technologies and applications to be rather limited (e.g. [Bughin07]).

### 3.5 Barriers

The studies identify a whole range of economic, cultural, and technical factors that can be seen as more or less great obstacles to the use of Web 2.0 in enterprises. From an economic point of view, the biggest drawback for a rapid adoption of Web 2.0 technologies and applications is the fact that cost-benefit analyses yield somewhat hazy results – while it is always possible to pin down the costs of adopting new technologies, it is very hard to determine the exact financial benefit. Further obstacles mentioned are high priority isn't given by the top management, assumed high security risks and inadequate control over the content (e.g. [Döbler 07]). The use of Web 2.0 is also seen as a potential source of distraction for employees (e.g. [Herrmann 07]). To sum up the respective findings of the individual studies, Web 2.0 is not conforming to the prevailing corporate culture. Management as well as employees seem to be quite reluctant to adopt Web 2.0 technologies and applications for doing business [Leibhammer 08]. Such a sceptical attitude is aggravated by the fact that companies rate the technological maturity of available Web 2.0 solutions as quite low, with the possible exception of the IT-affine information industry [Leibhammer 08]. Another important obstacle to the adoption of Web 2.0 technologies and applications in enterprises is their assumed technical complexity (e.g. [CoreMedia 07]).

## **4 Discussion**

### **4.1 Weaknesses of the studies**

Almost all studies feature serious weaknesses with regard to content and method. It is not only the comparison of the studies which is difficult, but in fact, their whole findings have to be questioned. Therefore it is necessary to check the individual findings of the respective studies critically. At this point, only some of the essential points of criticism are given which affect most of the studies.

In almost every study, central analytical terms are not defined or clarified. As aforementioned, this concerns especially fundamental term “Web 2.0”. This leads to surveys, in which aspects are parallelized and compared, which are not on the same level. For instance, one of the studies asks, whether the companies use Web 2.0 and the given possible answers amongst others contain ‘wikis’ and ‘collective intelligence’. But the use of collective intelligence is one aspect in the use of Wikis. A company can not choose between these two things. So, the conclusion “more companies are using wikis than collective intelligence” is useless.

Another point of criticism is that in almost every study the interview partners are members of the management. But especially the Web 2.0 application in enterprises is known to often start bottom up - from the level of the employees [Bughin 07]. Whether the Web 2.0 applications in the enterprise known by the management are used efficiently by the employees, cannot be concluded, but must rather be questioned. On the other hand, not all the tools used by the employees, are necessarily known to the management.

Empirical studies which survey quantitative data must factor these aspects and accordingly design their data acquisition, so that reliable conclusions can be made.

### **4.2 Need for more sophisticated analysis of the real requirements**

Web 2.0 is a trend that is followed first of all by larger enterprises. There, it is easier to allocate resources for Web 2.0 projects like employees, infrastructure or budgets than in small and medium enterprises (SME). Many studies accent, that the use of Web 2.0 in companies increases and will further rise (e.g. [T-Systems 08]). But only a few studies relate the use of Web 2.0 to the challenges, problems, and requirements that they are supposed to address (c.f. [CoreMedia 07] relates knowledge management to the use of Web 2.0 tools). These studies conclude that companies often don't see Web 2.0 as a solution for their problems but as a trend, which has to be followed. This impression is amplified by the development of the use of some application types over the years. While in 2007 32% of the interview partners said, they used or planed to use blogs [Bughin 07], only 21% answered this in 2008 in the following survey [Bughin 08]. So, every third company had stopped its blog project. The enthusiastic start of projects is often followed by the disillusioning result, that not all tools bring real improvements with them. Therefore, it is necessary to analyse the individual need and the requirement of the enterprise before introducing Web 2.0 applications. Appropriate methods for analysis are not available yet, but object of recent research.

### **4.3 Organisational potentials are hardly seen and exploited**

The studies compared show that Web 2.0 provides an enormous potential of innovation for enterprises and there are a lot of possibilities for the use of Web 2.0 in enterprises. But in contrast, our analysis of the studies also shows that the potentials of the use of Web 2.0 in enterprises for the design of new forms of work and organisation are hardly exploited or even seen.

The use of Web 2.0 in enterprises does not only mean the introduction of a new web technology. It also relates to a change of current work and organisational structures as well as business processes. In general, with the introduction and use of Web 2.0, an enormous organisational potential can be realised. This organisational potential of Web 2.0 relates particularly to the possibilities for the creation of new forms of work and organisation as well as new business models. For instance, by the means of Web 2.0 principles (c.f. participation), a conversational communication instead of a Tayloristic one-way-communication can be established, open innovation processes with partners, customers and suppliers can be realised, and group-oriented work can be designed. It supports the overcoming of hierarchical structures, the creation of decentralised entities, as well as individual, collaborative and organisational learning. It has been possible to implement fundamental findings of the work sciences regarding the improvement of the social relationships between employees, to which a great number of scientific investigations have repeatedly called attention. This way, Web 2.0 enables new work and organisational forms, which can promote personality and organisational development. But our analysis shows, there is not sufficient awareness of the necessary organisational changes. The highest benefit is mainly expected in the optimisation and speedup of existing processes. But the potentials of the creation of new forms of work and organisation are hardly seen. Obviously, enterprises are not aware sufficiently that with the introduction and use of Web 2.0 the related forms of work and organisation have to be changed fundamentally. In addition, the analysis of existing studies shows that these studies mainly focus on technical aspects. Only one study [IBM 08] focuses the possibilities of new organisational forms. It is not clear to which extent the results of the studies are influenced by this fact or reflect the real situation in the enterprises. New studies have to be conducted taking non-technical aspects into account in more detail.

One main reason for this situation is that consequences of the new organisational principles of Web 2.0 are not understood sufficiently and therefore the necessity of an intentional design and development of an enterprise towards an enterprise 2.0 is not fully obvious. If progress should be made in the field of the use of Web 2.0 in enterprises, it is necessary to intensify the work on theoretical foundations and methodology of Web 2.0 principles, their analysis as well as the transfer of this knowledge to the practice in enterprises. Further detailed and methodologically assured empirical analysis can provide an essential contribution to this.

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# Lightweight Document Semantics Processing in E-learning

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**Abstract:** There are plenty of projects aimed at incorporating semantic information into present day document processing. The main problem is their real-world usability. E-learning is one of the areas which can take advantage of the semantically described documents. In this paper we would like to introduce a framework of cooperating tools which can help extract, store, visualize semantics in this area.

**Key Words:** metadata, e-learning, Web 2.0, tagging, semantics, ontology, RDFS, XML, Wiki, Deep Thought, plug-in, visualization, metadata, Fresnel

**Category:** H.5.1, H.5.2, H.3.2, H.3.3, L.1.5, L.3.0

## 1 Introduction

The concept of the Semantic Web (SW) [Berners-Lee 2001] was introduced nine years ago but the development continued a slightly different way [Horrocks 2007]. There are more causes — unrealistic requirements on the users, excessive requirements on resources, and a theoretical focus of most research projects. A lack of interoperability is also an issue. Real-life applications using semantics are simple, single purpose tools, easy to work with [Pitner et al. 2007].

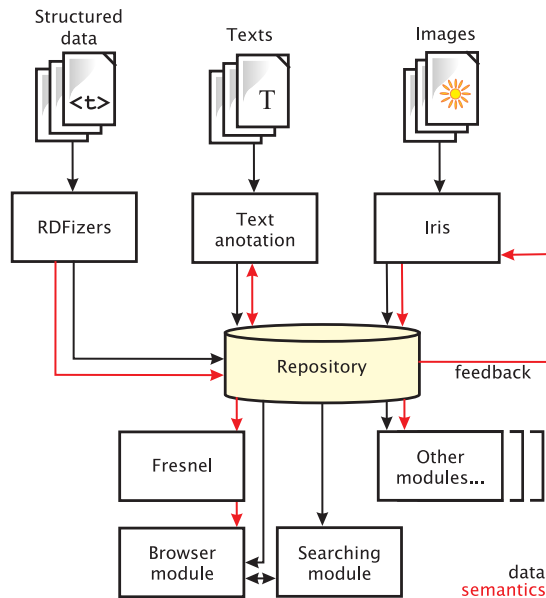
Learning is basically a knowledge transfer process. The student absorbs various explicit knowledge and also gains tacit knowledge via social interaction [Preece 2003]. An e-learning system requires an explicit formalization of the knowledge. However, users (both tutors and students) have limited computer-literacy and limited time available [Aroyo 2004, Zouaq 2007]. LM systems without semantics, like Moodle, are still the most used. We started to develop a lightweight suite of easy, small, and fast cooperating tools providing visualization capabilities that would proxy the semantic processing to a common user.

## 2 E-learning semantic framework

As our team teaches a couple of well-attended courses, we could identify the following key requirements on design and implementation of a prototype e-learning semantic framework:

- The goal is to create an interactive *tool*, not a sophisticated automaton [Berge 2002]. The tool must not be resource demanding thus we reduced requirements on knowledge storage and e-learning ontologies ‘degenerated’ into *hierarchical dictionaries* with just simple relations.

- *Open standards, open source, open interfaces* – it is together with a modular architecture vital for future development. Thus, we store semantics in *RDF Schema* and its visualization is described in *Fresnel*.
- The framework is developed with users in mind and integrated with our project management system. An interface with the university LMS is also prepared. A user tested, internationalized GUI represents another vital part of the development which is itself a part of the learning process — some modules are developed as Master- or Bachelor thesis or interim projects.



**Figure 1:** Framework structure

### 3 Repository

Key part of the prototyped framework is a *repository*, a place to store extracted semantics and documents. It comprises of the RDF(S) database *Sesame*, a *lightweight interface module*, and a *file repository* for documents. For the sake of simplicity, we avoided sophisticated systems like [Kiryakov et al. 2005].

Sesame was selected as a result of our survey [Čížek 2007]. It is an actively developed, standard-aware project. It can work with in-memory ontologies, and is sufficiently fast in management and searching. We had to make some modifications to satisfy our requirements, such as versioning of the repository content, ensuring editing atomicity, and an edit interface. Now, Sesame 2 is used.

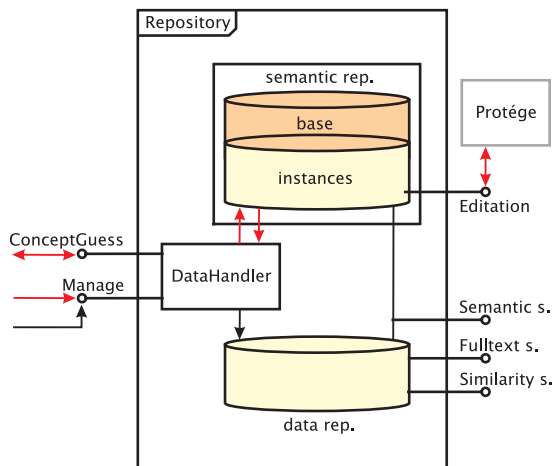


Figure 2: Repository structure

#### 4 Acquiring the semantics

The semantics of a document can be derived automatically or entered manually. For the learning purposes is an *annotation*, i.e. a facultative manual acquisition, probably the best option. It is relatively fast, lucid, and it gives the user full control power. Annotation tools should have no specialized GUI as a domain expert is not necessarily a computer expert.

The area of *text annotation* is relatively well-researched. We try to enrich tools we are using. For example, semantic wiki module of multi-project portal system Deep Thought [Gregar et al. 2009] is under development complying with the requirements in [Klamma et al. 2007].

The following area, *picture semantics acquisition*, has more issues. Project *aceMedia*, <http://www.acedmedia.org/aceMedia> was aimed to create a data framework and a semantic adaptive multimedia content management system. We adopt some of its ideas and modified them for our purposes.

Our framework subsystem for picture annotation is called *Iris*. It suggests concepts for picture segments depending on the selected domain. Users can select the proposal supplied automatically, or assign their own semantics. We proposed the following annotation algorithm in [Gregar and Pospíšilová 2006]:

1. *Segmentation* — the system is prepared to use various segmentation modules. In-house implemented module includes edge-based segmentation based on input settings and generating a multilevel segment structure.
2. *Graphics descriptor acquisition* — segment as a complex structure — must be identified by a vector of descriptors (MPEG-7-based, defined in *Visual*

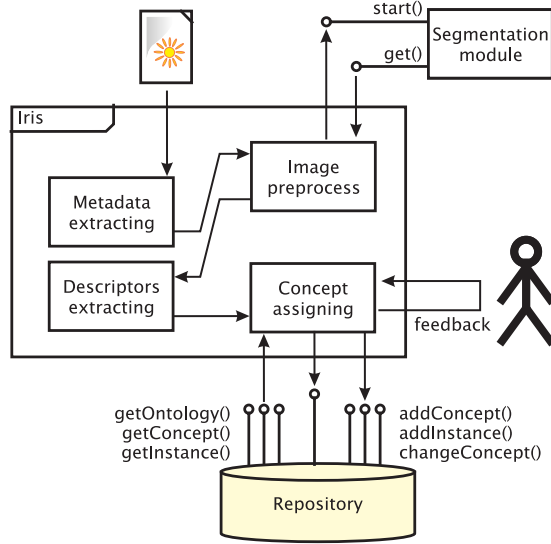


Figure 3: Structure of the IRIS

*descriptor ontology*, VDO) values. We gather various graphic descriptors: *Dominant colors*, *Texture*, *Shape* (Excentricity, Convexity, Compactness), its *Size*, *Position*; and also *Structure of the segment*.

Descriptors can be described by a single value (excentricity), a vector (shape), a histogram (dominant colors), or a set of histograms (texture).

- 3. *Saving the picture structure* — the structure is defined as a set of instances of a segment concept in the *Media structure ontology* and stored. Each segment is described by its VDO-values vectors.
- 4. *Automatic concept proposal*
- 5. *User approval and usage*

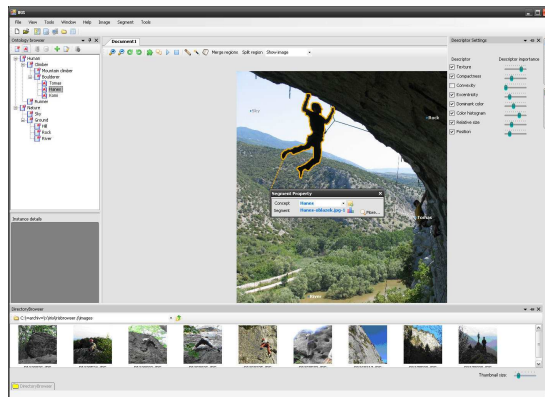
### 4.1 Automatic concept proposal

Furthermore, the domain ontology is modified to incorporate graphical information to make the annotation easier. Every concept in the ontology contains not only the definition or standard properties, but also a link to the archetypal graphical description of the concept. This description is extracted from a set of all depictions of the concept. This descriptions contains boundary values for simple descriptors or a value histogram and its weight. These descriptions allow to reduce resource requirements in the subsequent steps of the algorithm.

- 1. The domain ontology is walked throught from the top of the hierarchy (i.e. the most general terms).

2. The computed descriptor values of the processed segment and the archetypal ones are compared.
3. If the vector of the values does not correspond with the saved archetypal metadata (i.e. some descriptors are out of range), the whole concept tree is cut off from the search.
4. The pruned tree gives a list of concepts in different levels of the domain hierarchy. To find the most closest concept (i.e. processed segment can be its depiction) we utilize SVM (support vector machines) machine learning. We use all instances of the identified contestant concepts in this learning, i.e. we classify a processed segment among X classes (concepts).
5. Ontology driven revision (from the lowest level to larger segments). Modifications are driven based on the subsegment concept proposal. Other modifications can be driven by the user who can explicitly change the concept.

After the user endorses the assignment, the boundary values, histogram, and weight of the descriptors are modified. This advanced data processing is scheduled to less busy system time.



**Figure 4:** IRIS screenshot

## 5 Visualization module

Applications of the stored semantics in various domains also require some general process to visualize these data. For knowledge captured in RDF there is a proposed standard *Fresnel Display Vocabulary*. We implemented a visualization editor and browser called *Fresnel Editor*. There is currently no other editor with similar capabilities.

## 6 Conclusions and Future Work

Present semantics driven tools usually suffer from their user-complexity and/or a narrow specialization. This paper described design and implementation of a lightweight semantic framework. Its main goal was to facilitate the use of semantics in e-learning processes. Thus, we had to give up some common requirements, like logic inference or automatic semantics acquisition, and we focused on interactivity, processing speed, and user-friendliness.

The documented API of the framework enables further development of semantic tools for visualization of annotated text concepts in full text, tagging assistance, search augmentation using semantic relations, visualization of the output with Fresnel, or further development of the repository.

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# Visualization of Spatial Knowledge with Ontology Trees and Adaptable Search Result Grids in the Era of Web 3.0

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**Abstract:** With the emerging trend of Web 3.0 and the resulting huge amount of user-generated semantically-enriched data, improved ways of knowledge visualization and human computer interaction are needed. We present several techniques of visualizing particularly spatial knowledge in largely scalable, clear structured ontology trees on the web. In addition, we describe the representation of search results with a combined approach consisting of Ajax-based grids and Google Maps.

**Key Words:** spatial knowledge visualization, search results visualization, ontology  
**Category:** H.5.2

## 1 Introduction

The visualization of spatial knowledge in the era of Web 3.0 raises interesting new research questions. How can one represent huge collections of knowledge (e.g. ontologies with over 10 million concepts) as browsable trees in a scalable manner and with a clear user interface? Which is an easy-to-use and efficient representation of search results, especially over spatial data? These are the central questions we want to address with our visualization approaches.

The visualization techniques we present in this paper are part of the **UbisWorld** project, which focuses its research on ubiquitous user modeling [Heckmann 2006] and Web 3.0, i.e. the integration of the ideas of the Web 2.0 with the technologies of the Semantic Web [Wahlster and Dengel 2006]. The knowledge base of the system is built out of two ontologies: GUMO (General User Modeling Ontology) [Heckman et al. 2007] and UbisOntology. Several external ontologies (e.g. SUMO [Pease 2002], DOLCE, OpenCyc) and taxonomies (e.g. the Amazon.com category tree) have also been parsed and integrated into the UbisWorld.

The ontologies are represented as foldable trees whose nodes consist of classes and instances whereby the conversion from ontologies (usually represented as graphs) to trees is performed by using multiple heritage. All the trees can be browsed in a very efficient way by using Ajax technologies [Loskyll 2007] [Garrett 2005].



This means that the data needed to display the layer of a tree is sent to the client not before the user has opened the corresponding parent node. Using this visualization technique we are able to display huge ontologies as trees. In addition to classes and instances, we are also able to visualize relations and properties as well as limitation nodes which help to make the trees easier to browse. While other approaches like the GeoTree (<http://geotree.geonames.org/>) only display at most 999 nodes per tree layer, we are basically able to display arbitrary large numbers of nodes on one layer and to keep a clear structured user interface at the same time.

The second methodology described in this paper aims at an easy-to-use representation of search results. Again we use Ajax technologies to create an adaptable search result grid, which provides paging and sorting functionalities. Additionally, the currently shown search results are displayed as markers on Google Maps. Both approaches are highly optimized for collections of spatial knowledge. Therefore, we demonstrate them by means of our UbiEarth ontology.

## **2 Visualization of Spatial Knowledge and Search Results**

Nowadays, more and more spatial knowledge and location-aware data become publicly available due to user-generated content in the Web 2.0. Consequently, improved techniques for identification, visualization and interaction are needed for user interfaces.

### **2.1 UbiEarth: Visualization of Named Graphical Entities and their Spatial Relations**

In the UbiEarth ontology tree (our largest ontology with about 28 million nodes) we display the different instances of the world beginning on top and going down over continents, regions and cities up to even buildings and rooms. In addition, the tree contains many lakes, streams and mountains. In order to add further meaning to the different nodes and to give the tree more structure, we created different role (or relation) nodes as depicted in Figure 1.

The role "Country", for instance, not only tells us that Europe has 52 countries, but also the other way around, i.e. that Austria, for example, is a country located in Europe. This figure shows another strength of our approach: using a newly defined mechanism to define multilingual labels, which we call UbiLabel, we are able to display not only the English translation of a country's or city's name, but also the appropriate translations into all the languages spoken in the corresponding country.

Furthermore, this tree emphasizes the biggest strength of our visualization technique by pre-processing and displaying limitation nodes, which subsume large numbers of nodes depending on the number of nodes on one tree layer in ten

thousand or hundred packets, respectively. These nodes add additional structure to the tree hierarchy and facilitate an easy-to-use tree browsing. This is one of the big advantages of our approach compared with related work like the GeoTree mentioned above.



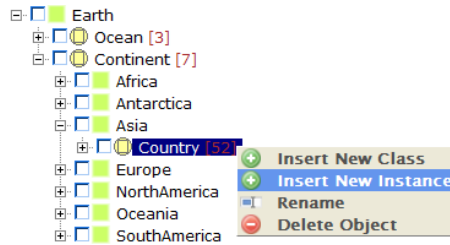
Figure 1: Part of the UbiEarth ontology tree

The properties of different locations are also integrated into the tree. For countries we show information like area, capital, currency, spoken languages and population (Figure 2 left), whereas cities can have properties like altitude, latitude, longitude, population, zip codes or dialing codes (Figure 2 right).



Figure 2: Left: Property nodes for Austria; Right: Property nodes for Graz

Based on this visualization technique, we implemented an extension of the ontology tree representation with additional editing functionalities. This online ontology editor (called UbiEditor) [Loskyll and Heckmann 2009] shall make an end-user friendly collective knowledge building possible. The editor already supports the most important functionalities for editing an ontology: creating new classes or instances, renaming and deleting objects. By using a context menu, we provide an efficient and easy-to-use way of performing these editor actions (Figure 3). With the help of UbiEditor our users could add new translations of location names, fix mistakes or add an instance of their residence, for example.



**Figure 3:** UbiEditor after right mouse button click

## 2.2 UbiSearch: Adaptive Search Results of Spatial Data

UbiSearch is our search engine, which can be used to find classes, instances and properties of our ontologies. This is an important feature, especially when a user plans to insert a new element into the UbiWorld ontology, but is not sure whether such a concept already exists. We built our own inverted index, in which we assign each term that occurs in a UbiLabel of our ontologies to the corresponding list of UbiPointers (our unique object identifiers). By doing so, we are able to perform search queries in an efficient way. However, the big difference compared with the Google search engine, for example, is that we search over a set of labels instead of documents.

We display the results by using a JavaScript grid, which supports on-demand-loading by using Ajax technologies and paging, i.e. we can present very large search result sets. The grid can be sorted either by relevance, UbiPointer, UbiLabel or population. By default, the information is sorted firstly by relevance and secondly by population (or UbiLabel in case of non-spatial data). Figure 4 shows the search results for the key word “Graz”. In addition, you can easily make sure that this is the Austrian city by looking at the parent column, which shows the different occurrences of this city in our ontology. One of the parents

tells us that this is a city in Austria. The idea behind the occurrence column is that we can have multiple occurrences of one location (e.g. a city can appear as located in a country, but also in a region). Selecting one of the occurrence links opens the corresponding node in the ontology tree.

**Search Results:**

12 search results found for 'graz': Relevance ↓

Relevance	UbisPointer	UbisLabel	Population	Occurrences	Parents
100%	<a href="#">CITY_2778067</a>	Graz [ Gradec ]	222326	<a href="#">M_G-0-1-3-0-3-0-0-33-72</a> <a href="#">M_G-0-1-3-0-3-1-5-0-7-21</a>	<a href="#">3301-3400OfCityAtAustria</a> <a href="#">701-800OfCityAtSteiermark</a>
70%	<a href="#">CITY_2773020</a>	Langegg bei Graz		<a href="#">M_G-0-1-3-0-3-0-0-63-75</a> <a href="#">M_G-0-1-3-0-3-1-5-0-14-10</a>	<a href="#">6301-6400OfCityAtAustria</a> <a href="#">1401-1500OfCityAtSteiermark</a>
70%	<a href="#">CITY_2770874</a>	Nestelbach bei Graz		<a href="#">M_G-0-1-3-0-3-0-0-78-4</a> <a href="#">M_G-0-1-3-0-3-1-5-0-17-2</a>	<a href="#">7801-7900OfCityAtAustria</a> <a href="#">1701-1800OfCityAtSteiermark</a>
70%	<a href="#">CITY_2766565</a>	Sankt Marein bei Graz		<a href="#">M_G-0-1-3-0-3-0-1-8-97</a> <a href="#">M_G-0-1-3-0-3-1-5-0-23-85</a>	<a href="#">10801-10900OfCityAtAustria</a> <a href="#">2301-2400OfCityAtSteiermark</a>
70%	<a href="#">CITY_2766420</a>	Sankt Radegund bei Graz		<a href="#">M_G-0-1-3-0-3-0-1-10-17</a> <a href="#">M_G-0-1-3-0-3-1-5-0-24-11</a>	<a href="#">11001-11100OfCityAtAustria</a> <a href="#">2401-2500OfCityAtSteiermark</a>
70%	<a href="#">CITY_2774894</a>	Kalsdorf bei Graz		<a href="#">M_G-0-1-3-0-3-0-0-52-40</a> <a href="#">M_G-0-1-3-0-3-1-5-0-11-32</a>	<a href="#">5201-5300OfCityAtAustria</a> <a href="#">1101-1200OfCityAtSteiermark</a>
70%	<a href="#">CITY_2779671</a>	Feldkirchen bei Graz		<a href="#">M_G-0-1-3-0-3-0-0-23-97</a> <a href="#">M_G-0-1-3-0-3-1-5-0-4-83</a>	<a href="#">2301-2400OfCityAtAustria</a> <a href="#">401-500OfCityAtSteiermark</a>
70%	<a href="#">SUBREGION_AT06601</a>	Graz Stadt		<a href="#">M_G-0-1-3-0-3-1-5-1-0</a>	<a href="#">SubregionAtSteiermark</a>
70%	<a href="#">SUBREGION_AT06606</a>	Politischer Bezirk Graz Umgebung		<a href="#">M_G-0-1-3-0-3-1-5-1-5</a>	<a href="#">SubregionAtSteiermark</a>
70%	<a href="#">STREAM_2778066</a>	Graz Bach		<a href="#">M_G-0-1-3-0-3-3-4-52</a>	<a href="#">401-500OfStreamAtAustria</a>

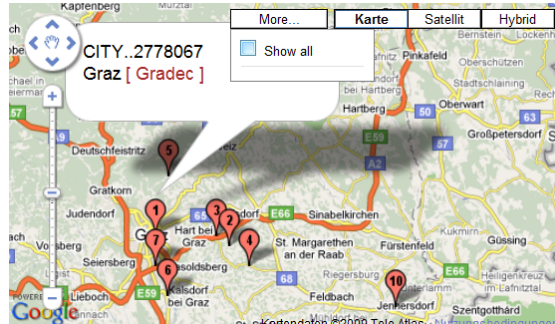
1 2 — Records from 1 to 10 of 12

Figure 4: Adaptable search results for “Graz”

In addition to the grid visualization, we display the ten search results that are currently shown on the selected page of the grid as numbered markers on Google Maps (Figure 5). The numbering of the markers make it easy to identify which search result corresponds to which location on the map. We also provide a functionality to show all search results at once as Google Maps markers.

### 3 Conclusions and Future Work

We have addressed the questions how to represent huge knowledge sets as scalable trees on the web and how the represent particularly spatial search results in an easy-to-use manner. As partial answers, we have presented improved techniques for visualizing huge sets of spatial knowledge with the help of newly defined ontology trees by means of our UbiEarth ontology. Our ontology tree representation approach includes concepts to define relations, properties and structuring nodes in an Ajax-based tree visualization. Furthermore, we described how our adaptable search result grid can be used to efficiently display, browse



**Figure 5:** Displaying search results with Google Maps

and sort large sets of search results. These technologies can be tested as registered user at [www.ubisworld.org](http://www.ubisworld.org).

In the near future, we are going to perform an extensive evaluation of the ontology tree and search result grid visualization techniques.

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# SACA : Software Assisted Call Analysis

## Structuring, Extraction and Storage of Contents

### Retrieval, Exploration, Comparison and Clustering of Phone Dialogues

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**Abstract:** 30.000 advisory calls per year! How to analyze, rate and improve them interactively? For getting these goals a novel technique is introduced, which is based on a structure similar to a music score. Via a “duet”, guided by the advisor called, the main contents of the dialogue are extracted and stored automatically. At this, *trained speech recognition* is applied for the (known) advisor’s part for monitoring and controlling the call’s course, and *keyword spotting* is used for the (unknown) “customer” to pick out instances from sets of expected values. The results thereof fill an abstract score annotated to the call conducted. Then, because of the strong structure of such scores, the archive of all these dialogues is an ideal base for retrieval, exploration, comparison and clustering of calls, using e.g. graphical tools like *knowCube*<sup>®</sup>.

**Keywords:** Communication in Healthcare; Telephony Applications; Knowledge Visualization; Speech Recognition; Keyword Spotting; Call Analysis; Human Computer Interfaces; Retrieval; Exploration; Clustering; Multi Criteria Decision Making; Knowledge Management.

**Categories:** H.3, H.4, H.5, M.0, M.4, M.7

## 1 Introduction

*Communication in Healthcare* is the main task of a telephone information service division in one of the biggest German institutes doing medical research [DKFZ, 2009]. In 2008 about 30,000 people (mainly patients or doctors) were asking the employees of this division by phone for advice. It obviously would be of high value to get some knowledge from this tremendous treasure of information contained in the calls. But up to now, nothing is kept back.

In an earlier test phase, some work was done in summarizing the main contents of the calls into text documents, immediately after the calls. But these efforts failed for two reasons: Firstly, because then a big part of an advisor’s working time was consumed for documentation, and lost for the principal purposes. Secondly, because it was observed additionally, that there were big discrepancies between the actual call contents and the summaries written down afterwards.

So, another method should be developed, that could extract and store the essentials of the dialogues automatically, or at least interactively, where the form of the resulting data base were suitable for arbitrary, user-friendly access, e.g. to retrieve and analyze single calls, to do statistics on selected sets of them, or to make comparison and clustering of calls. And, in the end, it would be very nice additionally to have an algorithm for rating all these calls via an impartial score method.

## 2 Telephony Applications

A central role in the complete process of phone call analysis will be played by *Speech Recognition*. What about its status quo?

Speech recognition means the automatic transcription from spoken language into written text. Today, in the so-called “trained mode” (where the recognition or translation software is adapted to the specific speaker a priori) and under optimal prerequisites (especially with respect to acoustic environmental and technical conditions) a recognition rate of more than 95% may be expected. In the “untrained mode” however (if an unknown person calls) only some few, within phrases embedded words can be detected, by a technique known as *Keyword Spotting*.

Altogether that appears a bit disappointing! But, besides the fact that the desire of a 100% transcription of a trained/untrained dialogue into text is utopian, at least today, such a perfect transcription wouldn't be very helpful anyway, because these results could not be analyzed automatically due to their unstructured form.

This leads to a concept for tackling *Software Assisted Call Analysis* in two consecutive steps:

- 1: Online structuring, extraction and storage of substantial contents of a call.
- 2: Offline retrieval, exploration, comparison and clustering of dialogue sets.

More details will be given below. In future, both steps should merge more and more, such that the leadership of the dialogue will be supported by automatic and interactive accesses on the complete knowledge stored in the data base of structured call contents.

A cut out of current information concerning the domain of *human language technology* in general and *telephony applications* in particular will be found in the following literature sources: [Varile, 98], [Sojka, 08], [Wahlster, 00], [Shneiderman, 00], [Boyce, 00] and [Horndasch, 06].

*Signposts to Tomorrow's Human-Computer Interaction* and *Experiences with Commercial Telephone-based Dialogue Systems* are the themes of [Bullinger, 07], [Nöth, 04], [Peissner, 04] and [Hipp, 08].

Finally follows, for the more practically oriented reader, a short (not complete, and not judged) list of software tools, which are widely used in real-life situations: *Dragon Naturally Speaking* (Nuance Communications Inc.), *SpeechMagic* (Philips Speech Recognition Systems GmbH) and *Voice Pro* (IBM Corporation) support the task of *Speech Recognition* on the counselor's side; *SymSpot* (Sympalog Voice Solutions GmbH), *AudioClipping* (Com Vision Betreibergesellschaft mbH) and *SpeechAgent* (SpeechConcept GmbH) enable *Keyword Spotting* for the caller's part.

### 2.1 Substantial Contents of a Call

First, a short abstract of a telephony dialogue will be given from the counsellor's point of view: An (unknown) caller introduces oneself, more or less detailed, and then states some questions. The (known) counsellor answers, usually asks for more details concerning the person and the questions, then the caller inquires again, ... – and, in the background, the dialogue is guided by the counsellor.

What is the quintessence of such a call, i.e. which data should be extracted, structured and stored (automatically)?

The calling person is characterized by a number of meta data, like sex, age, body size and weight, ..., family status, professional education, living region, ..., level of language. These data all are indispensable, how to get them automatically will be shown later on. And just as a remark, personal data of the counsellor are superfluous, they are known anyway.

Now, how to determine the essentials of the dialogue itself? In this telephony application primarily health topics are concerned, like illness, complaints, symptoms and treatments (in the caller's language) or anamnesis, diagnosis, therapy and course of illness (from the counsellor's point of view). For distilling the core of such a dialogue, a predominant multitude of its words obviously is not significant. Instead, a set of keywords (in most cases substantives and adjectives) will be sufficient for summarizing the content, as it is done for instance by a medical bulletin – or, rather “flowery”, the *libretto* of an opera.

## 2.2 Structured Dialogue Mappings

Under the assumption that all keywords to be annotated to an actual dialogue were identified and extracted online, they then had to be stored in a well-defined structure to be usable for automatic or interactive processing. Therefore, a logical arrangement of topic blocks and a temporal succession of phases present themselves as candidates for segmenting the complete dialogue. To each of these segments corresponds a set of parameters, where each of these parameters may attain none, one or more values of metric, ordinal or nominal elements (= keywords). Thus, the set of all dialogues is mapped on a set of structured tables.

## 3 The SACA Score

Musicians know about the enormous information density included in a music score. A well-known example is shown below.



Figure 1: The Magic Flute – Title page of W. A. Mozart's music score



This inspires to take an object similar to a score as a structural basis for the mapping range of phone dialogues: A score may be seen as the abstraction of e.g. an opera performance, where the libretto therein concentrates the complete “story” or plot upon comparatively short voice parts expressing merely “the very essentials”. The various acts in an opera correspond to specific phases in the dialogue, the voice parts are associated with caller and counsellor, and the conductor (= SACA) leads through the opera or dialogue.

There are still more parallels to find between music and SACA scores, like pitch, tempo, loudness, mode or mood. They all can be integrated fraught with meaning, as sketched in Figure 2 below.

### 3.1 A C-C Duet

Some concepts are visualized there, where the beginning of a *Caller-Counsellor Dialogue* is shown at the figure's lower part, together with a *Duetto* (between Pamina and Papageno – to support association) on top. The caller, e.g. a patient, tells something, recorded in the first Text-line, and the counsellor's spare comments (“So so”) are shown in the second Text-line. At this, three different pitches should be sufficient for each of the voices, and for the tempo and loudness well-known musical marks may be adopted. Even mode, mood and further features could be integrated similarly.

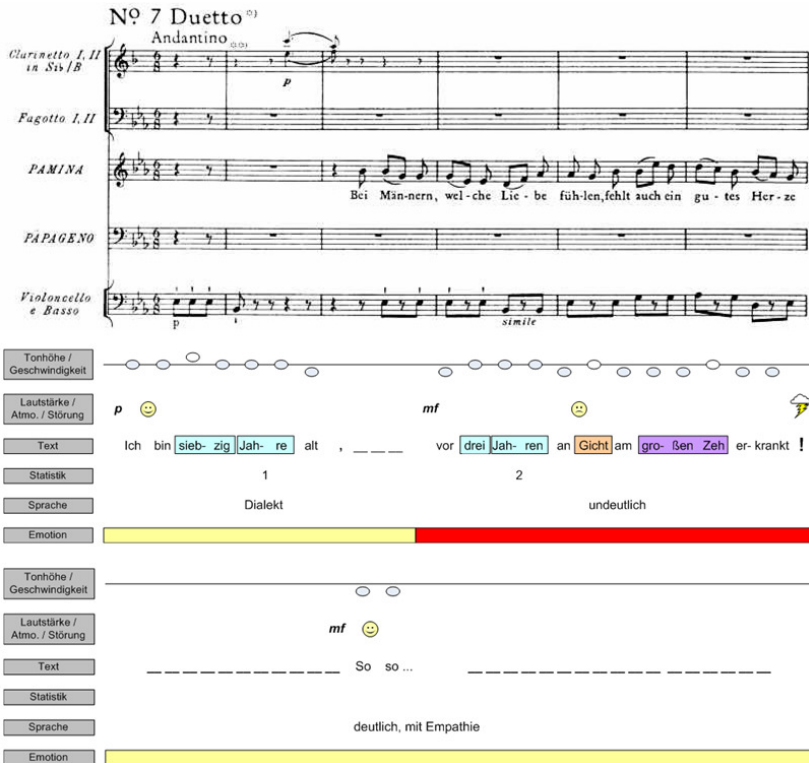


Figure 2: Prototype of a C-C Duet Score

Now, getting back to the text lines in the score, where some words are shown with coloured background: These colours correspond to different topics managed by the counsellor, as introduced in Section 2.2. Under optimal technical conditions, like e.g. separated voice stream channels of caller/counsellor and maximum frequency domain of the counsellor's microphone, *trained speech recognition* can be used by SACA to identify the current phase of the dialogue for activating a corresponding data base table. From the words and phrases contained therein, *keyword spotting* done on the caller's voice stream channel detects case specific items, and SACA fills all of them into a well-defined data structure annotated to the dialogue.

### 3.2 A Composition

The C-C Duet represents only a small part of an advisory call. Several of such pieces add to a phase (or *act* – like anamnesis, diagnosis, therapy), and the composition of all results in a complete counselling phone dialogue (or *opera*). A detailed structure for guiding this dialogue is prescribed by the DKFZ information service division.

In the course of such a “workflow” SACA realizes and shows what information still is missing for a sufficient characterization of the current dialogue. It gives hints to the counsellor which segments should be taken up again for discussing relevant topics and thereby getting some more “spotted values” of relevant, yet void parameters.

To summarize: The counsellor carefully conducts the caller through the dialogue, SACA detects the current segment, loads corresponding keyword sets, listens to the caller's part and picks out matching values. In the end, SACA has produced an abstract composition of the caller's demands and the counsellor's advices.

## 4 Outlook

SACA is a project in progress. At the moment, experiments are done to get answers to some questions concerning recognizing, qualifying and navigating calls, like e.g.:

- Speech recognition starts with the “trained part”. If 95% of the counsellor's information is extracted automatically, how much is grasped then from the complete dialogue content, based on a well-known knowledge domain?
- The caller's demands are characterized by structured lists of spotted items, and these are matched with the counsellor's set of information sources used during the dialogue. Does this lead to a suitable overall qualification note?
- A more detailed qualifying of a call is possible, if single notes are given to the various segments of the complete dialogue. How are the concepts of multi criteria decision making then transferable for retrieval, exploration, comparison and clustering of phone dialogues?

In the future, SACA will be an integrated software package showing two faces:

- A *D-GUI* supports the daily work, where dialogue information is extracted online, using current, most powerful tools for speech recognition, keyword spotting and emotion detection. In the background, the caller's requests are “compared” unobtrusively with available knowledge in the SACA data base and the advices given by the counsellor. Based on that, hints are posted to the GUI, telling which information could be more appropriate for arguing, or how to “guide” the dialogue into a better “emotion mode”. All these hints are

to be considered as suggestions, showing a red thread for the dialogue, similar to a project development process as introduced in [Trinkaus, 08].

- An *E-GUI* for the expert helps in doing offline statistics on the complete data base of SACA scores, and furthermore assists the retrieval or exploration of single dialogues, up to the comparison or clustering of selected dialogue groups. Therefore, based on the strong structure of the scores, the intuitive software package *knowCube*<sup>®</sup> is used, enabling information exploration by well-known graphical tools like pen, brush and text marker [Trinkaus, 07].

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# **Knowledge-Intensive Business Process Audit: The Practical Aspect**

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**Abstract:** Knowledge-intensive organizations that carry out many Knowledge-Intensive Business Processes (KIBP), seek to improve and enhance their KIBP for gaining competitive advantages. These organizations need to develop their Knowledge Management (KM) infrastructure of KIBP, starting from knowledge audit that is a necessary first step in any KM initiative. As KM infrastructure integrates social and technological disciplines, we developed a combined Socio-Engineering Knowledge Audit Methodology (SEKAM) for a systematic audit of the KM infrastructure in the context of KIBP. In this paper we present and discuss the conceptual framework of SEKAM and its instruments developed in this research.

**Keywords:** Knowledge audit, knowledge modelling, knowledge intensive business process

**Categories:** M 1, M 4, M 9

## **1 Introduction**

KM initiative is considered a primary managerial activity of any knowledge-intensive organization. However, observing organizational KM initiatives reveals that many of them do not comply with organizational expectations, partly because knowledge audit, that is a necessary first step in a KM initiative, is being avoided or underperformed [Hylton, 02].

Current knowledge audit methods in literature (e.g. [Bright, 07]; [Handzic, 08]) do not address several issues related to knowledge audit research, specifically in the context of KIBP: most of the existing methods propose general, cross-organizational knowledge audits, without focusing on specific KIBP; various methods suggest conducting knowledge audits, usually with a focus on a single perspective of the KM infrastructure, either culture, knowledge processes, or IT rather than the triple-perspective KM infrastructure audit required; most of the existing knowledge audit methods provide only a theoretical description of their audit steps, and lack practical instruments for information elicitation and analysis during the audit process. Some of the methods, which do provide such instruments, focus only on the technical or social aspects of knowledge modeling. Applying only one of these approaches is insufficient

when analyzing the comprehensive KM infrastructure requirements of KIBP, since KM is tightly linked to both the engineering and the social perspectives.

Our research aims at bridging these gaps by developing a systemic and flexible approach for knowledge audit in the context of KIBP, harnessing both the technical and the social approaches. In this regard we developed the Socio-Engineering Knowledge Audit Methodology (SEKAM) that provides structured detailed knowledge audit guidance regarding the KM infrastructure components in the context of KIBP. Each of the SEKAM steps is based on practical knowledge modeling instruments for information elicitation and analysis. For the construction of SEKAM, we utilized the method engineering approach [Hong, 93] in order to assemble a comprehensive knowledge audit framework. A detailed description of the construction process is presented in [Levy, 09]. In the current research, practical instruments within the framework of SEKAM for auditing KIBP were developed and applied in a real knowledge-intensive organization.

## **2 SEKAM Detailed Description**

In this section we present SEKAM's stages in general and in particular the newly developed SEKAM's instruments used during these stages.

### **2.1 Stage 1 – Organizational Analysis**

Identifying a high-level perspective of knowledge oriented problems and opportunities; prioritizes them and selects one or several fields to audit. In each selected area, the analyst identifies core KIBP for detailed auditing. A detailed description of this stage is presented in [Levy, 09].

### **2.2 Stage 2 – Define Audit Project Properties**

In order to provide a high-quality and consecutive audit process, it needs to be managed as any other organizational project, managing budget, schedule and scope – the “triple constraints” of project management [P.M.I., 04]. The detailed guidance for carrying out these activities can be found in PMBOK [P.M.I., 04].

### **2.3 Stage 3 – Knowledge Inventory of the Business Process**

In order to provide a high-quality and consecutive audit process, it needs to be managed as any other organizational project, managing budget, schedule and scope—the “triple constraints” of project management [P.M.I., 04]. The detailed guidance for carrying out these activities can be found in PMBOK [P.M.I., 04].

#### *2.3.1 Step 3.1 - Identify pivot employees involved in the chosen business process*

Identifying employees involved in the audited are for participating in audit processes, interviews and observation.

Structure	A structure chart of the considered (part of) organization in terms of its departments, groups, units and sections, which have direct or indirect knowledge-related relations with the audit process.
Goal	Goals and value of the business process.
Actors	Workers executing the tasks of the KIBP and the relations between them.
Customers	Workers who could benefit or lose from the changes in the business process (followed by knowledge management improvement).
Transformation	The inputs and outputs of the process.
Owner	Decision makers who have the authority to change the process.
External environment	Partners, suppliers, customers and other external figures involved in the business process.
Culture	'Unwritten rules of the game', including styles of working and communicating ('the way we do things around here') and informal influencing relationships and networks.
Resources	Examples: legacy systems, portal, office, wiki, email, shared folders, personal experience and others.

*Table 1: SEK 1 - General description of the business process environment*

### 2.3.2 Step 3.2 - Identify business process environment

Preparing a high level process description, including process flow, stakeholders and process's characteristics. This enables the audit analyst to profoundly explore the process environment, people involved, knowledge resources used during the process execution and cultural issues. The audit tool in this step is SEK 1 worksheet (Table 1).

### 2.3.3 Step 3.3 - Define business process workflow

Next, the audit analyst describes in details the audited process in terms of the tasks it is composed of using SEK 2 worksheet (Table 2), and their main knowledge characteristics using SEK 3 worksheet (Table 3).

No	Task name	Performed by	Preceding tasks	Follow-up tasks
1...n				

*Table 2: SEK 2 - High-level process description*

Task Name	No
Goal and value	The goal and value that the task's execution adds to the process.
Guidance	The existence of guidance, procedures or rules for task execution.
Agents	People, systems and other resources responsible for carrying out the task.
Knowledge input	Knowledge inputs involved in the task, the sources of knowledge and how people access/retrieve required knowledge
Knowledge output	Knowledge outputs of the task; how this knowledge is documented and where it is stored.
Frequency	How is often the task performed?
Duration	How long does the task's execution usually take?
Constraints	Constraints that must be satisfied during the task's execution.
Competence	Relevant skills and experience needed for successful task performance.
Measures	Organizational quality and performance measures for determining successful task execution.

*Table 3: SEK 3 - Detailed analysis of process' tasks*

Finally, the combination of SEK 2 and SEK 3 allows the analyst to generate a business process flowchart with emphasis on tasks that relate to the KIBP as illustrated in Fig. 1 within the rectangle zone.

#### *2.3.4 Step 3.4 - Analyze knowledge inventory within the business process*

Next, the audit analyst describes in details the audited process in terms of the tasks it is composed of using SEK 2 worksheet (Table 2), and their main knowledge characteristics using SEK 3 worksheet (Table 3).

The audit analyst carries out in-depth analysis of the knowledge assets involved in the audited business process, using the knowledge assets analysis worksheet SEK 4 (Table 4) as well as worksheet SEK 5 (Table 5). Knowledge assets refer to explicit and tacit knowledge involved during the execution of business process tasks. For each type of knowledge asset (defined in SEK 3 as knowledge input or output), the analyst may use SEK 4 in order to identify sources and locations of the needed knowledge for executing the process tasks. Sources can be legacy systems like CRM or ERP, intranets and portals, content systems, file servers, emails, PC, papers, people and so on.

Sources:	Knowledge asset 1	Knowledge asset 2	...
Source 1..n			

*Table 4: SEK 4 - Knowledge sources involved in the business process*

Next, for each type of knowledge asset (defined in SEK 3), the analyst should may SEK 5 in order to estimate its level of quality for the following parameters: accuracy, recency and ease of finding during task execution. Use scale from 1 (very bad) to 5 (very good).

N	Knowledge asset	Used in task	Ease of finding and retrieving	Recency	Accuracy and trustworthiness
1...n					

Table 5: SEK 5 - Knowledge assets involved in the business process

The next step is utilizing SEK 6 modeling technique for generating knowledge inventory diagram (Figure 1), as demonstrated through an example of its implementation for the Request For Proposal (RFP) process steps.

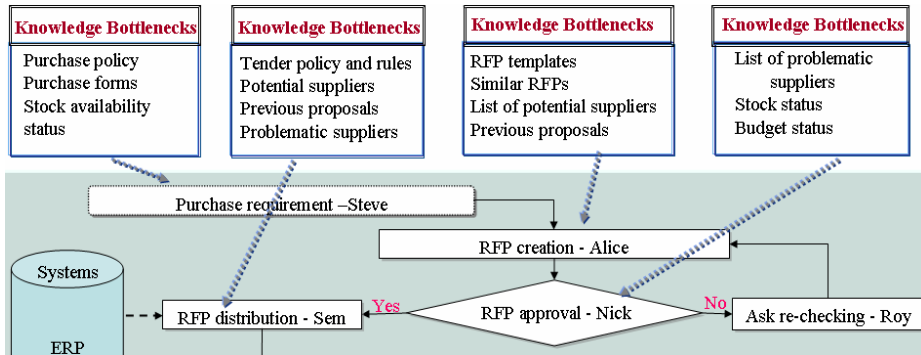


Figure.1: SEK 6 - Example of knowledge inventory diagram implementation of RFP

This diagram illustrates the knowledge bottlenecks within each of process tasks. While creating this diagram, the analyst decides which of the knowledge items revealed in SEK 4 and SEK 5 will be presented within the diagram. For example, during the RFP creation by Alice, “similar RFPs” knowledge item was identified as a knowledge bottleneck and presented within the knowledge inventory diagram. The reason for this choice is that during SEK 4 analysis, “similar RFPs” were identified within eight different sources such as team portals, file servers, emails, and co-workers’ desktops. During SEK 5 analysis, people ranked 2 (out of 5) the “ease of finding and retrieving” parameter for “similar RFPs”, 3 the “recency” parameter, and 3 the “accuracy and trustworthiness” parameter. This knowledge item was identified as partial, scattered and a non-updated knowledge input for the task “RFP creation” executed by Alice.

2.3.5 Step 3.5 - Analyze informal knowledge interactions within the process

In order to clarify informal knowledge interactions within the process and to reveal all possible scenarios where these interactions occur, the analyst may use SEK 7 (Table 6) worksheet. In addition, for combining hard elements such as process flowchart and



soft elements such as culture or social knowledge networking, the SEK 8 modeling technique, named knowledge interactions diagram, is used as demonstrated in Figure 2.

Worker Name	Description
Organization	The knowledge worker's role in the organizational hierarchy.
Involved in	The worker's tasks.
Responsibilities	The worker's responsibilities within the task execution, and any restrictions in this respect.
Communicates with	The communication with other workers, including various scenarios of knowledge interaction between workers.
Knowledge	The knowledge items possessed by the worker.
Constraints	The constraints that refer to authority limitations and professional norms.

Table 6: SEK 7 - Analysis of informal knowledge interactions

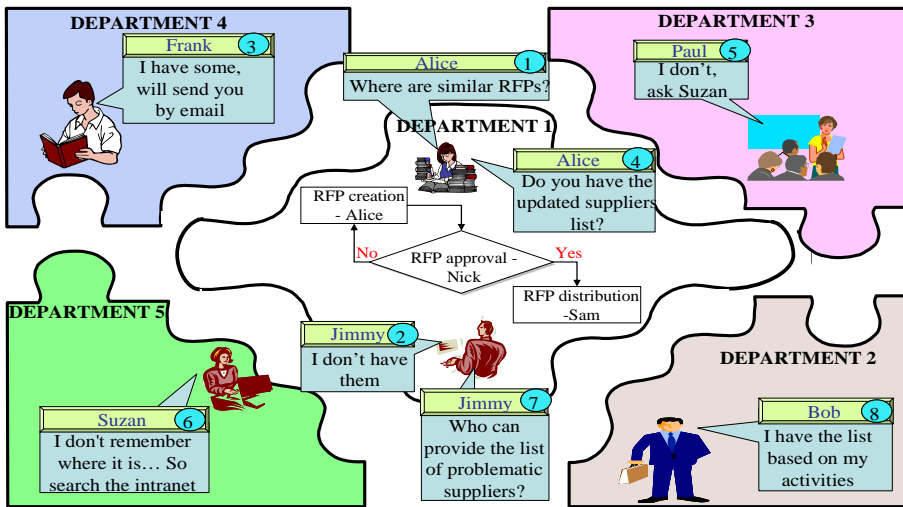


Figure 2: SEK 8 - Illustration of informal knowledge interactions diagram of RFP

Figure 2 demonstrates knowledge-related informal relationships among co-workers involved in a RFP process, including people from other departments, who can provide useful knowledge on demand. The process flowchart is the central focus of the diagram, while social activities are the natural complementary elements of the process activities. The diagram provides clarifications about knowledge sharing barriers. It's a simple diagram that is easily understood by managers, including those with no technical background. Figure 2 presents example of informal knowledge interactions that occur during the RFP process (the numbers represent the sequence of the social interactions). In this example, Alice can't perform her task (statement #1) using knowledge sources and asks for Jimmy's help. Jimmy transfers the question to Frank (statement #2), and so on. People from different teams and departments are asked to help and provide information. Finally, Frank from Department 4 and Bob

from department 2 transferred the information directly to Alice, avoiding the existing policy to publish this information with the defined templates. Due to these social interactions, Alice didn't receive the knowledge on time and the task execution was delayed. We propose to analyze such situations as much as possible in order to gain a better understanding of the KM infrastructure components.

#### **2.4 Stage 4 – Analyzing the KM Infrastructure of the Business Process**

The above SEKAM stages provide information elicitation instruments with regard to the KM infrastructure components. In this stage, we suggest guidance for analyzing the data collected in stages 1-3. In order to analyze KM infrastructure components, organizations should select from various existing frameworks, the one that best fits their particular set of circumstances. Various methods of KM infrastructure analysis are described in [Aviv, 08].

#### **2.5 Stage 5 – Audit Results Approval**

The KM analyst reviews and approves the audit results with the business managers. A detailed description and illustration of this stage is presented in [Levy, 09].

### **3 Conclusion**

In this paper, we suggest a methodology for eliciting and analyzing KM infrastructure requirements in the context of KIBP. SEKAM is a step-by-step methodology, highly connected to the business context through integrative audit of knowledge and business processes. SEKAM provides an integration of both aspects – social and engineering – for analyzing KM infrastructure solution requirements. Using SEKAM's visualization techniques aims at enabling managers to gain a wide and detailed picture of the current KM infrastructure environment within the business processes. They can thus uncover behavioral patterns of knowledge sources and identify knowledge bottlenecks towards defining requirements and expected business value of the desired KM solution. SEKAM is based on existing, already validated, methodologies and tools and thus can be theoretically justified. Nevertheless, examining the actual added value of this combined approach in real settings is important. Future work will focus on applying and validating the suggested methodology within knowledge-intensive organizations, and evaluating the actual benefits gained by using this methodology.

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# **Becoming Knowledge Focused: Classifying Explicit Knowledge for Transparency in International Organizations**

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**Abstract:** The paper makes an attempt to develop a business classification scheme for organizing information assets in an international organization. It proposes a conceptual model, to explain and enhance the understanding of complex issues involved in the organization of information in international knowledge-based organizations.

Eight different international organizations were studied, including the European Union (EU), the International Atomic Energy Agency (IAEA), the International Maritime Organization (IMO), the OPEC Fund for International Development (OFID), the Organization of the Petroleum Exporting Countries (OPEC), the Organization for Security and Co-operation in Europe (OSCE), the United Nations Industrial Development Organization (UNIDO) and the United Nations Office on Drugs and Crime (UNODC) and were classified according to their functional orientation. Over 40 interviews were conducted, with organizational leaders, knowledge managers, IT managers and human resources managers. The project also reviewed the current literature on managing knowledge, identifying aspects relevant to the international organization context.

Organizational leaders, knowledge managers, IT managers and consultants involved in creating and implementing knowledge management initiatives aimed at process improvements in international organizations context could benefit from the reflections and learning insights from this paper.

This paper does not address efficiency matters from the political or governing sphere, nor does it propose specific programmatic changes to work of international organizations; rather it presents a pragmatic "bottom-up" approach, based on case studies and interviews conducted.

**Keywords:** knowledge management, Business classification scheme, international organizations

**Category:** M.9

## **1 Introduction**

All international organizations are expected to serve as a repository of technical expertise for its member countries, serving its member countries and regional commissions, as well as other international organizations and in this capacity advise them on various questions of international and national significance. Conceptually, issues faced by international organizations can be classified, based on their functions (cf.[Ugbor and Chanduvi-Suarez 2007]).

International organizations are non-profit oriented and by nature have a significant purpose of trust, made explicit in their respective mandates. Trust is vital for knowledge management [Nonaka, et al. 2000] and is needed for influencing

multilateral actors in international organizations. Thus, information access was seen as a means to building and maintaining trust with both internal and external stakeholders of international organizations.

## 2 Towards a more transparent information management

Transparency is crucial for the effectiveness of international organizations [Mitchell 1998]. The processes of the knowledge chain (cf.[Ugbor and Chanduvi-Suarez 2007]), including the acquisition, analysis and dissemination of regular prompt and accurate information, underpins the one of the most important functions of international organizations. All organizations in the sample are making efforts to automate and codify their administrative and substantive work, using various systems for classifying and storing explicit knowledge, such as Enterprise Resource Management (ERM) systems, Electronic Document and Records Management (EDRM) systems, Electronic Workflow (WF) systems, and so on. These information systems enables activities of international organizations to mobilize resources on time, including staff, equipment, setting up offices, ensuring logistic support, to transfer resources from one operation to the next and to account for funds and in-kind contributions that make up parts of its administrative and substantive activities.

In order to enhance the transparency of information assets, a logical classification of information is necessary [MOREQ 2001]. Functions and activities of international organizations provide a stable framework for classifying information than organizational structures [NAA 2001]. For example, in UNIDO, the organizational structure has changed 24 times since 1985 [UNIDO 2007]—but its basic focus on operational matters of international development significance, remains the same. Therefore, a function-based approach can anchor information firmly in the processes of international organizations. A functions-based classification of information has the following advantages, as it helps international organizations to:

- Identify records that should be created because of their evidential value for the member countries;
- Recognize high priority records that should be captured because of their significance to member countries;
- Make decisions on retention; and
- Sentence records at the point of creation [Kennedy and Schauder 1998]

Building upon the accumulated knowledge of international organizations' functions (**operational** functions are centred on technical cooperation work and **normative** functions are centred on research, norms and standards) and its knowledge chain and knowledge products (cf.[Ugbor and Chanduvi-Suarez 2007]), a generic business classification scheme (BCS) can be developed, a hierarchical model of the relationships between an organizations functions, activities and transactions [DIRKS 2001] as shown in Figure 1.

The analytical process for creating a BCS (cf. Figure 1) starts with a “big picture” view of the organizations activity and breaks it down to more detailed parts [DIRKS

2001]. The component parts are broken down in descending order as the organizations functions, activities and transactions.

Operational functions in a BCS (cf. Figure 1) can be used to group everything related to field work i.e. technical cooperation activities, from project schedules and project logframe files to lessons learned, project assessments and so on. The normative function category in the BCS can be used to group all activities relating to the organizations multilateral networks with other actors in international affairs (such as information on outcomes of meetings with other international organizations and governments), as well as public information, like public websites, publications and public records. Management functions can be used to group the secretariat and administrative aspects, such as human resources management and finance information.

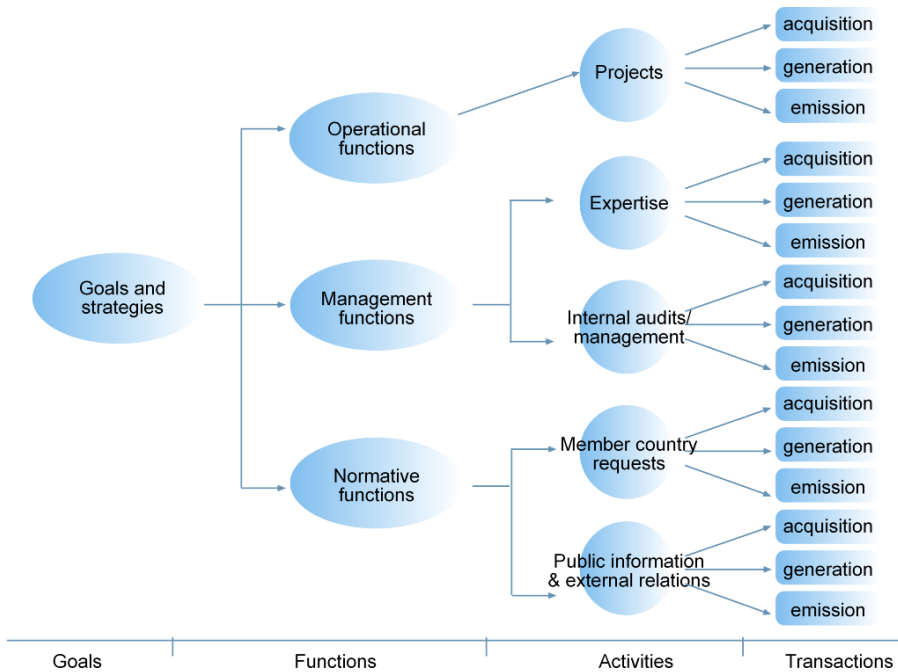


Figure 1: Analysis of business activity for a BCS

Although the analysis above, derived from a hierarchical depiction of generic functions and activities of international organizations (cf. Figure 1), can be used as a starting point for designing a BCS, the scale of these components are relative, rather than absolute. For example, business transactions are relative in scale to organizations. Transaction in an international organization include information coming in (acquisition), solutions being generated to meet these requests, taking into consideration prior knowledge (generation), and information going out to various stakeholders (emission) (cf. [Ugbor and Chanduvi-Suarez 2007]). In all cases, the scale of transactional components will need to be manipulated to create a meaningful, practical BCS for a particular organization, taking into consideration other aspects of

information management, like metadata, taxonomies, ontologies, security requirements and so on.

### **3 Knowledge Politics**

At the organizational level, information and knowledge dissemination are influenced by internal and external politics. For example, normatively oriented international organizations in the sample had a stronger bias towards using technology for securing access to information and documents, rather than to people. In IAEA information is controlled in such a way that security classifications and personnel clearances are complicated by an additional requirement described as “the need to know”. This requirement involves the implementation of special classes that define small categories of personnel who are able to view specific records according to their role within the organization and their relationship to a specific project and even nationality. Nuclear inspectors in the IAEA have access only to records and projects, based on their accreditation to a particular country, their nationality and their direct involvement in a particular project.

Operationally oriented international organizations used technology to represent “who knows what” rather than “what they know”. For operational functions like technical cooperation activities carried out in UNIDO, OSCE and OFID, a larger part of their substantive work is done in the field, including consultancy, project management and implementation support, requiring a greater degree of embodied, encultured and embrained knowledge [Blackler 1995], and thus there is a greater need to use technology to connect people and communities of practices [Wenger 1998, Wenger 2003]. UNIDO’s knowledge portal, “The Exchange” allows registered users to browse, search and find references to experts (people) within UNIDO’s worldwide network of offices, and from selected partner institutions. Overall, the portal serves as a central point for information dissemination, networking and matchmaking operations. Efforts at codification of tacit knowledge in UNIDO are mainly for strategic planning, monitoring/evaluation and service improvements.

A knowledge manager in an international organization needs to be aware of how these political and functional factors impact knowledge management initiatives, with a view to taking informed decisions about classification and information access.

### **4 Conclusions**

Information access, has been reported to be one of the keys to successful implementation of knowledge management in international organizations [Ugbor and Chanduvi-Suarez 2007]

Explicit knowledge can be classified according to the main functions and activities of the organization (cf. Figure 1) as a first step in the creation of a business classification scheme [DIRKS 2001], and other more detailed classifications like taxonomies, thesauruses, semantic networks, ontologies and so on [Klischewski 2003], that are useful for structuring electronic information and documents. Inherent in this process is the need for highly skilled information architects, which are able to classify and organize information assets for better user experience.

Increasing the understanding of political pressures faced by international organizations as they carry out their work, highlights what kinds of classification schemes are likely to be most effective. Preoccupation with individual work or technology alone, rather than organizational dynamics, prevents full comprehension of the organization's problems and limits the assistance that can be provided by knowledge managers and information architects to make the organization more transparent at managing its knowledge.

### **Acknowledgements**

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# **I-SEMANTICS '09**

## **International Conference on Semantic Systems**

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## **Towards a New Generation of Social Networks: Merging Social Web with Semantic Web**

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**Abstract:** This article investigates several well-known social network applications such as Facebook, LinkedIn, Last.fm, Flickr and identifies semantics and social data portability as the main technical issues that need to be addressed in the future. We argue that these issues can be addressed by building social networks like Semantic Web applications with FOAF, SIOC, and Linked Data technologies, and show how this can be done by implementing a prototype application using Java and core Semantic Web technologies. The developed prototype shows how features from semantic websites such as Freebase and DBpedia can be reused in social applications and lead to more relevant content and stronger social connections. In addition, the article discusses a number of issues that need to be addressed in the design and implementation of semantic social networks, which could serve as a guideline in the implementation of other semantic social applications.

**Keywords:** social networks, Semantic Web, Linked Data, semantic interoperability, ontology

**Categories:** H.1.2, H.5.1, H.5.2, H.3.4, H.5.3, H.5.4

### **1 Introduction**

Social web or Web 2.0 has fundamentally changed the way in which people interact, communicate and share information. The on-line collaboration, interaction and participation is facilitated by social networking sites (LinkedIn, Facebook) and social applications (YouTube, Flickr,) where the social dimension, and in particular the user community tightly integrated into the application domain is crucial for the success of the application. User communities are created around various domains like music sharing, photos sharing, videos sharing, social bookmarking sharing, professional networks, etc. On the Social Web, users are provided with means to express their views and are encouraged to provide content. User-generated content and metadata is provided in simple forms like tagging, ratings, comments, blogging, podcasting or wikis. Social networking applications are driven exclusively by the content provided by the users, which is one of the defining characteristics of the Social Web. As a result large amounts of data and information are gathered in “walled websites”. Relevant information is often poorly structured, buried in low-quality information or surrounded by highly subjective data. Most of the social networking applications are “walled websites” and the “online communities are like islands in a sea” [Bojars, '08].

Despite their tremendous success, social networking websites have a number of limitations that are identified and discussed below. Lack of interoperability between

data and lack of semantics in different social network applications limits access to relevant content available on various social networking sites, and limits the integration and reuse of available data and information. This may result in a growing dissatisfaction of the user community and a reduced usability of the websites. This article shows through the implementation of a prototype that Semantic Web technologies can be used to build a next generation of social networks that overcome limitations of current social network applications and enable new features currently not exploited by them. The article emphasizes the need for semantics and mechanisms to better structure this information and make it interoperable.

Research combining social networks and the Semantic Web is an interdisciplinary field, attracting researchers from both social and computer sciences. More research combining social networks and the Semantic Web is required to address the above-mentioned limitations. An important line of research combining social networks and the Semantic Web focuses on the extraction of semantic data from existing social applications, its representation and its analysis. Existing work in this area explores the possibilities of extracting ontologies from user contributed folksonomies through collaborative tagging systems and of integrating ontologies with folksonomies [Specia, '07; Xu, '06], while other approaches propose the development and evolution of lightweight ontologies in a collaborative way [Angeletou, '07; Mika, '07]. Researchers seem to agree that folksonomies and lightweight ontologies have more properties in common than differences and will be further integrated, and thus, in the future, a community-based bottom-up approach might prevail over top-down controlled engineering efforts. Much of the current research for representing simple user profiles is based on the Friend of a Friend (FOAF) project<sup>1</sup> – a project aimed at “creating a Web of machine-readable pages describing people, the links between them and the things they create and do”. FOAF is currently an important source of RDF data available on the Web which has already been used for social network analysis [Ding, '05; Finin, '05; Paolillo, '05]. A related initiative is the Semantically-Interlinked Online Communities (SIOC) project,<sup>2</sup> which provides an ontology for describing items and relationships from Internet discussion methods (such as blogs, forums, and mailing lists) to facilitate interconnection of these methods by publishing metadata [J. Breslin, '07; J. G. Breslin, '05]. Many recent papers highlight a growing interest in portability issues among social network applications; they are regarded as “fundamental problems”, and semantic technologies, mainly FOAF, are being proposed to solve them [Mika, '05].

Theoretical work combines the Semantic Web (SW) and social networks, especially for the analysis of social networks and the extraction of knowledge from existing data [Ding, '04]. However, neither the creation of new end-user semantic social applications nor their design and implementation is well explored. Existing social network applications do not employ SW technologies, although most of the standards infrastructure is already in place. Most are “walled” websites, which provide limited means for users and developers to control, publish, and access social data. This limits possibilities for reuse and integration, which are the driving forces

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<sup>1</sup> <http://www.foaf-project.org/>

<sup>2</sup> <http://www.sioc-project.org/>

behind both Web 2.0 and the Semantic Web, and results in growing dissatisfaction in the user community.

This article discusses some of the limitations of current social network applications and shows how Semantic Web technologies can be used to build a new generation of social networks which overcome these limitations and enable new features currently not exploited. The article is structured into six sections. The section below discusses a number of common features and technological limitations of current social networking applications. Section 3 identifies and describes a number of issues that need to be handled in the design and implementation of the next generation of semantic social networks. Section 4 presents a concrete scenario usage for a semantic social application. A presentation of a semantic social network prototype featuring semantic mashups is proposed in section 5. The last section summarizes the role of semantics for the development of a new generation of social networks in order to better harness and integrate the collective knowledge made available by the various social applications.

## **2 Study of Social Networks**

Social networking sites are developing at a very fast pace, attracting more and more users. These sites have become central points on the Web for sharing personal information and online socialization. They allow users to create a personal profile and link to profiles of their friends. The resulting network can be browsed to find common friends, friends that have been lost or forge potential new friendships based on shared interests [Mika, 07].

The core feature in all social networks is the user community, which is tightly integrated with the application domain. We have analysed applications which we personally use and which we think reflect the current state of the art in social networking: Last.fm, Flickr, YouTube, Facebook, LinkedIn. As an outcome of a review of social networks, we have identified a number of generic features that are common to the majority of social networks as well as a number of technological limitations.

Common features of social networks include:

- User-contributed content -The content is provided exclusively by the users.
- Recommendations - If a user shows interest in some resource, the application suggests other resources that might be relevant or similar.
- Folksonomies - Users are allowed to tag almost any resource.
- Comments - Users are allowed and encouraged to comment on almost any resource.
- Top lists can be of various types: lists of most interesting, most popular, most commented on, most recently added or updated resources and so on. Lists can be compiled on a personal or group basis, or for the whole website.
- Favourites are either built by users manually by adding resources, or compiled from the resources the user has shown interest in.
- User groups - Users can join groups, whether public or restricted. They are usually set up by people with similar interests or a circle of friends.
- Data accessed using Application Programming Interfaces (API). As a recent Web 2.0 trend, social networks have begun to open up some of their data to

the public, which is later most often used in various mashups. Most sites publish RSS or custom XML data feeds, while others provide programmatic methods to control the site to the same extent as using the graphical interface.

Social networking applications have a number of technological limitations as summarized below:

- It is not possible to export/import profile data from one application to another
- It is not possible to export/import social relationships from one application to another
- There is usually less data available in machine-readable formats than the application contains
- Application Programming Interfaces (APIs) are based on a variety of custom formats and protocols, some of which are non-standard (such as Facebook Query Language (FQL)-a language similar to SQL and Facebook Markup Language (FBML) which is HTML with custom elements in Facebook).

Our observations fit well with statements by initiatives such as *Open Social Web*,<sup>3</sup> *Social Network Portability*,<sup>4</sup> *DataPortability*,<sup>5</sup> *OpenID*,<sup>6</sup> *OpenSocial*,<sup>7</sup> which have emerged as a result of a growing dissatisfaction in user communities.

Semantic social networks will still focus on the community dimension while drawing on Semantic Web technologies to aggregate content. Some examples of semantic social networks are further discussed in section 2.1.

## 2.1 Examples of Semantic Applications

**Freebase** is an open database of the world's information. It acquires structured data spanning different domains such as music, people and locations from various sources such as Wikipedia and MusicBrainz.<sup>8</sup> The data is aggregated, identical or related concepts being linked together. In addition, users in the community can add, edit, and even upload data. Topics in Freebase are organized by types which are grouped into domains. An important feature is that users can not only fill already predefined types with instance data or edit it, but can also create their own types and define their properties, i.e. they can create new schemas and extend Freebase's domain model using the same interface. Furthermore, it provides an open but proprietary API for its data and encourages its use in applications and mashups.

**DBpedia** is a community effort to extract structured information from Wikipedia and to make this information available on the Web via a semantic representation. It provides an RDF dataset extracted from Wikipedia, which contains mostly free text but also structured information such as categories, lists, infoboxes, links to external

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<sup>3</sup> <http://opensocialweb.org/>

<sup>4</sup> <http://microformats.org/wiki/social-network-portability>

<sup>5</sup> <http://www.dataportability.org/>

<sup>6</sup> <http://openid.net/>

<sup>7</sup> <http://code.google.com/apis/opensocial/>

<sup>8</sup> <http://musicbrainz.org/>

pages etc. DBPedia makes it possible to perform complex queries (such as “*German musicians who were born in Berlin*”) over a SPARQL query interface. DBPedia is a prime example of Linked Data publishing and can be browsed using semantic browsers. It is interlinked with other semantic datasets such as Geonames,<sup>9</sup> MusicBrainz etc.

### 3 Towards Semantic Social Network Applications

The next generation of Social network applications using semantic technologies needs to address a number of issues that are identified and further discussed, e.g. the creation of metadata, user interface design, openness of domain models, the publishing and reusing of data and metadata. These four aspects are further elaborated below.

#### 3.1 Creation of metadata

Folksonomies use uncontrolled keywords (tags) like a simple form of metadata to annotate and categorize items on a website, making them easier to discover and retrieve. Folksonomies are the primary sources of metadata on Web 2.0. However, they have issues with consistency, ambiguity and lack of synonymy. A next step beyond Web 2.0 is the Semantic Web. Semantic Web or Web 3.0 is a new layer of the Web, a “Giant Global Graph” [Berners-Lee, 2006], which will make use of semantics and access machine processable data in order to better support navigation, searching and provide a number of enhanced services for the users. On the Semantic Web, creation of metadata, a data with machine-processable meaning, is as important as the data itself. Metadata derived from tag clouds and folksonomies may help aggregating various fragmented pieces of data and information into collective knowledge. It has been observed how folksonomy tags evolve into *property:value* triple-tags, which serve the same purpose as *subject property object* triple statements in RDF and thus folksonomies move towards becoming lightweight ontologies. This phenomenon has even been called “poor man’s RDF” [Andersen, '05]. Social networks will provide more sophisticated means to directly create RDF metadata, and collaborative tagging may evolve into lightweight ontology development and may be integrated into collaborative modelling of the social network domain.

#### 3.2 User interface

Much work is left on the issue of how to present semantic data to the user in applications, not to mention editing it [Ankolekar, '08]. There are a number of semantic browsers, such as Tabulator,<sup>10</sup> Disco,<sup>11</sup> OpenLink RDF Browser,<sup>12</sup> Objectviewer,<sup>13</sup> Zitgist.<sup>14</sup> They are able to render generic RDF data for human users

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<sup>9</sup> <http://www.geonames.org/ontology/>

<sup>10</sup> <http://www.w3.org/2005/ajar/tab>

<sup>11</sup> <http://www4.wiwi.fu-berlin.de/bizer/ng4j/disco/>

<sup>12</sup> <http://demo.openlinksw.com/rdfbrowser/index.html>

<sup>13</sup> <http://objectviewer.semwebcentral.org/>

<sup>14</sup> <http://dataviewer.zitgist.com/>

and navigate through different data sources through RDF links, just as conventional Web browsers navigate through HTML links. However, this kind of presentation is probably too advanced for mainstream Web users (see Figure 1).

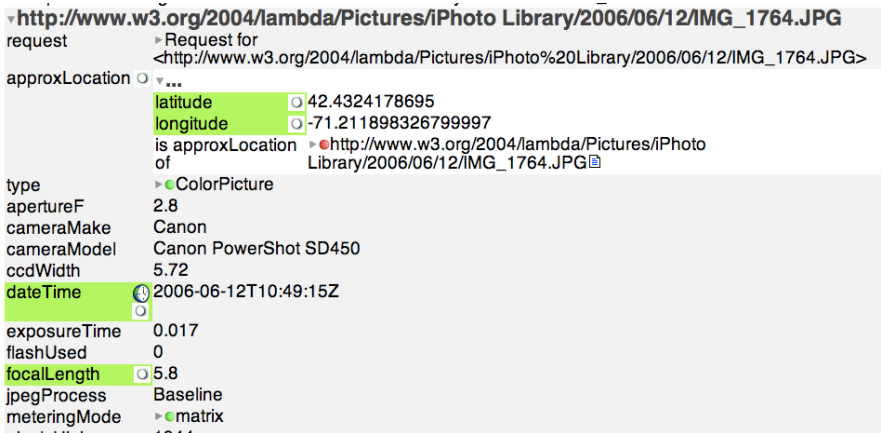


Figure 1: Tabulator view

It can be assumed that a Semantic Web application interface visualizes its domain ontology in such a way that each class and instance has its own page, linked to others through class-instance and instance-instance relationships. This *generic* approach is used in many semantic websites, and is probably best illustrated by Freebase. Another approach, which we call *specific*, is used by conventional Web applications, as well as social networks. Every type of information (such as a car, a user, or an event) has its own specific user interface. For each new type a new interface has to be created; the same interface cannot be used for different types, and interfaces have to be fixed when the schema changes. This approach is obviously not feasible on the Semantic Web, where ontologies are meant to be extended, reused, and integrated from different sources. If social networks are to become extensible semantic applications, it is likely that they will have to adopt the generic approach.

### 3.3 Domain model

Social network applications (Last.fm, Flickr, LinkedIn, etc.) are usually developed for different application domains such as music, photos, and business. However, they share a common property: the domains are fixed and non-extensible. Users are encouraged to contribute and improve application data, but this is restricted to instance data for predefined types. Semantic applications such as Freebase take a different approach and allow users to edit the domain model itself: not only to fill in instance data, but to extend and edit types, add new types, and define properties in the underlying ontology. Following this approach, social network applications would empower users to express their identities by creating or reusing concepts and relationships relevant to them, and share them with others. The domain model could be left to the community to control and further develop it in a direction which is currently of most interest to it, keeping it relevant over time. People would connect



through things they have in common, achieving object-centered sociality [Breslin, 07]. In the future, this may be achieved by integrating lightweight ontology development into the means of user collaboration and content contribution. In order to implement this approach, applications are usually modelled in RDF/OWL as they offer more expressivity than object-oriented and relational models. This data model is based on formal semantics and therefore interpreted unambiguously by different agents. Furthermore, they need to reuse FOAF and SIOC ontologies, which are currently the state of the art representations of social networks on the Semantic Web, as well as other relevant ontologies. Most current SW applications are also static and fixed in the sense that ontologies are known and mapped manually at design time [Razmerita, 03]. Although semantic technologies are designed with extensibility and openness in mind, current programming languages and tools are not able to fully exploit it. It is expected that future semantic applications will be using multiple ontologies, discover them and integrate them on request.

### **3.4 Publishing and reusing data and metadata**

Large amounts of meaningfully interlinked RDF data available on the Web are crucial for achieving the Semantic Web vision. However, many social networks do not offer interfaces and APIs to access application data. Others make the contents of the website (such as lists of users, songs, or pictures) available via a simple read-only REST interface in a software-processable data format, usually a custom schema of XML, Atom, or RSS. Some provide full APIs with add/update methods, invoked via various interfaces such as REST, XML-RPC, SOAP, Atom, or OpenSocial. A variety of publishing formats (especially non-standard) make reuse difficult. We advocate that semantic social networks should publish their data in RDF, designed specifically for distributed knowledge representation. Furthermore, all resources in social networks (including non-information, “real-world” resources) should be given URIs, distinguished from URIs of the representations that describe them, and published as Linked Data.<sup>15</sup> APIs should be replaced by SPARQL endpoints, which would allow running remotely structured queries against application data. Semantic data representation and advanced interfaces would help to overcome portability issues of proprietary APIs and interconnect social networks with different data sources, enable use of semantic browsers, and facilitate semantic mashups.

## **4 Use case scenario**

In this section, we provide a concrete scenario of how a semantic social network would enhance current Web 2.0 tools and the user experience. Consider Sarah, who is a socially active person both online and offline. She likes to go out several days a week and hang out in bars or clubs. She also likes art and cinema, and visits exhibitions and movie theatres once in a while. Sarah is also picky and busy, so she likes to evaluate all the cultural and night-out options she has, preferably planning them at least a week in advance and only visiting those which she finds interesting. Sarah is an advanced Web user, but she is still struggling to find information about

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<sup>15</sup> <http://linkeddata.org/>

what events are there, and where and when they take place. Most of the information is online, but it is spread across many different websites and is also incomplete. In a club-goers portal she usually finds a list of parties for the next week. However, it is compiled by editors from the official announcements received from clubs, and consequently many smaller venues or underground events are left out. For an overview of current exhibitions and opening hours, she has to visit homepages of several museums, check another portal to see the movie timetable, and finally put all the dates and times on one list to see how they match her schedule. Sarah often likes to try something new, so even when she finds an event of interest, she may have no previous knowledge of the venue it takes place in. Therefore she has to look up the address in yet another website, a mapping service, to find her way there. Now, imagine she comes across a website where users themselves are allowed and encouraged to contribute content about events and places. Places are listed by type (such as *Club* or *Museum*) and location, which can be shown on the map. Events are also shown by type (such as *Party* or *Exhibition*), and are related to place and time. Sarah can immediately see a list of events of any type, at any place, or any date, as well as a list of places at a certain location. Moreover, users are able to indicate which events they are attending and which places they usually prefer, and on the basis of this lists of the most popular events and places are built, which might help her to make her decision. She might subscribe to a feed of upcoming events and follow it in her RSS reader. If Sarah wants to contribute to the site or make use of the social features, she has to sign up and create her profile with some personal information. After that, she can add friends as well as favourite events and places to her profile. From an analysis of events and places she and her friends like, the application might suggest some new possibilities. If Sarah knows an event will be taking place but is not listed on the website, she can simply fill in a short description form, set the place for it, and save it. Since the website is built with semantic technologies, Sarah is also able to import friend profiles from other social networks that publish them in a semantic format. She is also able to run structured queries against the data in the website and put a list of events she will be attending in a mashup on her homepage.

## 5 Prototype application design and implementation

The application prototype is a social network that allows users to browse events (such as concerts and conferences) and places of interest (such as venues and hotels) and find those that are most relevant to them. As described in the previous section, the purpose of this application is to make it easier for the users to discover events and places that are most likely to be of interest to them.

The prototype features a generic user interface. Users are able to browse OWL ontology classes and their instances, and see properties with values, as represented in Figure 2. Within the application users are able to import a list of friends from an external FOAF source. The application provides Linked Data access by serving interlinked RDF/XML which can be visualized and browsed using semantic browsers such as Tabulator, or reused in other applications. It provides a SPARQL endpoint, which allows running structured queries. It also implements a semantic mashup: when a page of an instance is requested, the application queries remote DBPedia SPARQL

endpoint, retrieves its description and homepage address in real time and presents it to the user in the same fashion as local properties and values. The prototype is implemented based on a RESTful Web framework which treats HTTP resources as first-class objects and follows a Model View Controller (MVC) pattern and W3C standards.

On top of the data layer, Model-View-Controller (MVC) pattern is often used for logical separation of application domain and presentation layers [Krasner, 88].

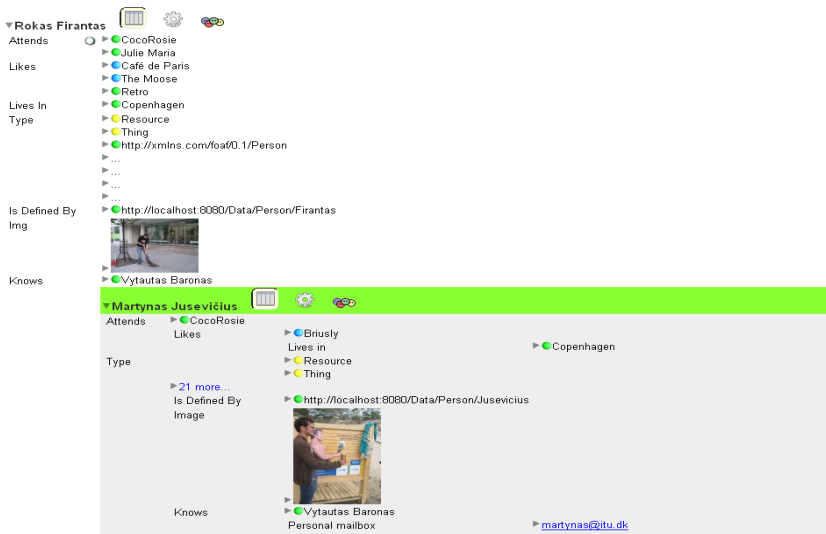


Figure 2: Browsing the ontology in a Tabulator view

## 5.1 Model View Controller (MVC) design pattern

Model View Controller is a design pattern used in software engineering. In complex computer applications that present lots of data to the user, one often wishes to separate data (model) and user interface (view) concerns, so that changes to the user interface do not impact the data handling and the data can be reorganized without changing the user interface. The MVC design pattern solves this problem by decoupling data access and business logic from data presentation and user interaction, by introducing an intermediate component: the controller. The controller translates interactions with the view into actions to be performed by the model. In a stand-alone GUI client, user interactions could be button clicks or menu selections, whereas in a web application they appear as HTTP GET and POST requests. The actions performed by the model include activating business processes or changing the state of the model. Based on the user interactions and the outcome of the model actions, the controller responds by selecting an appropriate view.

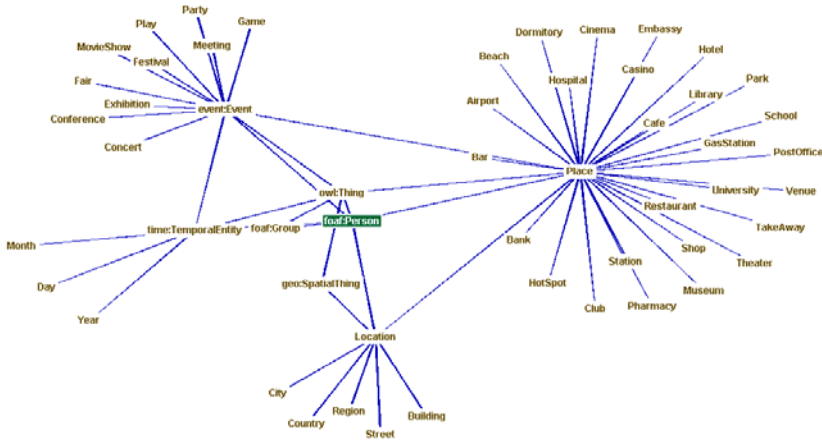


Figure 3: Domain ontology graphical view

Within the prototype, the Model is the ontology layer, the Java code is the Controller and Views are generated by integrating SPARQL queries results and transforming them into XHTML using XSLT. The application domain is modelled as an RDF/OWL ontology stored in a RDF triple store, accessed using Jena,<sup>16</sup> and queried using SPARQL. The domain ontology extends classes such as foaf:Person and adds a number of new classes such as: Place and Event as represented in Figure 3. FOAF and SIOC classes and properties are reused. Views become representations of REST resources (XHTML, RDF). They join several SPARQL XML results and transform them directly to output XHTML using XSLT, or serve raw RDF/XML for the Linked Data interface, depending on the HTTP *Accept* header. Controller dispatches requests to resources which have explicit URIs, implements HTTP methods, and can be related to domain instances using *foaf:topic*, and return view representations.

Most of the current object-oriented languages are statically typed and do not allow classes to be changed or extended at run-time. Thus it is not easy with the existing tools to map Event class in OWL to an Event class in Java so that it can be changed or extended at run-time.

Tools such as RDFReactor<sup>17</sup> and Elmo<sup>18</sup> generate object-oriented Java code from our ontologies, but this code is static and not extensible at run time and therefore it was not used.

## 6 Conclusions and future work

This article has provided an overview of the state of the art of actual social network applications. Common features and technological limitations were identified and

<sup>16</sup> <http://jena.sourceforge.net/>

<sup>17</sup> <http://ontoware.org/projects/rdfreactor/>

<sup>18</sup> <http://www.openrdf.org/about.jsp>

discussed in section 2. Based on this analysis, in section 3, the authors propose four main areas (creation of metadata, user interface design, open domain models, publishing and reusing data and metadata) that require further investigations and developments in order to implement semantic social networks. Semantics is the key for overcoming current limitations of social applications. Furthermore, social data portability issues are leading to dissatisfaction in both user and developer communities. This is caused by limited amounts of social data published openly and lack of tools to import them as well as formats and APIs of limited interoperability. Social networks would benefit from Semantic Web technologies. FOAF, SIOC, and Linked Data can solve portability issues and enable data reuse.

The prototype described in section 5 shows how features from semantic websites such as Freebase and DBpedia can be reused in social applications and lead to more relevant content and stronger social connections.

New generations of social applications may take advantage of the advanced data model that SW technologies provide. Semantic data representations and advanced interfaces would help to overcome portability issues of proprietary APIs, interconnect social networks with different data sources, enable the use of semantic browsers and facilitate semantic mashups.

Domain models could be collaboratively developed by users of the application. This approach requires a new generic user interface based on classes, instances, and properties. This could lead to more up-to-date and relevant content, which in turn would facilitate social connections through points of common interest. Another interesting approach that could be further explored in the future is the use of an AJAX-enabled application interface, a form-based interface for SPARQL and dynamic, run-time object-ontology mapping tools.

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## Towards a Collaborative Semantic Wiki-based Approach to IT Service Management

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**Abstract:** This paper proposes a collaborative approach to aspects of IT service management (ITSM) for agile information technology landscapes composed of technically knowledgeable users and fast changing requirements. The cost-intensive and time-consuming tasks of building and maintaining a configuration management database (CMDB) are accomplished in a distributed, collaborative way in a semantic wiki in cooperation between administrators, service desk personnel and users of the systems. Moreover, the paper introduces a flexible, wiki-based approach to change management for agile environments. Automatic consistency checks based on semantic information extracted from the wiki prevent misconfigurations and the unintentional application of conflicting configuration changes.

**Key Words:** semantic wiki, collaboration, ITSM, configuration management, CMDB

**Category:** H.5.3, I.2.4, K.6

### 1 Introduction

IT service management (ITSM) is the discipline which is responsible for dealing with all information technology processes which are relevant for successfully reaching a company's business goals. In contrast to IT management disciplines of the past, which dealt mostly with technical aspects of information technology, ITSM provides a customer-centric view, which focuses on the contribution of IT to the customer's business success. There are several frameworks, which give guidelines for implementing ITSM processes, with the Information Technology Infrastructure Library (ITIL) being the most prominent one [Clacy and Jennings 07].

Configuration management [Lacy and Macfarlane (07)] is the process within IT service management which is responsible for describing all entities, which are used to provide IT services, as well as the relationships between these entities. Entities relevant for configuration management are referred to as configuration items (CIs). Descriptions of configuration items and relationships between configuration items are stored in the configuration management database (CMDB),

which is the logical abstraction of all physical databases which contain information that is relevant to the configuration management discipline within an organization [Köhler (07)]. While there exists a variety of tools for automatically populating and updating CMDBs, not all information can be determined and put in context automatically.

Wikis are a special form of web sites, in which users are able to not only read published content but are also able to add new information as well as to change existing information. While the Wikipedia encyclopedia<sup>1</sup> is the most prominent example of a wiki, wikis are often used as collaboration tools in companies or projects in order to facilitate knowledge management between coworkers. The MediaWiki<sup>2</sup> software, which is used to run Wikipedia, is a freely available tool which is used for setting up wiki sites in many companies. Due to its extensibility and the availability of 3<sup>rd</sup> party extensions, MediaWiki is used as the basis for the solution proposed in this paper. Changes applied to wiki articles are stored with the editing user's name or IP address, which provides accountability. Version management allows to view differences between two versions of an article and to undo unwanted changes applied by rogue users. Talk pages are used to discuss the content of articles in order to find a generally agreed formulation. Basic security mechanisms allow to group users and assign access rights [Barrett (08)].

Semantic wikis add semantic features to wiki software. By adding explicit semantic statements [Staab and Studer (03)], wiki articles and their relation are able to be better processed by computers. Semantic wikis provide means to add relations and attributes to wiki articles. Relations in semantic wikis are used to give meaning to the links between articles, for example "London is Capital of United Kingdom" [Krötzsch et al. 06]. The freely available extensions Semantic MediaWiki (SMW) [SMW 08] and SMW+<sup>3</sup> are the implementations of semantic wikis used in this work. SMW+ provides additional features over SMW in the area of usability. Examples are autocompletion, a semantic toolbar, which simplifies text annotation, as well as an ontology browser for visualizing categories, instances and properties [Pfisterer et al. 08].

The paper is organized as follows: Section 2 describes the implementation of the ITSM wiki. In section 3, two problem scenarios and solutions for these problems are outlined. It is described, how configuration changes as well as conflicts between installed applications can be handled with an agile approach in a semantic wiki. After a discussion of related work in section 4, section 5 gives a conclusion and an outlook on future work.

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<sup>1</sup> <http://www.wikipedia.org>

<sup>2</sup> <http://www.mediawiki.org/wiki/MediaWiki>

<sup>3</sup> <http://wiki.ontoprise.com>



## 2 Implementation

The paper looks at the requirements for IT processes and procedures in small and medium-sized enterprises (SME) in the IT sector as well as in research groups at universities. When looking at researchers and developers, it can be observed that there exists a high demand for the agile application of changes to services as well as to hardware and software configurations. IT service management frameworks, e.g., ITIL, have a well-established procedure for requesting, testing, documenting and applying changes in order to ensure the compliance with service requirements. The time needed for following this kind of procedures is, however, hardly accepted by developers or researchers who, for example, want to instantly share a currently developed web application with project partners or set up a demo application. While this kind of services can be considered out of the scope of classical IT service management, it plays a significant role in research groups and amongst developers. When looking at the requirements of developers and researchers, there is a need for applying changes faster and more agile than it would be possible when precisely following change management procedures described in the ITIL framework. Moreover, some changes to development and testing systems are applied directly by the user of the systems, which makes it hard for the IT department to track and document these changes. The approach presented in this paper uses semantic wiki software as the basis for creating a platform, which allows users to participate in the documentation of configuration items and their relations to each other as well as best practices for the use of IT components. In order to convince users to participate in the wiki, incentives are provided in the form of recommendations for interesting software or hardware and notifications about conflicting configurations.

Fig. 1 shows a screenshot of a wiki article describing a configuration item. The upper part of the screenshot shows the text section of the wiki article, which contains free text as well as semantic relations and attributes expressed in the Semantic MediaWiki syntax. Facts, which are extracted from semantic statements given in the wiki article, are shown in the fact box found at the bottom of the screenshot. The fact box is used to summarize all facts found in a wiki article and allows to easily export all facts contained in a wiki article as RDF feed for the use in external applications. Facts formulate an attribute-value or a relationship-value statement. Relations describe which instances are linked to which other instances. For example, the relation “is connected to” shows that the notebook described in the wiki article is connected to a screen and a network plug. By clicking on the links representing these configuration items, their wiki articles are displayed. The “has IP address” relation is an example for a relation which links one individual to more than one other individual (n-ary relation [Noy and Rector 06]). The first part of the relation states that the notebook has the IP address “192.168.20.134”, which is described in the corresponding wiki

page discussion annotate edit history delete move protect watch refresh

## Test Notebook

- Owner: Frank Kleiner
- Manufacturer: Lenovo
- Distributor: Procom
- Purchase Date: 2007-12-05
- Warranty Expiration: 2009-12-04
- Location: Room 1.0.02
- Department: RuD
- Installed Software: Microsoft Windows Vista, Microsoft Office 2007, Mozilla Firefox
- Installation Date: 2007-12-06, 2008-11-14
- Connected to: Lenovo ThinkVision L200p 0013, Network Plug DV1.1-G11
- IP/MAC Address: 192.168.20.134 (00-18-E1-39-13-F2)
- Known Issues: Incompatible with (Video Projector in Conference Room 1.4.27)
- Service Contracts: Lenovo On-Site Service

**Facts about Test Notebook** ⓘ

RDF feed

Belongs to department	RuD +
Has IP address	192.168.20.134 (00-18-E1-39-13-F2) +
Has distributor	Procom +
Has installation date	2007-12-06 + , and 2008-11-14 +
Has installed software	Microsoft Windows Vista + , Microsoft Office 2007 + , and Mozilla Firefox +
Has known issue	Incompatible with (Video Projector in Conference Room 1.4.27) +
Has location	Room 1.0.02 +
Has manufacturer	Lenovo +
Has owner	Frank Kleiner +
Has purchase date	2007-12-05 +
Has service contract	Lenovo On-Site Service +
Has warranty expiration date	2009-12-04 +
Is connected to	Lenovo ThinkVision L200p 0013 + , and Network Plug DV1.1-G11 +

Category: Notebook

**Figure 1:** Screenshot of a Configuration Item Represented in the Wiki

article. The second part of the relation links to the MAC address “00-18-E1-39-13-F2” which is used in conjunction with the IP address stated in the first part of the relation. Attributes describe aspects of instances which can be expressed as literals, e.g., the purchase date of a hardware component.

The data model used in the IT service management wiki is an ontology [Staab and Studer (03)]. An ontology is a formal representation of classes and the relationships (relations) between these classes. A configuration item can have one or more categories. Categories are equivalent to classes in the underlying ontology. Classes are arranged in a class hierarchy. In the example shown in the screenshot, the computer is an instance of the class “Notebook”. The notebook class is a subclass of the “Computer” class, which on its part is a subclass of the “Hardware” class.

Information can be added and edited in two ways. The first one is the traditional way of using Wikitext [Wikipedia 09], a special syntax which is used for formatting wiki content. The second one is by using Semantic Forms [MediaWiki 08c], which help to simplify adding and editing of structured information by providing a form-based mechanism.

### 3 Problem Scenarios and Proposed Solutions

For illustrating some of the problems found in applying ITIL recommendations to the management of systems in an agile environment, the authors present two problem scenarios and propose solutions for the problems. The scenarios are examples in which the use of the proposed collaborative approach to IT service management would bring benefits for users as well as for service desk personnel and system administrators responsible for installing, configuring and maintaining the services and systems. The first scenario describes the problems encountered when dealing with configuration changes. In the second scenario, it is shown how conflicts and unwanted interactions between software applications installed by the users of computer systems or the installation of hardware components can lead to avoidable problems and support requests.

#### 3.1 Configuration Changes

**Problem Description:** Change management and the documentation of configurations in the configuration management database (CMDB) within the configuration management process are considered essential parts when implementing ITIL recommendations. The change management process makes sure that all stakeholders are informed of pending changes and that responsibilities and priorities are assigned to changes. Implementing a back-out plan makes sure that changes are reversible in case of problems caused by the change [Köhler (07)]. The change management process consists of the following steps as described in [Köhler (07)]:

1. Need for a change is determined by administrator, service desk or customer
2. Request for change (RFC) is sent to change manager
3. RFC is evaluated; if determined to be urgent, a higher priority is assigned
4. RFC is discussed in the change advisory board (CAB)
5. Solution is implemented, tested, approved and applied
6. CMDB is being updated

When looking at the formal process for applying changes, it can be seen that it generates too much overhead and inflexibility to be of use in an agile environment. Agile environments are characterized by fast changing requirements and fast deployment of services in order to meet the requirements. Moreover, services have to be deployed by developers without a formal change process in order to provide access to recent versions of software to testers and project partners. On the other hand, there exists a need for having a full documentation of all configuration changes in order to enable system administrators to track down and fix problems.

**Proposed Solution:** The authors' proposed solution to the problem of requesting, approving and documenting configuration changes makes use of several features of semantic wiki software. The steps for having a change applied in an organization which supports wiki-enabled agile change management are as follows:

1. Need for a change is determined
2. Change is documented in the wiki and automatic notifications are sent to stakeholders about the changes to the wiki articles – changes are approved by virtual CAB (vCAB) by not objecting
3. Solution is implemented and tested

As can be seen, the proposed solution greatly simplifies the tasks of application, approval and documentation of changes by simplifying the change management process. The three process steps are all conducted by either administrators, service desk personnel or customers who have access to the wiki and are able to perform changes to hosts or services. The automatic notifications to stakeholders are sent via the watchlist feature of MediaWiki. Watchlists allow wiki users to register for being notified when wiki articles are changed by other users. Notifications about changed articles on a user's watchlist are displayed in the wiki and sent via email [Barrett (08)]. By registering for articles about configuration items for which administrators or customers are responsible, it is made sure that notifications about changes are sent to all stakeholders. According to traditional change management procedures, it is the role of the change advisory board (CAB) to review proposed changes before implementation. The agile change management procedure replaces the CAB with a virtual CAB (vCAB), which consists of all persons monitoring an article for changes via the watchlist function. The formal approval process of traditional change management is replaced by a soft approval process which informs members of the vCAB of imminent changes to which vCAB members can veto if the changes would bring undesired consequences. This soft approval process shortens the time needed for having a change approved while giving the possibility to prevent the conduction of undesired changes to interested stakeholders.

The MediaWiki right system is used for restricting access to articles for certain groups of users. While MediaWiki does not provide a sophisticated rights management system in its current state [MediaWiki 08a, MediaWiki 08b], the rights management suffices for collaborative environments. Wiki articles which describe configuration items which should not be changed by a certain group of users are protected from changes by the MediaWiki protect mechanism. E.g., wiki articles about servers which provide infrastructure services (mail, domain controllers etc.) are protected from changes from customers. When a customer needs a change to a server or service whose wiki article is protected, the process for having the change applied follows the traditional change approval procedure. Changes to articles, for which a customer has the rights to edit, can be applied after documenting the changes in the wiki. Discussions among administrators, service desk personnel, change advisory board members and customers can be a time consuming and error-prone task. In some instances, it is not possible to have a meeting in which all stakeholders are able to take part or it is not even known who is a stakeholder for a certain change or configuration item. By using wiki talk pages, problems with configuration items or with proposed changes can be discussed within the wiki. In the Wikipedia encyclopedia, talk pages play a significant role in the resolution of conflicts. Other important roles are in the area of coordination, e.g., discussing which articles need reworking [Viégas et al. 07]. Talk pages in the ITSM wiki play an extended role by not only discussing the content of a wiki article but also of the underlying real world entities, e.g., services or hardware components represented by the wiki article. The wiki versioning system stores all versions of the talk pages so all information discussed in talk pages is retained. The history function of MediaWiki is used to store all versions of articles which describe configuration items. With this feature, it is possible to track all changes and to compare different versions of a configuration item which is necessary for troubleshooting and accountability.

### 3.2 Conflicts Between Installed Applications

**Problem Description:** Today's computer systems comprise a vast amount of applications and services. While most of these applications coexist peacefully, there is a number of applications that cause problems if installed or run at the same host at the same time. Examples are different versions of the same application or services which change aspects of the underlying operating system, e.g., anti-virus software or personal firewall software. Installing conflicting applications can lead to minor problems at best, up to systems not able to boot at worst. While in centrally managed environments there exists, according to ITIL recommendations, a process for testing applications for possible conflicts, and only deploying applications that are conflict-free, this is not always possible in an agile environment. In an agile environment, developers and researchers install

applications for testing purposes and for keeping on top of current developments in the software landscape. A centrally managed testing process which would definitely rule out all possible problems would impose a time delay which in most cases would be too big to tolerate. Furthermore, sometimes there exist incompatibilities between hardware components, e.g., a certain kind of notebook can be incompatible with a certain kind of projector. The use of shared resources is another area with potential for conflict. For example, if more than one wireless network is using the same frequencies, interferences will impact users using the conflicting networks.

**Proposed Solution:** In order to document known issues with hardware and software components, problem instances are created as members of the **Problem** class. An article describing a problem consists of a detailed description of the problem and a semantic description of the configurations which are affected by the problem. This allows for the creation of a list of all affected computers. If, for example, a problem exists which affects a certain type of computer model `computer_model_1` in conjuncture with a certain operating system `operating_system_1` and a certain application `application_1`, the statement in the problem article look as follows:

```
{#ask: [[Category:Computer]]
  [[has Model Type::computer_model_1]]
  [[has Installed::operating_system_1]]
  [[has Installed::application_1]]
}]
[[has Solution::solution_1]]
```

This query returns a list of all computers of the specified model type with the mentioned operating system and application installed. In the last line, a link to the solution of the problem is given, which could include, for example, the recommendation to upgrade to a newer version of `application_1`. A computer, which would be returned by the query in the problem article would contain the following statements:

```
[[has Model Type::computer_model_1]]
[[has Installed::operating_system_1]]
[[has Installed::application_1]]
[[Category:Notebook]]
```

As can be seen, the described computer is part of the **Notebook** class, which itself is part of the **Computer** class. By using inferencing mechanisms, instances of subclasses of a queries class are returned. By using an external script, owners of computers are notified of problems on their computers and receive a link to the solution of the problem.

## 4 Related Work

There exist several implementations of commercial (e.g., Peregrine) as well as open source (e.g., i-doit<sup>4</sup>, OTRS::ITSM<sup>5</sup>) solutions for managing CMDBs. However, these solutions lack features which support the collaborative editing of configuration information in agile environments. The specialized CMDB solutions known to the authors impose a rigid structure which lack the flexibility provided by the semi-structured semantic wiki approach. Implementing a CMDB and storing semi-structured information about configuration items in a semantic wiki, as presented in this paper, is a new approach which, in the authors' view, simplifies the population of CMDBs and the maintenance of configuration information in agile environments.

## 5 Conclusions and Future Work

The present paper described the IT service management (ITSM) wiki, which supports a distributed, collaborative approach to configuration management in agile environments. Built on top of MediaWiki, Semantic MediaWiki and SMW+, the extension adds ITSM specific functions to the wiki. It was shown that it is feasible to use semantic wikis as a platform to implement a configuration management database. By making use of relations, attributes and categories, all configuration items as well as their relations to each other can be documented in a satisfying manner. Furthermore, by providing incentives to users of the documented systems, it is expected that documentation will be kept up to date by the users of the systems. Tab. 1 compares the features of specialized CMDB software, a wiki without semantic extensions and a semantic wiki. The table shows, that while CMDB software is strong in structural aspects, it lacks flexibility and collaborative features. Wikis are strong in collaborative aspects and the ability to describe information informally. Semantic wikis provide the strengths of specialized CMDB software and wikis by adding structure to wikis without sacrificing collaborative aspects and free text. Currently, there exists a testing implementation with about fifty configuration items. In order to fully leverage its potential, the ITSM wiki has to motivate employees to participate. While there exist traditional incentives for employees for getting work done in a corporate context (e.g., pay, promotion), [Andersen 05] suggest using normative incentives (e.g., praise, citations, peer respect, influence) for successful corporate wikis. Research on incentives in Wikipedia has been done by [Rafaeli and Ariel 08, Forte and Bruckman 05]. Patterns for the successful adaption of wikis can be found in [Mader (07)].

<sup>4</sup> <http://www.i-doit.org>

<sup>5</sup> <http://www.otrs.com/en/products/otrsitsm>

	CMDB	MediaWiki	Semantic Wiki
Structure	+	-	o
Collaboration	-	+	+
Flexibility	-	+	+
Extensibility	o	+	+
Free Text	-	+	+

**Table 1:** Comparison of Features

In the future, the authors will test the proposed solution in a live environment with about two hundred users. It will be evaluated which of the incentives found in the literature can be realistically applied in our productive environment. Furthermore, a component for automatically populating and updating the wiki with configuration data will be implemented. In addition, a services and hosts monitoring component will be added, which allows the generation of configuration files for systems monitoring software from information expressed in semantic relations within the wiki. While the current implementation mainly exploits the collaborative aspects of wikis, future plans include making use of formal knowledge expressed in the wiki for improving conflict detection and recommending software to users. Furthermore, argumentation ontologies [Vrandečić et al. 05, Dellschaft et al. 08] will be evaluated as a tool for building consensus on configuration changes. In addition, an automatic check for conflicting changes, based on semantic descriptions, will be implemented.

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## An Open Distributed Middleware for the Semantic Web

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**Abstract:** The emergence of the Web2.0, Web services and the Semantic Web, have changed the WWW to an open interactive market. Heterogeneous and distributed information prosumers have to integrate data and to coordinate activities. This calls for novel middleware solutions that are compliant with the fundamental principles of the Web: persistent publication, scalability and asynchrony of communication. In earlier work we presented a semantic space-based approach, as answer to this challenge. Data is no longer queried directly via endpoint locators, but exposed via a space that offers a unified and virtual view of diverse databases. The space is accessed by use of a simple set of operations that have SPARQL-like constructs at the basis for semantic matching. In this paper we return to the proposed semantic spaces and focus on architectural issues, and describe an implementation with evaluation.

**Key Words:** Semantic Space, Knowledge Coordination, Middleware

**Category:** C.2.4, H.3.5, M.6

### 1 Introduction

Knowledge in the form of semantic data is becoming ubiquitous on the Internet. To access and use this knowledge, exposed in various ways in a multitude of platforms, end-user applications need an integration middleware that provides a loosely-coupled virtualization of the underlying technical complexity and the distributedness of the knowledge sources, e.g. repositories or Web services.

In earlier work we presented for a middleware approach at the intersection of tuplespace [Gel85], or blackboard-style computing [Eng88] and the Semantic Web, as answer to the challenges of large-scale data management and knowledge-intensive service computing on the (Semantic) Web [FKS<sup>+</sup>07, SKN07]. Our middleware proposal, a semantic spaces platform, is called “*Triple Space*” and is tailored to the management of information that is formalized using Semantic Web representation languages, to reason about the information, and to coordinate its exchange among distributed entities and data stores that process and maintain the information. Triple spaces have application to the Semantic Web in that they realize open knowledge spaces where (machine-interpretable) data can be persistently published, shared, and coordinated. The core principles behind this approach have been successfully demonstrated in a wide range of space-based systems applied to solve communication and coordination issues in areas which are highly relevant to (Semantic) Web-based systems: open distributed systems, workflow execution, XML middleware or self-organization.

In this paper we return to the proposed Triple Space middleware with a focus on architecture and implementation in large scale, open and distributed Web environments. We introduce an implementation called *tsc++* that delivers the core functionality to manage distributed spaces. We evaluate the work and show that already our simplistic realization provides a scalable approach to semantic middleware. The core notions of semantic spaces are shortly reconsidered in Section 2. Section 3 describes the architecture, whilst its technical realization and evaluation are presented in Section 4. This paper does not present P2P research, but we only apply an existing P2P framework to showcase our approach. Related work is in Section 5 and we conclude with Section 6.

## 2 Conceptual Model

A space can conceptually be seen as a database that delivers communication and coordination services. Tuples refer to records in a non-normalized database table without primary keys, the publish operation relates to an insert, the retrieval operation to a select statement. Indeed, many tuplespace systems use a database to ensure durability, and distributed systems are built by allowing an application to access several spaces (databases). A space acts as an abstraction layer that allows to coordinate distributed data sources and services invisible for the application developers. Applications must only take one virtually global access point into account, and the development and maintenance of distributed services is independent of the life-cycles, schemas and availability of other parties.

### Space and Data Models

The initial ideas for Triple Space were presented in [Fen04]. Tuples were defined to have the dimensions and semantics of RDF ( $\langle$ subject predicate object $\rangle$ ) and are interlinked by use of URIs (like resource on the Web) to form graphs.

The *tsc++* space is divided into semantic spaces that offer virtual data containers. The *tsc++* space model defines a forest of disjoint space trees in a meronymic structure: any virtual space may contain multiple subspaces, while it can be contained in one parent. This allows layering and limited nesting of spaces in order to create a more expressive interaction platform. Each space is identified by a unique identifier (URL), independently of its tree affiliation, and delivers its own communication channel. Whenever a new interaction context, or a new group of agents is in consideration, a new virtual space is installed that links together the involved applications and data stores. This approach provides at least local scalability by grouping related data and users, and hence inherently limiting the scope and size of the interaction patterns [KSF07].

## Interaction API

The operations of `tsc++` (Table 1) are based on recent complementary semantic space projects such as TripCom.<sup>1</sup> The API provides primitives for writing and reading sets of triples, seen as RDF graphs. Removal is currently not provided, as in distributed settings deletion of data, or even worse of knowledge - that includes inferred statements - inevitably leads to scalability problems. Omitting is might seem to contradict traditional database properties, however we argue that it can modeled via the available operations. Instead of removing data from a space, triples can be marked as invalid, or faded as proposed in [NTWM07]. Publishing a fading statement makes a triple less likely to be retrieved in a subsequent query, and eventually the fact disappears.

**Table 1:** Coordination primitives

1	write (Set⟨Triple⟩ ts, URI s):URI	3	read (URI g, URI s):Set⟨Triple⟩
2	read (Template t, URI s):Set⟨Triple⟩	4	query (Template t, URI s):Set⟨Triple⟩

The 'read' returns an RDF graph, which are the triples that were published via the same write operation. In contrast, 'query' exposes a SPARQL CONSTRUCT behavior and returns all matching triples in a space, no matter which graph they belong to. In order to allow Web-like access to data, the traditional template-based 'read' is enhanced with a URI-based primitive (Table 1(3)) that extracts a graph by identifier. This primitive emphasizes the sought convergence of space and Web technology: the data (triples) is shared in a space, but retrieved as resources by their unique name, and not only by associative matching.

The semantic templates take the form of graph patterns; `tsc++` however also supports SPARQL CONSTRUCT queries. Graph patterns provide the most generic construct to determine the data to retrieve, and can be embedded in almost any RDF query language. They thus do not restrict the retrieval process, but leave it up to the matching algorithms and the repository to determine the query language, and the expressivity to use.

## 3 System Architecture

The functionality of the semantic space is realized by a set of software components referred to as kernel that run on all participating nodes. The components of the kernel are the Interaction APIs, the Operation Component with Metadata Manager, and the Coordination and Data Access Components (Figure 1).

<sup>1</sup> TripCom (IST-4-027324-STP, [www.tripcom.org](http://www.tripcom.org))

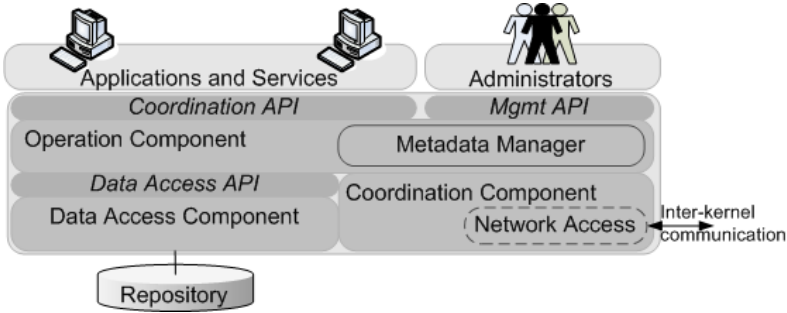


Figure 1: TS Kernel Architecture

The Operation Component implements the coordination primitives of (Section 2). Furthermore, it manages the kernel internal processes, which includes the transformation of user requests into formats that are processable by the underlying storage and coordination components.

The persistency framework (Data Access Component) is linked to the Operation Component via a Data Access API. This interface for storing and retrieving semantic data decouples the data sources' models from the kernel. Query rewriting is done by the Data Access Component and is invisible to the other components; e.g. at retrieval a template is embedded into an expression that can be interpreted by the query engine of the data store. This decoupling allows the integration of any persistency framework: RDF stores, relational databases, file systems, or Web services that store triples remotely.

The management of distributed spaces, in terms of network access and of communication matters with other kernels, is the responsibility of the Coordination Component: i) it serves as a proxy for the resolution of requests to a space that is not co-hosted at the local kernel,<sup>2</sup> and ii) it implements the access methods, distribution and discovery algorithms and any other network management-related process.

The Metadata Manager's job is the creation and processing of metadata: content metadata about published data, and structural metadata about spaces in terms of space hierarchies. This metadata enables reasoning about structures and behaviors, and allows for optimized management procedures.

## 4 Technical Realization

To the best of our knowledge, *tsc++* is the first fully distributed and open realization of a semantic space middleware.<sup>3</sup> Other proposals did either not

<sup>2</sup> A space can be accessed via kernels that do not share it; thus the need for proxies.

<sup>3</sup> The latest open source release is available at <http://tsc.sti2.at>.

consider distribution of data (Semantic Web Spaces [NSAT07], TripCom), rely on proprietary middleware components (TSC, [FKS<sup>+</sup>07]) or are not yet open source (Sedvice [OHZ08]). With *tsc++* we deliver a realization that offers an open and fully distributed implementation without a priori restrictions on the applicability and reusability.

#### 4.1 Prototype Implementation

As stated previously, the functionality of a kernel is mainly provided by the Coordination and Data Access components:

##### Coordination Component

The core of the Coordination Component is based on the JXTA framework [Wil02] that offers many important features: simplicity and ease of implementation, openness, distributedness. This matches our objective of an openly available, distributed and scalable semantic space implementation. JXTA provides a generic P2P platform with a standard set of XML-based services and protocols with standardized schemas. Peers are the basic building blocks, create virtual overlay networks and might be any type of network device with unique identifiable peer IDs. An interesting trait of JXTA are the peer groups in which nodes self-organize private parts of the global network; peers can at any time belong to multiple peer groups. *tsc++* uses this concept to model spaces. Kernels that authorize the same space are in *tsc++* equal to peers of the same peer group, and the data that is published to the space is managed within the group. On top of this structure, we implement various distribution and discovery algorithms that use and extend the available JXTA protocols. Currently, *tsc++* writes locally and queries remotely by means of flood, publish-subscribe, and random walker-based discovery. The different algorithms show their strengths or weaknesses depending on the system settings (Section 4.2). Flooding is simple and robust, has high tolerance to failures, low latency, and assures that all addressees eventually receive the messages. Search efficiency and completeness guarantees are in trade-off with response time and message overhead. In cases where scalability is not the primary concern, as in corporate spaces, 'flooding' delivers a reasonable approach; it is however no solution at Web scale. Random walker-based discovery decreases the message overhead by only evaluating a query on the path along a random set of peers. This increases in turn the latency and decreases the completeness expectations. The type of implementation is influenced by the application requirements and the relevant trade-offs.

## Data Access Component

As shown in Figure 1 the repositories are considered to be external to the kernel, and the Data Access Components translates the read templates into a queries that can be interpreted by the store's query engine. Currently, *tsc++* supports the Sesame RDF store (Sesame 2.x) [BKvH02], OWLIM [KOM05], and to some extent YARS [HD05b]. Although these repositories use different query languages (SerQL, N3QL, SPARQL), we can, by wrapping the templates according to the language, integrate them without altering the applications, API or other kernel components. This highlights the advantage of having a priori (only) graph patterns for our templates. For spaces whose stores all support SPARQL the flexible template interface allows however to expose the expressiveness of SPARQL also at the level of the API, and a kernel virtually provides a SPARQL endpoint on top of *tsc++*.

## 4.2 Evaluation

As to our knowledge, there are no comparable implementations, we cannot evaluate with a comparative analysis. Then, measuring the performance of a JXTA-based system is difficult, as there is no generic performance model available, and results largely depend on implementation details of the application and the JXTA reference implementation [HD05a]. We thus concentrate on scalability and performance indicators with respect to varying numbers of spaces, kernels and triples.

As *tsc++* is based on local write only, the performance of 'write' is equivalent to the performance of the repository: our experiments show an almost unmeasurable 20ms as upper limit for writing triples. We therefore limit the evaluation to the retrieval operations and depict the results of 'read' by means of two performance measures:

1. The number of messages per request: due to the nature of the flooding approach, we expect a linear base component with respect to the number of kernels that share a space.
2. A latency indicator: the time depends on the infrastructure, and is thus to consider with care; however, it showcases the relative change in latency.

The test results are shown in Table 2, and compare the results of the flooding and walker-based algorithms. The experiments were conducted with 1, 10 or 20 spaces that are shared by 1, 10 or 20 kernels. The evaluation setting thus defines  $n$  kernels that store data, and one kernel per scenario that reads from the  $n$ . Retrieval was configured to not consider local data. In this way, we focus on the performance in distributed environments.

**Table 2:** Evaluation Results for Read

Spaces		1			10			20		
Kernels		1	10	20	1	10	20	1	10	20
Flooding	Msg/read	2	11	21.1	2	11	21.1	2	11	21.2
	time [s]	0.25	0.71	1.31	0.23	0.69	1.47	0.21	0.67	1.24
Walker	Msg/read	2	6.7	9.5	2	6.4	11.4	2	6.4	10.9
	time [s]	0.27	0.73	1.54	0.28	0.89	1.47	0.29	0.77	1.98

The setup consisted of a server hosting up to twenty virtual kernels; each launched in its own execution environment.<sup>4</sup> One kernel instance consumed up to 20 MB of runtime memory. The published graphs contained between ten and twenty triples and were equally distributed over the test kernels. The number of triples was kept low, in order to focus on the discovery and not the transmission and processing time. Retrieval was governed by a simple triple pattern of the form  $\langle S ?p ?o.\rangle$ , where the subject 'S' was randomly chosen out of the possible subjects within the sample graphs. A response messages had then an average size of about 2kB.

A first observation shows that the number of spaces has neither an influence on the message count, nor on the retrieval time. This is explained with the fact that spaces are virtual entities at the level of the repositories only. While joining a space is time-wise a rather expensive operation (16-20 seconds), not using a proxy pays off once a node must manage increasing numbers of interactions. In fact, a proxy kernel has to temporarily join a JXTA peer group in order to interact with the space. This process is as costly as joining a space, and retrieval operation suddenly require noticeable more time.

Flood-based discovery has, as theory suggests, a message count that increases linearly with the number of spaces. For the trials with twenty nodes, some of the fifty test graphs were stored multiple times, which resulted in requests that were answered by two kernels. Therefore the total number of messages slightly exceed the expected 21 (20 flooding messages plus at least 1 response). Furthermore, we observe that the latency increases with the number of kernels. This might be, because all our test kernels had to be run on one server machine, or because in JXTA, some peers provide centralized management of the peer groups and become bottlenecks. Still, we argue that the latency shows quasi-constant behavior, or at worst a linear increase. This is acceptable, in particular as the tested setting chooses to query the whole network and hence to seek completeness for the price of latency. For the walker-based proposal, the number of messages shows still linear behavior, although roughly cut in half compared to flooding.

<sup>4</sup> Although we worked only with virtual distribution, we guarantee the described functionality also across multiple networks.



The implemented walker inherits flooding-style search, with the difference that messages are only passed on if a questioned kernel does not host the required data. As in our experiments, the RDF graphs are randomly stored on any of the kernels, the answers are discovered (in average) at kernel  $n/2$ , and message count is still in  $O(n)$ . The latency increases however faster with increasing numbers of kernels, also still linearly. For spaces that are shared by a large number of kernels with a significant request load, this alternative will eventually pay off; further improvements are however indispensable, e.g. by exploiting knowledge about data and queries for more selective walkers.

## 5 Related Work

Based on the initial ideas for combining tuplespaces with the Semantic Web [Fen04], several systems have been designed and to some extent been implemented. Within the project TSC, a space-based middleware for Semantic Web services has been developed. The TSC implementation is built upon an existing proprietary coordination middleware which led to many design decisions being simply carried over rather than being re-assessed. This and the fact that there are further scalability problems, lead to the development of *tsc++*, which – also due to its alignment with recent results from the TripCom project – is clearly compatible with both space-based computing and the Semantic Web.

We also point to the work on "dataspaces" by [FHM05]. They manifest the need for loosely coupled solutions to storage integration. Their framework does not rely on design time semantic integration, but rather on the co-existence of data sources. Dataspaces deliver a layer of core functionality on top of the data providers and virtually expose a data integration platform. This allows applications to focus on their own functionality rather than on data integrity and efficiency of integration. Furthermore, keeping individual sources on different machines preserves the advantages of distributed systems: decentralization, robustness, and scalability. Thus, *tsc++* can be seen as realization of such concepts from a Semantic Web perspective, which inherently adds further means for integration: data mediation and reasoning.

## 6 Conclusions

The paper revisited Triple Space middleware with a focus on architecture and implementation in large scale, open and distributed Web environments. We presented *tsc++*, an implementation of the Triple Space paradigm on top of an existing P2P framework. *tsc++* materializes many of the benefits that are expected from semantic middleware and that are necessary to realize large scale applications over distributed semantic artifacts. A well-received example was

established by the TripCom project with the eHealth showcase. A distributed Triple Space platform is used to realize a European Patient Summary infrastructure that enables the sharing of and easy access to medical records, independently of political and institutional boundaries, heterogeneities in technology and data or patient security and data protection policies [CKSF09, KSC<sup>+</sup>09].

The evaluation of *tsc++* shows that many challenges remain in implementing scalable semantic spaces. The plans are to examine how approaches to scalability in space-based systems may be applied to semantic spaces and the Semantic Web, and to further implement and test our approach. Alternative distribution and discovery algorithms have to be investigated and integrated, while complementary implementations that are not based on P2P or JXTA should be considered too; e.g. semantic spaces over Grid. Ongoing work is moreover concerned with exploiting the available metadata and enabling adaptivity through scalability-driven trade-offs.

While there is still work to do in terms of establishing the principles and technologies at large scale, we argue that *tsc++* is an important step towards a global infrastructure into which arbitrary information providers (e.g. databases, Web services) and consumers (applications) can be plugged at will. In that way, the Semantic Web can become one big virtual data store that provides knowledge anywhere, anytime to any application.

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# **Semantics to the Bookmarks: A Review of Social Semantic Bookmarking Systems**

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**Abstract:** In this paper we present a review of systems that follow the novel paradigm of Social Semantic Bookmarking. Social semantic bookmarking allows for the annotation of resources with tags extended by semantic definitions and descriptions that also evolve (collaboratively) within the same system. We analyzed nine different systems that extend social bookmarking in the direction of more semantics; i.e. that enable their users to add semantics to the folksonomy. We studied the systems regarding the realization of the social semantic bookmarking paradigm, the features offered to the users to add semantics, what kind of semantics can be added, and how the system makes use of the semantics. We will present commonalities, main differences and distinctive features, and future trends.

**Keywords:** social bookmarking, social tagging, semantic tagging, social semantic bookmarking

**Categories:** H.3.4, H.5.3, L.1.3, L.1.4

## **1 Introduction**

With the Web 2.0 many different kinds of novel, collaborative, and user centered applications have emerged. Aided by their ease of use, they have been remarkably successful and have found millions of users. Some of the most popular of these Web 2.0 applications are social tagging applications, in particular social bookmarking applications. These systems enable users to annotate web resources (e.g. bookmarks) with the arbitrary terms (so called tags) that they find most suitable for describing the resources. The popularity of these applications has shown that this principle of classification is much easier to use and understand than controlled vocabularies. These tags, however, are completely unstructured. Problems such as homonyms, synonyms, multilinguality, typos or different ways to write words, and tags on different levels of abstraction hamper their use for search and retrieval [Golder, 2006]; in particular in complex domains.

Recently, novel approaches have emerged that enable users to add semantics to the tags in order to overcome the limitations caused by the lack of semantic precision. These approaches allow extending tags with background knowledge such as synonymous names, super-, sub-topic relations or natural language descriptions. These approaches follow the paradigm of Social Semantic Bookmarking [Braun, 2008]. Social semantic bookmarking allows for the annotation of resources with tags extended by semantic definitions and descriptions that also evolve (collaboratively) within the same system. Similar to tagging approaches, new tags can be created whenever a need arises. Unlike these approaches, tags can have powerful descriptions and can be interlinked; for example allowing the system to understand that 'swimming bath' and 'swimming pool' are synonyms for the same concept. These powerful tag descriptions are similar to those used in traditional semantic annotation, but social semantic bookmarking allows for the simple adding and changing these descriptions within the same system and at the same time as the tags are used.

This paper presents a review of nine existing systems that follow the paradigm of social semantic bookmarking. The systems are analyzed and compared in their realization of the social semantic bookmarking paradigm, the features they provide to their users for adding semantics, the kind of semantics can be added, and how the system makes use of the semantics. We will present commonalities, main differences and distinctive features, and future trends.

## 2 Social Semantic Bookmarking Systems

We analyzed nine different systems: BibSonomy<sup>1</sup>, SOBOLEO<sup>2</sup>, Fuzzy<sup>3</sup>, GroupMe!<sup>4</sup>, Twine<sup>5</sup>, ZigTag<sup>6</sup>, Faviki<sup>7</sup>, gnizr<sup>8</sup> and Annotea<sup>9</sup>. Only systems under active development that we could try ourselves (either with a publicly accessible system or through installation on our systems) are included – criteria that lead to the exclusion of the gnizr and the Annotea system at the end. All systems allow their users to extend tags used for annotating with additional semantics. However, each of the systems realizes social semantic bookmarking in a different way – providing their users different features to add additional semantics. Social semantic bookmarking is a relatively new area – BibSonomy launched at the beginning of 2006, the youngest, Faviki, at the beginning of 2008<sup>10</sup> – and the systems vary in technical maturity. Most

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<sup>1</sup> <http://www.bibsonomy.de>

<sup>2</sup> <http://tool.soboleo.com>

<sup>3</sup> <http://www.fuzzy.com>

<sup>4</sup> <http://groupme.org>

<sup>5</sup> <http://twine.com>

<sup>6</sup> <http://zigtag.com>

<sup>7</sup> <http://faviki.com>

<sup>8</sup> <http://code.google.com/p/gnizr/>

<sup>9</sup> <http://www.annotea.org/>

<sup>10</sup> Indeed the Annotea system is older but lacks the 'social' part of Social Semantic Bookmarking, e.g. a website where the bookmarks from other users can be discovered.

of the systems started as R&D projects, over the half originated in academia. The development of every system is still in progress.

## 2.1 Analyzed Systems

In the following we will shortly introduce each system in order to give a quick overview on the main characteristics of the analyzed systems:

- **BibSonomy:** BibSonomy [Hotho, 2006] is a system for the management of bookmarks of internet resources and publication entries. BibSonomy is a research project of the Knowledge and Data Engineering Group of the University of Kassel, Germany, that has launched the system at the beginning of 2006. BibSonomy offers functionality similar to that of well-known social bookmarking services but also functionality specifically tailored towards academics – e.g., sophisticated support for uploading and exporting bibliographic information in bibtex format. At its core, Bibsonomy differs from social bookmarking services by additionally offering users the possibility to create broader/narrower relations between tags. However, tag relationships are only local, i.e., each user can (and has to) maintain his own relationships and cannot profit from others' contributions in that respect.
- **SOBOLEO:** SOBOLEO [Zacharias, 2007] is a system for annotating and organizing bookmarks of internet resources with concepts from a shared ontology. SOBOLEO is a research project developed since the beginning of 2007 at the FZI Research Center for Information Technologies Karlsruhe, Germany. Within SOBOLEO every user owns and shares his bookmarks with the whole community, i.e. a bookmark is added one time to the repository and there is one annotation that every user can edit. SOBOLEO's main unique functionality is that it integrates social bookmarking with ontology development; i.e. the users of one community collaboratively maintain and develop the ontology they use for the annotation.
- **Fuzzy:** Fuzzy [Lachica, 2008] is a system for managing bookmarks of web pages and ISBN numbers. Fuzzy is developed within the PhD project of Roy Lachica at the University of Oslo and its development started at the end of 2006. It is based on Topic Maps technology. Besides hierarchical and related tag relations, the users can choose of 22 specific predefined association types to link tags. These tag relations apply to the whole system and are editable by other users. Another main concept is voting for gardening and maintenance: the users can vote on bookmarks, tags a bookmark is annotated with, relations between tags, and users.
- **GroupMe!:** GroupMe [Abel, 2007] attempts to bridge the gap between the Semantic Web and Web2.0 with an RDF based social bookmarking application. The Semantic Web Group at the University of Hannover in Germany has been developing GroupMe! since 2007. The main unique functionality of GroupMe! is the extension of the tagging idea with the concept of 'groups' (collections): all annotated internet resources (websites, music, videos, photos, and news feeds) can be organized into groups. These form another level of information that can be used for browsing and search.
- **Twine:** is a system that supports organizing and sharing bookmarks of web pages, images, videos, products, and books. Twine is a commercial product run by Radar Networks has been publicly usable since October 2007. The main organizing

principle of Twine is so called 'twines', a kind of user interest group. The users can join or create such interest groups in order to share bookmarks. Through bookmarks grouped in the same twine group, tags are set into relation. Another functionality of Twine is the faceted filtering of search results; i.e. the users can filter by seven categories like tags, people, places, or item type.

- **ZigTag:** ZigTag allows tagging and organizing bookmarks of internet resources. ZigTag is run by ZigTag Inc., a small Canadian company, and had its beta release in April 2008. In contrast to the other approaches, the users can annotate their bookmarks with predefined tags, i.e. they choose from a given list of tags with a specific meaning. The users can additionally add their own tags for private usage. They cannot add further semantics. Tags are set into relation by the system.
- **Faviki:** The Faviki, launched in May 2008, is developed and by the Serbian Web designer Vuc Milicic. The system distinguishes itself by relying on Wikipedia terms for the annotation of bookmarks, i.e. users annotate with tags that are titles of Wikipedia articles. The Faviki system does not allow to use tags not contained in Wikipedia or to add semantic relations between tags.
- **ginzr:** ginzr is a system for managing bookmarks of internet resources using tags and folders. ginzr provides the users the possibility to define broader/narrower, related, and member-of relationships between tags according to the SKOS vocabulary [Miles, 2009]. Additionally, the users can add geospatial information to the bookmarks. The system has been published as open source application under Mozilla Public License 1.1 by the Image Matters LLC company in March 2008. There is no publicly available installation. The system can be downloaded and hosted on one's own. However, despite several attempts, it was not possible to get the system to work properly. Therefore, we excluded this system from the overall comparison as we could not evaluate the system provider's information.
- **Annotea:** Annotea [Koivunen, 2006] is a metadata standard for semantic web annotations, it is implemented in a number of tagging tools and server applications. Annotea and its implementations have been developed by the W3C. Annotea differs from other approaches to social tagging in its emphasis on standards on decentrality, that it has sharing of bookmarks among services build in from ground up. However, Annotea has not been under active development for some years and for this reason was excluded from the overall comparison.

### 3 Analysis

To give a comprehensive overview of the respective strength and weaknesses of the systems introduced above, Table 1 details the main discriminating features among the applications. The features used for the comparison relate to four main aspects: tags, relations, additional bookmark information, and miscellaneous functionalities. They will be discussed in detail in the following.

	<b>Bib-Sonomy</b>	<b>SOBO-LEO</b>	<b>Fuzzy</b>	<b>Group-Me!</b>	<b>Twine</b>	<b>ZigTag</b>	<b>Faviki</b>
<b>Tags</b>							
freely selectable / editable	x / x	x / x	x / x	x / x	x / x	x / x	x / -
meaning definable	-	x	x	-	-	-	-
editing others' tags	-	x	x	-	-	-	-
multilingual / automatic translation	- / -	x / -	x / -	- / -	- / -	- / -	x / x
auto completion	x	x	x	-	-	x	x
tag suggestion	x	-	x	-	x	x	x
rating of tags	-	-	x	-	-	x	-
<b>Relations</b>							
system internal	x	-	-	x	x	x	x
user defined	x	x	x	x	-	-	-
type definable	-	x	x	-	-	-	-
multiple / transitive	x / -	x / x	x / -	x / -	- / -	- / -	- / -
public / local	- / x	x / -	x / -	x / -	- / -	- / -	- / -
rating of relations	-	-	x	-	-	-	-
<b>Add. Bookmark Information</b>							
title suggestion	x	x	x	x	x	x	x
content suggestion	x	-	x	x	x	-	-
add selected text	x	-	-	-	x	-	x
title / content analysis	x / x	- / x	- / x	- / -	x / x	x / -	x / x
rating of bookmark	x	-	x	-	x	x	-
<b>Misc. Features</b>							
bookmarklet tool	x	x	x	x	x	x	x
bookmark import	x	-	-	-	x	x	-
bookmark export	x	x	x	x	-	x	-
RSS / REST API	x / x	x / x	x / x	x / x	x / -	x / -	x / -
discussion / interactive help	- / -	x / -	x / -	- / -	x / x	x / -	- / -
user incentives	-	-	x	-	-	-	-
activity logging	x	x	x	x	x	x	-
guest account	-	x	-	x	-	-	-
open source	-	-	-	-	-	-	-

Table 1: Comparison of Social Semantic Bookmarking Systems



### 3.1 Tags

Within all systems the users can freely select which and how many tags they want to use for annotating bookmarks. All but one system allow the editing and creation of tags; only the Faviki system restricts users to select tags from a predefined list of Wikipedia terms; i.e. only tags that have a reference to Wikipedia articles can be used for annotation. If users want to use other tags, they first have to create a new Wikipedia article. Users of the other systems can freely edit the tags they want to use. New tags are automatically added to the system when the annotation is saved. However, GroupMe! users cannot modify once added tags, i.e. errors made during annotation cannot be corrected.

SOBOLEO and Fuzzy offer their users the possibility to specify the meaning of a tag by adding additional information like a description or synonymous terms. The specification of synonymous terms can also be used for basic multilingualism support. However, Faviki is the only system that provides real multilingualism and automatic translation support for tags. Within ZigTag the provider predefine the specific meaning of tags, supporting in this way the disambiguation of syntactically identical tags. The users can discuss the predefined tags but it is not obvious how this global list of predefined tags and their descriptions is generated. Self-created tags cannot be further specified. Within the remaining systems, tags are limited to the string itself. [Abel, 2008] indicated for the GroupMe! system the usage of the property `moat:meaning` of the MOAT ontology [Passant, 2008] in order to specify a tag's meaning, however it seems to be not yet available in the current public system release. Changes to tags not declared as private apply to the whole system in SOBOLEO and Fuzzy, in all other systems the information added to tags is private. In ZigTag the users can request new tags to be added to the global list of predefined tags.

During the annotation process, all systems except Twine and GroupMe!, support the users with auto completion for tags. BibSonomy, Fuzzy, Twine, ZigTag, and Faviki further provide tag suggestions. Fuzzy users additionally can rate if a tag that is applied to a bookmark is suitable or not, whereas ZigTag users can discuss a tag in general.

### 3.2 Relations

All analyzed systems provide support for relations between tags: set by the system itself, defined by the users or both. BibSonomy allows both – it sets internally 'related' and 'similar' relations between tags by computing co-occurrence for the first and cosine similarity for the latter. These relations are used to support tag-based navigation. The users can also define broader/narrower relations between two tags, e.g. 'pet' -> 'dog'. He can relate one tag with multiple other tags. However, defining types of relations other than broader/narrower is not possible. Furthermore, these relations are only locally valid; i.e. for two tags of one user. Searching for resources annotated with a specific tag, e.g. 'pet', within one user's repository also retrieves resources only annotated with narrower tags, e.g. 'dog'. Only narrower relations are considered for retrieval. It is not possible to find resources only annotated with 'pet' when searching for 'dog'. Likewise, transitivity is not considered as well; i.e. if there

is also the relation ‘dog’ -> ‘poodle’, resources only annotated with ‘poodle’ cannot be found when searching for ‘pet’.

SOBOLEO and Fuzzy leave the definition of relations to their users. In both systems it is possible to set multiple relations between tags. SOBOLEO users can define broader/narrower and related relations between two tags – according to the SKOS vocabulary. Fuzzy users can add hierarchical and related relations which have to be further semantically specified by choosing one of 22 available association types. In both systems the relations apply systems wide. Likewise, the hierarchical and related relations support tag-based navigation in both systems. The specific association types within Fuzzy are not further considered. Additionally, Fuzzy users can rate the relations between tags. SOBOLEO’s search engine furthermore takes into account existing relations; i.e. it retrieves resources annotated with ‘poodle’ when searching for ‘dog’. It also provides query refinements and relaxations based on broader tags.

Within the GroupMe! system, users can define collections, so called ‘groups’ to which they can add resources or other groups. This results in the automatic creation of relations between the tags with which the resources within the same group are annotated. These relations are used for search support, e.g. searching for tag ‘a’ also retrieves resources only annotated with tag ‘b’ if both tags are used within the same group. Thus the relations are globally valid. Even though groups can be added to other groups, the relations are not considered as transitive. Other types of relations are not possible.

Twine, ZigTag, and Faviki only provide support for relations set by the system. Faviki relies on DBpedia and the semantic relations it provides, which is mainly the support for multiple languages. Within the ZigTag system there are predefined relations between tags with synonymous meaning, e.g. ‘NYC’ and ‘New York’, and relations for related tags (called “tags in common with”), however, it is not obvious how these relations are generated (e.g. for the latter case co-occurrence seems to be used but not every co-occurring tag is listed). This is also true for Twine. Twine extracts via content analysis if a tag represents people, places, organizations, and types of items. And it can also identify tags that are related. This information is used to support filtering of research results.

### 3.3 Additional Bookmark Information

All presented systems provide suggestions for the bookmark title during the annotation process. Half of the systems, BiboSonomy, Fuzzy, GroupMe!, and Twine, also make suggestions to describe the content of the bookmark. Within BibSonomy, Twine, and Faviki the user can select a paragraph within the web page to be annotated and add this via drag’n’drop to the content description. The content description in GroupMe! is not editable by the user. All systems also analyze the title or content of the resource, e.g. for tag suggestions (BibSonomy, Twine, ZigTag, Faviki), semantics extraction (Twine), or full text indexing (SOBOLEO, Fuzzy, Twine; facilitating search in the first two systems).

The users of the Fuzzy system can rate a bookmark as positive or negative; Twine and ZigTags users can leave comments on a bookmark and BibSonomy users can decline a bookmark as spam.

### 3.4 Miscellaneous Features

As additional feature all of the systems provide a bookmarklet that can be installed in the browser and to allow users to quickly tag and store a bookmark for the currently opened internet resource from within the browser.

Users can import existing bookmarks into BibSonomy, Twine, and ZigTag. BibSonomy allows the import of bookmarks from delicious or of publications via an EndNote and BibTex files. ZigTag users can import their delicious or browser bookmarks; Twine additionally supports the import from digg.

Regarding export, there is a wide range of diverse functionalities and formats – ranging from one user’s bookmarks annotated with a specific tag to the whole repository dump. Each system provides some export functionality via RSS feeds. BibSonomy provides various additional export formats for bookmarks and publications, such as XML, BURST, SWRC, BibTex, and EndNote. However, the defined semantic relations between tags cannot be exported. SOBOLEO can export the whole bookmark repository together with the ontology or only the ontology in the SKOS format. Likewise, Fuzzy provides on request an export of all bookmarks and the ontology in XTM format. GroupMe! offers an RDF based export functionality using FOAF, DCMI, Tag ontology and the proprietary GroupMe! ontology as schema. ZigTag users can export their bookmarks in the Netscape Bookmark Format; similar to BibSonomy, any semantic relations are lost in the export. BibSonomy, SOBOLEO, Fuzzy, and GroupMe! additionally provide a web service API using Representational State Transfer (REST), e.g. to post a new bookmark. Twine and Faviki don’t offer any API or export functionality beyond RSS feeds.

Due to RSS feeds the users of any system can stay up-to-date. BibSonomy displays the most recently added bookmarks and mostly used tags on the frontpage. It additionally shows the three most popular bookmarks over the last 7, 30, or 120 days. SOBOLEO displays the newest bookmarks on top within the browse area. Fuzzy differentiates between newly added tags and bookmarks and bookmarks annotated with one of the user’s favorite tags. GroupMe! users can see the latest activities within their groups as ‘Dashboard News’. Similar functionality is offered by Twine for a user’s twine group and by ZigTag respectively.

Discussions are supported by half of the systems. SOBOLEO integrates a chat for synchrones communication into the ontology editor. Fuzzy users can make propositions for improvement on which other users can comment and vote. ZigTag and Twine both have an integrated forum. All systems offer instruction guidelines or tutorial on how to use the system, but only Twine provides an interactive help directly integrated with the systems UI elements.

The Fuzzy system highly encourages its users to engage in community activities. They can make propositions for improvement, there are special voluntary tasks for gardening, users can be voted to get special privileges or they can gain so called ‘karma points’ as incentive for each contribution. It is the only system offering such functionality.

None of the system is open source. Each system requires user registration in order to use the systems. SOBOLEO and GroupMe! additionally offer guest accounts to test the systems without registering.

## 4 Conclusions

As a general conclusion, there is a big interest to extend social bookmarking in the direction of more semantics. Social Semantic Bookmarking allows a group of users to collaboratively create and evolve an index of resources together with the powerful semantic vocabulary used to organize it. Social Semantic Bookmarking promises better retrieval, better use of annotation, better integration of the repository with semantic web infrastructure etc. while avoiding the problems commonly associated with semantic annotation approaches – such as a high initial cost to build ontologies.

The analyzed systems show a wide range of how social semantic bookmarking can be realized and supported. One major distinctive aspect is the degree of freedom of what users can contribute and what is done automatically. Fuzzy and SOBOLEO highly rely on the user community. Because both systems aim at supporting the collaborative development of ontologies, they give their users the greatest latitude to freely define and edit tags and relations. BibSononomy and GroupMe! limit their users to one specific type of relations they can add. The commercial systems ZigTag and Twine aim in offering highly automated support. The semantics in these systems are internally derived and predefined, the users have only little influence. At the other end Faviki relies on standardization based on Wikipedia/DBpedia, only allowing the users to select tags for annotation.

Another characteristic is the scope and impact of the (user added) semantics. Within BibSononomy user added relations are only locally relevant and set on top of one user's tags. Within SOBOLEO and Fuzzy changing tags and semantics have a system wide effect on every user. The additional semantics are mainly used to support better retrieval and tag-based navigation: e.g. on the retrieval of all bookmarked pages for one tag, the bookmarks associated with its subtags are also returned. All kinds of relations are used to facilitate navigation from one tag to another. The SOBOLEO system also uses the semantic information to augment the full text search of the contents of the bookmarked internet resources. Formal semantics seem not to play an important role with the current generation of systems; to the authors best knowledge none of the systems employs an actual inference engine.

There is a big interest in particular to tackle the problem of how tagging data can be exchanged between systems. All the systems are offering (often multiple) ways to export the created annotations. However, at the same time this analysis shows that there still is considerable disagreement about the most important features and – even more crucially – about suitable formats to exchange the tagging data. Without an agreement in this domain, the promise of exchanging tagging data can obviously not be achieved.

Social Semantic Bookmarking applications hold a huge potential for future development as part of the developments towards a Web 3.0 as a user-centered semantic web. However, in addition to the technical questions about the right functionality of a Social Semantic Bookmarking system there is also a lack of understanding of the emergence and evolution of semantics as part of everyday collaborative activities. The research community still lacks a comprehensive model that describes the process of such a collaborative knowledge maturing; a model that then could also guide the development of support mechanisms. The authors will

further explore this with their SOBOLEO system as part of the European Integrating Project MATURE<sup>11</sup>.

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<sup>11</sup> <http://mature-ip.eu>

# **A Knowledge Workbench for Software Development**

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**Abstract:** Modern software development is highly knowledge intensive; it requires that software developers create and share new knowledge during their daily work. However, current software development environments are “syntactic”, i.e. they do not facilitate understanding the semantics of software artefacts and hence cannot fully support the knowledge-driven activities of developers. In this paper we present KnowBench, a knowledge workbench environment which focuses on the software development domain and strives to address these problems. KnowBench aims at providing software developers such a tool to ease their daily work and facilitate the articulation and visualization of software artefacts, concept-based source code documentation and related problem solving. Building a knowledge base with software artefacts by using the KnowBench system can then be exploited by semantic search engines or P2P metadata infrastructures in order to foster the dissemination of software development knowledge and facilitate cooperation among software developers.

**Keywords:** Software Development, Knowledge Workbench, Semantic Annotation, Semantic Wiki

**Categories:** M.0, M.3, M.4

## **1 Introduction**

Modern software development consists of typical knowledge intensive tasks, in the sense that it requires that software developers create and share new knowledge during their daily work. Although most software developers use modern state of the art tools, they still struggle with the use of technologies that are “syntactic”, i.e. they use tools that do not facilitate the understanding of the concepts of the software artefacts they are managing (e.g. source code).

Flexible ways of solving problems are necessary when a developer is frustrated investigating source code that he has never seen before (i.e. when extending a third party’s software system) and is not capable of understanding its rationale. Additionally, there are many situations that find a developer seeking source code that is already developed by others. He might not be aware of its existence, or even if he is, he is not able to find it effectively [Bauer, 06], [Thaddeus, 06].

Recent trends in data integration and combination have led to the Semantic Web vision<sup>1</sup>. The Semantic Web strives to provide integration among information scattered

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<sup>1</sup> <http://www.hpl.hp.com/semweb/sw-vision.htm>

across different locations in a uniform fashion. It defines a “common language” between these information resources.

Additionally, there is a growing interest in the last few years on exploiting Semantic Web technologies in software engineering. Since 2005 the Semantic Web Enabled Software Engineering (SWESE) conference takes place every year with promising results. The Semantic Web Best Practice and Deployment Working Group (SWBPD) in W3C included a Software Engineering Task Force (SETF) to investigate potential benefits of applying semantics in software engineering processes. As noted by SETF [Primer, 06], advantages of applying Semantic Web technologies to software engineering include reusability and extensibility of data models, improvements in data quality, enhanced discovery, and automated execution of workflows.

In this paper we propose a new system – code-named KnowBench for knowledge workbench – which is the result of exploiting Semantic Web technologies in the context of a well known software development IDE such as Eclipse<sup>2</sup>, in order to provide the basis for better collaboration in the software development domain and strive against the aforementioned problems. KnowBench aims at providing software developers such a tool to ease their daily work and facilitate source code documentation and problem solving.

The rest of the paper is organized as follows. In the next section, we describe what motivated us in developing the KnowBench system. Afterwards, we describe its functionality. Thereafter, we give the results of its preliminary evaluation and we discuss the benefits of using the system. Finally, we conclude the paper indicating our thoughts for future work.

## 2 Motivation

Modern IDEs such as Eclipse provide means for documenting and annotating source code, e.g. JavaDoc and Java annotations. However, this kind of documentation is unstructured and the means to retrieve it are limited.

In most cases, software developers when in need of specific functionalities find themselves seeking in forums, web sites or web search engines using keyword search for an API capable of delivering these functionalities. Additionally, software developers often use dedicated forums and mailing lists to report on bugs and issues they have with specific source code fragments and have to wait for answers from experts. This switching of environments while developing code is obtrusive and requires a great amount of effort in order to maintain scattered resources of software development related knowledge [Gall, 08].

We argue that a more formal description of the aforementioned knowledge could be beneficiary for the software developers and the means to articulate and visualize this knowledge should be unobtrusive i.e. in the IDE itself in order to provide unified access to it. On top of that, knowledge about source code or software components should be described in a common way in order to avoid ambiguities when this knowledge is retrieved and used by others.

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<sup>2</sup> <http://www.eclipse.org/>

Documentation of software, bug fixing and software related knowledge transfer between employees of a large software house can be facilitated by the use of ontologies to sufficiently capture and describe software artefacts in a coherent way. Furthermore, ontologies are ideal for interlinking software artefacts and the resulting semantic relationships can be exploited in order to maximize productivity when seeking related knowledge of a specific software artefact.

Towards this end we have been motivated to design and implement an environment – namely KnowBench – that offers the opportunity to articulate and visualize software artefacts driven by an ontology backbone. The created artefacts formulating an organization’s software development knowledge base can be exploited by semantic search engines and P2P metadata infrastructures to enable knowledge sharing and reuse in order to boost the collaboration among the employees and speedup time-consuming procedures when facing problems with code or searching for APIs or components to be reused.

### 3 KnowBench

The KnowBench is designed and implemented in order to assist software development work inside the Eclipse IDE exploiting the power of semantic-based technologies (e.g. manual/semi-automatic semantic annotation, software development semantic wiki).

KnowBench exposes functionality that can be used for articulating and visualizing formal descriptions of software development related knowledge in a flexible and lightweight manner. This knowledge can be then retrieved and used in a productive manner by integrating the KnowBench with a semantic search engine and a P2P metadata infrastructure such as GridVine [Mauroux, 07]. This integration will assist the collaboration and the formation of teams of software developers who can benefit from each others’ knowledge about specific problems or the way to use specific source code while developing software systems. We have already integrated and tested KnowBench with a semantic search engine and GridVine in the context of the TEAM project [Team, 08]. However, the description of these systems is out of the scope of this paper. A demo of the TEAM system is available online<sup>3</sup>.

#### 3.1 Ontologies

We have deployed a set of software development ontologies to the KnowBench system in order to describe and capture knowledge related to software artefacts. The system architecture allows for the extension or even the use of different software development ontologies. The set of the deployed ontologies constitutes of three separate ontologies.

*The artefact ontology* describes different types of knowledge artefacts such as the structure of the project source code, reusable components, software documentation, knowledge already existing in some tools, etc. These knowledge artefacts typically contain knowledge that is rich in both structural and semantic information. Providing a uniform ontological representation for various knowledge artefacts enables us to

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<sup>3</sup> <http://www.team-project.eu/demo.php>



utilize semantic information conveyed by these artefacts and to establish their traceability links at the semantic level.

An artefact is an object that conveys or holds usable representations of different types of software knowledge. It is modelled through the top level class *Artefact*. There are some common properties for all types of artefacts such as:

- *hasID* – which identifies an artefact in a unique manner. Recommended best practice is to identify the artefacts by means of a string conforming to a formal identification system;
- *hasTitle* – which defines a title of an artefact (e.g. class name or document title);
- *hasDescription* – which describes what an artefact is about;
- *createdDate* – which models date of creation of an artefact;
- *usefulness* – which models how frequently an artefact is used as a useful solution.

*The problem/solution ontology* models the problems occurring during the software development process as well as how these problems can be resolved. This ontology is essential to the KnowBench system, as source code can be documented when a certain problem is met and the respective solution to it is described.

A problem is an obstacle which makes it difficult to achieve a desired goal, objective or purpose. It is modeled through the class *Problem* and its properties:

- *hasID* – a problem is identified by its identifier;
- *hasTitle* – a summary of a problem;
- *hasDescription* – a textual description of a problem;
- *hasSeverity* – it models how severe the problem is;
- *hasSolution* – every problem asks for a solution. This is the inverse property for the property *isRelatedToProblem* defined for the class *Solution*;
- *hasSimilarProblem* – it models similar problems.

A solution is a statement that solves a problem or explains how to solve the problem. It is represented through the *Solution* class and its properties:

- *hasID* – an unambiguous reference to a solution;
- *isRelatedToProblem* – a solution is defined as the means to solve a problem;
- *hasCreationDate* – date of creation of a solution;
- *hasDescription* – a textual description of a solution;
- *hasPrerequisite* – a solution requires a level of expertise in order to be used;
- *hasComment* – a solution can be commented by the people that used it;
- *suggestsArtefact* – a solution recommends using an artefact in order to resolve a problem the solution is defined for;
- *isAbout* – a solution can be annotated with the domain entities (see below);
- *isRelatedToSEEntity* – a solution can be annotated with the general knowledge about software engineering domain (see below).

*The annotation ontology* describes general software development terminology as well as domain specific knowledge. This ontology provides a unified vocabulary that ensures unambiguous communication within a heterogeneous community. This vocabulary can be used for the annotation of the knowledge artefacts. We distinguish two different types of annotations: (a) domain annotation – software providers in

different domains should classify their software using a common vocabulary for each domain. Common vocabulary is important because it makes both the users and providers to talk to each other in the same language and (b) software engineering annotation – general knowledge about the software domain including software development methodologies, design patterns, programming languages, etc.

By supporting different types of annotation it is possible to consider information about several different aspects of the artefacts. We note here that the vocabulary will be used for the annotation of the artefacts, e.g. code, knowledge documents, etc. as well as expertise of the users and solutions of problems. These annotations will be used to establish the links between these different artefacts.

### 3.2 Software Development Semantic Wiki

KnowBench utilizes the SoWiSE2 system which is the successor of SoWiSE [Panagiotou, 08] in order to assist software developers in the articulation and navigation of software development related knowledge. SoWiSE is a Semantic Wiki for Software Development and provides common functionalities with a conventional wiki with semantic capabilities. It provides software knowledge articulation support with the usage of ready to use templates. On the other hand, SoWiSE2 uses a lightweight and flexible editor with auto-completion and popup support to eliminate the need of templates which sometimes are cumbersome to use. Browsing through knowledge is done like surfing through a conventional wiki using the semantic links between different knowledge artefacts. This browser is available inside the Eclipse IDE so that the software developer does not have to switch to another external browser.

SoWiSE2 provides assistance to software developers in accomplishing their tasks in a more flexible fashion and shortens their total effort in terms of time. In order to achieve this goal, we approach software development documentation and related problem solving by combining lightweight yet powerful wiki technologies with Semantic Web standards.

An overview of the provided functionality is given below:

- Validation of the user input when incorrect values for selected concepts, properties, related instances or property values are introduced. The semantic wiki informs the user about the wrong input value and assists him/her in the way to track down the problem and resolve the issue.
- Auto-complete facilities provide assistance to the user for selecting the right concept, properties and related instances of an object property as a value.
- Intuitiveness – the software developer is able to understand what is required as input using the auto-complete facilities of the Semantic Wiki.
- Syntax colouring – the software developer is assisted with syntax colouring to easily determine what kind of information is recognized by the wiki engine in order to avoid mistyping.
- Multipage editor consisting of the semantic wiki editor and the semantic wiki browser which facilitates navigation of the knowledge base in an HTML-fashion inside the Eclipse environment.
- Navigation through the semantic wiki is enabled via following an instance's semantic links to other related instances.

- On the fly synchronization with the knowledge base. SoWiSE2 keeps no files anywhere and all information is persisted directly to the knowledge base. Figure 1 depicts the user interface of SoWiSE2.

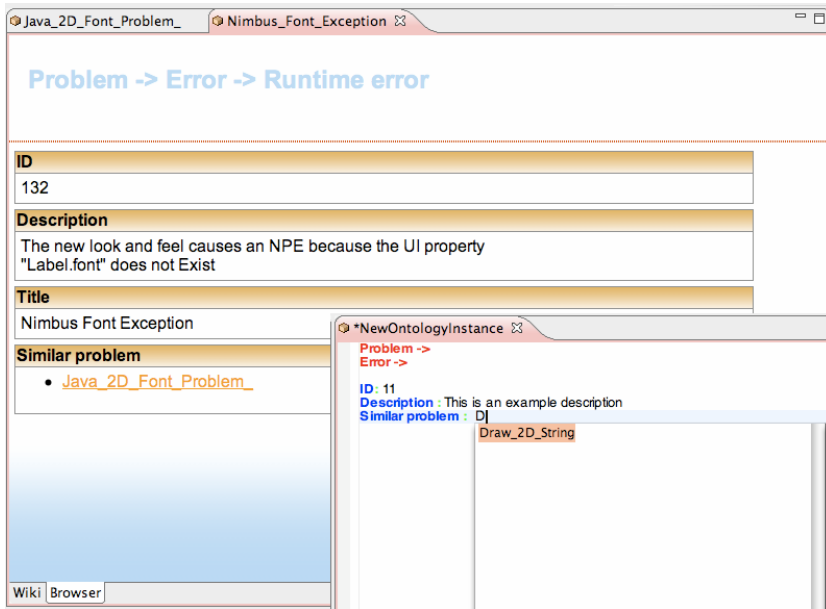


Figure 1: SoWiSE2 browser and editor

### 3.3 Manual Semantic Annotation of Source Code

An important aspect of the KnowBench is the ability to annotate semantically source code. We have extended the standard Eclipse JDT editor to add this possibility. The software developer is able to annotate source code with semantic annotation tags that are available or define new tags and extend the used annotation ontology.

The manual semantic annotation of source code provides granularity regarding the respective source code fragment to be annotated. This granularity level is restricted by the underlying Eclipse platform itself as the `IJavaElement` interface is exploited to map between source code fragments and metadata. This limits the selected source code fragments to be annotated in the nearest Java elements that surround the source code fragment at hand (e.g. package/class/method/variable etc.). Additionally, by using `IJavaElement` the semantic annotation mechanism is capable of managing annotations of several objects, such as Java packages, classes, methods, etc.

### 3.4 Semi-automatic Semantic Annotation of Source Code

This kind of annotation is supervised by the user and results in new concepts and sometimes in their classification inside the annotation ontology hierarchy tree. These new or existing concepts of the annotation ontology are then used to annotate

semantically the source code corpora. This procedure assists and shortens the time consuming task of manually annotating source code.

The need for assisting the software developer in annotating semantically source code (either one single file of code or a batch of files residing in a directory) is evident. The notion of semi-automatic comprises a user-controlled process with the system acting as a mediator (proposing semantic annotation concepts/taxonomies of concepts) and the user having the final decision of acceptance or rejection or revision and acceptance of the system's propositions. Thus, the time consuming task of manually annotating source code can be significantly decreased.

In order to achieve this goal in KnowBench we had to elaborate on ontology learning [Maedche, 04] and information extraction techniques [Cunningham, 02]. Ontology learning is needed in order to extract ontology concepts from source code corpora that can be used for annotating it. On the other hand, information extraction is needed in order to instantiate the annotation ontology with individuals (like in manual semantic annotation), either of newly proposed and created or existing ontology concepts. A framework exploiting both technologies is Text2Onto [Cimiano, 04] which we adopted in order to implement the desired functionality.

The architecture of Text2Onto is based on the Probabilistic Ontology Model (POM) which stores the results of the different ontology learning algorithms. A POM as used by Text2Onto is a collection of instantiated modelling primitives which are independent of a concrete ontology representation language.

KnowBench takes advantage of two modelling primitives, i.e. concepts and concept inheritance. In the respective modelling primitives KnowBench employs different Text2Onto algorithms in order to calculate the probability for an instantiated modelling primitive. In particular the following measures are calculated:

Concepts are identified using the following algorithms: Relative Term Frequency (RTF), Term Frequency Inverted Document Frequency (TFIDF), Entropy and the C-value/NC-value method in [Frantzi, 98]. For each term, the values of these measures are normalized into the interval [0..1], after taking the average probability of the algorithms output combination which is used as the corresponding probability in the POM.

Regarding concept inheritance, KnowBench combines Text2Onto algorithms such as matching Hearst patterns [Hearst, 92] in the corpus and applying linguistic heuristics mentioned in [Velardi, 05].

The KnowBench semi-automatic semantic annotation editor is depicted in Figure 2. After processing a source code corpus, the developer can supervise and change the proposed annotations and their position in the concept hierarchy as per his/her needs using this editor. He/she is able to filter the results dynamically by dragging the threshold slider, which means that if a given proposed annotation concept has a lower confidence value than the selected threshold then this is not included in the list, which is refreshed dynamically. The confidence percentage is the calculated probability of a concept to be precise and it reflects the POM probability of a term. Additionally, the developer can rename the proposed concepts and change their position in the concept hierarchy (by choosing their parent concept in the annotation ontology tree). Changing the position of a concept is automatically reflected on the annotation type (Domain or Software Engineering).

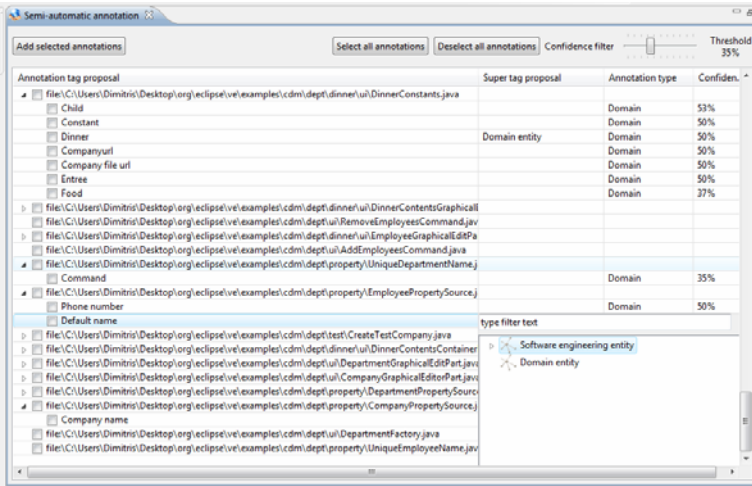


Figure 2: Semi-automatic semantic annotation editor

### 4 Usage Scenario

Dave is writing an XML editor as a plug-in for Eclipse. He uses the semi-automatic semantic annotation mechanism to annotate the source code. He reviews the suggestions provided by the system (see Figure 3) and submits them to the system.

<ul style="list-style-type: none"> <li>[-] \XMLEditor\src\editor\editors\XMLPartitionScanner.java                             <ul style="list-style-type: none"> <li><input type="checkbox"/> Partition Scanner</li> <li><input type="checkbox"/> Tag</li> <li><input type="checkbox"/> Xml</li> <li><input type="checkbox"/> Xml comment</li> </ul> </li> <li>[-] \XMLEditor\src\editor\editors\XMLEditor.java                             <ul style="list-style-type: none"> <li><input type="checkbox"/> Xml editor</li> <li><input type="checkbox"/> Text editor</li> </ul> </li> <li>[-] \XMLEditor\src\editor\editors\XMLWhitespaceDetector.java</li> <li>[-] \XMLEditor\src\editor\editors\XMLConfiguration.java</li> <li>[-] \XMLEditor\src\editor\editors\XMLTagScanner.java</li> <li>[-] \XMLEditor\src\editor\editors\NonRuleBasedDamagerRepairer.java</li> <li>[-] \XMLEditor\src\editor\editors\TagRule.java</li> <li>[-] \XMLEditor\src\editor\editors\ColorManager.java</li> </ul>			
		Domain	48%
		Domain	26%
		Domain	24%
		Domain	24%
	Editor	Software engineering	48%
		Domain	48%

Figure 3: Annotation suggestions for source code of an XML editor

He also describes some guidelines in the wiki about “validating and character encoding XML code” as in Figure 4.

John is a new Eclipse developer and intends to write an XML editor. He is connected to the P2P network and performs a structured query to find knowledge or source code that is related to “XML editor” as in Figure 5.

He retrieves the results as in Figure 6 and now he is able to reuse existing source code and take into consideration the guidelines documented by Dave.

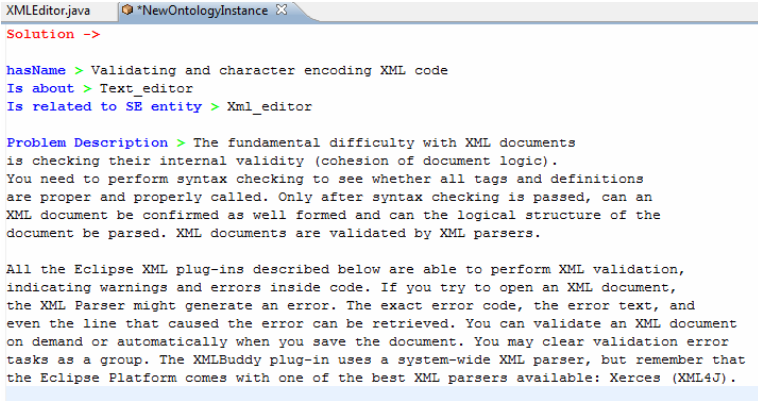


Figure 4: Wiki page describing guidelines about “validating and character encoding XML code”

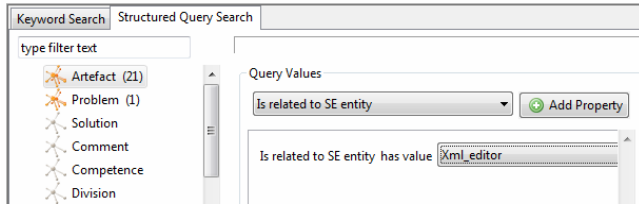


Figure 5: Structured P2P query for finding knowledge that is related to “XML editor”

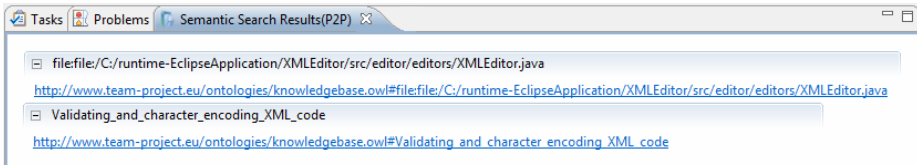


Figure 6: Search results of the query sent as in Figure 5

## 5 Preliminary Evaluation

We have conducted a preliminary evaluation of KnowBench in small teams of software developers in a total of 9 persons in the following organizations: (1) a Brussels based company specializing in the field of Information and Communication Technology (ICT) services (Intrasoft International S.A. – 2 developers), (2) a leading hungarian association dealing with open source software at corporate level (Linux Industrial Association – 2 developers), (3) an italian company which operates in the Information Technology market, focusing on business applications (TXT e-Solutions – 2 developers) and (4) the corporate research laboratory of the Thales group – a

global electronics company serving Aerospace, Defence, and Information Technology markets worldwide (Thales Research & Technology – 3 developers). A more formal evaluation of the system is currently underway and the results are expected in the next few months.

Overall, the KnowBench system has been well appreciated by the software developers. It is a simple, user-friendly and intuitive system aiming to improve their productivity. In that respect, the provided functionalities seem to integrate well with the Eclipse IDE without encumbering the developer with time-consuming functions. In fact, these functionalities demonstrate a good value proposition for the developers' work.

The initial effort needed to start working with the system is minimal; nevertheless, it seems that some of its functions convey deeper logic which is not immediately capturable by the end users. The graphical user interface could be improved further in order to reveal this logic, while some help functions could also be of great value on this. Users were also satisfied by the level of "contextualization" offered by the system (meaning helping the developer know where he/she is at every moment). Finally, the performance of the KnowBench system i.e. response time left the developers with very good impressions.

More specifically, annotations are a powerful tool in managing knowledge and the KnowBench implementation seems to be very efficient. Developers were rather comfortable with the use of annotations and could use them in an intuitive manner i.e. name annotations freely. Additionally, semi-automatically creating annotations was even more appreciated and greatly assisted them in speeding up the error-prone and cumbersome annotation process. However, they did not seem to understand their real value and thus their deeper connection with the inner logic of the system.

The developers showed great comfort in using the SoWiSE2 wiki of the KnowBench. Instantiation takes place quickly and the types of information that are needed for the creation of a wiki page are clear, while interactive mechanisms i.e. pop-ups make the creation a very simple task.

## **6 Discussion**

There are emerging efforts in research towards exploiting Semantic Web technologies in software engineering. For example, SemIDE [Bauer, 06] is a framework which is based on meta-models in order to describe semantically software engineering processes. OSEE [Thaddeus, 06] is a tool which aids the construction of a knowledge base which captures software related artefacts. SeRiDA [Athanasiadis, 07] combines object-oriented programming and relational databases, with semantic models.

With KnowBench integrated into an IDE, it is easier for software developers to create new knowledge. The advantage of recording the solution to difficult or frequently asked questions/problems is that developers are recording their explicit knowledge about particular problems, as well as tacit knowledge that they have internalized, while creating software development knowledge artefacts that can be organized, managed, and reused.

Wikis can significantly help developers fill this knowledge management need. KnowBench provides this kind of wiki-based support for knowledge provision. SoWiSE2 offers innovative features especially in software development but is also a

contemporary semantic wiki in the general sense since it provides many features common in most of the state-of-the-art semantic wikis [Maalej, 08].

KnowBench is seamlessly integrated into the Eclipse environment and thus gives software developers the incentives to develop or explore knowledge without bothering to open an external tool or web browser to accomplish this task which has the advantage of leaving the user in his/her current work context and not distracting him/her from the rest of his/her tasks. For example, he/she can develop source code and at the same time document problems that he/she encounters or provide guidelines and workarounds for a specific problem in source code that is commonly known to his/her organization by simply choosing to open the SoWiSE2 editor next to the source code editor.

## **7 Conclusion**

In this paper we presented the KnowBench system, a knowledge workbench which is integrated in the Eclipse IDE based on Semantic Web technologies, in order to assist software developers in articulating and visualizing software development knowledge. The resulting knowledge base can be exploited by semantic search engines or P2P metadata infrastructures in order to foster better and more flexible collaboration among software developers scattered across the globe.

We aim at providing support to the software developer for documenting code, finding the best solution to a problem or the way to move forward in critical decisions in order to save time during the heavy task of software development. Thus, in KnowBench we provide an easy to use semantic wiki.

Since manual creating knowledge may be very time-consuming and error-prone activity, the KnowBench system takes advantage of ontology learning and information extraction techniques to propose annotations. Both manual and semi-automatic semantic annotation of source code is facilitated by automated generation of corresponding metadata that assist also in describing and mapping Eclipse resources to the knowledge base.

We are planning to enhance the semi-automatic semantic annotation mechanism in order to derive more precise annotations by introducing JAPE grammar rules [Cunningham, 02] of the GATE system that will be customized for source code. Furthermore, we want to further extend the manual semantic annotation in order to add the capability of annotating arbitrary lines of code regardless of the surrounding Java elements. However, this is a hard to solve and non-trivial issue.

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# **The European Dictionary of Skills and Competences (DISCO): an Example of Usage Scenarios for Ontologies**

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**Abstract:** DISCO uses a structured classification of data, a taxonomy of skills and competences to provide web users with a supporting tool for filling in and translating online forms like e.g. online versions of the Europass CV of National Europass Centres (NEC). But structured terminological classifications like the DISCO thesaurus can be used in several contexts and fields of applications. The DISCO-based creation of competence profiles for CV or job advertisements can be seen as a prerequisite for the matching of qualification supply and demand based on the same vocabulary. At the same time the structured and well-defined DISCO thesaurus can be used for the description of curricula and learning outcomes in the context of Diploma and Certificate Supplements, ECVET and EQF.

**Keywords:** Competence; skills; qualifications; thesaurus; glossary; taxonomy; ontology; structured data; matching; labour market; vocational education and training; dictionary; European Qualifications Framework (EQF); European Credit System for Vocational Education and Training (ECVET); Learning Outcomes.

**Categories:** L. 1.3, L. 1.4, L. 3.2

## **1 Introduction**

EU policy underlines the importance of the transferability and comparability of competences, skills and qualifications<sup>1</sup> within Europe. In this context labour market and learners mobility within Europe is promoted and lifelong learning is seen as a prerequisite for reaching the aim of a competitive knowledge-based economy. Important measures to reach these goals are the European Credit System for Vocational Education and Training (ECVET) and the European Qualifications Framework (EQF) as a common European reference framework which links national qualifications systems together as a kind of translation device to make qualifications more readable and understandable across different countries and systems in Europe. Beside this, several European transparency documents like the Europass CV, the Mobility Pass, Certificate and Diploma Supplements and the language pass were developed to support the mobility of learners and labour force with standardised description formats for competences acquired in another country.

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<sup>1</sup> In this article the understanding of competences is based on the definition of [Erpenbeck, Rosenstiel 2007] as 'dispositions to act in a self organized way', while qualifications are seen as 'knowledge and skill positions' which can be tested and improved based on performance parameters.

This focus on the importance of skills and competences in European policy reflects the shift of attention from occupations to qualifications in the context of Public Labour Market Services, human resource development and competence research. While in the 1990s Public Employment Services used mainly occupational classifications for the matching of vacancies and job advertisements, later on skills and competences have been increasingly regarded as crucial factors.

This was reflected also in the creation of job advertisements: While in the past the mentioning of an occupational name in combination with the educational background, some keywords and special competences seemed to be a sufficiently distinctive description criterion for a demanded or offered set of competences, there is a clear shift to more competence orientation and detailed profiling today. Detailed requirement and competence profiles are e.g. used for resource and competence management and vocational training planning in human resource development. In this context O\*Net, the Occupational Information Network developed by the U.S. Department of Labour provides an elaborated and quite sophisticated classification system for occupational skills and requirements as well as for the description of occupations. O\*Net offers a hierarchically structured terminology for the description of vocational activities in job advertisements and for requirement analysis. O\*Net's occupational profiles include skills, abilities, knowledge, work activities, work context, necessary education, relevant tools and technologies, work styles and work values, labour market data, similar occupations and so on<sup>2</sup>. Unlike its former version, the Dictionary of Occupational Titles (DOT), O\*Net uses consistent attributes and taxonomies to describe cross-functional, particular characteristics and requirements for occupations and activities<sup>3</sup>.

In the past two decades many Public Labour Market Administrations in Europe developed taxonomies of abilities, skills and competences in addition to their occupational taxonomies to describe occupations in the context of job openings and personal competence profiles. While some Public Employment Services (PES) like the Austrian Labour Market Service (AMS) kept occupations separate from skills and competences in classification systems (classification of competences: 'Qualifikationsklassifikation' and classification of occupations: 'Berufsklassifikation') which can be used independently from each other or in combination, others used one classification system for occupations or occupational groups as well as skills and competences. An example for the latter is CO.BR.A, the COmpetenties en Beroepen Repertorium voor de Arbeidsmarkt (Directory of Occupations and Competences for the Labour Market)<sup>4</sup> which is used in Belgium by the Flemish Labour Market Service. The CO.BR.A classification system contains 550 files of occupational groups (occupations with similar basic requirements). Occupations are classified in 22 sectoral categories which include 63 domains. The 550 occupational groups are correlated with 6.000 competences. CO.BR.A is used for the creation of CV and job advertisements as well as for the selection of search criteria on the website of VDAB.

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<sup>2</sup> Examples for occupational profiles in O\*Net: [O\*Net OccupInfoNetwork, 2006].

<sup>3</sup> [Grote, Kauffeld, Frieling, 2006] S. 24

<sup>4</sup> CO.BR.A was modelled based on the French ROME, the Répertoire Opérationnel des Métiers et des Emplois (Operational Directory of Occupations and Jobs) developed by ANPE, the French Labour Market Service. [VDAB COBRA, 2009]

On an international level the European portal for job mobility, EURES provides a multilingual taxonomy for the creation of CV and job advertisements as well as for their matching. The EURES taxonomy includes occupations, skills and competences as well as some certificates and diplomas. It was developed in close connection to the taxonomy of occupations and competences used by the Swedish Labour Market Service. This taxonomy bears considerable resemblances to ISCO, the International Standard Classification of Occupations, which is a standard used worldwide to support the exchange of statistical information about occupations. It is structured according to jobholder's educational levels.

The orientation of occupational and competence classifications towards ISCO refers to two general problems in creating occupational or competence classifications. On the one hand a standardised vocabulary that is commonly used and understood and thus supports the transferability and exchange of information is still missing.

On the other hand ISCO is an example for the classification of occupations with regard to their educational background and thus shows some limits in terms of its applicability for the labour market context. ISCO's classification of occupation based on education is limited e.g. with regard to knowledge and competences acquired non-formally or informally. This is why a competence oriented approach in the actual context of increasing interdisciplinary aspects in education and labour market seems to be more promising.

The fact that occupations as well as diplomas and certificates are usually described by using skills and competences does not mean that these descriptions can be linked or compared to each other. A standardised and commonly used terminology for the description of occupations as well as curricula and learning outcomes is needed to guarantee transferability and comparability.

The European Dictionary of Skills and Competencies (DISCO) was developed in the context of all these developments and open questions and therefore aims to provide a much needed standardised vocabulary for the description of skills and competences. Unlike other classifications DISCO provides a vocabulary that is neither linked to occupations nor to educations. It offers just a thesaurus of skills and competences which is based on existing standards and classifications and thus could be the basis for a terminological standard for the description of competences in different contexts. DISCO terms can be used for the description of occupations, personal competence profiles or the requirements for a job as well as for the description of learning outcomes, diploma and certificate supplements. DISCO supports not only the comparability of competences acquired in educational or work context but also the transferability of competence descriptions within Europe by offering several language versions.

## **2 DISCO background information**

The DISCO project was funded by the European Commission (Leonardo da Vinci programme) and the Austrian Federal Ministry of Education, the Arts and Culture. It took place between September 2004 and February 2008. During the project the following main products were developed:

- \_\_a multilingual thesaurus of skills and competences
- \_\_a website offering:

- \_\_ search and translation of single terms
- \_\_ multilingual tree-structure view of the thesaurus
- \_\_ tool for creation/translation of competence profiles, Europass CV, Mobility Passes
- \_\_ a web service interface for the integration of DISCO services into other portals
- \_\_ a trilingual print version of the thesaurus (EN, FR, GE)

The following will concentrate on the DISCO thesaurus as an example of usage scenarios for ontologies, since DISCO provides a multilingual terminology based on existing European classifications and standards that is not context-bound and therefore can be used in different contexts ranging from competence descriptions for the labour market or in human resource development to descriptions in vocational and higher education.

The DISCO thesaurus is based on a comprehensive understanding of skills and competences that includes personal attitudes, values, behavioural patterns etc. independent of whether they have been acquired formally or informally.

The thesaurus consists of about 70.000 terms (about 45.000 preferred terms and 25.000 synonyms) in seven European languages: CZ, EN, FR, GE, HU, LIT, SWE.

DISCO was developed in accordance with several already existing European qualification classifications and standards like the following national classifications of project partner countries and international classifications:

- \_\_ AMS-Qualifikationsklassifikation (AT)
- \_\_ Kompetenzkatalog (GE)
- \_\_ Répertoire Opérationnel des Métiers et des Emplois – ROME (FR)
- \_\_ Taxonomy database of Arbetsförmedlingen (SWE)
- \_\_ EURES CV (EU): <http://europa.eu.int/eures>
- \_\_ ISCO-88 (International Standard Classification of Occupation)
- \_\_ ISCED 1997 (International Standard Classification of Education)
- \_\_ NACE Rev. 1.1 (Statistical Classification of Economic Activities in the European Community)

The following semantic relations are used in DISCO:

- \_\_ Semantic equivalence: every skill concept has a preferred name (descriptor) and might have one or more alternative terms (synonyms)
- \_\_ Hierarchical relations: the hierarchical structure is based on broader and narrower terms which follow a “genus/species” or “whole/part”-logic
- \_\_ Associative relations: related terms have a semantic, contextual or usage association with a descriptor that is exclusive of a ‘genus/species’ or ‘whole/part’ relationship

The thesaurus is subdivided into ‘domain specific skills and competences’ distinguishing twenty five subject fields and ‘non-domain specific skills and competences’ distinguishing nine subject fields.

The subject fields used in DISCO were developed to group skills and competence descriptors under suggestive headings and therefore correspond to well-known European categorisations, namely to ISCED broad fields of study in the case of ‘domain specific skills and competences’ and to the categorisation used in the European transparency tools in the case of ‘non-domain specific skills and competences’. However, the subject fields of the domain specific area can be connected easily with occupational sectors or branches. To give examples for some domain specific subject fields of DISCO: ‘architecture and building’, ‘education’, ‘health’, ‘law’ and some

non-domain specific subject fields that can also be found in a Europass CV: ‘personal skills and competences’, ‘managerial and organisational skills and competences’.

### 3 DISCO and the attributes of a competence ontology

DISCO can be understood as a competence catalogue with a structuring that is based on a ‘is part of’-logic and thus defines a controlled vocabulary for competences that can be used in every context where competences are relevant. The vocabulary of DISCO – like other competence catalogues – includes a distinct descriptor of the competence and a definition of its meaning.

In competence catalogues the competences are related to each other. The most important type of relation is the hierarchical relation of a taxonomy. Besides this, composition and affinity relations can be found. If the structure of a competence catalogue is linked to a well-defined semantic we speak about ontology-based competence catalogues or competence ontologies.

Important applications for competence catalogues are the description of requirement (target-profile) or competence profiles (actual profile). In the requirement profile the competences and competence levels needed are defined for a certain role or organisational unit. In this context a differentiation between necessary and desired medium-term developments has to be made. The competence profile lists the competences an individual holds. Since competences can only be assessed via work performances or exams the description of competences is often linked to competence levels and references to assessment results.<sup>5</sup>

In the context of human resource development requirement profiles and competence profiles are matched. As a result of the matching competence gaps may be revealed which can be used for the planning of vocational training measures. Competence catalogues have to be maintained and permanently actualised.

If a competence catalogue is linked to a well-defined structuring of a domain and semantic relations like similarities, generalisations, compositions and so on are made explicit these catalogues and their implicit domain knowledge can be automatically processed by using ontology-based methodologies.

The most important operations in the context of ontology-based methodologies are the comparison of the similarities of profiles (taking into account competences that can substitute a demanded competence in matching) and the subsumption of competences (the ‘being-part-of’-relation of competences can be semantically relevant e.g. with regard to vocational training measures).

DISCO meets the requirements of a competence catalogue only partly since it doesn't offer competence levels or an explicit semantic with regard to the structuring of terms. But even if DISCO is still a prototype and provides just the starting point for a competence ontology so far, it offers some advantages mentioned already above:

\_\_independency of context supports use in different applications and thus provides a basis for cross-domain comparison,

\_\_multilinguality based not just on a 1:1 translation of terms but on a research of ‘similar’ commonly used terms for a competence offers multinational transferability,

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<sup>5</sup> See [Schmidt, Kunzmann, Biesalski, 2006]

\_\_being based on international standards and peer-reviewed competence taxonomies the thesaurus provides a possible terminological ‘common denominator’.

DISCO is also trying to be compatible with the HR-XML standard developed by leading organisations in the field of human resource development and labour market.

In general DISCO offers the same usage scenarios as other taxonomies and supports the creation of competence or requirement profiles as well as a refined matching of demand and supply in job placement and human resource development.

DISCO's controlled vocabulary can also be used to describe learning outcomes in education and to support the completion of diploma or certificate supplements. The identification of competence gaps and appropriate vocational training measures can be facilitated by using the same vocabulary for the description of learning outcomes as well as for profiling in job placement and human resource development.

Beside this, DISCO can be used to support the comparability and transferability of competence terms within Europe by providing a peer-reviewed common vocabulary as well as translations which are based on a search for the most adequate competence term in another language. Unlike other ‘normal’ dictionaries the thesaurus structure provides a transparent understanding of a domain which can support the selection of a certain competence term and can as well give hints to the user which other terms might be of relevance. The user is guided by the thesaurus structure and learns from it.

Last not least DISCO like other thesauri can be used as a basis for selection lists in online applications to improve the usability of websites.

Search and translate | CV profiler | About DISCO | Help | Contact

**DISCO** European Dictionary of Skills and Competencies ...DISCO makes your skills visible...

Search:  Language: English

Sector: all sectors

Specify a word or word fragment; optionally, select a language and a sector to search in.

1. Select a CV profile
2. Select a profile section on the right side
3. Search or browse for a skill in the term browser
4. Add a skill term to the selected profile section
5. To remove a term from your profile click on it
6. Click on the flags to translate the CV

**Term browser**

Browse skills and competencies

- domain specific skills and competencies
  - agriculture, forestry and fishery
  - architecture and building
  - arts
  - business and administration
  - computing
  - education
  - electrical engineering
  - environmental protection
  - health
    - diagnostic and medical imaging techniques
    - forms of therapy
    - health service management
    - health administration**
      - administration of appointments
      - administration of patient records
      - health economics
      - medical services clearinghouse
    - hospital management
    - medical laboratory management
    - nursing management
    - quality assurance in healthcare

**health administration**

**synonyms:** medical administration support

**translations:**

- Hungarian egészségügyi igazgatás
- German Medizinische Verwaltung
- Czech zdravotnická správa
- French administration de santé
- Lithuanian sveikatos apsaugos administravimas
- Swedish sjukvårdsförvaltning

**CV:** Europass-CV

**Work experience / Main activities and responsibilities**  
managerial and organisational skills

**Work experience / Type of business or sector**

**Education and training / Titles of qualification awarded**

**Education and training / Principal subjects / occupational skills covered**

**Personal skills and competences / Mother tongue(s)**

**Personal skills and competences / Other language(s)**

**Personal skills and competences / Social skills and competences**

**Personal skills and competences / Organisational skills and competences**

**Personal skills and competences / Technical skills and competences**

**Personal skills and competences / Computer**

Figure 1: DISCO CV profiling tool (www.disco-tools.eu) with CV-profiler

## **4 Using DISCO to create and translate competence or requirement profiles**

The DISCO website offers a service called CV profiler where the thesaurus is used for the creation and translation of Europass CV, unformatted competence lists and Mobility passes. If the Europass CV format is selected, a list of the Europass CV subtitles for competence descriptions is shown. As soon as a subtitle is chosen, the corresponding part of the DISCO thesaurus which holds the relevant vocabulary for the chosen section is displayed in a separate window. The user can navigate from superior terms to more detailed ones and choose a term by clicking on it. If a term was chosen all available information like related terms and synonyms as well as all translations are displayed. The selected term can be transferred into an active category of the Europass CV by clicking a button. Alternatively, the navigation in the term tree window can be used to select a new term.

Users can switch the language of a CV and the thesaurus just by clicking a flag on top of the page. So, even if it is very likely that users fill a CV in their native language and translate it afterwards into another language, they could also check their language knowledge and train their vocabulary during the CV creation process. And this could be done for several languages at once. Thus DISCO implicitly supports the learning of foreign languages as well as the information on the vocational competences of a certain domain.

When users have added the terms selected from the thesaurus to all sections of the Europass CV, they can translate the chosen terms and the Europass CV into several languages with a mouse click. The different language versions of the CV can be saved in several formats such as word, pdf, html, xml etc. on the user's computer. Personal and other data as well as changes or additions to data selected from DISCO can be made after saving and opening the document again from the desktop.

In the case of the Europass CV a predefined format is used for the representation of the data. This is due to the fact that the Europass CV form is offered for download at the Europass websites in an XML format which can be reused by the DISCO application in order to save the data immediately in the standardised format. The created data is offered in an XML format too, that can be reimported into the Europass applications.

The 'unformatted list' format of DISCO can be used to create and translate competence or requirement profiles for different contexts like e.g. job advertisements, job descriptions, personal competence profiles for human resource development etc.

Furthermore, it would be easy to define a new profile in DISCO. If the thesaurus should e.g. be used in the context of a special job advertisement tool, one could use XML or HR-XML to define the format and structure of the advertisement, specify necessary subtitle categories and define which thesaurus part should be displayed for term selection in each subtitle category of the advertisement.




	
<b>Europass Curriculum Vitae</b>	
<b>Personal information</b>	
First name(s) / Surname(s)	Heidemarie Müller-Riedlhuber
<b>Work experience</b>	
Dates	2001 - 2006
Main activities and responsibilities	multimedia project management, editing, translation and interpreting, development of educational opportunities
Type of business or sector	journalism and information, publishing and literature
<b>Education and training</b>	
Dates	1983 - 1987
Title of qualification awarded	literature, Slavic studies, multimedia project management
Principal subjects / occupational skills covered	business academy (secondary education upper level, Austria), Slavic studies
<b>Personal skills and competences</b>	
Mother tongue(s)	German
Social skills and competences	team-working skills, team leadership, sales talent, competence in written expression, intercultural competence
Organisational skills and competences	ability to organize oneself, ability to coordinate, entrepreneurial thinking, management of personnel resources, management of financial resources

Figure 2: example of Europass CV created and translated in DISCO

## 5 Matching profiles by using competence ontologies like DISCO

Based on the use of the same competence catalogue for the creation of CV and job advertisements, supply and demand in job placement can be matched.

In this context several European Public Employment Services are at the moment working on improvements of their matching processes by shifting more emphasize to competences. The German Bundesagentur für Arbeit for example already uses its

elaborate occupation and competence classifications (“Klassifikation der Berufe” and “Kompetenzkatalog”) for the matching vacancies and job seekers and currently works on an improvement of the classification of occupations with regard to automatic matching too. The Bundesagentur für Arbeit has linked competences to occupations and to education and could use this information for the improvement of matching results. At the moment however the separation between competences related to occupations and competences related to education is still present in the “Jobbörse”, the job placement portal of the German PES.

Several approaches of using competence catalogues in the context of searching and matching can be observed in Europe: for example the Norwegian PES offers at its website an advanced search where users can, beside the common search criteria (occupation, region etc.), search just for a set of skills and competences<sup>6</sup> too. This focus on competences alone can however not be found too often in other portals. An exception is Joinvision offering a semantic search based on a competence catalogue:

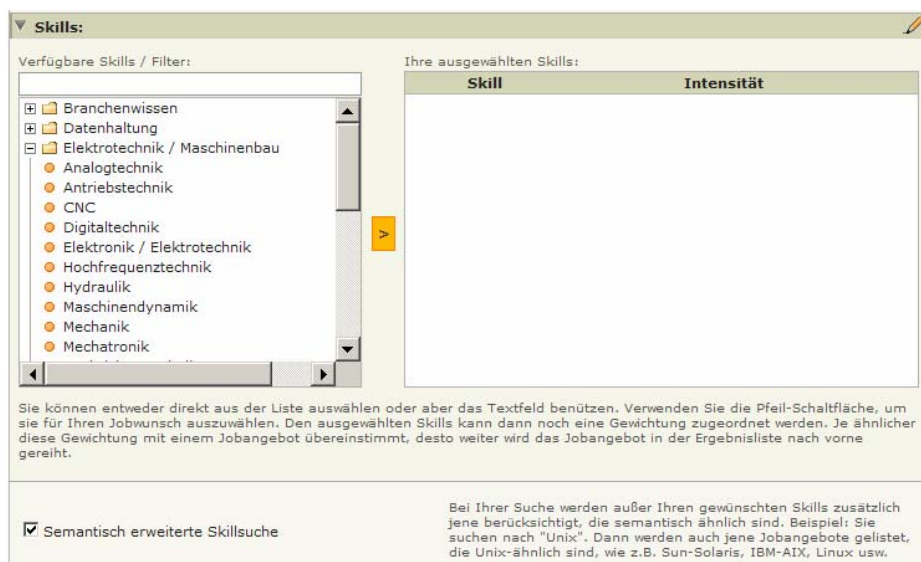


Figure 3: competence catalogue used at the Joinvision portal

These examples show that competence catalogues are already used in the context of automated job placement in order to provide semantic components for matching.

The hierarchical structuring of the skills and competences in a thesaurus structure like DISCO supports the systematic enlargement or narrowing of a searched competence area. Thus alternatives for a given competence term that are derived from the interpretation of relations within the competence catalogue can be taken into account in the matching process. If for example the term ‘MS Word’ brings no result, the search query can be enlarged to the superior term e.g. ‘MS Office’ or ‘text processing’ or even a related term like e.g. ‘Open Office’ and thus will deliver more

<sup>6</sup> See advanced search of NAV Norway.

relevant results than searches using just the occupation name and other criteria not linked to the competence area (like region, working time etc.).

Since DISCO also links corresponding terms of different language versions, matching could as well be done across language versions. Implemented in an appropriate technical solution it could become even possible to match a competence profile against several job advertisements written in different languages. The automatic matching could use one or several translations of the matched competence profile.

## **6 Using DISCO for the description of learning outcomes**

DISCO is already used by to describe learning outcomes at an university level by research projects in Slovakia and Portugal and it is foreseen to enlarge the DISCO thesaurus in the context of a follow-up project and to provide phraseological competence descriptions in addition to the existing noun compositions in order to enable the description of learning outcomes especially in Electrical Engineering.

Since Certificate Supplements sometimes require phraseological descriptions of competences (more task-oriented approach), it is foreseen to add competence description phrases that are frequently used in Certificate Supplements or other task-oriented descriptions to the existing DISCO terms. The phrases will be collected by partners. A text mining software will be used to recognise relevant terms and phrases in documents and to link them also to semantic web concepts. The phrases will be linked to a DISCO competence term as a collection of use case and the terminology will be further adapted to the needs of learning outcome descriptions. However, it is not foreseen to provide competence levels for terms at the moment.

DISCO should be used rather as a controlled vocabulary that allows the creation of different documents dealing with the description of learning outcomes. These descriptions might range from Diploma and Certificate Supplement to curricula and the description of competences within Memoranda of Understanding in ECVET.

DISCO provides a perspective to bridging the gap between the world of labour market and the world of education and training by providing a structured vocabulary that can be used to describe competence profiles independently of the context in which they are used. Thus and by providing translations of terms into several languages DISCO makes competence profiles also more comparable within Europe. Transparency and comparability of competences however offers a basis for workforce and educational mobility within Europe.

## **7 Using DISCO to improve user guidance in online applications**

As mentioned above the structure of the DISCO thesaurus offers at the top level twenty five areas of domain specific competences which can be seen as connected with occupational sectors. This means that the DISCO thesaurus structure supports users in the selection of a suitable area of skills and competences when describing their profiles. The terms subordinated to these top level terms can be seen as terms describing the most important competence areas of an occupational sector and could be used to give a rough overview on a domain. The tree view of the thesaurus as well as the offered related terms may raise the awareness for existing own competences

users probably do not always have in mind immediately when creating their competence profile.

Besides these learning effects DISCO and other terminological classifications can improve user guidance by offering a reliable vocabulary. There are many different options for displaying the thesaurus terminology in a way that supports users in the selection of a specific term. They are ranging from a folder-based term tree structure to drop down menus offering the top terms (or term of another level) of the thesaurus. While for example the Austrian Europass Centre refers to DISCO online portal as a helpful online tool for the completion of the Europass CV, the Hungarian Europass Centre offers DISCO as an integrated online glossary of its Europass CV wizard. During the DISCO project several web services were developed which also should demonstrate how the thesaurus terminology can be offered in an application in order to improve user guidance and usability. One example combines the auto-complete function for text inputs in the Europass CV online form with the terms offered based on the DISCO thesaurus:

The screenshot shows the 'Personal skills and competences' section of the Europass CV online form. The interface includes a navigation menu on the left with steps 1-8. The main content area is titled 'Personal skills and competences' and contains a form with several input fields. The first field, labeled 'Social skills and competences', has a dropdown menu open showing a list of skill hints provided by DISCO. The hints include terms like 'able', 'able programming', 'ability to concentrate', 'ability to cooperate', 'ability to coordinate', 'ability to cope with pressure', 'ability to find a compromise', 'ability to handle conflict situations', 'ability to learn new languages', 'ability to learn new software applications', 'ability to organize oneself', 'ability to reach consensus', 'ability to work in a team', 'absence of allergies', 'absence of claustrophobia', 'absence of colour blindness', 'absence of hearing medicine conditions', 'absence of perception defects', 'absence of phobias', 'Adabas', 'Arabic', 'cable', 'cable manufacturing', 'cable-operated excavators', 'cable production', 'capable of multitasking', 'cognitive skills and problem solving ability', 'collaborate', 'database management systems', 'establishing contacts', 'fibre optic cable', 'fruit and vegetables', 'initiative ability', 'learning ability', 'network cable (IT)', 'personal qualities and abilities', 'physical attributes and abilities', 'problem solving ability', 'products for diabetics', 'programmable logic components and ICs', 'reliability', 'special abilities', and 'teaching ability'.

Figure 4: DISCO web service using a thesaurus-based autocomplete function

## 8 Conclusion

Whereas DISCO already provides a good basis for a common multilingual vocabulary that can be used in education as well as in labour market and human resource development, further development has to take place to provide an optimised competence ontology for semantic profiling and matching tools. The extension of the vocabulary as well as the offering of additional language versions will be part of the DISCO II project. During this project more experience will be collected with regard to the practical use of DISCO in the context of Memoranda of Understanding, Certi-

ificate and Diploma Supplement completion. At the same time DISCO will be used in the context of labour market related projects e.g. at the Hungarian Europass Centre or in an international project where DISCO provides a multilingual common vocabulary to describe the competences of occupations in Austria, the Czech Republic, Slovakia and Hungary. These practical experiences will contribute to further develop DISCO.

One main problem for the future however will be the considerable effort necessary to maintain such a comprehensive multilingual vocabulary. This becomes obvious especially if one takes into account the mass of new education and training offers and new arising occupations in the labour market, the competence profiles of which often need time to take recordable shape.

In an international and multilingual context things get even more complicated. For example it turned out that even the simple translation of a competence term from one language into another might become a challenge, because several skills and competence terms of one language do not have equivalents in other languages and cultural background (e.g. competences in the field of law are difficult to transfer because of the many national specifics). Thus the challenge in developing a common vocabulary for competence descriptions that can be used in different contexts and can be transferred into several languages is to offer a terminology that is elaborated enough to provide all necessary terms for describing skills, abilities, personal attitudes and so on and that is at the same time flexible enough to support also a more context-bound description of tasks.

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# A Corporate Semantic Wiki for Scientific Workflows

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**Abstract:** State-of-the-art business process management tools provide only limited support for weakly-structured scientific workflow processes which involve knowledge intensive human interactions and are subject to frequent changes and agile compensations and exceptions. In order to address these shortcomings we propose a novel combination of a BPM system with a Corporate Semantic Web wiki. The user-friendliness of the later as regarding multi-site content generation and the power of semantic technologies as w.r.t. organizing and retrieving organizational knowledge, business rules and business vocabularies are likely to complement one another, leading to a new generation of collaborative Web 3.0 BPM tools.

**Keywords:** Semantic WIKI, Scientific Workflows, e-Science Infrastructure, virtual e-Laboratories, Business Process Management, Semantic Web, Web 3.0

**Categories:** A.1

## 1 Introduction

In the past years much effort has been spent on creating new computational and huge data infrastructures to facilitate e-Science in various research disciplines such as chemistry, bioinformatics, health care, business information systems, etc. Progress has been made with standards for service-oriented computing, grid computing, cloud computing, business process management and semantic representations of data with many projects creating a host of (grid-enabled) web services and cloud resources for e-Science infrastructures.

A few have started bringing together these information sources and infrastructures in e-Science infrastructures for scientific workflows. First scientific workflow management systems such as Gridbus (<http://www.gridbus.org/workflow/>), SwinDeW-G (<http://www.swinflow.org/swindow/grid/>), Kepler (<https://kepler-project.org/>), and Taverna (<http://taverna.sourceforge.net/>) are developed or evolved from existing systems.

Scientific workflow is a new special type of workflow that underlies the large-scale complex e-science applications such as lab experiments and simulations and answering of complex knowledge-intensive research questions. Compared with business workflows, scientific workflow has special features such as computation, data or transaction intensity, knowledge-intensive human expert interaction, and a large number of activities including management of virtual organisations such as research collaborations and research teams. Nevertheless, the current BPM technologies and languages, which promise agility and flexibility in process management, qualify as a good basis for simulating, modeling, executing, monitoring, and managing key e-Science workflows by abstracting the underneath technical

system, application logic, and other aspects of IT. They need to be extended by user-friendly interfaces for integrating researchers and other involved human partners in the execution activities of the scientific workflows, in order to support the reality of daily work in e-Science infrastructures.

In this paper, we present a solution for this through the integration of our Process Makna Semantic Wiki system with a BPM system (Apache jBPM). While the Wiki makes it easy to collaboratively author and add the required information at runtime at the user front-end, the BPM system running in the back-end executes and enforces the scientific workflow processes. The Semantic Web extension of the Wiki allows establishing an explicit domain model in the back-end, which represents the knowledge about the scientific domain as ontologies and rules / goals / policies. This additional semantic knowledge base is used to integrate heterogeneous information resources and services (i.e. semantic web services), mediate between different vocabularies over domain boundaries and provide semi-automated decision support and enforcement via rule reasoning and execution. Ultimately this leads to a novel Semantic Business Process Management (SBPM) Wiki environment - called Process Makna (Makna stands for "knowledge" in Indonesian) - which is in particular tailored for knowledge-intensive agile scientific processes, typically realized through weakly structured workflows with many human interactions.

We present our proposal for the limited (semantic) coordination, collaboration and integration capabilities of standard BPM tools: combining a semantic wiki and a workflow management system. We have designed a model integrating the semantic wiki's data model with the WfMC process definition reference model (<http://www.wfmc.org/standards/referencemodel.htm>). Following an introduction to the semantic wiki used in this work, namely Process Makna, we describe its integration with the workflow engine jBPM. We evaluate the implementation towards a workflow example and conclude by discussing related work and considering the contribution of this work.

## 2 Rules for Scientific Workflow Execution

Process Makna is a Wiki-based tool for distributed knowledge engineering. It extends the existing Makna Wiki engine with generic, easy-to-use ontology-driven components for collaboratively authoring, querying and browsing Semantic Web information. The architecture of Makna consists of the Wiki engine JSPWiki (<http://www.jspwiki.org/>), extended with several components for the manipulation of semantic data, and the underlying persistent storage mechanisms. A more detailed description of core Makna wiki and the user interfaces it supports can be found in [DPT06].

For this work we integrated the semantic Wiki Makna and the workflow engine jBPM 4.0 ([jboss.com/products/jbpm](http://jboss.com/products/jbpm)) and the RuleML Rule Responder Enterprise Service Bus middleware ([responder.ruleml.org/](http://responder.ruleml.org/)). The architecture of the distributed system with jBPM and Makna consists of a J2EE server, J2SE server(s), the RuleResponder middleware including the Mule Enterprise Service Bus ([www.mulesource.org/](http://www.mulesource.org/)), a workstation and an AllegroGraph triple store server ([agraph.franz.com/](http://agraph.franz.com/)) that serve as Semantic Web persistence stores. In this section we



consider the aspects of the architecture and the integration of its components which were implemented for Process Makna.

### 2.1 Semantic Workflow Annotation and Rule Integration

It is necessary to reflect the workflow instances (e.g. tasks and processes) in the semantic model in order to support search for and enhanced presentation of tasks and processes. The insertion of workflow concepts into the semantic model at runtime has two prerequisites: first, a mechanism must be provided which assigns the URIs of the ontology concepts to the syntactic constructs used in the business process models (BPMN 2.0 models) describing the scientific workflows the domain-specific workflow instances; second, these URIs must be made accessible in the BPEL process executions. This integration of ontologies in the process models has the advantage of allowing access to existing domain specific glossaries, taxonomies and ontologies from within the processes. Different scientific domain vocabularies can be mediated via the semantic inference capabilities.

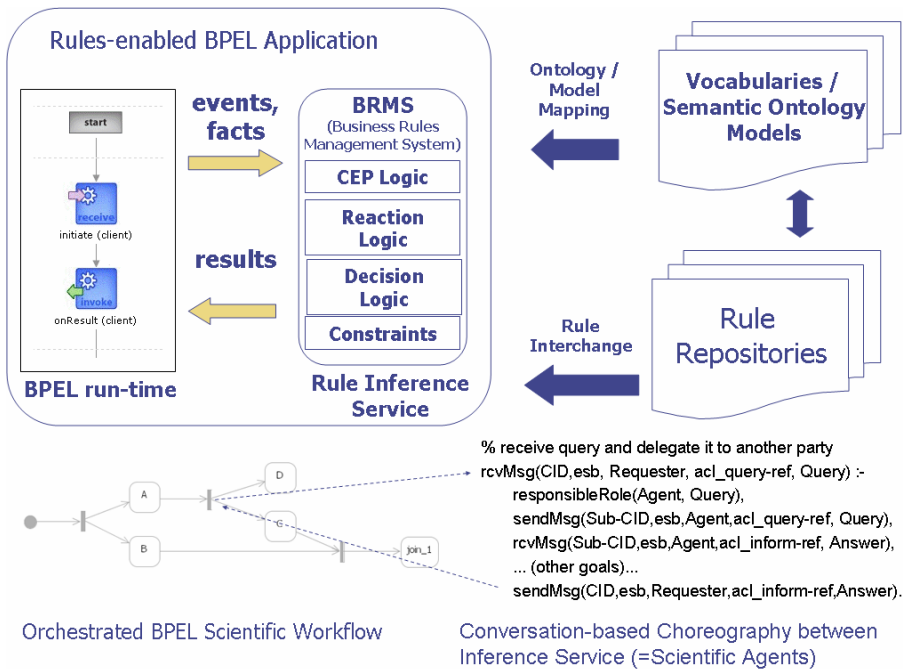


Figure 1: Integration of Rules and Ontologies into BPEL Scientific Workflows

With these prerequisites met, semantic decoration of workflow execution can be performed with standard BPEL procedures which invoke declarative rule inference services implemented as semantic web services – see figure 1. While traversing a process graph the BPM engine fires events (event messages) – e.g. at certain decision points in the workflows which require complex decision logic or complex event processing logic. Therefore, the BPEL engine invokes rule inference web services

(rule-based agents) and sends the event messages to them. The internal rule engine of the agent / service runs messaging reaction rules in combination with declarative decision rules for, e.g. semantic rule-based event processing, conditional decision logic or triggering custom actions and choreography sub-conversation workflows with other distributed inference services on the ESB (leading to a distributed rule-based multi-agent system deployed on an ESB). The multi-agent approach can be, e.g. employed for distributed problem solving or intelligent semantic data integration and federation from external distributed data sources such as RDF triplestores, rel. databases, web services etc., which are provided on the web.

In our rule-based BPEL extension for Process Makna arbitrary complex decision and reaction logic can be declaratively represented in terms of combinations of derivation and reaction rules (see section 2.5) which associate the BPEL event with the reaction rule events and with rule conditions (implemented as chained logic programming derivation rule sets) and actions, including, e.g. SPARUL RDF update queries based on URIs for workflow instances (i.e. the progress of a workflow can be directly reflected in the semantic model).

## 2.2 Semantic Flow Conditions

Facilitating semantically enhanced flow conditions in the process execution phase is desirable, because inference allows for transitions and control flow, based on the description of a workflow in the semantic model itself. BPEL already supports the association of transitions with implicational Boolean expressions (or simple rules in BPEL) which are based on workflow relevant data. Our rule-based extension provides much higher expressiveness for complex declarative flow conditions (decisions) and processing of reaction logic in terms complex events and actions. The process execution continues via the first transition whose associated rule sets in the rule agent (inference service) resolves to true, or via the default transition if none of the expressions resolves to true, though this behaviour can be customized in a declarative rule-based way. This procedure facilitates sophisticated rule-based control of the BPEL process based on semantic model state of the rule agents which might follow internal choreography flows to efficiently solve complex tasks such as federating and deriving knowledge from information clouds consisting of large distributed Web/Grid-based scientific data sources (e.g. Semantic Web linked open data).

## 2.3 Semantic Assignments

Strategies for the assignment of tasks to Wiki users that build on semantic user and task descriptions are supported by the system. Semantic user descriptions can be based on customized formalizations such as DOAC (<http://ramonantonio.net/doac/>). User models, task descriptions and responsibility assignments can use common concepts from shared domain ontologies, e.g. for describing experts in FOAF, and based on these ontologies represent a responsibility assignment matrix (RAM) ([ruleresponder.ruleml.org](http://ruleresponder.ruleml.org)). Figure 2 gives an example of a RAM and its ontological representation in OWL. The actual assignment of tasks to users is realized through a jBPM *AssignmentHandler* implementation which can be configured with a SPARQL query that references these concepts.

Role	Definition
Responsible	This role conducts the actual work/owns the problem. There can be multiple Rs (this is called teamworking)
Accountable	This role approves the completed work and is held fully accountable for it. There should be only one A
Supportive	This role provides additional resources to conduct the work or plays a supportive role in implementation.
Consulted	This role has the information and/or capability to complete the work. Two-way communication (typically between R and C).
Informed	This role is to be informed of progress and results. One-way communication (typically from R to I).
Verifies	This role checks the work to ensure that it meets all defined criteria and standards.
Signs	This role signs off on the completed work.

ACTIVITIES	George	Glenda	Tom	Susan	Mary	Craig
Investigate	R	A	I	C	C	
Design SW	I	A	C			R
UAT Plan	R	A	I			C
Phase Signoff	R	A	I	C	C	C

```

<owl:Ontology rdf:about="RuleML-2007.owl">
  <owl:versionInfo 0.01/>
  <owl:versionInfo 0.01/>
  <rdf:comment>Describes the role model of RuleML-2007</rdf:comment>
</owl:Ontology>

<owl:Class rdf:ID="RuleML-2007" />
<!-- Model of the RuleML-2007 Organizing Committee -->

<owl:Class rdf:ID="Program_Chair">
  <rdf:subClassOf rdf:resource="#Organizing_Committee" />
</owl:Class>

<owl:Class rdf:ID="Challenge_Chair">
  <rdf:subClassOf rdf:resource="#Organizing_Committee" />
</owl:Class>

<owl:Class rdf:ID="Panel_Chair">
  <rdf:subClassOf rdf:resource="#Organizing_Committee" />
</owl:Class>

<owl:Class rdf:ID="Publicity_Chair">
  <rdf:subClassOf rdf:resource="#Organizing_Committee" />
</owl:Class>
  
```

**Role Model and RAM in OWL**

Figure 2: Responsibility Assignment Matrix and representation as OWL ontology

### 2.4 Semantic Search and Presentation of Workflow Individuals

For the structured presentation of semantic resources we have added support for formatting SPARQL XML responses with XSLT. This functionality is encapsulated as another JSPWiki-Plugin, which additionally has support for expressions that are resolved at rendering time (e.g. logged in user and page URL). Via an endpoint parameter remote triplestores are also supported. The plugin enables the structured presentation of workflow individuals such as tasks and process instances in the wiki. It can be called from the JSPWiki template level (invoked from a JSP) or from the wiki page level (invoked from wiki syntax). Another application of this plugin is in the generation of lists such as semantically enhanced task lists. The tasks that have been assigned to the logged in user can be arranged by domain specific structures, thus enabling semantically enhanced descriptions of task lists.

### 2.5 Rule-based Choreography Workflow Execution

As described in section 2.1 we have implemented a heterogeneous integration of rules into WS-BPEL which exploits Reaction RuleML (see ruleml.org and Reaction RuleML) as platform-independent Web rule standard and the Rule Responder ESB middleware (responder.ruleml.org) for deploying and communication between rule inference services which run a Prova rule engine (prova.ws) as platform-specific execution environment. The rule inference services are invoked by the main orchestrated scientific workflow by sending BPEL event messages to Prova messaging reaction rules and receiving result messages from the Prova agent. Input and output variable bindings are used to bind the messages to the partnerlinks of the

BPEL process. Each agent implements an internal rule-base with rules for decision logic, rules for reaction logic and further rule-based constraints or transformations (e.g. data federation from external data sources). A Prova agent can communicate with other agents via messaging reaction rules and can interact with them following a choreography-style interaction flow. The messaging reaction rules maintain a local conversation state and support performing of different activities/tasks in simultaneous conversation branches. Figure 3 gives an example of such a distributed multi-agent eScience infrastructure, where Prova agents (rule inference services) communicate via the ESB and derive decisions and reactions from the occurred events (messages from BPEL or other agents) and the facts from external data sources such as the PubMed publications or the W3C HCLS KB which is a RDF triple store, etc.

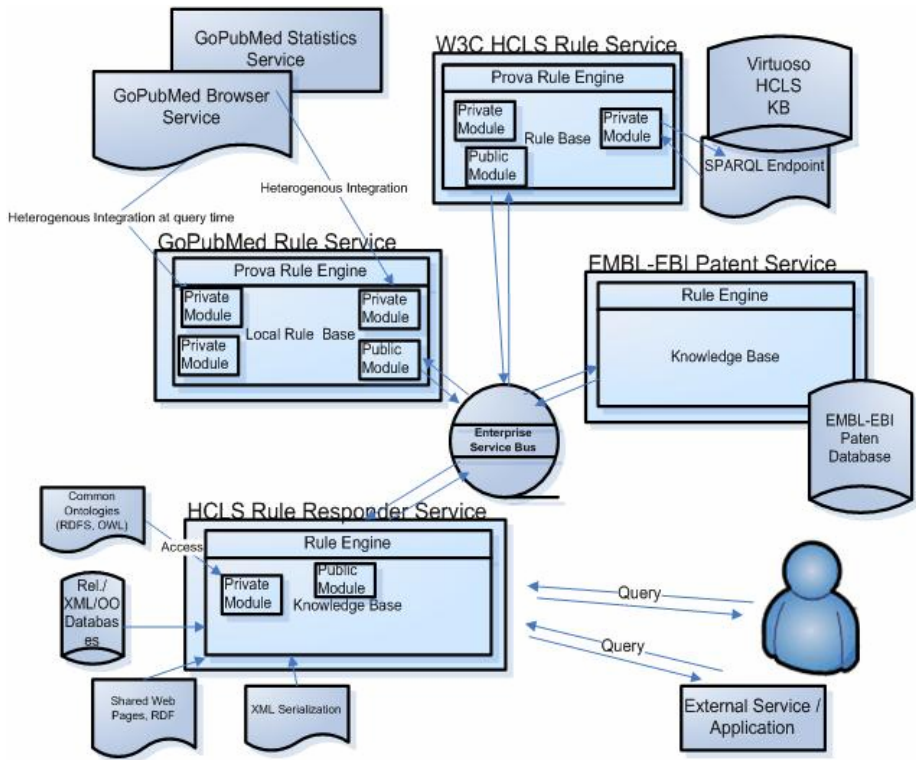


Figure 3: RuleResponder Health Care and Life Science e-Science Infrastructure with Prova Agents (rule-based inference services)

The rules transform the data into knowledge of practical relevance for the main scientific workflow and send it to the BPEL process as a result to the original invoke event message from the BPEL process.

As an independent system, the Rule Responder Enterprise Service Bus middleware with the Prova rule engine is running as a distributed parallel running

platform that analyses and processes events. The jBPM- and the RuleResponder-platform interact via event messages which are interchanged on the ESB.

**Rule Responder** (<http://responder.ruleml.org>) is a middleware for distributed intelligent rule-based inference services and complex event processing on the Web. It adopts the OMG model driven architecture (MDA) approach:

1. On the computational independent level rules are engineered computational independent e.g. in a natural controlled English language using blueprint templates and user-defined controlled vocabularies.
2. The rules are mapped and serialized in a interchange format such as Reaction RuleML (or RIF XML) which is used as platform independent rule interchange format to interchange rules between the rule inference services and other arbitrary execution environments.
3. The Reaction RuleML rules are translated into the platform specific rule language for execution, e.g. the Prova rule language.

Arbitrary (reaction) rule engines and CEP engines can be deployed on an enterprise service bus (ESB). Translator services translate from the respective execution syntax of the platform-specific rule / CEP engine into Reaction RuleML which is used as common rule interchange format and vice versa. Arbitrary transport protocols (>30 protocols) such as MS, SMTP, JDBC, TCP, HTTP, XMPP can be used to transport rule sets, queries and answers (e.g. event instance data) between distributed inference service endpoints on the Web. For workflow-like intelligent message processing it employs the Web rule engine Prova (<http://prova.ws>) and messaging reaction rules to describe (abstract) processes / situations and complex event processing logic in terms of message-driven conversations between inference services / agents, i.e. it represents their associated interactions via constructs for asynchronously sending and receiving event messages.

### 3 An e-Science Use Case

Virtual e-Science infrastructures supporting network-based scientific workflows are a good example for knowledge-intensive collaborative and weakly-structured processes. These virtual environments need to integrate the necessary heterogeneous scientific resources, services, data and documents. They need to interlink the information objects and transfer them into meaningful knowledge. And, they need to interact with the human scientists to support them in their collaborative research workflows. In this section we present an example scientific workflow to illustrate improvement of coordination, collaboration and integration support with Process Makna as part of a virtual e-Science infrastructure. Thereby, we are able to capitalize on the fact that the data resources, service, process activities, and organizational roles are already represented in terms of Semantic Web representations and are accessible via an e-Science infrastructure in our case-study domain - which is the health care and life sciences (HCLS) domain. For more information see e.g. [Paschke08] and the W3C HCLS project ([corporate-semantic-web.de/hcls.html](http://corporate-semantic-web.de/hcls.html)).

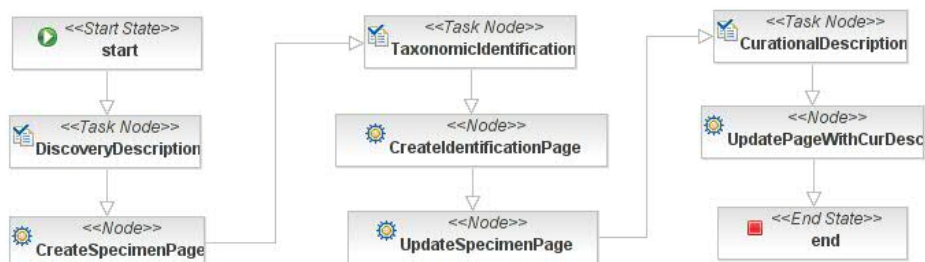


Figure 4: Sample workflow for the processing of a new specimen. The three columns are associated with the process swimlanes *FieldWorkParticipant*, *Taxonomist* und *Curator*

We have derived a couple of example workflows from a business model within the EDIT (European Distributed Institute of Taxonomy) project (<http://www.e-taxonomy.eu/>). Figure 4 shows a typical workflow: the processing of a specimen. The involved actors in this workflow are associated to agent roles which are rule-based agents (Prova rule inference services) wrapping the communication interfaces of a real human actor, i.e. its obligations, permissions, functions etc. The workflow involves three actors: a field trip participant who describes the finding of the specimen, a taxonomist who performs the taxonomical identification and a curator who is responsible for the curatorial administration. First, somebody in the role of a *field work participant* triggers the start of the process<sup>1</sup> and describes the discovery of a new specimen through an associated task form in the user console, whereby a new wiki page is created from a template. This template contains enhanced wiki syntax with placeholders for subjects of statements, which are replaced with corresponding user input. User input consists of literals (e.g. from text area and input fields) as well as URIs of concepts and instances (e.g. from JSF *SelectItem* elements). Predicates used in the template are taken from existing ontologies.<sup>2</sup> Notification by email (via the ESB) is sent to somebody in the *taxonomist* swimlane to inform him/her that he/she is due to perform a taxonomic identification of this specimen. Again, the results are committed to the workflow engine through a task form. Upon completion a new page with the results of the taxonomic identification is created, and a typed link to it is inserted on the discovery page. A last action must be taken by somebody in the role of a *curator*. The selection of the actor is formalized as a SPARQL query and executed upon creation of the task instance. It is based on semantic description of curators' responsibilities and the results of the taxonomist's identification and user resources. Further on, Process Makna's click-searches which are provided with every resource in the wiki can also be helpful for collaboration. Examples include a list of

<sup>1</sup> Workflow related functionality (e.g. listing and starting of processes) in Makna use the RuleResponder ESB to interact with the jBPM engine.

<sup>2</sup> In our example we reuse the FungalWeb ontology [SNBHB05] for mycological classifications and TDWG's LSID ontologies for taxonomic data.

all users with tasks in a certain process and a list of all specimen that have been identified by a certain taxonomist.

Another aspect of the improvement of collaboration support is the selection of an actor in the curator swimlane based on the results of the taxonomic identification and the semantic responsibilities descriptions in the wiki. In this example the taxonomic identification requires the selection of a *FungalWeb* concept and responsibility descriptions of actors refer to the same ontology. Because of the hierarchical structure of the *FungalWeb* ontology it is possible to infer the responsible actor, thus realizing a dynamic assignment strategy.

## 4 Related Work

There are many Wiki systems. TWiki has been an early perl/cgi implementation [TWiki]. MediaWiki is a free wiki implementation based on PHP. It was originally written for Wikipedia, but is broadly used today [MedWiki]. Semantic Media Wiki [SemWiki] is a well-known semantic wiki implementation with the purpose to create a Semantic Wikipedia [SeWiPe]. IkeWiki is a semantic wiki created by Salzburg Research [IkeWiki]. OntoWiki is another semantic wiki system [OntoWiki]. To the best of our knowledge none of these (semantic) wikis has an extension for BPM and is used as human-friendly interface during BPM execution and enforcement.

Semantic Business Process Management (SBPM) has been addressed by various projects in the past, e.g. the Semantic Business Process Management Working Group [SBPM], the Super project [Super], the Rule-based Service Level Agreement Project (RBSLA) [RBSLA], or the Semantic Business Process Management workshop series [SBPMW]. The contributions in these projects mainly address the combination of ontologies and/or rules with business process models, and the enriching of web services to semantic web services including non-functional properties and policies / SLAs. While these approaches have demonstrate the usefulness of Semantic Web technologies for BPM and automated IT service execution within business processes they have not addressed the problems of knowledge-intensive weakly structured processes with many human interactions which motivated our work in this paper.

The current extensions of BPM languages such as BPEL4People [BPEL4P] are purely syntactic and introduce “Peoplelinks”, “Partnerlinks”, “Exceptions”, “Compensations”, “HumanTasks” etc. They do not address the semantics of these interactions and do not investigate the combination of social software + semantic technology (=Web 3.0) with BPM.

## 5 Conclusion

Manifold BPM languages<sup>3</sup> and tools have been developed. Typically these tools are applied in repetitive, high-volume production or administrative workflows where a central orchestration process definition can be created, optimized, and then used as a prescriptive, standardized model for process enactors or for workflow automation.

---

<sup>3</sup> Currently, it seems that BPMN (for modelling) and BPEL (for execution) will become the broadly accepted standards

However, practical experiences have shown that scientific workflow processes are often weakly-structured, agile / change quickly, and need to dynamically integrate heterogeneous information resources and services as well as collaborative human knowledge and tasks.

We have considered in this paper how the limited coordination, collaboration and (human) integration support of BPM approaches could be improved by a Web 3.0 Semantic Process Wiki, named Process Makna, and we have presented a solution based on the integration with a BPM workflow system (jBPM) in combination with semantic technologies (rules and ontologies). Initial evaluation of the Process Makna Wiki in a HCLS e-Science infrastructure [Paschke2008] has demonstrated promising improvements in terms of integration of non-technical persons (humans) into knowledge-intensive scientific workflows. This, in the authors' view, can prove to be of importance to the future uptake of semantic wiki systems, particularly in the corporate and scientific environments. We see two major advantages of our proposal:

1. lightweight dynamic user-friendly acquisition of required knowledge for scientific workflows – (human) end users bring in their process knowledge in a simple, effortless, manner - the low-barrier wiki approach provides and intuitive interface to collect knowledge from humans.
2. collaborative (conversation-based) human interactions on the basis of an agent-based role model is a powerful, instrument to integrate humans in scientific process models.

Beside the contribution of a new design artefact – a semantic BPM Wiki – the extension of the existing standards BPMN and BPEL with Semantic Web ontologies and rules provides significant more expressiveness and leads to a novel semantic BPM (SBPM) approach. Moreover, a typical problem of Corporate Semantic Web wikis is that they are rarely moderated and hence quickly grow with a lot of redundant, outdated or simply wrong information. Current and obsolete information cannot be distinguished, and it is hard to find the relevant information and navigate the wiki. A process model for content authoring which runs in the back-end of the wiki can serve this role of a moderator and can enforce respective content management policies.

We are continuing the development of Process Makna, and particularly currently explore in a practical manner the deployability of it in different enterprise environments through our Corporate Semantic Web project (<http://www.corporate-semantic-web.de>). We are currently implementing a larger virtual e-Science infrastructure within the scope of the W3C HCLS interest group.

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# Exchanging Knowledge in Concise Bounded Descriptions

## An Approach to Support Collaborative Ontology Development in a Distributed Environment

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**Abstract:** Collaborative ontology environments are faced with two main challenges that are not yet sufficiently supported: supporting private and shared workspaces and controlling version during development. One solution is to split an ontology into small pieces and synchronize the changed pieces between local and remote sites. In this paper we describe an approach that uses Concise Bounded Descriptions to support collaborative editing. We will discuss how to transfer, compare and merge ontologies with this approach in detail.

**Key Words:** Incremental synchronization, Version control, Concise Bounded Descriptions, Compare and merge.

**Category:** H.4 H.3 J.1 M.3

## 1 Introduction and Motivation

Building ontologies is often a large collaborative effort, involving many contributors who work together in synchronous or asynchronous ways. Defining features for collaborative working is not easy. But we can use a remarkable process for reference, which is software developing. During the developing phase programmers are loosely connected. Every programmer is working in his own environment, creating classes for his part. He then synchronizes his result with a shared repository by the help of versioning tools after making a bunch of modifications. During the synchronization he needs to manage the conflicts when someone edited the same class he changed. Other programmers' results are updated to local environment after the synchronization so that application code is up to date. CVS or SVN support rollback source code if necessary.

Similar procedure may be happened during ontology developing, however they are not fully supported by current developing environments. Developers need to work in a shared space in many current ontology development environments. Compared with software development, two main issues [NCA08] that they do not support although important are: 1. The system should support private and public workspaces respectively; 2. We need to better control version on

ontology during developing. In this paper we propose a new mechanism simulating the process of software developing. In this approach, ontology developers can first describe knowledge locally, focusing on the specific part of the ontology relevant to them and possibly applying their individual perspective to some extent. They can then integrate the ontology segments into a shared knowledge base by actions of updating, comparing, merging and committing.

The paper is structured as follows: Section 2 describes the specific challenges and existing approaches. Section 3 presents a simple scenario showing how to support distributed ontology development. In the section 4 we discuss the approach in detail. A discussion of the applicability of the approach and issues for future work are presented in the last section .

## 2 Challenges and State Of Art

Currently, several systems are already available that aim at supporting collaborative ontology development (e.g., [TN07, SKKM03, TMN06]). Most of them use a centralized shared workspace. An approach that supports private and shared workspaces is HOZO [SKKM03]. HOZO tries to split large ontologies into several small sub-ontologies and manage their dependences. sub-ontologies can be stored locally but only one developer can modify a sub-ontology at one time.

We have to provide mechanism to control version [KFKO02] either. A few ontology development tools such as [VG06] and [GSV04], support versioning. However a problem for them is that they give only one version number for entire ontology so that rollback one ontology resource is not possible. For example they can not rollback current 'mammal' definition to a previous version unless you rollback the entire ontology.

In order to fulfill the two requirements discussed in section 1 we need an appropriate method for an incremental synchronization of ontologies. We encapsulate knowledge in a fine level of granularity and transfer them between locals and a shared repository. We will synchronize only the changed knowledge segments and mark tracing information on them. In developing such a method the following questions need to be addressed:

- What is an appropriate level of granularity for the synchronization?
- How can anonymous nodes be synchronized?
- How can we ensure a valid synchronization with respect to the relations between ontology concepts?

Named graphs [CBHS05] and MSG [MTEBG07] are two possible approaches for incremental synchronization. However they both are not fit for our requirements. MSG is too small in our case – if two nodes in RDF graph are named

nodes, then a MSG contains only one or two triples. But ontology developers care more about ontology resources and resource graphs are much larger than MSG. Named graphs defines a good method to give constraints and extra information to sub-graphs of an ontology, however how to define these sub-graphs depends on the publishers and they do not have a standard that tells developers how to split an ontology.

To compare two anonymous nodes is also difficult. Comparing graphs needs time [MB95]. One solution is to rewrite RDF document in a canonical format [CC03]. Another solution has to *pollute* the original RDF. It sets an *Inverse-Functional-Property* to each anonymous node and gives additional ID information to them.

A further issue is to find the relations between the pieces of knowledge we want to synchronize. Modifying one ontology resource, such as a class, potentially influences other resources, e.g. when this other resource is connected to the one changed through a domain property. Solutions are needed to detect such conflicts and resolve them during synchronization.

### 3 A collaborative scenario

In this section we describe a brief scenario illustrating how ontology development can be supported in a distributed environment. We use a small sample animal ontology and define several concepts of it. In order to keep it simple, we ignore many information of the ontology, such as annotations and header of the file. The ontology is written in OWL format as follows:

```
<owl:Class rdf:ID = "Mammal"> -----//version 1.0
</owl:Class>
<owl:Class rdf:ID = "Predator"> -----//version 2.0
</owl:Class>
<owl:Class rdf:ID = "NonVegetarian"> -----//version 2.0
</owl:Class>
<owl:Class rdf:ID = "Felid"> -----//version 6.0
  <rdfs:subClassOf>
    <owl:intersectionOf rdf:parseType="Collection">
      <owl:Class rdf:resource = "Mammal">
      <owl:Class rdf:resource = "Predator">
    </owl:intersectionOf>
  </rdfs:subClassOf>
</owl:Class>
```

Assume both Tim and Lang are working on an animal ontology, of which they have local replicas on their own computer. At 13:00, Tim adds a new definition of *Mammal*, defining that mammals have fur by adding a new property

*vo:isCoveredBy* and a new class *vo:Fur*. Lang changes the definition of felid at 14:00, which defines it as a subclass of both mammal and non-vegetarian. The version number of the *vo:Felid* will be set as 6.0\*<sup>1</sup>, which means something changed in the class of *vo:Felid*. Lang commits his change at 14:10 so that *vo:Felid* is committed to the server. Now *vo:Felid* has version number 7.0 on both the server side and Lang's computer. Tim synchronizes at 14:30. The system detects that *vo:Felid* has been changed by a remote collaborator and that two new concepts have been created locally. The system commits Tim's changes *wo:isCoveredBy* and *vo:Fur* to the server, while *vo:Felid* is received from the server update the local ontology. After the synchronization the ontology on Tim's computer looks as follows:

```
<owl:Class rdf:ID = "Mammal">          ----//version 1.0
</owl:Class>
<owl:ObjectProperty rdf:ID = "isCoveredBy"> ---//version 1.0
  <rdfs:domain rdf:resource = "Mammal">
  <rdfs:range rdf:resource = "Fur">
</owl:DatatypeProperty>
<owl:Class rdf:ID = "Fur">            ----//version 1.0
</owl:Class>
<owl:Class rdf:ID = "Predator">      ----//version 2.0
</owl:Class>
<owl:Class rdf:ID = "NonVegetarian"> ----//version 2.0
</owl:Class>
<owl:Class rdf:ID = "Felid">         ----//version 7.0
  <rdfs:subClassOf>
    <owl:intersectionOf rdf:parseType="Collection">
      <owl:Class rdf:resource = "Mammal">
      <owl:Class rdf:resource = "NonVegetarian">
    </owl:intersectionOf>
  </rdfs:subClassOf>
</owl:Class>
```

Lang will receive the concepts *vo:isCoveredBy* and *vo:Fur* after his next synchronization. On the server side, the system records all modifications for each concept so that future rollbacks and history tracing are possible.

#### 4 Supporting distributed ontology developing with help of Concise Bounded Description

As described in the previous scenario we can notice several key issues in this process. First we need to determine the level of granularity used for synchro-

<sup>1</sup> \* means the flag *ChangedAfterLastSynchronization* discussed later

nization. This also implies the question of how to set version numbers for an ontology. Secondly, we need to know what to synchronize after some changes have happened. Thirdly we also have to know how to compare and merge the local and remote versions.

#### 4.1 Find a fine level of granularity

[KF01] discussed that it is necessary to control version for ontologies. Some systems give each modified ontology a new version number to trace evolution. However it is not sufficient to support tracing evolution for a specific ontology resource, for example the specific OWL class 'vo:Mammal'. In order to support a more fine-grained tracing policy we need to give each resource a version number.

However it is not so straightforward to define what are resources in ontologies. An ontology can be seen as a set of URIs, a set of nodes and their relations, or a set of triples. Different views lead to different strategies to define ontology resources. Our approach aims to build a distributed ontology developing environment thus we need to find a solution that fits for ontology developers' view. In 2005 Nokia submit their form of resource description called *concise bounded description* [W3C05] to W3C as a member submission, and used it in the project *URIQA*. It defines an unit of specific knowledge about a particular resource to be utilized by, and/or interchanged between, semantic web agents.

After analyzed some popular ontology editors, such as Protégé [TN07] or OntoEdit [SAS03]. We found that these prevalent editor perspective is very much in line with the definition of CBDs. So we believe that CBDs can be used as the smallest conceptual blocks to build an ontology from the developers' point of view. One important fact need to be noticed is that CBD may contain redundancy. A CBD of one resource contains parts of other CBDs when an anonymous node stays in the object position in triples more than one time. This will influence the process discussed later. If we use CBD to represent an ontology resource, we give each URI node, which stays in the subject position in triples at least once, a version number to trace evolution. Anonymous nodes do not have version numbers because they can be seen as partial information of named ontology resources.

#### 4.2 Detect changes and do synchronization

There are three scenarios that may be happened in synchronization:

1. If the version state in the local has been set as *ChangedAfterLastSynchronization*<sup>2</sup>, it means that we need to get the CBD of the resource from the

---

<sup>2</sup> We will use the abbreviation '*CALS*' to delegate the version status *ChangedAfterLastSynchronization* in the remaining parts of this paper

local ontology model and commit it to the server, and then increase the version number.

2. If the version number in the server side is greater than the local version number, we need to receive CBD of the named resource from the server and update the local model.
3. If both happened, it means that there may be conflicts, and we need to merge both resources first and then update the local version, we submit it to the server at last.

Marking the local state of *CALS* results committing actions, it gives the system a message indicating modifications of the resource. How to set the state need to be considered. From the triples point of view, editing an ontology resource means adding or removing relevant triples. Thus the added or removed triples could tell us which resources have been changed and need to be marked as *CALS*. There are two situations:

1. the modified triple's subject is a named node. In this case, the version status of subject node is marked as *CALS*. Its CBD should be committed to the server.
2. the modified triple's subject is an anonymous node. In this case, taking the anonymous node as start point, recursively find the triples which object is the start point, for each named subject node in these triples, set it as *CALS*. We can see that if an anonymous node has been connected to several named nodes, modifications made on the CBD of the anonymous node will cause many resources setting their version status.

History tracing and updating local model usually need to find out the differences between two or several different copies of an resource. The main idea of the comparing algorithm we used is to split the CBD into small sub-graphs and compare these sub-graphs. We split sub-graph following these regulations: 1) If a triple contains only named nodes, the sub-graph contains only this triple along. 2) If a triple contains anonymous nodes, we get sub-graph following CBD regulation and take the first anonymous node as start point. We illustrate it in the Fig 1.

For those sub-graphs with only named nodes we will compare them by their URIs or IDs<sup>3</sup>. And for those containing anonymous nodes we will compare them following [CC03] regulation. We will then remove the sub-graphs existed only in the local CBD and add those existed only in the remote CBD to synchronize local resource with remote one.

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<sup>3</sup> We will discuss ID in describing renaming a resource

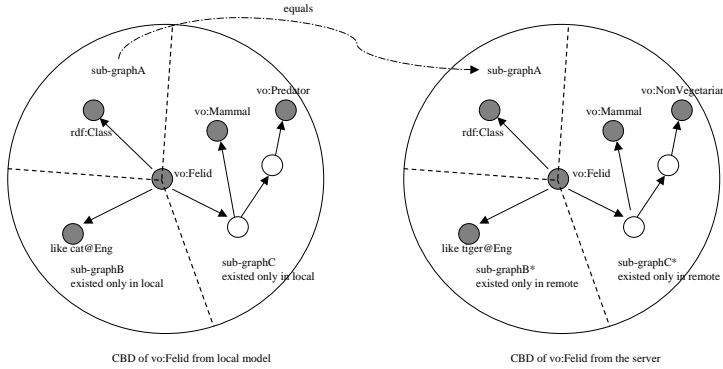


Figure 1: Comparing two CBD graphs by comparing their sub-graphs independently. Darker nodes indicate URIs and lighter nodes indicate bnodes

Conflicts are usually inevitable in distributed environments. They indicate that two or more users modify the same resource simultaneously. In this case an interactive method for merging the resources need to be offered through a GUI, allowing users to resolve the conflicts.

### 4.3 Support Special editing actions

With the previous discussion we could build our environment which deals with most modification actions, such as add a new super class or remove a equivalent class. The system could mark the *CALS* state and synchronize resources. However there are two distinct actions that are not supported yet. They are resources removing and renaming.

Removing a resource may cause changes happening in several resources, such as child resources. If one resource has been removed from the local model, we have to mark related resources' version statue as *CALS*. Based on the fact that removing a resource may use different algorithm and result different modification actions, such as removing the parent only or switching to the grandparent for children, we apply the following rule for local updating: If the CBD received from the server is marked as *removed*, we will **only** remove the triples in the CBD of the removed resource. Other relative resources, which have been changed their meaning because of removing the current resource, need to be synchronized to the server independently.

Renaming a resource also cause changes in multiple triples, however it **only** changes the semantic meaning of the resource itself. The triples in related resources may change but there is no semantic changes happened. For example we change *vo:Mammal* to new name *vo:Mammals*, in this case a new triple



'vo:Felid rdfs:subClassOf vo:Mammals' will be added and the triple 'vo:Felid rdfs:subClassOf vo:Mammal' will be removed. However the semantic meaning of *vo:Felid* does not change and we do not need to set a new version number on it. Some evolution algorithms, such as [KFKO02], cannot check properly for resource renaming since they do not know that two resources with different URIs are the same. In our system we give each URI a hidden ID<sup>4</sup>, which is managed outside the ontology model, to support history tracing. Different URIs with the same ID are thus identical. If a resource has been renamed, only the resource itself needs to be committed to the server. This regulation breaks the rule we described earlier. We will ignore the *CALS* status if it is set only by renaming relevant nodes.

## 5 Summary and future working

In this paper we describe a mechanism which supports developing ontologies in a distributed environment. Using CBD as a container, knowledge can be exchanged between different locations. Unlike many current collaborative ontology development platforms, our environment supports private and public workspaces and better version control. During the updating, comparing, merging and committing actions, users could share their ontology in a public place when they still have their local replicas.

An implementation of the methods described is currently under way as an extension of the existing Ontoverse collaborative ontology development tool [MWH<sup>+</sup>07]. We need to mention here that in this paper we do not consider issues related to consistency checking or dependency management. We believe these functionalities should be offered by the ontology editors themselves. As we focus on the services supporting incremental synchronization here, providing general mechanisms for building robust ontologies, although important, is outside the scope of this paper but will be addressed in the environment. And we also believe that recording errors is important for a version control system but cannot discuss this further here.

Besides the version control issues discussed in this paper, the method introduced has a wider range of implications for supporting the collaborative aspects of ontology creation. For example, we can support the creation of initial, incomplete versions and alternative proposals more effectively. Users can construct their own perspective of a domain individually and then submit it for discussion and consensus building in the group. Ontology managers or curators could compare and merge the different proposals to build a definitive ontological model. Discussion and voting mechanisms can quite easily be added to the

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<sup>4</sup> The ID is assigned by the server when we commit the named resource the first time. It is permanently remains the same for every named node.

process. Defining ontological models on the basis of initial, incomplete versions and alternative or competing candidates can be expected to be more effective than more controlled and central approaches and better represents the social processes resulting in the shared conceptualization.

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## Revision Support for Modeling Tasks, Topics and Skills

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**Abstract:** Whatever purpose models are created for, they need to be evaluated in order to ensure that they will serve their intended use. Unfortunately, model evaluation is a significant effort and no standard clear-cut evaluation methodology exists today. In this work we introduce our approach of distributing the evaluation effort over the whole modeling process. This is achieved by providing (partly automated) feedback on the models in different stages of development. We illustrate our approach based on the specific goal of modeling tasks, topics and skills for the adaptive work-integrated learning system APOSDLE.

**Key Words:** knowledge management, knowledge representation, modeling, model evaluation, semantic technologies

**Category:** M.4 (Knowledge Modeling)

### 1 Introduction

Intelligent automated support for knowledge workers is a key challenge for knowledge management research. To cut down on the time wasted by knowledge workers in searching for information both on their desktops or on the intra- and internet, a variety of intelligent technologies have been proposed. Examples include systems for semantic information processing of online documents as is the goal of the Semantic Web, knowledge-based systems [Buchanan & Smith, 1988], or adaptive systems [Jameson, 2003]. What all these systems have in common is their commitment to a conceptualization of the domain [Gruber, 1995]. Systems for work-integrated learning need a representation of tasks on the one hand and of users in terms of their respective skills and preferences on the other hand

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in order to provide personalization [Fischer, 2001]. In a more general context, such conceptualizations of the domain have also been termed *enterprise models* [Fox & Grüninger, 1998]. In addition to a description of processes and activities, key concepts and skills, enterprise models often describe also other aspects of an enterprise such as organizational structure. The quality of the models underlying an intelligent system baselines the quality of the support that can be achieved with it. The focus of this paper is to introduce tools that trigger model revisions iteratively throughout a process of modeling tasks, topics and skills. The modeling process and tools have already been applied in six domains in the context of the APOSDLE project<sup>2</sup>. These domains comprise requirements engineering, statistical data analysis, innovation management, industrial property rights, a software library and simulation of electromagnetic phenomena.

## 2 Revision Support as Integrating Evaluation into Modeling

Our approach to evaluation is to give feedback on desired qualities of the models as immediately as possible during modeling. We see evaluation not as separate activity with the purpose to “grade” the models (after they have been created) but as an inherent part of the modeling activities. This includes that revisions must be triggered in case the models are found to be lacking in any aspect. Furthermore, model evaluation has to be done with respect to the purpose for which the model was created. Such an approach is related to the idea of “competency questions” [Fox & Grüninger, 1998] which specify which queries a model should be able to answer. Our integrated modeling method (IMM) [Rospocher et al., 2008] adheres to these principles and is similar to [Angele et al., 1996] but extends this approach by additionally integrating the modeling of skills.

### 2.1 Tasks, topics and skills

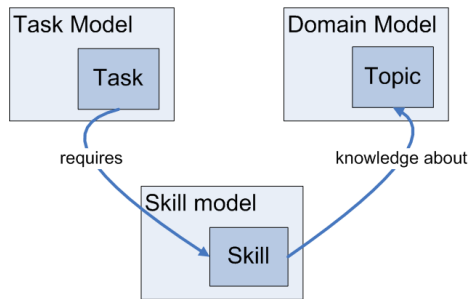
As argued above, knowledge-based systems that aim at delivering context-based, personalized information to workers at their workplace need to be aware of tasks, topics and skills within a given business or learning domain. The knowledge base whose creation is supported by the IMM therefore consists of three submodels which are constituted by these different elements (see Fig. 1).

A *task model* provides a formal description of the tasks the prospective user of the system (knowledge worker, learner) can perform. The task model identifies and groups tasks occurring in a business domain. In a task model, the control flow and other interdependencies between tasks are described. A *domain model* provides a semantic and logic description of the topics within a business or learning

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<sup>2</sup> APOSDLE (<http://www.aposdle.org>) is partially funded under the FP6 of the European Commission within the IST Workprogramme (project number FP6-IST-2004-027023).

domain as well as the relationships between them. A *skill model* establishes a relationship between the domain model and the task model. A task is mapped to those topics of the domain model knowledge about which is required in order to perform the task successfully. That way, a skill is defined as knowledge about a specific domain topic together with the ability to apply this knowledge within the specified task. For conceptual clarity, skills are modeled as entities separate from topics. Building skill models as *overlay* of the domain model is popular in the context of adaptive learning systems [Brusilovsky & Millán, 2007].



**Figure 1:** Knowledge base constituted of tasks, topics and skills.

**Example** In the domain of innovation management, a typical task is for instance “Carry out situation analysis”. “Core competency analysis”, “benchmarking” or “brainstorming” are exemplary topics in the domain. For this short example, one could state that in order to “carry out a situation analysis” one needs to have basic knowledge about “core competency analysis” and “benchmarking”. “Basic knowledge about core competency analysis” and “Basic knowledge about benchmarking” then constitute skills.

## 2.2 General requirements on formal descriptions

We argue that the following requirements for formal descriptions of tasks, topics and skills hold in general. Additionally, specific requirements on the knowledge base have to be derived based on every concrete system.

**Tasks** are typically utilized to provide support contextualized to the task at hand. In order to fulfil this goal, tasks need to have names and verbal descriptions that are intelligible to prospective users. Furthermore, they need to be at a level of granularity that would provide an appropriate answer to the question “What are you currently doing?”. Clearly, the modeled control flow needs to be correct.

**Topics** are typically needed to identify relevant resources to the user. Therefore,

topics also need to have intelligible names and verbal descriptions. Furthermore, the specialization hierarchy between topics should be correct and the established relationships between topics should be meaningful.

**Skills** typically enable the system to personalize its functionality to the characteristics of an individual user. First, it is desirable that skills are required by multiple tasks in the domain<sup>3</sup>. Second, the relation between tasks and skills needs to be correct.

Naturally, the formal descriptions need to be satisfiable and consistent. Additionally, *completeness* (every task/topic/skill which is relevant is represented in the models) and *agreement* by preferably many domain experts are desirable qualities for the knowledge base. Any assessment of correctness must also include implicit knowledge, i.e. inferences that will be made by a system based on the explicitly asserted knowledge base.

### 3 Integrated Modeling and Model Revision

The integrated modeling methodology (IMM) provides a coherent framework to create models integrating tasks, topics and skills. Accompanied by a variety of semantic tools, the IMM establishes revision support as inherent part of the modeling process. An overview of the IMM, supportive tools, and techniques is given in Figure 2. The description below focuses predominantly on the aspect of revision support. An extended description of the IMM, its accompanying tools, and evaluation of both method and tools is given in [APOS DLE D1.6, 2009].

Note that the revision support given by the IMM is not a rigorous evaluation of taxonomic relations such as provided by OntoClean [Guarino, 2004]. Instead, it focuses on triggering revisions regarding multiple properties of an ontology such as usability, intelligibility, appropriate connectivity etc. as shall be made clear below.

#### 3.1 Phase 1. Scope & Boundaries

In this phase the scope and boundaries of the application domain are determined and documented. This phase also encompasses collecting knowledge about the target domain. No differentiation between different kinds of elements such as tasks, topics or skills or structuring of elements needs to be made yet. At the end of this phase, the suitability of the chosen target domain for a knowledge based system should be confirmed. Furthermore, the scope of the application domain should be clear, and core concepts (tasks, topics, or skills) should be identified.

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<sup>3</sup> Otherwise the skill model would become redundant and only a task model would be necessary (indicating whether or not someone has performed a given task).

IMM Phase	Modeling Tools	Revision Support
Scope	Knowledge elicitation techniques Textmining functionalities in MoKi	Interpretation guidelines
Tasks / Topics	MoKi	Modeling and revision guidelines Automated checks Ontology Questionnaire
Skills	TACT	Modeling and revision guidelines Automated checks

**Figure 2:** The IMM, tools and revision support.

Knowledge is elicited from domain experts and from digital resources. For the first, standard techniques such as structured interviews, card sorting and laddering are used. For the second, text mining functionalities such as term extraction and document clustering [Pammer et al., 2007] are offered. These functionalities are integrated in the MoKi (see next section for details), to allow easy integration of extracted terms into the modeling environment.

#### *Revision support.*

Revision support in this phase must identify the suitability of the application domain to the target knowledge based system. For instance, a rapidly changing domain is a counter-indication for the application of a model-based system. Beyond this, revision support in this phase is by nature system specific. As an example, for the APOSDLE system questionnaires help elicit the main tasks and learning needs of the prospective users and additional aspects of their workplace context which may affect the success of APOSDLE in the environment. These questionnaires are accompanied by written guidelines which provide first-cut rules to early identify potential problems [APOSDLE D2.8/3.5, 2009, Chap. 7.3]. The parallel approach to knowledge acquisition from different sources (experts and documents) helps to ensure completeness of the models.

### **3.2 Phase 2. Integrated Modeling of Tasks and Topics**

The goal of this phase is to provide a complete description of the task and topic models and their inter-relations, starting from the knowledge elicited in Phase 1. At the end of this stage, the task and topic models should be correct and complete, verbal descriptions should be available, both models should reasonably overlap and be related to digital resources.



*Modeling tool: MoKi.*

Modeling in this phase takes place in MoKi [Ghidini et al., 2009], a wiki-based tool which extends Semantic MediaWiki (SMW) [Krötzsch et al., 2005] with the specific goal to support domain experts in creating the task and topic models. A demo version of MoKi is available on-line at [moki.fbk.eu](http://moki.fbk.eu).

Users provide the descriptions of tasks and topics by filling out pre-defined templates provided in MoKi. Interaction with the models is simplified by providing convenience functionalities such as visualizing hierarchies as trees. The content of the templates is converted into OWL descriptions based on a specification of how to formalize the content of distinct fields. For instance, the topic template contains a field “is a”. If for the topic “brainstorming” this field is filled with the topic “creativity technique”, this gets translated into the OWL subsumption statement that “‘brainstorming’ is a subclass of ‘creativity technique’”.

*Revision support.*

Model revision in this phase is supported through *guidelines* for modeling and reflecting on existing models. They are formulated as questions to the knowledge engineers and domain experts. For instance, one question regarding the domain model is “Should some concepts be grouped together below a common super-concept?” These manual checks are in practice highly integrated with actual modeling, and target all requirements on task and domain models as described above.

Second, *automatic checks* provide an overview over formal properties of the models such as missing verbal descriptions or isolated elements which are not connected to other elements. Such properties are directly computed from the OWL version of the models contained in the MoKi.

Finally, Phase 2 encompasses an automatically generated *ontology questionnaire* in which implicit knowledge in the models is fed back to the knowledge engineers and domain experts in order to assess its correctness. The underlying rationale is that, depending on the underlying formalism and complexity (“size”) of the models, it is often not obvious which knowledge can and will be automatically inferred. For instance, in a domain model on innovation management the statement “Imaginary brainstorming is a creativity technique” was inferred from the explicit statements made in MoKi, that “imaginary brainstorming is a brainstorming technique” and that “brainstorming is a creativity technique”. The objective is to trigger a reflection process on the side of the domain expert about whether the modeled hierarchy is modeled as intended. In case of disagreement, the ontology questionnaire offers the possibility to examine the reasons for unwanted inferences and to remove them selectively. In contrast to displaying the hierarchy in a tree view, as e.g. in MoKi or in Protégé [Protégé, 2000], the ontology questionnaire displays each subsumption in a separate line.

### 3.3 Phase 3. Modeling of skills

In this phase, the skill model is created by relating tasks to topics via a specific “requires” relation. The goal is to create a complete and correct model through multiple iterations, i.e. all but only relevant mappings between tasks and topics should be present after this phase.

*Modeling tools: TACT.*

The *T*Ask-*C*ompetence *T*ool (TACT) supports the activity of creating a skill model by assigning required topics to tasks. Obviously, the minimum required functionality consists of importing the task and topic models, assigning topics as required knowledge to tasks and exporting the skill model. TACT exports a skill model as an OWL ontology, and a symmetric import functionality exists. Furthermore, a functionality to compute a prerequisite relation [Ley et al., 2008] between skills exists. To provide an integrated modeling environment, TACT also offers a specific import functionality for the preliminary skill model created in MoKi through simply linking tasks and topics.

*Revision support.*

Revision in this phase targets the whole knowledge base, but particular emphasis is on revising the properties that refer to skills. In particular, a tight integration of task and topic models via the skill model must be ensured since this connectedness is the basis for personalization. TACT provides feedback on disconnected elements by highlighting tasks and topics which are not yet connected through the skill model.

Additionally, as in Phase 2, there is a set of automatic checks based on the OWL version of the APOSLDE knowledge base. Again, they uncover unconnected tasks and topics, as well as give an overview over skills which are only required for a single task (see requirements on the skill model in Sec. 2.2 for why this is undesirable).

## 4 Conclusion and Outlook

With this contribution we have introduced a suite of methods and tools embedded within the integrated modeling method for enterprise model creation. The IMM and tools have been specifically developed for the modeling activities required for the adaptive work-integrated support system APOSDLE. Within the context of the APOSDLE project the IMM as well as early versions of the tools have been applied and evaluated [APOSDLE D1.6, 2009]. In more recent work the described revision support was found to be very helpful for conveying

desired model characteristics and improving the resulting domain, task and skill models.

Ongoing work is dedicated to an in-depth systematic evaluation of the method and tools with regard to perceived support and usefulness for knowledge engineers, as well as with regard to the quality of resulting models. Future work is directed towards improvement and integration of MoKi and TACT.

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# Reengineering Patterns for Ontologizing the Business Processes

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**Abstract:** This paper discusses how to resolve knowledge gap between the business process models and the ontological models as a way to semantic interoperability among both enterprise engineering and knowledge engineering. The complexity of such a problem is reflected in the range from improving semantic exchange of the knowledge between ontologies and business processes by involving process theory to designing the reengineering patterns that can help in articulating knowledge about the business processes. In this work we have additionally employed the DDPO (DOLCE Descriptions and Situations (D&S) Plan and Tasks Ontology) module of the DOLCE foundational ontology to serve as a formal framework for ontological description of business processes. As a result of reengineering different models into each other, two reengineering patterns that we have called WSDL-DDPO and BPEL-DDPO patterns have been noticed. The generic role of these patterns have been seen in facilitating ontological description of business processes and theirs possible (semi)automatic execution by the workflow engine.

**Keywords:** Ontology Design Patterns, Semantic Web, Business Processes, BPEL, WSDL

**Categories:** D.2.12, D.3.3, A.1, M.1, M.8,

## 1 Introduction

Nowadays, the enterprise engineering connects two fields: (a) *management of enterprises*, which encompass the knowledge and principles related to an enterprise (life cycles, business operations, activities, products), and (b) *software engineering*, which deals with the modelling and integration of business processes [Vernadat, 1996]. Up to now, a variety of the enterprise engineering methods have been used such as the following: Integrated DEFinition methodology (IDEF), Petri nets, Unified Enterprise Modelling Language (UEML), Enterprise Function Diagram (EFD). Each of these methods and methodologies only partially close the gap between the knowledge about processes associated with an enterprise, on the one hand, and reusable and (semi-)automatically executable business processes, on the other hand. As a promising solution in achieving interoperability between the real enterprise needs and the business process models, we already pointed out the importance of involving process theory in [Damjanovic, 2008].

This paper describes the focus of the ImportNET<sup>1</sup> project, which lies in the intersection of three mechatronic domains such as mechanical engineering, electrical

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<sup>1</sup> The ImportNET project is co-funded by the European Commission within the Sixth Framework Programme under Contract 033610, in the area of ICT for Networked Businesses

engineering, and software engineering [Damjanovic et al., 2008]. For each of these engineering domains there exists ontological model and the exchange and usage of knowledge between them should be pragmatically interpreted. Here, we report on the results of our efforts in integrating diverse knowledge models, and at the same time - connecting the knowledge models and the business process models. We call such a design process - ontologizing the business processes and their encoded pragmatic structures - Reengineering Ontology Design Patterns (ReODP) for the business processes.

The approach taken by ImportNET project is to move from a cognitive model to a computational model [Damjanovic et al., 2008]. For this purpose, we have used the DOLCE foundational ontology (upper ontology), which “aims at capturing the ontological categories underlying natural language and human commonsense” [Pisanelli et al., 2002]. The DOLCE was originally developed in the EU WonderWeb project [Masolo et al., 2004] and extended in the METOKIS<sup>2</sup> project by adding an ontology module called D&S (Descriptions and Situations). The D&S module includes a representation language for tasks and processes [Gangemi et al., 2004], and it serves as a base for the DDPO (DOLCE D&S Plan and Tasks Ontology) ontology module, which we found to be necessary for modelling mechatronic tasks and processes. More specifically, we have used the DDPO module to help us getting a good understanding of business process models at the different levels of abstraction and to provide implicit rules for the facts that explain behaviour and structure of both executable and abstract business processes [Masolo et al., 2004][Damjanovic, 2008].

The introduction section gives a brief view of the research problem and questions tackled in this paper. In Section 2 related work in ontology design patterns is presented. Section 3 describes our main motivation for aligning business processes into the Semantic Web ontologies. We have explained the syntax and semantics of both the BPEL (Business Process Execution Language) and the WSDL (Web Service Description Language) that are used in designing business process models, as well as the DDPO module of the DOLCE foundational ontology that is used in formulating ontological models. In addition, an excerpt of a comparison analysis between the DDPO tasks and the BPEL activities is briefly reported. Section 4 describes the major research question addressed by the paper: how to ontologically support knowledge that describes business processes and allows (semi-)automatic execution by the workflow engine. Hence, we propose two ReODPs called the WSDL-DDPO and the BPEL-DDPO patterns for ontologizing the business processes. In Section 5, some brief conclusion remarks are drawn.

## 2 Related Work

The notion of *design patterns* is well-known software engineering paradigm that describes proven and documented solutions to a known modelling problem that repeatedly appears when designing different software systems [Aranguren, 2005]. Analogous to software engineering’ design patterns, Ontology Design Patterns (ODP) bring similar advantages to the ontology engineers.

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<sup>2</sup> <http://metokis.salzburgresearch.at/>

The notion of ODP is introduced in 1999 for a particular problem domain in biology [Reich, 1999]. Then, semantic patterns as a language independent description of a certain concepts, relations, and/or axioms are described in [Staab et al., 2001], whereas in [Devedzic, 2002] main similarities between traditional design patterns in software engineering and ontologies are emphasized. The knowledge patterns as conceptual patterns that are “morphed” into a given knowledge base by a set of mapping axioms are represented in [Clark et al., 2003], whereas both [Svatek, 2004] and [Gangemi, 2005] are more focused on designing patterns for Semantic Web ontologies that are now called - ODP.

Today, there are two communities around ODP: the one located at the University of Manchester, covered by the Gene Ontology Next Generation (GONG) project<sup>3</sup> in which ODPs are promoted to enable migrating current bio-ontologies to a richer and more rigorous level; another one is represented by the ODP community<sup>4</sup>, also known as *ontologydesignpatterns.org*, started under the NeOn project<sup>5</sup> that investigates both development lifecycle and evolution lifecycle of networked ontologies. Both communities collect ODPs through online, public catalogs, support their evaluation, improvements and reuse.

### 3 Towards Semantic Business Processes based on ODP

In ImportNET project, the design and development of ontologies was based on DOLCE foundational ontology. More specifically, we employ the DDPO ontology module to be the main working paradigm [Damjanovic et al., 2008] and to provide semantically meaningful usage of knowledge that describes tasks, description and situation in which business processes would be applied [Damjanovic, 2008]. We suggest reading [Gangemi et al., 2004] and [Masolo et al., 2004] to gain deeper insight into the DDPO formal characterization.

Moreover, the main motivation of this research was to support the ontological description of the business processes and to facilitate (semi)automatic execution of ontology-supported business processes through the proposed ReODPs. As the process of creating an executable business process requires both the WSDL description of all business operations and the BPEL description of business processes that orchestrate Web services, we define ReODPs for both the WSDL and the BPEL.

The WSDL is an XML (eXtensible Markup Language) set of definitions for describing operations and messages that constitute a network endpoint [W3C WSDL, 2001]. Services (abstract endpoints) are defined using the following elements: *types*, *message*, *portType* (a set of abstract operations and messages), *binding* (e.g. SOAP binding), *port* (specifies an address for a binding), *service* (aggregates a set of related ports), *operation*.

The BPEL activities consist of the following [Baretto et al., 2007]:

-the BPEL activities, such as: *assign*, *compensate*, *empty*, *wait*, *throw*, *terminate*;

---

<sup>3</sup> [http://www.gong.manchester.ac.uk/?page\\_id=7](http://www.gong.manchester.ac.uk/?page_id=7)

<sup>4</sup> <http://ontologydesignpatterns.org/wiki/Odp:About>

<sup>5</sup> <http://www.neon-project.org/web-content/>

- the BPEL partner activities: receive, reply, invoke;
- the BPEL structure activities: pick, sequence, flow, while, switch.

### 3.1 A Comparison Analysis between the DDPO Tasks and the BPEL Activities

The first step in constructing the proposed ReODP to support ontologizing of the business processes and handling them into the executable business processes is based on the syntactic comparison of the BPEL activities and the DDPO tasks. Table 1 illustrates the result of a comparison of the BPEL receive activity and the DDPO hybrid task.

Table 1: A syntactic comparison of the BPEL activity and the DDPO task

Syntax of the BPEL activity [Barreto et al., 2007]	Syntax of the DDPO task [Masolo et al., 2004]
<pre>&lt;receive partnerLink="nc" port Type="qn" operation="nc" variable= "nc"? createInstance = "yes no"? standard-attr&gt; standard-elem &lt;correlations&gt;? &lt;correlation set="nc" initalize=" yes no"? +&lt;/correlations&gt; &lt;/receive&gt;</pre>	<pre>HybridTask(x) = df ComplexTask(x) ^ (∃y, z.Component (x, y) ^ Component(x, z) ^ y ≠ z ^ Co ntrolTask(y) ^ ActionTask(z)</pre>

The connection points between the BPEL receive activity and the DDPO hybrid task can be explained as follows: the BPEL receive partner activity allows receiving messages from an external partner [Barreto et al, 2007]. Therefore, the receive activity specifies the partner link and operation of the partners. Additionally, it specifies a variable (or a set of variables) that holds the requested data that will be received from the partner. The requested data is specified by source and it comes either from messages exchanged with a partner, or it is intermediate data that is private to the process [Barreto et al, 2007]. The source of the requested data is specified by the link name that can have a transition condition, which offer a mechanism to split the control flow based on the required conditions. Therefore, we connect the BPEL receive activity with the DDPO hybrid task, which is a complex task that has at least one control task and one action task as components. The way of connecting the BPEL receive activity to the DDPO hybrid task is shown in the next Section.

## 4 The Reengineering Patterns: WSDL-DDPO and BPEL-DDPO

We are interested to enable ontology (re)engineering of an existing domain, which is DDPO-based, to fully support the knowledge stack that is required for executing the business processes by the workflow engine.

Following the syntax and the semantics of both the WSDL and the BPEL business process definition, we have noticed the collections of the WSDL and the BPEL business process elements that can be connected with the DDPO concepts. Thus, we have specified two ReODPs called the WSDL-DDPO and the BPEL-DDPO patterns. As the process of modelling the transition conditions (rules) is application specific, we conclude that the WSDL-DDPO and the BPEL-DDPO patterns enable reuse of knowledge, whereas the transition rules of business processes must be defined separately (and manually). Hence, we conclude that the BPEL-DDPO pattern that defines the transition rules is only semi-automatically applicable.

Table 2: The WSDL-DDPO pattern

```

edns : description
--- wsdlDefinition : wsdlTargetNamespace (>0)
--- wsdlMessage : wsdlName (=1)
      : ∃ dol:proper_part some wsdlPartOfMessage
--- wsdlPartOfMessage: wsdlName (=1)
      : wsdlType (=1)
      : wsdlElement (optional)
      : ∃ dol:proper_part some wsdlPortType
--- wsdlPortType : wsdlName (=1)
      : ∃ dol:proper_part some wsdlOperation
--- wsdlOperation : wsdlName(=1)
      : wsdlInputMessage(=1)
      : wsdlOutputMessage(=1)
      : wsdlFaultName(optional)
      : wsdlFaultMessage(optional)
      : ∃ edns:d_uses some edns:task
--- wsdlBinding : wsdlName(=1)
      : wsdlType(=1)
      : wsdlSoapBinding(=1)
      : ∃ edns:d_uses some wsdlOperation
--- wsdlService : wsdlName(=1)
      : wsdlDocumentation (=1)
      : ∃ edns:d_uses some wsdlPort
--- wsdlPort : wsdlName(=1)
      : ∃ edns:d_uses some wsdlBinding
      : wsdlSoapLocation(=1)
--- plnkPartnerLinkType: wsdlName(=1)
      : ∃ dol:proper_part some plnkPartnerRole
--- plnkPartnerRole: wsdlName(=1)
      : ∃ edns:d_uses some wsdlPortType
--- wsdlSoapBinding: soapStyle(rpc I document)
      : ∃ edns:d_uses some soapTransport

```

#### 4.1 The WSDL-DDPO Pattern

The proposed WSDL-DDPO pattern is shown in Table 2 and described as follows: a `wsdlBinding` element has two attributes: a `wsdlName` that defines the name of



the binding and a `wSDLType` that points to the port of the binding. Additionally, the `wSDLBinding` element has a `wSDLSoapBinding` and uses certain `wSDLOperation`. The `wSDLSoapBinding` element has a `soapStyle` attribute and uses some `soapTransport` attribute. The `d_uses` and `proper_part` relations represent connections between the WSDL elements and the DOLCE concepts (`dol:` stands for DOLCE concepts, whereas `edns:` is used in the DDPO).

## 4.2 The BPEL-DDPO Pattern

The BPEL-DDPO pattern is shown in Table 4. The very essence of this pattern consists in considering a `bpelSource` element, which has a `bpelLinkName` attribute and can have a transition condition associated with the status of the link (true or false). The transition conditions are application dependent and influence on the BPEL-DDPO patterns to be semi-automatically applicable.

An example of the transition conditions is given in Table 3.

Table 3: An example of the transition conditions

```
<bpel:sources>
  <bpel:source linkName="target-to-request">
    <bpel:transitionCondition>$decision.tRequest = 'yes'
and $decision.changes = 'no'</bpel:transitionCondition>
  </bpel:source>
  <bpel:source linkName="target-to-assign">
    <bpel:transitionCondition>$decision.tRequest = 'no'
and $decision.changes = 'no'</bpel:transitionCondition>
  </bpel:source>
</bpel:sources>
```

Table 4: The BPEL-DDPO pattern

```
edns:description
---  bpelProcess   : bpelName(=1)
                        : bpelTargetNamespace(>0)
                        : bpelImportLocation(=1)
                        : bpelImportNamespace(=1)
                        : ∃ dol:proper_part some bpelPartnerLink
                        : ∃ dol:proper_part some bpelVariable
                        : ∃ dol:proper_part some bpelFlow
---  bpelPartnerLink : bpelName(=1)
                        : bpelPartnerLinkType
---  bpelMyRoleLink  : bpelMyRole
---  bpelPartnerRoleLink : bpelPartnerRole
---  bpelVariable    : bpelName(=1)
                        : bpelMessageType
---  bpelCatch       : bpelFaultName(=1)
                        : bpelFaultMessageType
```

```

      : bpelFaultVariable
      :  $\exists$ dol:proper_part some bpelFaultReply
---  bpelFaultReply: bpelFaultName
      : bpelReplyOperation
      : bpelPartnerLinkReference
      : bpelVariableReference
---  bpelFlow      : bpelLink(>0)
      :  $\exists$ dol:proper_part some bpelReceive
      :  $\exists$ dol:proper_part some bpelSource
      :  $\exists$ dol:proper_part some bpelReply
      :  $\exists$ dol:proper_part some bpelInvoke
---  bpelReceive  : bpelName(=1)
      : bpelOperation
      : bpelPartnerLinkReference
      :  $\exists$ edns:d_uses some wsdlPortType
      : bpelVariableReference
      :  $\exists$ dol:proper_part some bpelSource
---  bpelSource   : bpelLinkName(=1)
                  => bpelTransitionRule
---  bpelReply    : bpelName(=1)
      : bpelOperation
      : bpelPartnerLinkReference
      : bpelVariableReference
      :  $\exists$ edns:d_uses some wsdlPortType
      : bpelTarget(>0)
---  bpelInvoke   : bpelName(=1)
      : bpelOperation
      : bpelPartnerLinkReference
      :  $\exists$ edns:d_uses some wsdlPortType
      : bpelInputVariable(restrictedString)
      : bpelOutputVariable(restrictedString)
      : bpelTarget(>0)
      :  $\exists$ edns:d_uses some bpelSource
---  bpelAssign   : bpelName(=1)
      :  $\exists$ dol:proper_part some bpelSourceTargetPair
      :  $\exists$ edns:d_uses some bpelCopyTo
---  bpelCopyTo   : bpelName(=1)
      : bpelVariableReference
---  bpelSourceTargetPair: bpelTarget(=1)
      :  $\exists$ edns:d_uses exactly 1
      :  $\exists$ edns:d_uses some bpelSource

```

## 5 Conclusion

The process of creating an executable business process requires both the BPEL process description and the WSDL description of all business operations that will be invoked to carry the activities of the BPEL process. Thus, in this paper we have proposed two patterns called the WSDL-DDPO and the BPEL-DDPO to connect the

knowledge from the business process models (BPEL and WSDL) with the ontological models (DOLCE foundational ontology).

As the transition conditions in the BPEL are application dependent, they must be modelled separately, which causes that the BPEL-DDPO pattern cannot be automatically applied and executed by the workflow engine. Hence, our further work will investigate the new possibilities in modelling the transition conditions as a part of the proposed BPEL-DDPO pattern.

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# **Semantic Web Awareness Barometer 2009 - Comparing Research- and Application-oriented Approaches to Social Software and the Semantic Web**

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**Abstract:** The paper presents statistical findings from an online survey conducted among Semantic Web specialists from science and industry. It provides the reader with a brief overview over current trends and possible future topics from the perspective of research-oriented and application-oriented participants in the fast evolving and dynamic field of social software and web semantics.

**Keywords:** Semantic Web, Social Software, Survey

**Categories:** A.m, K.o, K.3, K.4, K.6., K.7.

## **1 Introduction**

The Semantic Web Awareness Barometer is an online survey on the adoption of and expectations towards Semantic Web technologies. The survey has been primarily conducted among Semantic Web specialists from science and industry with the aim to provide comparative views on current developments and future trends in the fast evolving and dynamic field of web semantics.

The current survey was based on the assumptions that (1) there exist differing notions among research- and application-oriented respondents about the roll out pattern of Semantic Web technologies and (2) the first broad roll out of Semantic Web technologies will happen along the increasing diffusion of social software applications. For this reason we included several questions that addressed the adoption of social software within organizations and the perceived benefits of and barriers to the use of these systems.

The survey is dedicated to the tradition of participatory technology assessment [Braun, 1998] which takes an integrative stakeholder-approach in exploring and evaluating technology trends. It aimed at generating data that helps better understand the adoption and rejection patterns among users of semantic technologies. As we can

still see a close interlinking of research- und application-oriented actors in the emerging field of the Semantic Web it was obvious to compare these groups with each other and help them to streamline their efforts in supporting the roll out of Semantic Web technologies from science to industry.

## **2 Related Work**

Since the year 2003 we have seen several surveys that investigated into the roll out and adoption of semantic technologies in various scientific and industrial domains. While some surveys take an industrial economic approach towards semantic technologies [Davis, 2004; Provost, 2008], others concentrate on the evaluation of specific technologies and their potential success within specific application areas [Davis, 2004; Pellegrini, 2006].

None of these has so far looked at semantic technologies from an adopter's perspective. Instead we can find highly supplier-oriented market development scenarios, sometimes with anecdotal references, but without hard empirical backing. In our survey we tried to address this flaw by particularly looking at the differences between practitioners and researchers in the Semantic Web community when it comes to assess their notions towards benefits and challenges generated by Semantic Web technologies.

## **3 Methodology**

Our survey consisted of 24 questions covering the following areas of interest: usage of, benefits of and barriers to social software; familiarity with, usage of, benefits of, barriers to and expectations towards the Semantic Web. Furthermore, respondents were asked for demographic data including age, gender, IT-competence, professional role, company size and geographic location. Since we were especially interested whether target groups differ in their opinions, we also asked them whether they came from the application- or research-oriented community.

The online survey was conducted between November 1, 2008 and January 22, 2009 by the Semantic Web Company in cooperation with the Know-Center Graz and the Corporate Semantic Web Working Group of Freie Universität Berlin.

It was distributed among the affiliation networks of the project partners covering a good deal of the Austrian, German and Swiss Semantic Web community but also generating broader international feedback from 22 countries. From the 532 responses a total of 257 valid data sets were derived from which 96 were from Application-oriented and 161 from Research-oriented participants. The data was analysed with SPSS mainly by Pearson's Chi-Square Test. Despite the statistical testing the reader should be aware that data produced by anonymous online surveys generally lack representativeness and validity, why they should be interpreted with caution [Sue, 2007].

Due to these methodological constraints we recommend to read this report as a snapshot on the development of the Semantic Web. It shall give the reader a brief overview over current trends and possible future topics. It shall provide orientation at a broader scale that helps the reader to compare his/her personal notion of the current

development with the aggregated views from other specialists. Beside that the results of this survey can be used to formulate further hypothesis for testing under more advanced empirical circumstances.

### 3.1 Who participated in the survey?

There exists a significant difference between the regional distribution of the participants. The survey produced a broad response (61,5 %) from Austria, Germany and Switzerland from application-oriented participants. The regional distribution of responses from research-oriented participants is more balanced, obviously due to the international research culture. Just 42,2 % are from Austria, Germany and Switzerland.

Application-oriented participants are significantly older than the research-oriented participants (more than 80 % are older than 30 years) while the opposite holds true for research-oriented participants (just 70 % are older than 30 years).

Both groups have a high level of IT competence either as certified experts with a formal degree in engineering arts or similar or experts that are not formally certified but see themselves as users with above average IT-skills. Unsurprisingly the formal IT-skills are significantly higher among research-oriented respondents.

IT Competence	Application-oriented	Research-oriented
Certified IT-expert	46,9	70,2
IT-expert (without certificate)	29,2	21,7
regular IT-user	24,0	8,1

Table 1: IT-competence among the participants ( $p = 0,000$ )

## 4 Survey Results

### 4.1 Social Software – Awareness & Use

The Chi-Square test revealed no significant difference between both groups with respect to the various social software applications that have already been introduced to the participants' organisation. The data clearly indicates that **wikis** are so far the most popular social software application already in use. While the distribution of all other application types is rather even, it is interesting to observe that **social bookmarking** has not found its way into organizational settings yet.

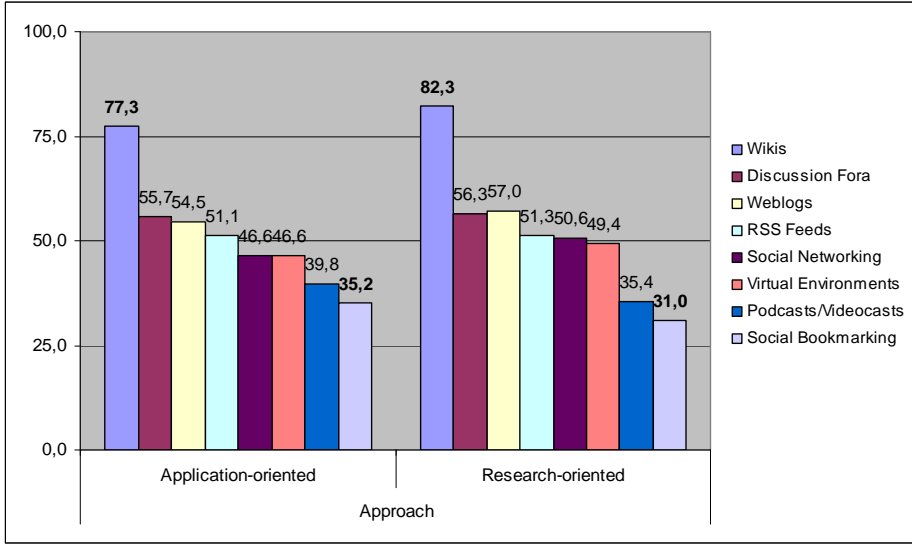


Figure 1: Social Software applications already introduced to the participants' organisation

Benefits of Social Software	Application-oriented	Research-oriented	p
Access to information / knowledge quickly	59,4	61,9	0,737
Networking with others easily and staying in touch	57,3	49,4	0,202
Access my documents / data anywhere and anytime	41,7	42,5	0,929
Combine information and communication	39,6	42,5	0,676
Maintaining a better overview of relevant documents / information resources	28,1	30,6	0,695
Longterm benefits that are generated for me or the company	18,8	15,6	0,503
The immediate benefit that is generated for me or the company	15,6	6,9	0,024
Ease of use of available tools	14,6	20,0	0,284
Because it's fun	11,5	5,6	0,089
Being able to contribute / present myself	8,3	22,5	0,004

Table 2: Benefits of Social Software



The general distribution of motives among both groups is rather even. Both groups say that **quick access to information and knowledge** is the biggest benefit generated by social software, followed by **social networking functionalities** and **ubiquitous access** to documents and data. Nevertheless the Chi-Square test reveals that application-oriented participants believe that the **immediate benefit** generated by social software is of big importance ( $p = 0,024$ ), while research-oriented participants put a stronger emphasis on the **ability to contribute and present oneself** ( $p = 0,004$ ).

Concerning the barriers to social software the Chi-Square test reveals no significant differences. Generally both groups perceive the **amount of time to use and maintain** Social Software applications as the biggest obstacle. Additionally application-oriented participants see the **redundancy to other systems, the danger to lose control over data and knowledge**, as well as the **bad usability** are most relevant obstacles to its use. On the contrary research-oriented participants believe that **losing control over data and knowledge, the feeling to be monitored and surveilled**, as well as **the low amount or quality of contributions** are the biggest barriers to Social Software. Interestingly, **strict terms of use** are widely accepted by the respondents.

Barriers to Social Software	Application-oriented	Research-oriented	p
Amount of time that is required	37,9	43,4	0,398
Redundancy with regard to other systems	36,8	28,9	0,188
Losing control over one's data / knowledge	31,6	35,8	0,496
Complexity / lack of usability of the system	30,5	26,4	0,475
The benefit is not clear	29,5	26,4	0,592
The feeling to be monitored / surveilled	27,4	35,8	0,168
Too few contributions, or of low quality	25,3	34,6	0,124
If contributing is mandatory / compulsory	24,2	23,9	0,948
The costs of implementation	20,0	15,1	0,310
Effort it takes to learn to use the systems	17,9	12,6	0,243
Strict terms of use	6,3	9,4	0,385
Amount of time that is required	37,9	43,4	0,398
Redundancy with regard to other systems	36,8	28,9	0,188

Table 3: Barriers to Social Software

## 4.2 Semantic Web – Experience, Expectations & Readiness

Drawing from the fact that the survey was mainly conducted under web specialists, it is not surprising that the **overall Semantic Web familiarity is already rather high** but with significant differences in expertise. 85 % of research-oriented respondents claim to have at least good knowledge about the Semantic Web, while this is only the case for 58,5 % of application-oriented participants.

<b>Familiarity</b>	<b>Application-oriented</b>	<b>Research-oriented</b>
very good	25,3	54,7
good	23,2	30,4
the basics	45,3	14,3
not at all	4,2	0,6
don't know	2,1	0,0

Table 4: Familiarity with the Semantic Web ( $p = 0,000$ )

Correspondingly, 50,3 % of the research-oriented participants have dealt with the topic for **more than three years** compared to 29,2 % of application-oriented participants. But the data reveals that the amount of “newbies” among application-oriented participants is significantly higher than in the research-domain.

<b>Experience since ...</b>	<b>Application-oriented</b>	<b>Research-oriented</b>
haven't started yet	13,5	3,7
about 6 months	14,6	5,6
about 1 year	16,7	14,3
1 to 3 years	26,0	26,1
more than 3 years	29,2	50,3

Table 5: Experience with the Semantic Web since ... ( $p = 0,001$ )

„I taught myself about the Semantic Web“ is the general pattern among both groups. For obvious reasons participants from the research-domain have a stronger emphasis on **formal education** (41,3 %) than application-oriented participants (25 %). On the other hand application-oriented participants are acquiring more information from the **media** (24 %) and **friends / acquaintances** (24 %) than respondents from the research-domain.

Barriers to Social Software	Application-oriented	Research-oriented	p
own research / self-study	59,4	63,1	0,593
Education / training (school, apprenticeship, university)	25,0	41,3	0,009
Media coverage	24,0	7,5	0,000
Friends / acquaintances	24,0	9,4	0,001
Continuing education (courses, congresses, workshops)	21,9	20,0	0,702
Software companies	10,4	6,3	0,223
(external) consulting	4,2	2,5	0,453
Other	2,1	5,6	0,179

Table 6: Semantic Web Training & Education

There exists no doubt among all participants that **Semantic Web has a corporate relevance**. More than 80 percent of application-oriented and research-oriented participants think that Semantic Web technologies are at least relevant to be used for corporate and/or business purposes.

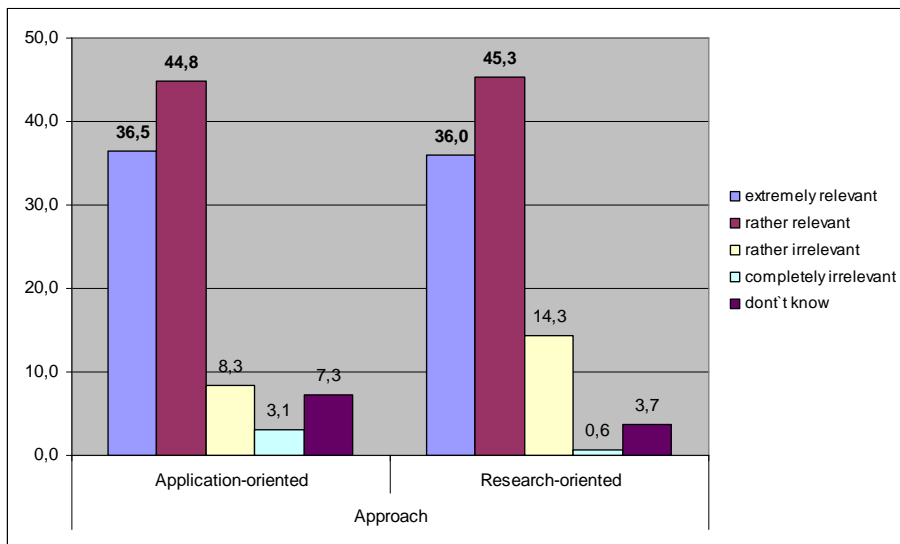


Figure 2: Corporate Relevance of the Semantic Web ( $p = 0,222$ )

No significant differences exist between both groups concerning the benefits of the Semantic Web. **Improved search and lower search effort** will be the primary benefits generated, followed by **improved tagging / annotation quality** and **recommendations**. Attention should also be paid to the aspect of **lower integration**

**costs.** Awareness about this topic is slightly higher among research oriented participants than among application-oriented participants.

Benefits	Application-oriented	Research-oriented	p
Improving search relevance	81,3	81,0	0,396
Lower search effort	72,5	73,5	0,937
Support Annotation / Tagging	71,4	67,3	0,075
Improve Recommendations	65,9	66,0	0,427
Lower costs to structure information	60,4	63,9	0,555
Better overview over documents / data	60,4	64,6	0,431
Improved personalization	52,7	58,5	0,803
Improved social networking & collaboration	52,7	50,3	0,254
Better control over data / documents	46,2	53,1	0,431
Lower costs of data integration	45,1	59,2	0,083

*Table 7: Benefits of the Semantic Web*

The data reveals significantly differing notions with respect to barriers to the Semantic Web. Generally both groups believe that **the organisational culture is not yet ready** for the Semantic Web. Additionally application-oriented participants believe that **Semantic Web technologies are too complex**. On the contrary research-oriented participants believe that **the lack of success stories, a lack in quality of available software, the problem to quantify the benefits, the costs of implementation and the general heterogeneity of information** are the biggest obstacles to the application of Semantic Web technologies.

Barriers	Application-oriented	Research-oriented	p
The organisational culture is not ready for the Semantic Web	69,5	67,7	0,082
Semantic Web technologies are too complex	68,4	65,2	0,034
Lack of experts who maintain the system	64,2	72,8	0,260
Lack of success stories	63,2	79,7	0,018
Lack in quality or availability of software	56,8	72,8	0,015
Problem to quantify the benefits	56,8	69,0	0,075
Lack in training of users	55,8	59,5	0,714
Costs of implementation	46,3	53,2	0,045
Heterogeneity of information in general	42,1	57,0	0,047
Other	11,6	13,9	0,877

Table 8: Barriers to the Semantic Web

A fairly even distribution among both groups exists in respect to the changes the Semantic Web brings along. While just a small minority believes that there won't be any changes at all, most participants expect changes in regard to **competencies** of the knowledge worker and **new forms of collaboration** – either between or within companies.

Changes	Application-oriented	Research-oriented	p
No changes	8,6	8,3	0,942
Competencies of the knowledge worker	72,0	73,1	0,863
Forms of company-wide collaboration	62,4	52,6	0,140
Forms of team work	55,9	58,3	0,713
Forms of organization	38,7	37,8	0,891
Models for the protection of personal data	36,6	33,3	0,919
Models for the protection of intellectual property	33,3	32,7	0,608
Business, collecting and licencing Models	31,2	28,2	0,621
Job skills	23,7	17,9	0,275

Table 9: Changes the Semantic Web brings along

While the majority of both groups expects a broad commercial availability of Semantic Web technologies within the next **two to five years** (see Fig. 3), there exist significant differences in the readiness to implement Semantic Web technologies (see Fig. 4). Although the readiness to do so is generally **high among both groups** application-oriented participants seem to be a more reluctant. Nevertheless just 8 % of both groups feel that they are not prepared yet to take this step.

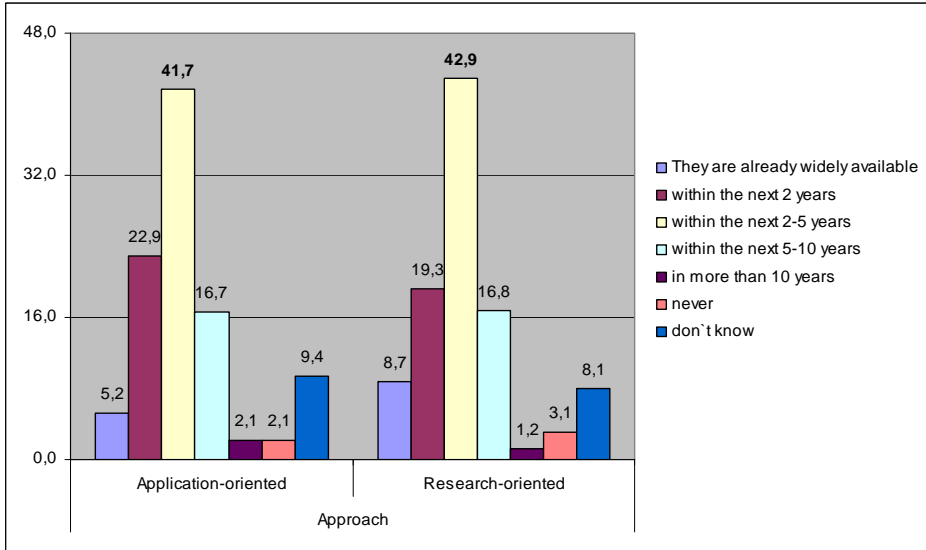


Figure 3: Time to market of Semantic Web technologies ( $p = 0,918$ )

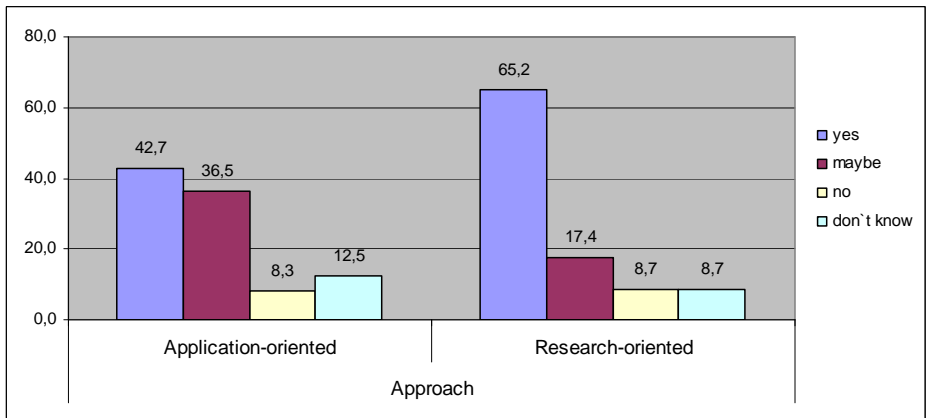


Figure 4: Readiness to implement Semantic Web technologies ( $p = 0,002$ )

The last question of the survey was asked about the relevance of Semantic Web technologies in times of crisis. The data reveals that **expectations towards the**

**Semantic Web are relatively high**, although significant differences exist between research- and application-oriented participants. Especially the application-oriented participants believe that the relevance of Semantic Web technologies in times of crisis, where scarcer resources require increased efficiency, is growing.

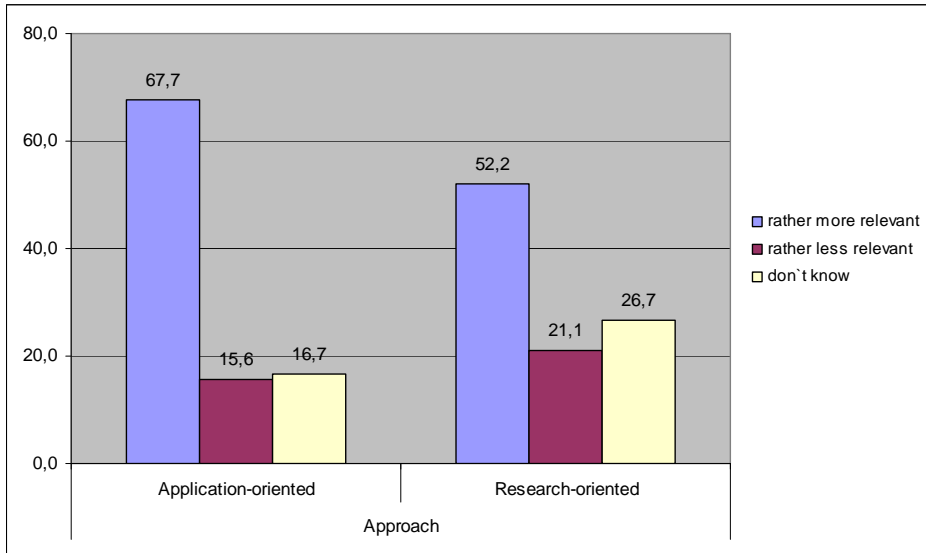


Figure 5: Readiness to implement Semantic Web technologies ( $p = 0,047$ )

## 5 Conclusions

From a technical perspective the report indicates that there are smaller differences between application- and research-oriented participants than the general notion might suggest.

Wikis are the most popular Social Software application and have found there way into organizations. Quick access to information and knowledge is the most important argument for the use of Social Software, while the amount of time spent to use and maintain such systems is seen as the biggest obstacle. Correspondingly, the practical value of the Semantic Web is seen in search-related aspects like improved relevance of search results, lower search effort, well structured annotations and better recommendations. Over 80 % of the participants think that Semantic Web technologies are relevant for corporate use, while organizational changes will occur with respect to competencies of the knowledge worker and new forms of collaboration.

Beside the commonalities of the two groups a look at the differences reveals some interesting aspects that might need further discussion.

First of all not all people dealing with the Semantic Web are certified IT experts. Although the general IT literacy is generally high it should be paid respect to the fact that a lot of people do not necessarily approach the topic from an engineering

perspective especially when it comes to communicating the benefits and risks of Semantic Web technologies. This is especially important from an education / knowledge transfer perspective as the data indicates that nearly a quarter of application-oriented participants get their information from the media while this is the case for just 7,5 % from research-oriented participants. But knowledge about the media discourse is an important precondition for a sustainable technological roll out especially as the media tends to simplify complex issues and developments. Hence researchers should follow the media discourse closely and take a more active role in informing the public about the challenges and risks of Semantic Web technologies.

Close attention should also be paid to the differing notions about the barriers to the Semantic Web. Generally both groups believe that the organisational culture is not yet ready for the Semantic Web. Additionally application-oriented participants believe that Semantic Web technologies are too complex. On the contrary research-oriented participants believe that the lack of success stories, a lack in quality of available software, the problem to quantify the benefits, the costs of implementation and the general heterogeneity of information are the biggest obstacles to the application of Semantic Web technologies. This illustrates a major gap in the notion of both groups and indicates that more attention should be paid to the non-technological aspects of Semantic Web technologies with respect to organizational effects and emerging governance issues.

Finally the data indicates that the expectations in Semantic Web technologies are very high in both groups. Over 50 % of the research-oriented participants and nearly 70 % of the application-oriented participants perceive a growing relevance especially in times of crisis. To avoid a rude awakening it is necessary to bring the expectations down to a realistic level, which is best achieved by a balanced discourse about Semantic Web technologies and the economic, social and cultural changes they might bring along.

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## **Maturity and Applicability Assessment of Semantic Web Technologies**

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**Abstract:** This article analyses the maturity and applicability of Semantic Web (SW) technologies, providing the cross comparison of the key SW technology segments and the key application areas. Based on the analysis of the W3C collection of Case Studies and Use Cases, the benefits of using semantic technologies are identified. As a result of comprehensive survey of SW tools and technologies and extensive study of the SW scientific literature we extrapolate the trends in SW research and development. The overall analysis has shown that SW technologies are finding their ways to real-world applications, and that, rather than being another fashionable research issue, the Semantic Web is becoming our reality.

**Keywords:** Semantic Web, Semantic Web Technologies, Maturity, Assessment, Adoption, Applications, W3C

**Categories:** L.1.4, L.0.0, A.1, H.4.0, J.0

### **1 Introduction**

Management of new technology development process includes several steps that range from idea generation and concept development, via market definition and product research and development to manufacturing and market launch and follow-on [Souder, 1994]. Generally speaking, when a new technology is first invented or conceptualized, it is not suitable for immediate application. Instead, in order to support strategic decision on technology, a comprehensive research is conducted that go well beyond the simple reading of a few newspaper or journal articles and sales brochures. Furthermore, new technologies are usually subjected to experimentation, refinement, and increasingly realistic and exhaustive testing. This kind of information gathering, that aims at looking beyond the immediately obvious and analysing the ramifications of a given technology in as wide-ranging and far-sighted a manner as possible is known as technology assessment [Braun, 1998].

Technology assessment is usually based on: different forecasting methods including extrapolation, expert opinion (the Delphi method) and modelling, cost-benefit analysis, cross-impact analysis, and others. Prior to incorporating that technology into a system or subsystem, many of the world's major companies and some governmental agencies are using a measure named Technology Readiness Level. For example, the USA Department of Defence and the National Aeronautics

and Space Administration distinguish nine technology readiness levels. At the lowest "level" of technology maturation the scientific research begins to be translated into applied research and development. At the middle level the prototype system (technology) is tested in real environment, while on the highest level the new technology is integrated into an existing system.

In order to locate the achievements in the Semantic Web field, especially the status of adoption of these technologies by industry, and predict the future development of SW technologies, we studied and analysed many different sources. These range from deliverables from projects financed by European Commission in 6<sup>th</sup> and 7<sup>th</sup> Framework programmes (EU FP6+FP7), via scientific papers from prestigious international conferences and journals and Web resources of standardization bodies to Semantic Web technologies and tools from industry top vendors and open source communities. In our view, the most complete analysis of the SW technologies maturity, applicability and adoption is given in the white paper "The Technology Roadmap of the Semantic Web" conducted in 2007 in the framework of the EU FP6 KnowledgeWeb project [Cuel, 07]. Herein, the authors use the Gartner Hype Cycle Curve [Linden, 03] to discuss the development and adoption of the SW technologies and applications both from the researchers' and the business point of view. They had found out that: „research community considers that developments from the past ten years have resulted in some tools and standards, which are reliable and mature enough to be transferred to industry and successfully integrated into SW applications. The developers' community however is not yet fully aware of the availability of such tools, which, consequently, has to be promoted further, together with the innovative functionalities they can provide to software applications.”

The paper is organized as follows. Section 2 presents the research framework. Next, Section 3 summarizes the main findings of a survey of semantic tools, while Section 4 presents the results of an analysis of the W3C collection of Case studies and Use cases. At the end, Section 5 discusses the future development of Semantic Web technologies.

## **2 Research framework**

Semantic Web is one of the fastest developing fields within the ICT sector and, as such, under constant examination by scientists and IT professionals. Most academic work, up to now, has focused on the global public gains of adopting SW technologies, and somehow neglected the industry development and migration needs to meet SW challenges. As a result, many organizations hesitate to be early adopters and still view the Semantic Web with some skepticism [Alani, 08]. Therefore, this paper aims at (see Fig. 1):

- reporting about the main findings of a survey of semantic tools from more than 30 different commercial vendors and open source communities; and
- a snapshot of the key application areas of Semantic Web technologies and a summary of the achieved benefits based on the analysis of the W3C collection of Case Studies and Use Cases, as well as
- predictions about the future development of semantic technologies based on the above results and the analysis of the state-of-the art research in EU.

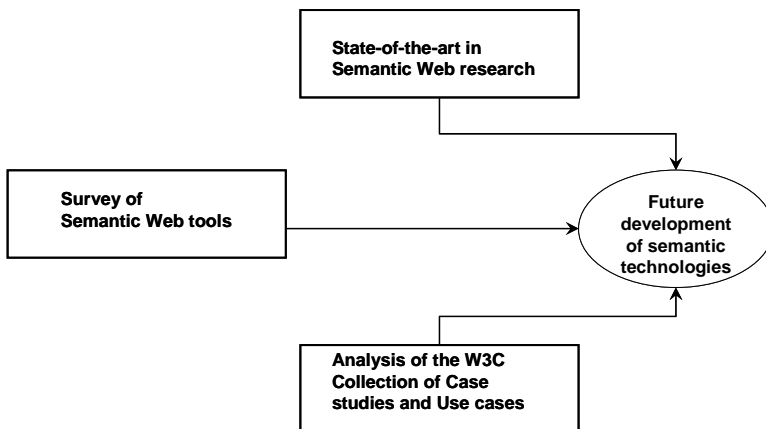


Figure 1: Research Framework

Technology	Definition
RDF, 2004	RDF is a general-purpose language for representing information on the Web. Information is described in terms of objects ("resources") and relations between them using RDF Schema.
RDFS, 2004	RDF Schema serves as the meta language or vocabulary to define properties and classes of RDF resources.
SPARQL, 2008	SPARQL Query Language for RDF is a standard language for querying RDF data.
OWL, 2004	OWL is a standard Web Ontology Language that facilitates greater machine interpretability of Web content than that supported by XML, RDF, and RDF-S by providing additional vocabulary along with a formal semantics.
WSDL, 2007	WSDL provides a model and an XML format for describing Web services.
SAWSDL, 2007	Semantic Annotations for WSDL and XML Schema (SAWSDL) defines how to add semantic annotations to various parts of a WSDL document such as input and output message structures, interfaces and operations, etc.
RDFa, 2008	A collection of attributes and processing rules for extending XHTML to support RDF.
GRRDL, 2007	A mechanism for Gleaning Resource Descriptions from Dialects of Languages (e.g. microformats).

Table 1: An overview of mature (recommended) Semantic Web technologies

One of the crucial dilemma that has to be clarified when analysing new technologies (in our case Semantic Web technologies) is how to distinguish "Semantic Web" technologies from others. Semantic Web technologies form the basic building blocks of the Semantic Web that is '...an extension of the current Web in which information is given the well-defined meaning, better enabling computers and people to work in cooperation' [Berners-Lee, 01]. Or, we can say that "Semantic Web technologies are technologies that enable explicit, unambiguous and shared definition of domain terms and relations (for humans and machines to interpret), and preferably

a global system for identification and a global system for reuse” [Norheim, 08]. Since the Semantic Web was conceived, numerous web technologies have been accepted as standards or recommendations by the W3C’s Semantic Web Activity. In an attempt to structure and relate these technologies, Berners-Lee, presented several versions of the Semantic Web architecture where these technologies were layered into a so-called stack of increasingly expressive languages for meta-data specification. After the standardization of the RDF and the Ontology layer (see Table 1), main efforts of the Semantic Web research community in last years were/are devoted to: standardization of technologies (WSDL and SAWSDL recommended in 2007) for development Semantic Web Services and provision of tools that enhance interoperability; development of rule languages (SWRL, RuleML), rule exchange language (RIF) and provision of engines (ontology reasoning and rule) that enhance reasoning; improvement of OWL and invention of new knowledge representation formalisms (see Table 2).

<b>Technology</b>	<b>Definition</b>
OWL-S	OWL-S (formerly DAML-S) is ontology of services that enable software agents to discover, invoke, compose, and monitor Web resources.
OWL 2	OWL 2 extends the W3C OWL Web Ontology Language with a small but useful set of features (EL, QL, RL) that enable effective reasoning.
WSMO	WSMO provides a conceptual framework and a formal language for semantically describing all relevant aspects of Web services in order to facilitate the automation of discovering, combining and invoking electronic services over the Web.
WSML	WSML provides a formal syntax and semantics for the Web Service Modeling Ontology WSMO. WSML consists of a number of variants such as: WSML-Core, WSML-DL, WSML-Flight, WSML-Rule and WSML-Full.
SWRL	SWRL aims to be the standard rule language of the Semantic Web. It is based on a combination of the OWL DL, OWL Lite, RuleML, etc.
RuleML	RuleML constitutes a modular family of Web sublanguages including derivation rules, queries, and integrity constraints as well as production and reaction rules.
RIF	RIF aims to be the standard rule language of the Semantic Web for rule interchange.

*Table 2: An overview of emerging Semantic Web technologies*

### **3 A survey of Semantic Web tools**

SW tools and technologies are named using different keywords: ontology design/management/maintenance tools, data integration and management platforms, RDF triple storage systems, web services, SOA middleware platforms, semantic annotation tools, content indexing and categorization tools, search engines based on NLP, linguistic analysis and text mining, collaboration and other social networking technologies, knowledge visualization/presentation technologies, ontology mediated portals, ontological querying/inference engines, rule-based engines, ontology reasoners, etc. According to our investigation, most of the scientific studies analyze a

single application area of SW technologies such as: semantic annotation [Reeve, 05], ontology platforms and semantic integration [Ahmad, 07], semantic search and retrieval [Mangold, 07; Andrews, 07], ontology learning and reasoning techniques [Gómez-Pérez, 03] or collaborative knowledge construction and social networking [Correndo, 07; Gootzit, 07]. Some studies attempt to provide an overall picture of the ontology methods and techniques [Cali, 05] and discuss the key trends in the Semantic Web field [Cardoso, 07; d'Aquin, 08]. Therefore, we conducted a comprehensive survey of functionalities of the SW tools and technologies provided by more than 30 different commercial vendors and open source communities (see [Vraneš, 08]) taking into consideration all aspects of the ontological engineering (OE) process. Ontological engineering studies the ontology development process, the ontology life cycle, the methods and methodologies for building ontologies, and the tool suites and languages that support them. Common goals in developing ontologies are: sharing common understanding of the structure of information among people or software agents, enabling reuse of domain knowledge, separating the domain knowledge from the operational knowledge, analyzing domain knowledge, etc.

<b>Tools / Technologies</b>	
○	Tools that enable design and development of OWL ontologies, RDF/OWL knowledge stores, as well as tools for development semantic services applications
■	Technologies that support automatic semantic annotation, information extraction, text mining, other language processing tasks
▲	Ontology-driven information systems and server platforms that enable RDF triple storage, semantic data integration and management, semantic interoperability based on W3C standards (XML, RDF, OWL, SOA, WSDL, BPEL4WS).
♣	Semantic data access and search tools based on W3C standard query languages (Xquery, SPARQL), semantic search engines based on NLP, linguistic analysis and text mining, as well as technologies, including content classification, categorization and clustering; fact and entity extraction; taxonomy creation and management (tagging engines); knowledge presentation, etc.
☼	Portals based on semantic standards (RDF/OWL), semantic wiki technology, as well as solutions that support social networking, data aggregation, dynamic publishing (RSS format) of contents and media
☺	OWL reasoners, ontology learning tools, rule engines

*Table 3: Semantic technology segments*

The results of this survey were used to establish the Web4Web repository of SW tools (see [http://www.web4web.org/portal/Semantic\\_Web\\_Tools](http://www.web4web.org/portal/Semantic_Web_Tools)). The repository is based on Semantic MediaWiki. Each tool is described with semantic properties such as *dc:description*, *dc:type*, *swrc:name*, *swrc:homepage*, *swrc:developedBy*. In general, SW tools can be classified in one of the following technology segments.: ○ - semantic modelling and development, ■ - semantic annotation, ▲ - semantic data management and integration, ♣ - semantic search and retrieval, ☼ - semantic collaboration including portal technologies, ☺ - learning and reasoning. Table 3 gives a short description of these technology segments and identify SW tools and technologies that fit in the concrete segment.

According to our analysis, vendors have made recognizable progress towards the specification and acceptance of semantic standards, but still lack reasoning support that is crucial for the realization of the Semantic Web vision. Investigating the adoption of the SW technologies by enterprises, we have identified the following open issues: scalability and run-time support, interoperability between different knowledge organization schemas, data synchronization between OWL/RDF based knowledge bases and the traditional persistence mechanisms, migration from traditional to semantic-enabled technologies, and others.

## **4 Analysis of the W3C Collection of Case studies and Use cases**

The World Wide Web Consortium (W3C) is the main standardization body in the Semantic Web field that was created in October 1994, to "lead the World Wide Web to its full potential by developing common protocols that promote its evolution and ensure its interoperability." The W3C collection of Semantic Web Case studies and Use cases was established in year 2007, based on an enterprise survey conducted by the SW Education and Outreach Interest Group (SWEIO). Use cases include examples of built prototype systems that are not used by business functions. Case studies include descriptions of systems that have been deployed within an organization, and are now being used within a production environment. Currently (retrieved from <http://www.w3.org/2001/sw/sweio/public/UseCases/> on March 20, 2009), the database stores 36 entries, where 24 are case studies. Herein, we will use the cross-tabulation to analyse the SW applications using variables such as the enterprise area of activities, the application area of SW technologies, the SW technologies used and the benefits of SW technologies.

Cross tabulation analysis, also known as contingency table analysis is most often used to analyze categorical (nominal measurement scale) data. A cross-tabulation is a two (or more) dimensional table that records the number (frequency) of respondents that have the specific characteristics described in the cells of the table. Cross-tabulation thus provides a wealth of information about the relationship between the variables. Usually, in cross-tabulation analysis a surveyed item responds to one value of the analysed variable. E.g. A SW application refers to "data integration" only. However in our analysis one SW application could tackle many problems, e.g. "data integration" and "search".

### **4.1 Relating Company activity area to SW technologies used**

The primary objective of this analysis is to assess the applicability of a specific SW technology in a particular business activity. The first row in Table 3 shows how many applications are related to activities such as public, e-government, health, IT, energy, life science, oil & gas, publishing and others. According to this distribution, one third of the organizations are from public sector (12) and six of them are performing e-government activities. Not presented in this table is the information that there is just one SW application in the financial sector, one in the utilities sector (eTourism), and one in education.

The first column in Table 4 shows the number of items (SW applications) that are using one specific technology. This distribution shows that almost all applications are

based on RDF(S), and most of them use in-house vocabularies. However, half of the applications incorporate public vocabularies, and just one tenth of them have implemented SKOS. Analyzing the use of public vocabularies in SW applications, it is obvious that all SW applications in health care incorporate public vocabularies, while the two SW applications in automotive industry and the SW application from finance sector rely on in-house vocabularies. Further on, we could notice that in this set of SW applications, SPARQL is ten times more frequently used than SeRQL. Considering the use of rule languages, we could conclude that they are used in just a small number of applications in public institutions (3), health care (2) and IT (1).

	12	6	5	4	4	4	3	2	2
	Public	E-govern.	Health	Telecom.	IT Ind.	Energy	Life Sc.	Oil & Gas	Publishing
33 - RDF(S)	11	6	4	3	4	3	3	2	2
25 - in-house voc.	9	6	3	2	2	2	3	2	1
17 - public voc.	7	3	5	1	1	2	2	1	2
17 – OWL	7	4	5		1	2		2	
10 - SPARQL	3		1		2	1	1		1
6 – Rules	3		2		1				
3 - SKOS	2	2							1
1 - SeRQL							1		1

Table 4: Relating Activity area to SW technologies used

#### 4.2 Relating Application area of SW to SW technologies used

This analysis (see Table 5) aims at identification of the SW technologies applied in particular application domain such as: data integration (DI), portals, improved search (IS), content discovery (CD), semantic annotation (SA), social networks (SN), natural language interfaces (NL), service integration (SI) and customization ( C ). The results of the analysis have shown that in almost all SW applications the data integration function is based on RDF(S) ontological models. Less than half applications use OWL models for data integration. It is interesting to notice that SPARQL, which is a standard query language for RDF, is more exploited for data integration i.e. syntactic matching of different knowledge schemas, than for querying and retrieval. The search and content discovery function rely both on public and in-house vocabularies. It is encouraging that, besides the mature SW technologies (RDF and OWL), technologies such as OWL-S and WSMO that are still in the process of standardization are considered to be used for service integration.

	23	14	14	10	7	3	2	2	2
	DI	P	IS	CD	SA	SN	NL	SI	C
33 - RDF(S)	20	14	13	10	7	3	2	1	2
25 - in-house voc.	15	13	10	8	4		2		1
17 - public voc.	12	8	7	7	4	2			1
17 - OWL	11	7	8	6	4		1	1	1
10 - SPARQL	9	2	3	3	3	3	1	1	
6 - Rules	2	2		1	1		1		
3 - SKOS	1	2	2	3	2				
2 - RDFa	1	1	1	2	1				1
1 - GRRDL	1	1	1	1					1
1 - WSMO	1							1	

Table 5: Relating Application area to SW technologies used

### 4.3 Relating Benefits of SW to SW technologies used

The last analysis reports about the benefits the end user organizations have utilizing SW technologies. The analyzed benefits are as follows: data share and re-use (SR), improved search (IS), incremental modelling (IM), explicit content relation (ER), identifying new relation (IR), personalization (P), open model (OM), rapid response to change (RR), and reduced time to market (TM). From the results presented in Table 6, it is obvious that SW technologies are very suitable for data sharing and reusing, as well as knowledge search. Using faceted navigation technique, knowledge bases could be full-text searched, as well as filtered and sorted using semantic relations. Semantic technologies make the content relationships explicit and hence machine processable. This analysis has shown that semantic technologies could be used for identifying new relationships. The British Telecom Use Case has shown that adoption of the SOA could lead to reduction of time to market.

## 5 Future development of Semantic Web technologies

Although many Semantic Web related technologies have emerged or have been elaborated in the last few years, yet a lot has to be done until the Berners-Lee's vision of Semantic Web becomes true. In [Benjamins, 02], the authors identified six main SW challenges (i) the availability of content, (ii) ontology availability, development and evolution, (iii) scalability, (iv) multilingualism, (v) visualization to reduce information overload, and (vi) stability of SW languages. As the ontologies are the backbone of the Semantic Web, first we will discuss the future development of SW technologies from the ontology engineering perspective.



	20	20	11	10	5	4	4	2	2
	SR	IS	IM	ER	IR	P	OM	RR	TM
33 - RDF(S)	17	19	11	11	5	4	4	2	1
25 - in-house voc.	13	13	9	8	3	3	3	2	
17 - public voc.	10	11	5	4	3	3	3	1	1
17 - OWL	10	11	11	7	1	3	3	1	
10 - SPARQL	8	6	3	4	1	1	1		1
6 - Rules	3	3	6	4				1	
3 - SKOS	1	2		1					1
2 - RDFa	1					2	1		1
1 - WSMO	1								1

Table 6: Relating SW Benefits to SW technologies used

**SW methodologies:** Ontology building exhibits a structural and logical complexity that is comparable to the production of software artefacts. Unlike the conventional software development, where methodologies have matured, and are usually facilitated by well defined modelling languages (like UML) and computer-aided software engineering tools (like Rational Rose), SW methodologies and tools are in their inception phase. Depending on the type of ontology to be developed, a SW methodology could be classified as a centralized or collaborative approach in the development of ontologies [Jimenez-Ruiz, 06]. In [Cardoso, 07], the author surveys the most frequently used OE methodologies and has found out that (60%) of responders develop ontologies without using any methodology. Our analysis of methodologies used in recently ended and on-going EU FP6+FP7 projects indicated that each project developed / develops its own methodology (see [Vraneš, 09]).

**The availability of content:** Semantic Web is an extension of the conventional Web, and therefore existing contents should be available on Semantic Web as well. For this purpose, W3C recommended several technologies including GRRDL, RDFa, and microformats. Also SW contents in RDF and OWL could be provided by semantic annotation and ontology learning techniques that involve use of advanced text mining, natural language processing and statistical algorithms. The process of online conversion of the existing unstructured contents on the web into a format understandable by computers is not a trivial and not a generally solvable task. Therefore, ontology learning is still a hot research topic.

When the content stored in RDBMS is exported into RDFS the problem of consistency and synchronization appears, because the RDF store should be updated each time the RDBMS is updated. Therefore, it is a trend lately to use the RDBMS as a SW endpoints and SPARQL+SPARQL/Update for ontology-based read and write access to relational data [Hert, 09].

**Ontology availability:** One of the most challenging and important tasks of ontology engineering is integration of ontologies with the purpose to build a common

ontology for all Web sources and consumers in a domain. Up to now, a lot of high quality domain ontologies have been produced and made publicly available. Some of them are already adopted in real world applications (see [Doms, 08]). However, the available ontologies often exhibit different conceptualizations of similar or overlapping domains, thus leading to the interoperability problem. The problem could be overcome by detecting of semantic relations between concepts, properties or instances of two ontologies i.e. ontology matching. Due to the increasing number of methods available for schema matching/ontology integration, the Ontology Alignment Evaluation Initiative was started with the aim to compare systems and algorithms on the same basis and to allow anyone to draw conclusions about the best matching strategies. The recent and future trends in ontology matching consider using reasoning languages (e.g. Distributed Description Logics [Meilicke, 09]) to reason about ontology alignments in distributed environments.

**Standardization and stability of languages:** While the W3C is making extensive efforts to define and standardize the upper layers of the W3C SW architecture model that refers to logic, inference, and reasoning, the research communities come out with new SW languages. E.g., a new TRREE rule language is proposed in the framework of the FP6 TripCom project [Momtchev, 08]. Reasoning is a distinctive feature of the Semantic Web. However, various W3C standards related to the Semantic Web are not easy to use by a reasoner, especially due to their heterogeneity. As a result, the available reasoning tools and technologies are mainly delivered by open source communities, while the contemporary SW development frameworks offer integration with reasoning engines such as Pellet, KAON2, or Jess.

**Scalability:** Scalability is one of the key SW issues that relates to large ontology creation and maintenance, semantic metadata extraction of massive and heterogeneous content and inference mechanisms [Sheth, 03]. The scalability issue was identified very early in SW research community and adequately addressed. However, despite of huge number of SW applications today, advanced SW technologies are hardly applicable in real time on web scale. Thus, we come to the problem of adoption of SW technologies in situations where existing Web technologies already proved useful. Therefore, additional investments are needed to mature SW technologies, especially, to optimize the querying and reasoning strategies. One way to do this is to adopt concepts already proven in data base community, e.g. using caching to improve the performance of distributed systems.

## 6 Conclusion

The study presented in this article aims to answer the question “Is Semantic web another fashionable research issue or rather our reality and future?” It analyses the current status and trends in the Semantic Web and discusses the adoption the semantic web technologies by practice.

The results reported in this article have shown that semantic-based technologies have been increasing their relevance both in the research and business worlds in recent years. W3C, together with universities and IT research organizations, and in cooperation with the major software companies and governmental agencies have already accepted many specifications, guidelines, protocols, software, and tools that are the basis for realization of the Semantic Web vision. Innovative enterprises,

interested in catching new opportunities from the Semantic Web and also developing new business models are involved in research projects and are introducing semantic technologies that facilitate data integration and interoperability, as well as improve search and content discovery. Considering the benefits from introducing SW applications, the analysed early adopters from the W3C collection of Case studies and Use cases prove that SW technologies are useful for sharing and reusing of data, improving search and establishing explicit content relations. To summarise, based upon the overall analysis we have performed, we could conclude that SW technologies are finding their ways to applications, and that rather than being another research project, the Semantic web is becoming our reality.

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# Can Software Developers Use Linked Data Vocabulary?

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**Abstract:** One of the next research goals in Semantic Web-enabled software engineering is to naturally use Semantic Web data within arbitrary applications. This will in most cases require some kind of mapping between object-oriented and graph-based information representations. In this paper, we investigate how well Semantic Web vocabularies specified in different formats can be mapped onto object-oriented representations. We examine what a software engineer would expect from such mappings, and how well existing, widely used vocabularies meet these expectations.

**Keywords:** Design Patterns, Linked Data, Object-Orientation, RDF

**Categories:** D.1.5, D.2.13, M.6, M.8

## 1 Introduction

Publishing, consuming, and processing RDF data is becoming more common for modern desktop and Web applications. Web-scale data integration is the dedicated goal of the Linking Open Data (LOD) initiative providing RDF-based vocabularies with billions of RDF-triples [Bizer et al. (2008)]. However, compared to developer support for traditional data structures and storage systems, such as relational databases, developer support for linked data is still in its infancy. Good support will allow software developers to process RDF [Manola and Miller (2004)] data within the programming environment and using the programming language of their choice. E.g., in an object-oriented (OO) programming language [see Gosling et al. (2005)], RDF resources should be represented as objects, and RDF schemata should be represented as ready-to-use packages for the desired programming environment [Quasthoff and Meinel (2008)]. Because Semantic Web programming interfaces have been designed rather by knowledge engineers than by traditional software engineers, using Semantic Web data structures is not straightforward for the software engineer not being an expert in Semantic Web knowledge engineering. We believe that the missing ease of use is one of the main reasons why Semantic Web technology entered the field of software engineering so hesitatingly.

As the main contribution of this paper, we define general requirements to RDF-to-OO mappings from the point of view of the software engineer, and investigate which parts of RDF schema [Brickley et al. (2004)] and OWL [Patel-Schneider et al. (2004)] contribute to such mapping. We also examine a number of RDF and OWL vocabularies widely used on the World Wide Web (WWW) how they make use of the features of their schema language helping software engineers to take full benefit, e.g., for generic mapping technologies, or for simplified data access. Finally, we lay out guidelines for the definition of Semantic Web schemata to simplify their usage in software projects while retaining their full potential.

The rest of this paper is organized as follows: In Section 2, we discuss related work on the Web of data and the mapping between data representations. In Section 3, we discuss expectations and limitations of mappings between RDF and OO and how such mappings can be obtained. In Section 4, we examine several popular RDF vocabularies on their suitability for automatic mapping. Section 5 concludes the paper.

## 2 Related work

Linked Data has become one of the most popular topics among the emerging Semantic Web [Bizer et al. (2008)]. By *Linked Data* we refer to a method of exposing, sharing, and connecting data via dereferenceable URI on the WWW. The Linking Open Data community project has picked up this approach to extend the Web of data by publishing various open data sets being represented as RDF and by defining links and mappings between vocabularies and data items from different data sources. Thus, the data available within the LOD has grown to more than 4,5 billion RDF triples and about 180 million RDF links<sup>1</sup>. This publicly available interconnected data enables the development of numerous data mash-up applications. To clear the way for efficient application development, a straightforward inclusion of these semantic data into the traditional software engineering process has to be implemented.

To achieve this goal, design patterns for implementation tasks of linked data applications have to be identified and described. Design patterns are not programming libraries, but solutions to frequently recurring problems, and have been introduced to software engineering by [Gamma et al. (1994)]. In previous work we showed that object-relational mapping (ORM) [Fowler and Rice (2003)] can be adopted to suite mapping between RDF and OO data [Quasthoff and Meinel (2008)], which we refer to as object-triple mapping (OTM). A number of software projects<sup>2</sup> address the need of OTM, but do not describe underlying design patterns for retrieving information, obtaining a mapping between RDF and OO definitions, mapping the data, and checking for policy or license compliance [see Miller et al. (2008)].

## 3 Requirements to linked data software engineering

### 3.1 Schema mapping basics

Mixing different types of programming languages (e.g., imperative and declarative languages) creates programming overhead that should be avoided for various reasons [Fowler and Rice (2003)]. Rather, OO software developers must be able to process Web resources as objects native to their programming language. That is, not triples, URI, and other entities making up RDF data should be primarily visible to software developers, but classes and objects carrying the triple information as fields and values. The goal is to support the whole life-cycle of a Web resource from the OO perspective: resources need to be retrieved or created locally, to be processed with imperative statements, and to be published as linked data, or stored locally.

*Joint model.* The OO equivalent to vocabulary are packages containing classes, whose fields are equivalent to properties in the vocabulary. Intuitively, one would expect a

1 <http://esw.w3.org/topic/SweoIG/TaskForces/CommunityProjects/LinkingOpenData#dbpedi-a-lod-cloud>, (March 2009)

2 <http://sommer.dev.java.net/>, <http://semanticweb.org/wiki/RDFReactor>

one-to-one mapping of RDF classes to OO classes, and RDF properties to OO fields. However, due to the open world assumption, the number of properties an RDF class has depends on the context, i.e. the vocabularies we are considering. Hence, a single RDF class can have more than one OO representation. Inheritance relationships between RDF classes can be mapped on equivalent OO inheritance relationships. Also, most OO programming languages do not allow multi-valued fields, but use collection (or list or array) objects containing an arbitrary number of values to achieve this. Depending on the cardinality of the property to map, a developer would expect a field to contain a collection or just a plain object. And of course, a useful mapping translates typed literals, e.g., from XML Schema Definition [Thompson et al. (2004)], as accurate as possible onto primitive types of the programming language.

*Differing expressivity.* While some restrictions on properties such as cardinality, range, and domain can be mapped onto class definitions in most OO programming languages, other features of either sides cannot be trivially mapped. Inverse-functional properties cannot be enforced on OO classes without explicit validation code. Also, sub-property relationships do not have a direct OO equivalent. Vice-versa, not all features of OO programming languages can easily be represented in RDF schemata. E.g., OO classes frequently feature fields containing string objects, whose content varies depending on localization settings of the runtime environment. Restricting a property's cardinality per language in RDF or OWL is not trivial and involved rules.

*Implicitness vs. explicitness.* According to RDF Schema, from statements using some property one can conclude that subject and object belong to the property's domain and range. Hence, anything appearing as a property's domain or range (which are RDF properties themselves) can be concluded to be an RDF class. In many OO programming languages, classes and fields have to be explicitly defined as classes and fields. Therefore, an automatic translation from RDF schema to OO cannot happen by syntax only, but requires at least some kind of inferencing.

### 3.2 Schema mapping process

In this section we will present three options how software developers can obtain OO packages for specific vocabularies. The options are influenced by two parameters:

- automatic vs. manual mapping;
- local generation vs. retrieval.

These parameters result in three basic ways to obtain a RDF/OO mapping:

1. Mapping an existing domain model: software developers can manually map OO classes to RDF within their software projects;
2. software developers can automatically generate OO classes from vocabularies or download such generated mappings from the WWW;
3. software developers can download hand-edited mappings from the WWW.

From a general point of view, an automatic mapping, or retrieval of mapping information is preferable over local, manual mapping. Still, either of the three alternative has benefits and drawbacks being discussed in this section.

*Mapping an existing domain model.* To enrich an existing application with linked data, those fields of OO classes that do have an RDF or OWL equivalent can be mapped

locally and manually onto the respective vocabulary. This way, OO data can be rendered to RDF and made available to other applications. Retrieving RDF data from the WWW and rendering it as OO objects can be difficult, as application-specific initialization data required to instantiate the class might be hard to obtain for a generic mapping mechanism. Also, if a retrieved resource belongs to RDF classes mapped to two disjoint concrete OO classes, for most OO programming environments only one of the classes can be instantiated, and hence only some of the resource's properties be reflected in OO. This can be circumvented by separating the mapping to abstract interfaces and letting the domain model implement the respective interfaces. That way, domain objects can still be rendered to RDF, but RDF data can now be instantiated to OO objects implementing the relevant interfaces. The manual effort for the software developer includes choosing the vocabulary to map to, and mapping existing OO classes to RDF, after optionally separating this mapping into abstract interfaces. The benefit for software developers is that they can use their coding conventions for the domain model and only map those parts relevant for the specific application to RDF, especially if a class is expected to contain properties from different vocabularies.

*Generating OO classes.* Instead of letting software developers manually generate OO classes corresponding to vocabulary, the schema definitions can be used to generate OO class definitions. The source code generator needs conventions for

- converting schema namespace to OO package, i.e., URI to hierarchy;
- converting RDF class and property to OO class and field names, i.e. relative URI to OO identifiers, following coding conventions for, e.g., capitalization;
- storing the actual mapping information, which can happen separately, or inside the source code, e.g., as annotations [see Gosling et al. (2005)];
- resolving conflicts of class or property names with the programming language's reserved words or conflicting OO class and field definitions.

From the developer's perspective, there is no fundamental difference between automatically generating such a mapping locally, or retrieving a mapping package from the WWW. After obtaining the mapping, local domain classes can be modified to implement the abstract interfaces generated or retrieved. Although simplifying the bootstrapping overhead for the developer compared to manual mapping, automatic mapping heavily relies on accurate schema definitions. This includes among others reasonable domain and range specifications for properties, cardinality constraints where feasible, and good schema documentation using RDFS labels and comments. As will be shown in the next section, automatic source code generation from existing schema can sometimes give disappointing results. Hence, a hybrid approach using generated classes, which will be hand-edited and offered for download along with the schema definitions will be a good solution.

*Publishing manually edited OO definitions.* To circumvent the shortcomings of automatically generated OO classes, service providers can fine-tune the generated OO packages and let software developers download the results as commonly usable packages. The packages could be provided by the authors of the vocabularies themselves, or be published in special repositories. This approach would also mitigate some problems, such as naming incompatibilities between RDF and OO.



## 4 Evaluation of automatic RDF to OO mapping

We used an extended version of the RDF/OO mapping prototype presented in previous work [Quasthoff and Meinel (2008)] to process 33 vocabularies. The schema definitions have been downloaded from the WWW and used to generate abstract Java classes. We investigated vocabulary listed in a schema directory<sup>3</sup>, and vocabulary we used in previous work. All in all, these vocabularies contained 1519 classes and 1727 properties. The primary findings concerned compliance to OO coding conventions on the one hand side, and the correctness of the mapping on the other.

Abbrev.	Namespace	#c	#p
cc	http://creativecommons.org/ns#	6	10
dbpedia	http://dbpedia.org/ontology/	174	720
dc	http://purl.org/dc/terms/	22	55
dcel	http://purl.org/dc/elements/1.1/	0	15
dcmi	http://purl.org/dc/dcmitype/	12	0
doac	http://ramonantonio.net/doac/0.1/	15	16
doap	http://usefulinc.com/ns/doap	7	30
eor	http://dublincore.org/2000/03/13/eor#	4	3
foaf	http://xmlns.com/foaf/0.1/	12	54
kaos	http://ontology.ihmc.us/	134	88
mm	http://musicbrainz.org/mm/mm-2.1#	19	10
rddl	http://rddl.org/rddl.rdfs#	2	3
rev	http://purl.org/stuff/rev#	3	13
sioc	http://rdfs.org/sioc/ns#	11	66
sw	http://sw.nokia.com/SWArch-1/	3	3
swrc	http://swrc.ontoware.org/ontology#	54	74
umbel	http://umbel.org/umbel/ac	748	9

Abbrev.	Namespace	#c	#p
bibtex	http://purl.org/net/nknout/ns/bibtex#	15	40
cv	http://kaste.lv/~captsolo/semweb/resume/cv.rdfs#	16	72
cv-base	http://kaste.lv/~captsolo/semweb/resume/base.rdfs#	8	0
eswc	http://www.eswc2006.org/technologies/ontology	72	38
fresnel	http://www.w3.org/2004/09/fresnel#	16	29
geo	http://www.w3.org/2003/01/geo/wgs84_pos#	2	4
ical	http://www.w3.org/2002/12/cal/ical#	14	48
iswc	http://annotation.semanticweb.org/2004/iswc#	33	35
photo	http://purl.org/net/vocab/2003/11/photo#	1	10
pim	http://www.w3.org/2000/10/swap/pim/contact#	7	19
rei	http://www.cs.umbc.edu/~lkagall/rei/ontologies/	65	57
schema	http://www.schemaweb.info/schemas/meta/rdf/	2	10
skos	http://www.w3.org/2004/02/skos/core#	4	28
vs	http://www.w3.org/2003/06/sw-vocab-status/ns#	0	3
vcard	http://www.w3.org/2001/vcard-rdf/3.0#	7	43
wot	http://xmlns.com/wot/0.1/	5	13

Table 1: Vocabularies investigated in this paper (#c: classes, #p: properties)

*Complex mapping logic required.* Two vocabularies have been found leaving some parts of the specification implicit by relying on the semantics of RDF Schema (Creative Commons, *cc*) and OWL (Friend of a friend, *foaf*). The *cc* vocabulary does not explicitly declare classes, but describes some resources appearing as range or domain of RDF properties, and hence being classes. Similarly, for all *foaf* properties it is explicitly stated whether it is an OWL datatype or object property. Only for *isTopicOf*, which is inverse to an object property, this is left implicit.

A similar finding, yet not related to inferring, concerns the definition of restrictions on properties in OWL. In RDF schema, for each class *c* to map we can issue a straight-forward query on properties having *c* as range. In OWL, we need to query for *Restriction* superclasses of *c* and map the properties following the restriction's *on-Property* predicate. This kind of schema processing makes processing OWL ontologies harder than RDF schemata, and again proves that average software developers need support when processing such vocabularies. Even worse, the OWL method of indicating property range per domain class is incompatible with OO programming languages like Java. E.g., the *KAoS* vocabulary cannot be accurately mapped to Java classes: *Groups* can have arbitrary *members*, but *ActorGroups* and *PersonGroups* can only take *Actors* and *Persons* as *members*. Java requires the *member* field defined in the OO *Group* class to have the same type for the *ActorGroup* and *PersonGroup* subclasses, hence *ActorGroup* and *PersonGroup* cannot be accurately translated to OO.

<sup>3</sup> <http://schemaweb.org/>

*Empty OO classes.* By average, 48% of all classes defined in the vocabulary evaluated never appeared as domain of a property nor did they extend any OWL restriction class. Four vocabularies contained only such “empty” classes. E.g., the Description of a project (*doap*) vocabulary defines a class *Repository*, which has several empty subclasses for different revision control systems. RDF classes without properties will be translated to OO classes without any fields. If an OO developer was about to model such structure, she would probably generate an enumeration datatype for the revision control system and add a *type* field to the *Repository* class taking one of the enumeration values. For future automatic mapping mechanisms, a heuristic or schema extension needs to be defined, whether a empty RDF class should be mapped to an OO class, or to a logical field value indicating class membership, or an enumeration field.

*Naming conflicts.* As mentioned before, any mechanism generating an RDF/OO mapping will have to translate names of RDF classes and properties to OO class and field names. As the OO names should somehow reflect the relative URI of the RDF or OWL names, it can happen that two distinct properties will be mapped to distinct fields carrying the same name. In our evaluation, conflicts arose with the *fresnel:label* and *rev:comment* vs. the respective RDFS properties and with *foaf:publication* vs. *doac:publication*, both having domain *foaf:Person*. If a generator has access to all vocabularies subject to OO class generation, as would be the case with local mapping or generation, the technical part of the problem can be solved, e.g. using such rules:

1. prefix the OO name of that conflicting property that has a domain outside its own vocabulary (e.g., *doacPublication* on *foaf:Person*);
2. prefix the OO name of properties conflicting with a superclass’ properties (e.g., *fresnelLabel*, *revComment* to avoid conflicts with the RDFS properties)

But if, as would be the case with pre-produced mappings scattered over the WWW, different vocabularies would be translated independently of each other, any resource belonging to two classes from different vocabularies sharing a conflicting property name could not be instantiated as OO object. These problems could be solved using dynamically-typed programming languages, which are becoming more popular.

*Documentation, correctness, usability.* Three of the vocabularies investigated did not include any comments or labels on the classes and properties they defined. One vocabulary had no comments and labels on classes, but only property labels. Two more did not include any comments, but did include labels, which have mostly been human-readable versions of the relative class or property URI, and hence did not provide additional information. By average, 60% of the classes and 43% of the properties of the vocabularies investigated had comments. Comments are very important for modern software engineering, as they allow external developers to efficiently use code from other sources. On the contrary, the *doap* vocabulary features comments in English, French, and Spanish. Further investigations how to optimally use this multi-lingual information within the software development lifecycle will be interesting.

Besides limited developer support through comments or labels, typing errors and unavailable schemata have been a problem during our evaluation. E.g., the *eswc* vocabulary specifies additional properties for a *foaf:Organisation* class, whereas *foaf* only specifies a *foaf:Organization* class. Such errors just reduce the usability of the affected vocabularies. Also, the *umbel* vocabulary includes an OWL *Restriction* having *minCardinality*’s parse type not explicitly set to non-negative integer, resulting in

the Jena framework parsing the numeric value as a string and hence, in our class generator ignoring the cardinality information. Over the course of the evaluation, several vocabularies could not be retrieved temporarily (*dbpedia* and *umbel* on April 2, *KaoS* on April 3, 2009). Since vocabulary is central to developing simpler linked data applications, the schemas should be highly available.

The usability of a vocabulary is reduced if for the sake of generality an RDF property's range or cardinality is less restricted than software engineers would wish in their specific applications. Reading the *foaf:name* (or any other of the 92% unrestricted properties found) of an OO object requires to get the collection of *foaf:names* of the object, checking if this collection is empty, and if not so, choosing the right name from this collection. If a specific application is guaranteed to only store one name per *foaf:Person*, a direct access to this name is desirable, resulting in reduced recurring programming. To mock this, our OO class generator currently creates for each property both a scalar field and a collection field in the OO class unless the property is restricted otherwise, and the developer can choose which field she preferably reads or writes. Also, 15 vocabularies did not follow the linked data principles, as they could not be retrieved using the namespace URI only.

## 5 Conclusion and outlook

In this paper, we argued for simplified access to linked data for the average software engineer. Such simplifications include transparent access to RDF and OWL schemata with the means of widely accepted OO programming languages. We analysed the expectations to such mapping between RDF/OWL and OO, and discussed general limitations. We then used an extended version of our RDF/OO mapper presented in previous work to actually process a number of relevant RDF/OWL schemata from the Web of data, and investigated certain mapping-related features of these schemata. As a result of this investigation, we can postulate recommendations from the software engineering perspective for the development of future schemata:

1. *Be explicit.* If a resource is an RDF class, say so. Leaving this information implicit makes processing schemata unnecessarily complex and prevents software engineers from becoming familiar with linked data.
2. *Be accurate.* Restrict domain, range, and cardinality of properties, if possible. Leaving this overly flexible will lead to interpretation among data sources and hence limit automatic processing.
3. *Be concise.* If you are about linking data (and not creating a taxonomy), you don't need lots of classes that never appear as range or domain of a property.
4. *Be cooperative.* Many vocabularies exist for various purposes. If you want to create a property with the same (relative) URI of an existing property, re-think. If it is inevitable, give your property a distinct name.
5. *Be perfect.* Add comments and (multi-lingual) labels to classes and properties that help software developers or can be used in some application's presentation logic. Avoid typos in URI at any time as they break links from your vocabulary to others. And make sure you follow linked data principles.

Unfortunately, these recommendations have been violated for a large number of vocabularies we found on the WWW. For our current research, we are following three directions: We will extend our OO class generator and make it and the class mappings a-

available as a Web service ready to be included in standard build processes, so software developers can actually start using OO representations of RDF and OWL vocabularies. As the second direction of research, we will further improve our mapping mechanism, which facilitates runtime access to the actual linked data inside OO software. For these two directions of research, we also want to investigate how our approach can further simplify software development with dynamically-typed languages and languages that, e.g., use prototypes instead of class definitions. Helping software developers in complying to service policies and data licenses is our third direction of research. This will involve identifying those processes in our mapping framework relevant for policy evaluation and providing software developers with both simple tools for complying to standardized policies and licenses, and with developer hooks where they can add customized policy evaluation strategies.

To gain full benefit of RDF, OWL, and linked data, the WWW needs more data, hence more data sources, and as demand determines supply, more data consumers. By drastically simplifying the development of applications consuming and publishing linked data, we hope to contribute to shaping the future Web of data.

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## Augmenting Video Search with Linked Open Data

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**Abstract:** Linked Open Data has become one of the driving forces for the emerging Semantic Web, which enables interlinking and integrating former proprietary data to the global linked data by using RDF as a standard data format. In this paper we show how to integrate the database of the open academic video search platform yovisto.com with the linked open data cloud and how to augment yovisto video search by including semantically interrelated linked open data.

**Key Words:** semantic web, linked data, multimedia retrieval, video retrieval

**Category:** H.3.3, H.5.1, H.5.4

### 1 Introduction

Publication of audiovisual content in the World Wide Web (WWW) has never been so popular as the tremendous success of video sharing platforms such as YouTube or Google-Video is proving. ComScore announced that more than 147 million U.S. Internet users have watched an average of 101 videos per viewer in January 2009 [comScore, Inc., 2009]. Therefore searching, serializing, categorization, and filtering of web video are essential to assist the user to localize videos of their interests.

Yovisto.com<sup>1</sup> is a video search engine specialized on video recordings of academic lectures and conference recordings. Its search index provides efficient access to more than 6 200 content-based searchable lecture recordings from universities and scientific institutions all around the world. To enable pinpoint search access within the video recordings a combination of automated video analysis and user generated collaborative annotation is deployed in connection with fine-granular, time-dependent metadata [Sack and Waitelonis, 2006].

Videos available at yovisto are annotated with time-based MPEG-7 encoded metadata [Day and Martínez, 2000], which demands sophisticated search methods, to provide the user with a powerful tool to investigate the data. State-of-the-art keyword based search technologies are used to provide a fast and efficient access, but nevertheless the keyword based search experience is rather unidimensional. Although users might filter search results by categories, tags, and other facets, the scope of the achieved results is only narrowed with these techniques. If users are not able to specify what exactly they are looking for, they easily got

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<sup>1</sup> <http://www.yovisto.com/>

lost in a funnel trying to focus the achieved search results. E. g., "more-like-this" queries are suggesting similar results giving a clue about other resources, which could be in their scope of interest. Determined by statistical clustering, these results usually are very similar to the primary result set, i. e. users are only moving within the same cluster or domain without the chance to look what is waiting outside. Social network based methods such as, e. g., collaborative tagging can help to broaden the search scope beyond similarities, e. g. "Users who bought X, also bought Y."

In this paper we will show how to deploy Semantic Web technologies to enrich search results of the yovisto video search engine and how to improve user experience by enabling a semantically supported explorative search. To achieve this, we have connected yovisto's content with the Linked Data web [Bizer et al., 2008] to incorporate external additional information (link-up) as well as to use this external information to uncover cross-connections back to yovisto's own content (link-back).

The rest of the paper is structured as follows. Section 2 refers to related work, while Section 3 introduces use cases that show how the video search data can be complemented with Linked Open Data. Section 4 details the realization of all steps to proceed the linkage, Section 5 points out briefly first experiences, results and first bits of evaluation. Section 6 concludes the paper.

## 2 Related Work

Linked Open Data (LOD) has become one of the most popular topics among the emerging Semantic Web [Berners-Lee, 2006]. By Linked Data we refer to a method of exposing, sharing, and connecting data via dereferenceable URI on the WWW. The Linking Open Data community project has picked up this approach to extend the Web of data by publishing various open data sets being represented as RDF and by defining links and mappings between vocabularies and data items from different data sources [Bizer et al., 2008]. Thus, the data available within the LOD has grown to more than 4.5 billion RDF triples and about 180 million RDF links<sup>2</sup>. This publicly available interconnected data enables the development of numerous data mash-up applications.

One of the most prominent datasets among LOD is the DBpedia that provides all structured data of the well known online encyclopedia Wikipedia<sup>3</sup> being represented as RDF triples [Auer et al., 2008]. DBpedia contains about 2.18 million concepts described by 218 million triples, including abstracts in 11 different languages.

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<sup>2</sup> <http://esw.w3.org/topic/TaskForces/CommunityProjects/LinkingOpenData/DataSets/Statistics>, (March 2009)

<sup>3</sup> <http://www.wikipedia.org/>

Another dataset which is important for our work is the Digital Bibliography & Library Project (DBLP)<sup>4</sup>. DBLP is hosted at the University of Trier (Germany) and originally it was a database and logic programming bibliography site, which has broadened its scope to become one of the largest scientific bibliographical databases on the Web. The D2R Server at the L3S Research Center of the Leibniz University in Hannover (Germany) provides a weekly updated RDF-extract of DBLP's 950 000 scientific articles and 570 000 being encoded in about 28 million RDF triples<sup>5</sup>.

GeoNames<sup>6</sup> is a geographical data base available and accessible through various Web services, under a Creative Commons attribution license. It contains more than 8 million geographical names corresponding to over 6.5 million unique features and additional data such as, e. g., latitude, longitude, elevation, or population. GeoNames data are linked to DBpedia data and other RDF Linked Data.

The Friend of a Friend (FOAF) ontology is describing persons, their activities and their relationships to other people and objects [Brickley and Miller, 2007]. With FOAF people are able to describe social networks without the need for a centralised database. People are publishing FOAF profiles as RDF encoded files on their homepages, where they can easily be found with the help of specialized Semantic Web search engines such as, e. g., Sindice [Tummarello et al., 2008].

### 3 Use Cases for Linked Data in Video Search

#### 3.1 Complementing Video Data with Linked Open Data

For the first use case, we use Linked Open Data to complement already existing information about entities within the scope of the domain of our academic video search engine. Each of yovisto's video recordings features one or more speakers, who give a presentation about one or more specific scientific subjects. E. g. the resource "organisation" denotes the university or company to which a speaker belongs. By default, yovisto's database only provides the following properties for the organization: name, country, city, type (university or other), and website.

For universities, DBpedia provides numerous complementary information such as, e. g., an abstract summary, the motto of the university, the president, celebrities who studied or worked at the university, geographical information, and so forth. By identifying a university by its name and location, one can access the according DBpedia dataset and integrate all interesting information into yovisto automatically.

<sup>4</sup> <http://www.informatik.uni-trier.de/~ley/db/>

<sup>5</sup> <http://dblp.l3s.de/d2r/>

<sup>6</sup> <http://www.geonames.org/>

To obtain scientific (and other) publications of a speaker, one can also use DBpedia data about the speaker, if unique identification is possible and if the speaker actually has a DBpedia entry. Otherwise, i. e. if the speaker is not prominent enough to have an DBpedia article (and Wikipedia article respectively), we might query the DBLP bibliography about the speakers publications. By using DBLP data, yovisto speaker data can be endorsed with bibliographical data about the speaker's publications automatically.

By including geographical information via DBpedia and GeoNames, locations of search results such as, e. g., the place where the lecture was recorded or the organization (university) where the speaker is employed can be arranged in a geographical map mash-up (cf. Fig. 1).

### 3.2 Enable Explorative Search with Linked Open Data

In the second use case we utilize Linked Open Data information to enable an explorative video search, i. e. related search results will be arranged in a way to guide the user on his expedition through yovisto's entire search space. Traditional search engines work on a strict input/output basis, i. e. the user inputs a search phrase and the search engine delivers a list of results ordered by their relevance. If the user changes the search phrase, the result list is also altered. By including or excluding new search terms and connecting them with Boolean connectors, the search scope can be narrowed or broadened. But, this way to explore the entire offering of a search engine is rather inefficient.

By connecting yovisto resources with Linked Open Data resources, previously implicit cross connections can be made explicit. This means to connect video resources amongst each other, which are not related at a first glance. E. g., suppose a search query for the american novelist "Ernest Hemingway". Via DBpedia we can find out that Hemingway refers to a person and that many other persons are related with Hemingway via the properties `dbpedia:influenced` and `dbpedia:influences`. By evaluating the property labels we can enrich the displayed result with links to other people's Wikipedia information pages labeled with "influenced (by)" and "influences", accordingly. We are not able to locate these interrelationships without the help of Linked Data. The following simple SPARQL query on DBpedia delivers a list of people influencing or being influenced by Ernest Hemingway:

```
SELECT ?label ?person WHERE {
    ?ernest foaf:name "Ernest Hemingway" .
    {?person dbpedia2:influenced ?ernest .
     dbpedia2:influenced rdfs:label ?label . }
    UNION
    {?ernest dbpedia2:influences ?person .
     dbpedia2:influences rdfs:label ?label . }
}
```



By passing the result as a list of speakers to yovisto, new video suggestions can be made that would not be possible by using yovisto data only. These newly created exploration paths are displayed within an additional widget as navigation element besides the regular video metadata on the yovisto website (cf. Fig. 1). In general, all places, person names, proper names of entities, or dates

The screenshot displays the Yovisto website interface. At the top, the Yovisto logo and navigation menu are visible. The main content area shows search results for "hemingway".

**1. Video Metadata:** A video titled "Lecture Introduction to Literary Studies, 1. Lesson" by Ingrid Hotz-Davies is shown. The metadata includes ID (video/7568), Name, Category (Literature), Language (en), Duration (00:59:51), Format (video/vnd.rn-realvideo), Name (Prof. Dr. Ingrid Hotz-Davies), Collection (Introduction to Literary Studies), University (Eberhard-Karls-Universität Tübingen), and Bibtext (@electronic(yovisto\_video\_; Author = { Ingrid t

**2. Explore more:** A widget providing related content, including "At Yovisto" (People influenced by Ernest Hemingway: Ezra Pound (2 videos), More novelists: Amy Gutman (1 video), Christopher Buckley (1 video), More writers: Laurie Weeks (2 videos), Nell Freudenberger (1 video), 21 more related videos ...), and "At Wikipedia" (Works by Ernest Hemingway, International Imitation Hemingway Competition).

**3. Search Results:** A list of search results, including "1 Lecture Introduction to Literary Studies, 1. Lesson" and "2 Ezra Pound Modern Poetry". Each result includes a thumbnail, title, author, and duration.

**4. Search Filter:** A widget for filtering search results, including fields for "SEARCH" (hemingway), "Organisation:", "Language:", and "Tag:". It also displays "Popular tags in results: daf (1), ernest (1), funk (1), hemingway (1)".

A map visualization at the bottom right shows geographical data for the results set, with red pins indicating locations in North America, Europe, and Africa.

Figure 1: Search result for “hemingway”. Next to the standard display of video metadata (1) the exploration navigation (2) as extension to regular keyword based search (3) and search filters (4) is displayed. In addition, geographical data referring to organizations of the results set are visualized.

stemming from video segment keywords can be interlinked with DBpedia concepts. In fact, almost all entities are subsumed within a system of categories, which can be determined via the property `rdf:type`. Now, by retrieving other entities of the same category (type) gives way to an explorative search within the yovisto database by retrieving video segments being indexed with the name of these entities. Thus, video results related to the original search with regard to categories (super-classes) enable a new way to explore the yovisto search space. E. g., the following SPARQL query results in video segment identifiers that are

related to entities of the same categories as `dbpedia:Ernest_Hemingway`, i.e. other writers or novelists:

```
SELECT DISTINCT ?item ?type ?segment WHERE {
  dbpedia:Ernest_Hemingway rdf:type ?type.
  ?item rdf:type ?type.
  ?segment rdf:type yovisto:videosegment.
  ?segment foaf:depicts ?item.
}
```

By connecting all occurring concepts within the yovisto search engine index data to the Linked Data space, we are contributing audiovisual data (i.e. video segments containing these concepts or being related with these concepts) to the Linked Open Data initiative.

## 4 Linked Data and Interlinking Concepts

This section briefly describes how the yovisto database has been interconnected to Linked Open Data. To establish yovisto as a linked data application we follow the principles and guidelines described in [Hausenblas, 2009]. Accordingly to the Linked Data concept, we gather external data first, weave it together with our own data, and publish the resulting linked data finally.

There are various points of contact to tie yovisto's data to other resources such as, e.g., organizations (DBpedia, GeoNames), persons (DBpedia, FOAF, Sindice), categories and scientific fields (DBpedia, OpenCyc) [OpenCyc, 2009], or publications (DBpedia, DBLP).

Interlinking with yovisto should be automated as much as possible. For that reason, we matching algorithms had to be implemented to map yovisto resource labels to the labels of concepts of the other linked data provider. Matching the yovisto top level categories was performed manually, because of the small number of about 30 items only. Matching organization and university labels was more difficult. Comparing names directly with all `rdf:label` subjects of DBpedia was not possible, because of performance issues. Therefore, we reduced the search space by restricting the `dbpedia-owl:country` to the country set in our database and `rdf:type` to `dbpedia-owl:organisation`.

Additionally, by removing stopwords and tokenizing the labels, regular expressions for every token have been constructed using the boolean AND operator to be invariant from the serialization of words (e.g., by querying for “Univ AND Yale” we can match “Univ. of Yale” well as “Yale University”). To match persons we utilized the sindice API to retrieve FOAF profiles and links to DBpedia resources. We used the combined search method of sindice API to query for given name, family name, and both with restriction to `class:Person` and `foaf:name`, `foaf:givenname`.

Besides the automated mapping to (already existing) resources from e.g. DBpedia an indirect manual mapping can be applied to reveal proper matchings. E.g., if a user is creating a new organization, which is not in the yovisto database, she will be assisted by automated suggestions in the course of a step-by-step navigation. When a user is creating a university that is not in the yovisto database, she has to choose the country first, then the city and finally, a list of universities for that particular city are displayed to choose from. For every step a suggestion list is generated from DBpedia (and/or Geonames).

Publishing the data means first to have a look on the non-RDF data structure and express this structure as taxonomy, create URIs for the resources (minting), choose existing description vocabularies, and publish the data via RDFa or a SPARQL endpoint.

Yovistos data consist of certain cascaded entities. A video (e.g. a recorded conference talk) is part of a collection (e.g. conference session, lecture, podcast, etc.). A collection belongs to an organization (e.g. university or conference). A video is related to one or more agents (e.g. speaker, presenter) and is subdivided into coherent video segments as regards content. Hence, a taxonomy can be defined almost straightforward and described with SKOS [Miles and Brickley, 2005, Summers et al., 2008].

Yovisto data being structured in a relational database and the Virtuoso [OpenLink, 2009] triple-store. Resources are identified via URIs such as <http://www.yovisto.com/resource/video/2359>. Depending on the client's content type acceptance, content negotiation redirects to either RDF-documents (if set to `application/rdf+xml`), or the HTML documents. Furthermore, <http://www.yovisto.com/resource/lecture/2142> dereferences a particular lecture instance with identifier 2142, and <http://www.yovisto.com/resource/lecture> dereferences the class lecture (in sense of yovisto), which has a link `skos:broader` to <http://www.yovisto.com/resource/collection> as a super-class and a `owl:sameAs` connection to <http://dbpedia.org/resource/Lecture> on DBpedia.

We use the following vocabularies to describe the yovisto resources: yovisto ontology<sup>7</sup>, FOAF and VCARD [Iannella, 2001] for persons, SKOS to define taxonomies, DublinCore [International Organization for Standardization, 2003] for bibliographic metadata, LOM [Hodgins and Duval, 2002] for educational metadata. For the description of technical characteristics as well as the temporal segmentation of videos, yovisto deploys MPEG-7 metadata, which can be mapped to the Core Ontology for Multimedia (COMM) [Arndt et al., 2007].

Finally, the data get exposed via RDFa annotation being embedded in the human-digestible XHTML [Pemberton, 2002] pages as well as via a SPARQL endpoint<sup>8</sup> for public access implemented by Virtuoso.

<sup>7</sup> <http://www.yovisto.com/ontology>

<sup>8</sup> <http://sparql.yovisto.com/sparql>

## 5 Results and Brief Evaluation

This section gives a brief overview of a few first results and evaluations of our very first approach to connecting yovisto to Linked Data. There is no full confidence achievable when working with Linked Data. Therefore, automated solutions for mapping entities to Linked Data such as, e. g. DBpedia cannot guarantee correct and exhaustive results, because of the manifold and various application of categories and properties as regards content. For every usecase described in section 3 a set of queries had to be created to obtain valid results. Different queries have to be created for obtaining similar results regarding the content.

A secondary outcome of the work was to find out how many items of yovisto can be interlinked at all with this first (semi-automated) approach. From 1100 speakers we were able to interlink automatically 130 (12%), with 5 (3.9%) of them incorrect. 88 persons were linked to DBpedia, for the other 44 we found FOAF profiles via sindice to gather additional information.

From 440 organizations we were able to interlink 80 (18.2%), with 5 (6.25%) of them incorrect. The incorrect matchings occurred most frequently on universities being represented in different DBpedia articles such as, e. g., “Columbia University” was likewise matched to “Columbia International University”, “The School at Columbia University”, “University of the District of Columbia”.

Similar to Kobilarov et. al. who succeeded in linking 20% to 30% of BBC media brands, locations, names, and subject to DBpedia [Kobilarov et al., 2009], we observed too, that the most items don’t have an article in Wikipedia, where to link to or an existing FOAF profile in case of persons.

## 6 Conclusion and future work

In this paper we showed how the video search engine yovisto has been augmented with Linked Data to improve user experience by enabling a semantically supported explorative search. We used Linked Data to complement yovisto video data and to uncover implicit cross connections within our data. We discussed, how we have realized the interlinking through gathering of Linked Data and mapping our concepts to Linked Data, to finally publish the results embedded in RDFa and a SPARQL endpoint.

Not all problems could be discussed in detail and there are open issues to solve in future work. Matching single keywords to concepts in DBpedia needs disambiguation methods, which have not been discussed. Preparation of high frequent queries beforehand, caching and pre-indexing workflows have to be discussed in future work. Furthermore, the concept of explorative search being introduced in this paper can be generalized to traditional WWW search engines.

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# Weaving Social E-Learning Platforms Into the Web of Linked Data

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**Abstract:** In this paper we present an approach for interlinking and RDFising social e-Learning Web 2.0 platforms like ELGG based on semantic tagging and Linked Data principles. A special module called SID (Semantically Interlinked Data) was developed to allow existing tagged and published user generated content an easy entrance into the Web of Data and to enrich it semantically on the other hand. Our approach uses commonly known vocabularies (FOAF, SIOC, MOAT and Tag Ontology) for modelling and generation tasks along with DBPedia as reference dataset for interlinking.

**Key Words:** semantic web, interlinking, semantic tagging, social platforms, e-learning

**Category:** H.3, H.4

## 1 Introduction

User generated content and social platforms play a major role in today's Web. The work presented in this paper aims at tapping this information source and shows approaches for improving the user experience by semantic interlinking and content enrichment in the case of a social e-Learning platform. Content generated by individuals can be enhanced with more objective semantics and thus becomes more valuable for all users.

Most content in the form of text, images, or video is also accompanied with associated meta data such as information about the creator, categorisations, or tags which can be used for search. The use of tags also enables a more selective information retrieval and appealing information visualisations like tag clouds. However, known issues such as ambiguity and the individual diversity of tag choice can lead to unsatisfying results. The approach described in this paper

proposes to enhance the descriptions and tags with semantics as a possible solution for this problem. By linking tags to datasets like DBpedia the content descriptions are given a well-defined meaning. If the meaning of a tag cannot be automatically resolved by the implemented interlinking module, the user is provided with a list of different meanings to choose from. This option implicitly also enables re-tagging of automatically falsely assigned meanings of tags done in the automatic interlinking step before. Content creators can contribute more reliable information by adding semantics to their content descriptions which in turn could positively influence the contributor's overall trustworthiness and reputation.

Social e-Learning platforms like ELGG<sup>1</sup> combine the advantages of social networks, Web 2.0 principles and educational techniques. They represent very interactive platforms with semi-controlled (tag generation is partly driven by the system) content generation but are limited to the area of their community. The exchange of information between two installations of the same platform (e.g. between two collaborating universities) cannot be done easily as there is no standardised exchange format used and it would require the implementation of specific Web services. The use of RDF and Linked Data in particular could solve this problem and enable the exchange and integration of information across platform boundaries. As a first step a module was implemented that focuses on tag-based semantically interlinked content.

## 2 Related Work

Recent research on tagging and folksonomies in social environments [Gruber 2007, Gruber 2008] emphasizes the meaning of tags for the Semantic Web and outlines the need for describing them by ontologies. These ontologies contribute to sophisticated knowledge representation, enable knowledge exchange among users and applications, and expose the human knowledge to the machines [Halb 2008, Kim 2008b]. All these three aspects fit into the vision and needs of social and e-Learning platforms, especially those used for higher education [Ebner 2008, Ebner 2008a] where the knowledge transfer along with knowledge and resource exchange is based on intensive interaction between the actors of learning process.

A review of current tag related ontologies can be found in [Kim 2008a]. The most relevant ontologies in this context are the Tag Ontology<sup>2</sup>, MOAT (Meaning Of A Tag) [Passant 2008a, Passant 2008b], and SCOT (Social Semantic Cloud of Tags) [Kim 2008] which also offer features that underline social relatedness, relation to content and creators of content described by tags and the possibility of

<sup>1</sup> <http://www.elgg.org/>

<sup>2</sup> <http://www.holygoat.co.uk/projects/tags/>

involving external resources into the representing model. The results of comparisons and evaluations made between different tag ontologies based on recommendations and experiences of experts and on heuristics [Kim 2008b] are suggesting the usage of a tripartite model for the tagging process [Mika 2005, Halpin 2006]. This model is represented by a triple (U,T,R) containing information about users (U) that participate in tagging, set of available tags (T), and related resources (R) that should be tagged.

Our research work also focuses on the social ambience of tagged content and exposing this information to the Web of Data. This notion provides the escape from the “walled garden” of closed social platforms [Rowe 2008] and enables attaching social values to tags. For this purpose the widely deployed FOAF (Friend Of A Friend) [Brickley 2000] ontology seems to be the missing gap in a twofold way: Firstly it makes the social information exposed to humans and machines and secondly it allows to link the tags to its owners using *foaf:maker* property and MOAT description [Kim 2008a].

Motivated by prior works in that area (such as [Fernandez 2007, Bojars 2008, Hausenblas 2007]) our approach of RDFising and exposing the personal blogs, that every such platform includes, is based on the SIOC vocabulary [Breslin 2005] which is well suited for this purpose. Furthermore, in this way an easy integration of existing vocabularies into the proposed combination (MOAT and FOAF) can be realised building a pragmatic composition.

### 3 Modelling Approach

#### 3.1 Platform and Data Characteristics

The ELGG Platform is one of many open source e-Learning environments used by numerous educational institutions and organizations around the world. Based on Web 2.0 technologies and its modular structure users can establish digital identities, connect with other users, collaborate with them and discover new resources through their connections. The common characteristic of Web 2.0 applications is the central role of the users. They are the actual content creators who share information with other users in form of blogs or some other type of content. Tagging plays an important role in this area. Similar data are inter-linked to each other within the system through tags. The search functionality of the platform bases on this principle, so that searching for items results in retrieval of resources that are tagged with those items as keywords. The fact that tags do not have a defined meaning and are considered merely as literal strings is a disadvantage for the entire application. Semantically interlinking tags with resources which describe tags such as DBpedia could lead to more appropriate search results.



### 3.2 Interlinking Model

Our proposed interlinking model for tag based semantic enhancement of user contributed content in social e-Learning platforms and its interlinking into the Linking Open Data cloud follows the recommendations for the usage of tripartite models [Mika 2005] containing information about users, tags, and related resources [Kim 2008b]. As simplicity is one of our model design goals the MOAT and Tag ontologies appear to be appropriate. The MOAT ontology offers to define meanings and to differ between different meanings of a tag. Additionally the context and scope of a tag can be explicitly described.

Inspired by the idea of linked data [Berners-Lee 2007], the meaning of tags is aligned with linked datasets in order to enrich them and the content they belong to. In a first phase interlinks with DBpedia have been generated. Based on the initial results it is possible to let the user refine the definitions as an applied way of User Contributed Interlinking (UCI) as proposed in [Hausenblas 2008].

The interlinking model for social e-Learning platforms makes use of the three wide spread ontologies MOAT, SIOC, and FOAF and simple relations between them (cf. example for ELGG Community in [Fig. 1]). For relating the user generated content with tags the Tag Ontology and restricted tagging method are used.

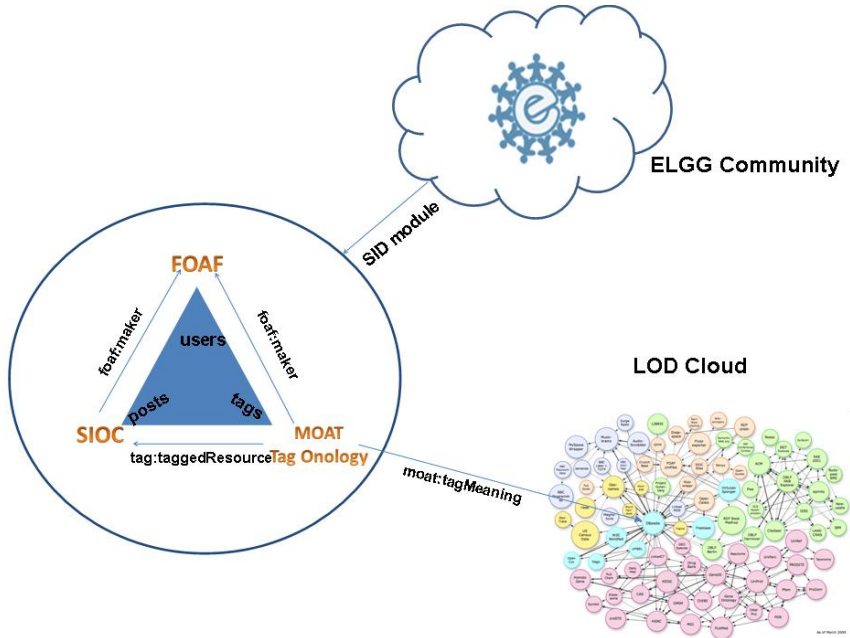
The proposed approach was inspired by recently introduced research work like SCOT Ontology [Kim 2008, Kim 2008a] and prior research efforts [Breslin 2005, Bojars 2008, Passant 2008b], but differs from them in its simplicity. The complexity of the interlinking model is intentionally kept at a low level to allow an easy implementation and thus potential higher acceptance.

The weaving process occurs basically in two steps: In the first step the content is RDFised. This includes social content represented through users and relations between them based on FOAF, user generated content represented through blog posts based on SIOC, and tags as binding member between them based on a combination of MOAT and Tag Ontology.

As depicted in [Fig. 1] a tag's meaning described with MOAT is related to the user's profile via the *foaf:maker* property which is also used for connecting the SIOC representation of a user's blog post to the FOAF profile.

The relation between blog posts and tags is realised using the *Restricted-Tagging* class and *tag:taggedResource* property of the Tag Ontology combined with *moat:tagMeaning* property from MOAT. The example in [Listing 1] demonstrates this constellation. Social e-Learning platforms like ELGG allow embedding of other social relevant resources like videos, slides, images, files, bookmarks or RSS Feeds as well. Those resources are also tagged and can be interlinked in an analogous manner.

In the second step a preliminary interlinking of RDFised tags to the meanings in DBpedia is done which is described in the following section.



**Figure 1:** Model for tag-based interlinking of social content in ELGG.

## 4 Interlinking Module

The proposed interlinking model was applied in TUGLL (TU Graz Learn Land), an ELGG platform running at Graz University of Technology. It contains several thousands of users and tagged blog entries. ELGG is an open source PHP based social e-Learning network with a modular structure of functionality. Modules can be easily added as a plug-in to expand the functionality of the system. For the purpose of RDFising and interlinking we developed the SID (Semantically Interlinked Data) module containing classes for exporting FOAF profiles, SIOC posts and MOAT tag meanings. The module itself has an object oriented architecture which can also be used by other similar applications. The only modifications that need to be made for use in other applications concerns the queries for retrieving tags, user data and blog content from the corresponding platforms. The retrieved data must be prepared as input of SID classes. Once the input data is provided the classes can begin to parse the input data to create the triples in different RDF files using FOAF, SIOC and MOAT ontologies correspondingly. Finally the triples are stored in a RDF store (ARC2 RDF with MySQL <sup>3</sup>). A SPARQL endpoint is provided for potential further processing.

<sup>3</sup> <http://arc.semsol.org/>

```

1 @prefix foaf: <http://xmlns.com/foaf/0.1/> .
2 @prefix moat: <http://moat-project.org/ns> .
3 @prefix tag:
  <http://www.holygoat.co.uk/owl/redwood/0.1/tags/> .
4 @prefix rdf:
  <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
5
6 <http://tugll.tugraz.at/tag/post> a
  tag:RestrictedTagging;
7   foaf:maker <http://tugll.tugraz.at/96784/foaf/> ;
8   tag:tagName "post";
9   moat:tagMeaning <http://dbpedia.org/resource/Post>;
10  tag:associatedTag <http://tugll.tugraz.at/tag/post>;
11  tag:taggedResource
    <http://tugll.tugraz.at/96784/weblog/6965.html>.

```

Listing 1: Relating SIOC and FOAF with interlinked tags using RestrictedTag class.



Figure 2: Auto completed semantic tagging.

The trade-off made here is, that currently only one preliminary interlinked meaning per each found tag for all creators is assigned if the interlinking is done ex post where the user has no immediate possibility to interact and help refining the meaning. Although this is not the basic intention of MOAT vocabulary (that allows multiple meanings assignment for single tag) this approach provides a base for the semantic enrichment of social e-Learning platforms.

The semantic tagging mechanism provides an auto-complete function for disambiguation as depicted in [Fig. 2] that the user can optionally turn on. The feature makes use of the web service based DBpedia lookup API<sup>4</sup>.

<sup>4</sup> <http://lookup.dbpedia.org/api/search.asmx>

## 5 Example Implementation

As preliminary result a simple user scenario represented through a recommender widget for a single resource (post, bookmark, slide, file, RSS ,video etc.) was implemented containing related resources tagged with same tag meaning or alternatively users having resources tagged with the same meaning. In [Listing 2] an exemplary query for the latter case used by widget to gather information is shown. All further relevant information can also be easily retrieved in this simple way.

```

1 SELECT DISTINCT ?pers WHERE {
2
3   ?reftag a tags:RestrictedTagging;
4           tags:taggedResource
5           <http://tugll.tugraz.at/medien07/weblog/778.html>;
6           moat:tagMeaning ?meaning_ref.
7
8   ?tag a tags:RestrictedTagging;
9         foaf:maker ?pers;
10        tags:taggedResource ?res;
11        moat:tagMeaning ?meaning.
12
13  FILTER(?meaning = ?meaning_ref && ?res!=
14         <http://tugll.tugraz.at/medien07/weblog/778.html>)
15 }

```

Listing 2: Selecting related persons who tagged their resources with the same meaning.

As mentioned in section 4 the optional auto-complete function leads to a meaningful tagging in the whole system. Keywords are set more precisely in the sense of context than the case no auto-complete function is used. One of important advantages of RDFising the content is the interoperability. RDFising provides other learn management systems (LMS) with the whole public data (triples) as an open service. In a personal learning environment (PLE), for instance, it is possible now to access and consume the data generated or contributed through users (blogs, bookmarks, files, videos, etc.), build recommender widgets, and perform much more things by merely crawling the RDF triple store exposed using the SPARQL endpoint, even for users from external platforms, without any need to implement special web services for this purpose any more.

## 6 Conclusions

The presented approach for RDFising and interlinking a platform like ELGG shows several benefits: The problem of sharing information inside the community and to the outer world is diminished. The knowledge base of the community gets enhanced by reliable sources. Data present in RDF can be used for internal analysis or for integration of Semantic Web modules into the learning environment. Privacy issues are implicitly solved as users of the platform can generally choose the dissemination level (public or restricted to certain users or groups) of their content. Even though there are still open issues to be solved, with the proposed approach a large community finds its entrance to the Web of Data.

## 7 Future Work

Future work will focus on improvements of the data quality and user experience. This includes also evaluation of integration of semantics based tagging and re-tagging services like LODr [Passant 2008] and similar semantic applications which can contribute to knowledge expansion on the targeted social e-Learning platforms. Using the APIs for social relations resolution and presentation as existent e.g. in Facebook or based on Google Social Graphs will be considered. We also aim at stronger and more reliable interlinking with other linked datasets like e.g. RDF Book Mashup, Project Gutenberg, W3C WordNet, or GeoNames and between the social e-Learning platforms with focus on reliable educational content and social relevance. The benefits of open linked data enable e.g. that further related information existing on Flickr or in geographical database, can be retrieved for the given keyword and recommended to the user in form of additional information. It is also planned to make the SID module publicly available as plug-in for the ELGG platform and as independent RDFising and tag based interlinking tool for all resources containing tags.

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## The Linked Data Value Chain: A Lightweight Model for Business Engineers

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**Abstract:** *Linked Data* is as essential for the Semantic Web as hypertext has been for the Web. For this reason, the W3C community project *Linking Open Data* has been facilitating the transformation of publicly available, open data into Linked Data since 2007. As of 2009, the vast majority of Linked Data is still generated by research communities and institutions. For a successful corporate uptake, we deem it important to have a strong conceptual groundwork, providing the foundation for the development of business cases revolving around the adoption of Linked Data. We therefore present the *Linked Data Value Chain*, a model that conceptualizes the current Linked Data sphere. The Linked Data Value Chain helps to identify and categorize potential pitfalls which have to be considered by business engineers. We demonstrate this process within a concrete case study involving the BBC.

**Key Words:** Linked Data, Linking Open Data, Value Chain, Business Case, Business Models

**Category:** H.m, L.1.4, M.0, M.4

### 1 Introduction

For several years now, the *Semantic Web* [Berners-Lee et al. 2001] has been of great interest to the international research community. As a subtopic, the concept of *Linked Data* has gained much attention in the recent months.

Linked Data is based on four simple rules [Berners-Lee 2006]:

1. Use URIs as names for things
2. Use HTTP URIs so that people (and machines) can look up those names (see also [Sauer mann et al. 2008])
3. When someone looks up a URI, provide useful information
4. Include links to other URIs so that they can discover more things

To seed the Semantic Web with Linked Data and to promote its adoption, the W3C community project *Linking Open Data*<sup>1</sup> was founded in 2007 [Bizer et al. 2007]. The project helps to solve the causality dilemma (chicken-egg problem) between Semantic Web content and Semantic Web applications by providing RDF<sup>2</sup> data sets from existing open data repositories. To enable intelligent applications that generate a valuable output for the end user, a critical amount of high-quality interlinked datasets across different domains is a crucial precondition, as shown by [Jaffri et al. 2008] and [Raimond et al. 2008]. The vision of the scientific Linked Data community can therefore be described as follows: First, facilitate the generation of semantically enriched Linked Data, and as a result, semantic applications will be built on top of this data.

Linked Data incorporates a lot of potential for enterprises [Servant 2008]. However, there is a significant difference between the aims of a scientific community and the demands and requirements of enterprises, such as revenue flow and generated value. Furthermore, every successful commercial adoption requires the discussion of inherent technical, social and business risks connected to the Semantic Web and Linked Data.

We propose that limited commercial Semantic Web adoption is, among other reasons, caused by the lack of conceptual work supporting the development of business cases and the identification of associated risks. Our publication is motivated by these factors and intends to start a discussion which moves the Semantic Web and Linked Data closer to businesses.

In section 2 we present the Linked Data Value Chain, a model of the Linked Data life cycle along with participating entities and involved roles and types of data. In section 3, we apply the Linked Data Value Chain to an existing business case from the BBC and use the aforementioned model to highlight potential pitfalls. We conclude our results and present an outlook to potential future research in section 4.

## 2 The Linked Data Value Chain

As a prerequisite for the development of successful business cases in the emerging context of Linked Data, three concepts have to be introduced first: *Participating Entities*, their assigned *Linked Data Roles* and processed *Types of Data*, as depicted in Fig. 1.

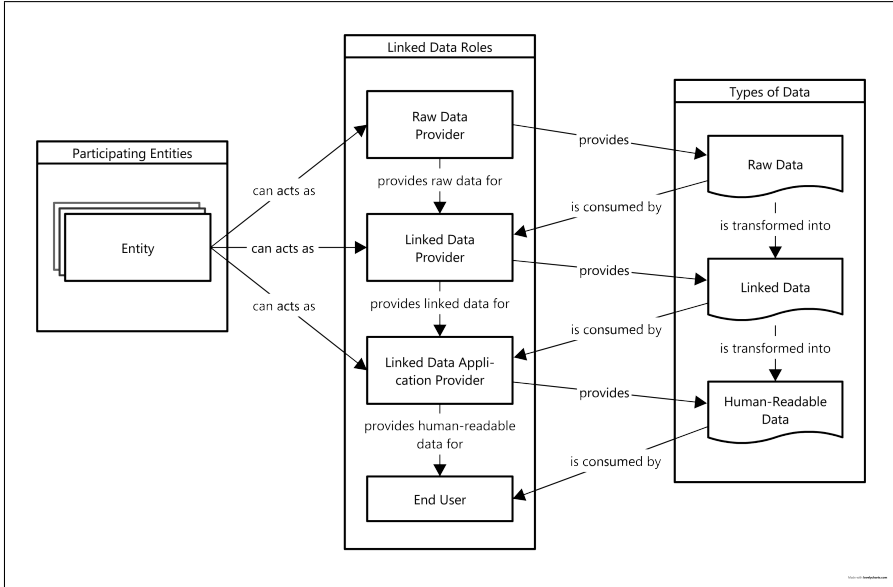
Our contribution tries to support business engineers with the process of assigning Linked Data Roles to Entities, modelling interactions and responsibilities of Linked Data Roles, and transforming data from Raw Data to Linked Data and Human-Readable Data, thereby increasing its value along the way.

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<sup>1</sup><http://esw.w3.org/topic/SweoIG/TaskForces/CommunityProjects/LinkingOpenData>

<sup>2</sup><http://www.w3.org/RDF/>





**Figure 1:** The Linked Data Value Chain

We propose the Linked Data Value Chain as a lightweight model, which builds upon the concepts of Linked Data and Value Chains and makes the interdependencies of entities, roles and different types of data – as the output of the value creation process – explicit.

The value chain as introduced by [Porter 1985] is a concept from the business domain: In a nutshell, a value chain is a chain of activities producing outputs, each activity increasing the value of its particular output, finally shaping a highly valuable end product. In the case of Linked Data with respect to business cases, Human-Readable Data is the most valuable output for the targeted End User.

## 2.1 Participating Entities & Linked Data Roles

In the context of Linked Data, participating entities – both corporate and non-corporate, e.g. persons, enterprises, associations, and research institutes – can occupy one or more of the following roles:

- A *Raw Data Provider* is a role that provides any kind of data in any non-RDF format.
- A *Linked Data Provider* is a role that provides any kind of data in a machine-readable Linked Data format. Such data is currently provided through dereferenceable URIs, a SPARQL endpoint or an RDF dump.

- A *Linked Data Application Provider* is a role that processes Linked Data within an application and generates human-readable output for human end users.
- An *End User* is a human, consuming a human-readable presentation of Linked Data. He or she does not directly get in touch with Linked Data, and typically does not even want to.

The Linked Data Value Chain allows a flexible assignment of roles to entities: In most cases, one entity just occupies one role, but it may – in extreme cases – also occupy all roles at once. For example, one enterprise could own the role of a Data Provider, a Linked Data Provider, and a Linked Data Application Provider all at the same time. The Linked Data Value Chain also supports multiple sources of data: A Linked Data Provider may acquire Raw Data from more than one Raw Data Provider simultaneously, and will usually provide Linked Data to more than one Linked Data Application Provider.

## 2.2 Types of Data

Three different types of data can be identified within the Linked Data Value Chain:

- *Raw Data* is any kind of data (structured or unstructured) that has not yet been converted into Linked Data. Such data usually has some structure, but generally less structure than Linked Data, and is in most cases also not universally identifiable.
- *Linked Data* is data in a RDF format that uses dereferenceable HTTP URIs to identify resources and is linked with other RDF data. This data can be generated by the Linked Data Provider itself, or data provided by a Raw Data Provider can be "RDFized". Linked Data is intended to be consumed and processed by machines only.
- *Human-Readable Data* is any kind of data which is intended, arranged and formatted for consumption by humans. Consuming this data generates value for the human end user, which is crucial to the success of any Linked Data business case.

## 2.3 Interaction between Roles and Data

Entities can act in different roles. These roles are closely connected through three types of data, which they provide and/or consume: A *Raw Data Provider* provides *Raw Data* as the input for a *Linked Data Provider*, who turns it into *Linked Data*, increasing its value by semantically enriching it. Linked Data in

turn serves as the basis for a *Linked Data Application Provider*, who generates *Human-Readable Data* as the most valuable output for a human *End User*.

Each combination of roles and entities as well as every transformation step of data holds inherent risks, some of which will be presented in the next section along with a concrete case study. Knowledge about such risks is crucial for the development of successful business cases. If not considered properly, these risks may become pitfalls to business success.

We identified two main areas where pitfalls may arise, grouping them into Role-Related Pitfalls and Data-Related Pitfalls. In a nutshell, Role-Related Pitfalls are either related to individual roles or to the interaction of different roles. Data-Related Pitfalls are either related to the data itself or the data transformation process. We will explain selected pitfalls emerging in the following BBC case study.

### 3 Applying the Linked Data Value Chain

#### 3.1 BBC Case Study

As the idea of Linked Data is still young, there are not many appealing Web interfaces for human end users yet. One enterprise that is on the cutting edge, both in regard to deployed Semantic Web technologies and the end-user interface, is the BBC<sup>3</sup>. Furthermore, the BBC is a pioneer when it comes to adopting Linked Data within a business case. Their system utilizes Linked Data technologies to interconnect distributed micro-sites within the BBC network, e.g. BBC News<sup>4</sup> and BBC Music<sup>5</sup>, and reuses external data from DBpedia and MusicBrainz [Kobilarov et al. 2009]. By doing so, the BBC generates additional value for the human end users, while allowing them to immediately consume

Linked Data Roles	Participating Entities
Raw Data Provider	BBC Wikipedia
Linked Data Provider	BBC MusicBrainz DBpedia
Linked Data Application Provider	BBC

**Table 1:** Linked Data Roles and Participating Entities in BBC case study

<sup>3</sup><http://www.bbc.co.uk/>

<sup>4</sup><http://news.bbc.co.uk/>

<sup>5</sup><http://www.bbc.co.uk/music/>

contextually and semantically relevant content from third party sites as well as interconnected BBC sites.

We apply the Linked Data Value Chain to examine role assignments along with their interactions as well as the data transformation processes within the BBC business case. As summarized in Table 1, BBC acts as Raw Data Provider and Linked Data Provider for their own data as well as Linked Data Application Provider for all data, including external data from Wikipedia (Raw Data Provider) via DBpedia (Linked Data Provider) and from MusicBrainz (Linked Data Provider).

### 3.2 Discussion of Potential Pitfalls

In the BBC case study, BBC micro-sites utilize data from DBpedia as an important input for the business case. Unfortunately, *transforming Raw Data* (from Wikipedia) *to Linked Data* (via DBpedia) is a very *time-consuming* and, at best, *semi-automated* effort, which is currently undertaken by a team of researchers [Auer et al. 2007]. Linked Data generated this way is therefore hardly ever *complete, correct and up-to-date* [Jaffri et al. 2008]. There are no service level agreements or similar contracts between BBC and DBpedia or DBpedia and Wikipedia securing all these issues. If not considered well, such performance and data quality risks may become pitfalls.

Second, BBC end users may want to edit content on BBC Websites which is provided by DBpedia / Wikipedia. Unfortunately, BBC does not provide an *automated feedback loop leading back to the Linked or Raw Data Providers*, in this case DBpedia and Wikipedia. Such feedback loops are neither implemented nor, most of the time, conceptualized yet. Currently, users are requested by BBC to directly edit the respective articles in Wikipedia. Unfortunately, a synchronization of data between Wikipedia and DBpedia will take a very long time, depending on Wikipedia's *data dumping* and DBpedia's *transformation intervals*, possibly annoying a human end user, who certainly is not interested in such technological issues, but wants to see his or her changes promptly, if not in real time.

Third, BBC provides related *links to third party sites*. Such a procedure is a pitfall to successful commercialization, because users may leave the site of the Linked Application Provider (BBC). Reusing data should be based on *widgets and embedded content*, thereby making users stay on the site longer, but still having the benefits from consuming third party contents.

Fourth, users need information about the *provenance of Linked Data* in order to be able to assess whether the displayed data comes from a *trustworthy provider*. Therefore, Linked Data Application Providers should state clearly from which Linked Data Providers and Raw Data Providers they present data. Completeness, correctness and actuality of data strongly depends on the involved

Raw Data Provider, the underlying algorithms and techniques which convert Raw Data into Linked Data as well as on the quality of service provided by Linked Data Provider.

Fifth, the BBC is currently integrating content from only a few *selected Linked Data Providers* (DBpedia, MusicBrainz), thereby not utilizing the full potential of the Linked Data sphere. On the other hand, the BBC retains *firmer control* over the displayed content and also avoids problems that may occur when displaying large amounts of semantic data from different data sources in a human-readable way [Heath 2008].

Sixth, the BBC has *chosen the data* which they retrieve from Linked Data Providers *in respect to its provenance*. BBC Music takes their introductory texts for bands from Wikipedia, whose content is inherently unstructured. Discographies and related links are taken from MusicBrainz, which is a well-structured music database by design. By not yet using e.g. content extracted from Wikipedia info boxes, BBC avoids the problems related to the transformation process of less-structured data into Linked Data.

## 4 Conclusion and Outlook

Our contribution is dedicated to facilitate the commercial uptake of the Semantic Web vision. We have presented the Linked Data Value Chain as a lightweight model for business engineers to support the conceptualization of successful business cases. Thereby, we identified three main concepts: Different *Entities* acting in different *Roles*, both consuming and providing different *Types of Data*.

We demonstrated that the assignment of roles to entities, the combination and involvement of roles, the data selected as well as the data transformation process hold inherent business risks. We exemplarily applied the Linked Data Value Chain within a concrete case study from BBC to showcase selected business risks.

Our future research will deal with a more detailed classification scheme for pitfalls arising when businesses strive to adopt the Semantic Web, and we will elaborate our concept of the Linked Data Value Chain.

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# Boundary-based Module Extraction in Weakly Acyclic $\mathcal{EL}^{++}$ Ontologies: Theory Foundation and Preliminary Evaluation

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**Abstract:** Modularization is a promising technique to meet the scalability challenge in reasoning with very large ontologies. In this work, we introduce a novel boundary-based modular extraction method for ontologies in weakly acyclic  $\mathcal{EL}^{++}$  description logics. The proposed method is capable of identifying relevant axioms in an ontology based on the notion of boundaries of symbols, with respect to a given reasoning task. We present the theoretical foundation and a practical algorithm for computing boundary-based modules. The proposed algorithm is implemented for the weakly acyclic DL  $\mathcal{EL}^{++}$ . Experimental results on real-world ontologies show that boundary-based modules generated by our method are very close to the optimal result.

**Key Words:** Boundary, Modularization, Available Interpretation, Axiom-based Module

**Category:** I.2.4, H.3.3

## 1 Introduction

Modularization is an important technique that facilitates reasoning with very large ontologies. With the identification of the modular structure of an ontology, a reasoning task may be carried out more efficiently by pinpointing the relevant modules. To achieve high accuracy and efficiency of inference, a modularization-based reasoning approach needs to meet several requirements. In particular, we need to ensure: (i) *Exactness*, which means that the answer of a reasoning task performed in the modular way and the answer to the same task that is performed in the conventional way on the whole ontology are always identical; (ii) *Compactness*, which means that a reasoning task should involve the minimal set of modules or axioms that are necessary for performing the reasoning task. The goal of this work is to develop a method of module extraction that can satisfy those requirements and is suitable to improve reasoning scalability.

Most relevant work to our study is ontology modularization by using structure [Stuckenschmidt and Klein 2004, Seidenberg and Rector 2006, Noy and Musen 2004] or logic-based methods [Cuenca Grau et al 2008, Cuenca Grau et al 2007]. However, modules extracted by using structural methods in general may not be exact in query answering. Logic-based approaches provide ways to extract modules with exactness guarantee, e.g., by signature-based module extraction. In this method, given a set of symbols (i.e., a signature), a fragment can be extracted from an ontology that can answer any reasoning problems for that signature in the exact manner. However, the modules discovered by this approach are in general not compact.

In this work, we present a novel axiom-based approach for module extraction that behaves well for both exactness and compactness. The main idea of our approach is

that an axiom may specify the “boundaries” for the interpretations of a symbol. Given the validity test task of an axiom against an ontology, the set of axioms that might be relevant to the reasoning task includes those axioms that may be relevant to the boundaries of symbols used in the testing axiom. Thus, instead of considering the entire ontology to do the validity test, we only need to use the relevant subset (module).

Boundary partition and intersection operations are used to ensure the compactness. Given the validity test task of an axiom against an ontology, firstly, for a symbol in the testing axiom, the set of axioms that is relevant to the reasoning task is in general included in axiom set which is relevant to either lower boundary or upper boundary of the symbol; secondly, the final module is the intersection of all axiom sets which is relevant to the boundaries of symbols in the testing axiom. Experimental results show that modules generated by our method are close to optimal axiom-based modules.

Exactness is ensured by discovering all axioms in the original ontology that may be directly or indirectly relevant to boundaries of symbols in the testing axiom.

The present paper focuses on the description logic  $\mathcal{EL}^{++}$  [Baader et al. 2008] which is a notable subset of OWL DL. The advantage of  $\mathcal{EL}^{++}$  is that it combines tractability with expressive power that is sufficient for many important applications of ontologies, especially for life science ontologies. Due to these merits,  $\mathcal{EL}^{++}$  serves as the underlying logic of the OWL 2  $\mathcal{EL}$  profile.

The boundary-based module extraction approach has been implemented for the weakly acyclic  $\mathcal{EL}^{++}$  language. Preliminary experiments on realistic  $\mathcal{EL}^{++}$  ontologies have been performed and the results are discussed in Section 5.

## 2 Related Work

**Signature-based module.** As outlined in Section 1, Signature-based module extraction method [Cuenca Grau et al 2008, Cuenca Grau et al 2007] uses semantic information to extract modules of ontologies and the modules generated are exact. However, it is targeted at extracting a module that can preserve all knowledge about the signature in question from the entire ontology. This may result that axioms that are only needed in rather different reasoning scenarios to be included in the generated module. Thus the modules generated contain many unnecessary axioms.

**Modularization using structural information.** In [Stuckenschmidt and Klein 2004], a partitioning algorithm is proposed in order to facilitate the visualization of an ontology. In [Seidenberg and Rector 2006] and [Noy and Musen 2004], authors present methods to extract modules of ontologies for a given signature. All these methods only use structural information of ontologies without providing a characterization for the logical properties of the extracted modules, so they are not exact.

**Justification.** Another related work is justification which is intended to be a debugging technique [Kalyanpur et al. 2007]. Justification of an entailment is a minimal set of axioms sufficient to produce the entailment, it is obviously a minimal axiom-based



module, but it can only be calculated *after* the process of inference, so it cannot be used to optimize reasoning. In this paper, justification is used as the optimal module to compare with module extracted using our method.

### 3 Preliminaries

A description logic language contains a set of atomic concepts  $(A, B, \dots)$  representing sets of elements, a set of atomic roles  $(r, s, \dots)$  representing binary relations between elements, and a set of individuals  $(a, b, c, \dots)$  representing elements. It also provides constructors for defining the set of (general) roles  $(R, S, \dots)$ , the set of (general) concepts  $(C, D, \dots)$ , and the set of axioms  $(\alpha, \beta, \dots)$  which is an union of role axioms (RBox), terminological axioms (TBox) and assertions (ABox). The semantics for a description logic language is defined using the *Tarski-style* model-theoretic semantics. An interpretation  $\mathcal{I}$  is a pair  $\mathcal{I} = (\Delta^{\mathcal{I}}, \cdot^{\mathcal{I}})$ , where  $\Delta^{\mathcal{I}}$  is a non-empty set, called the domain of the interpretation, and  $\cdot^{\mathcal{I}}$  is the interpretation function that assigns to every atomic concept  $A$  a set  $A^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$ , to every atomic role  $r$  a set  $r^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}$  and every individual an element  $a^{\mathcal{I}} \in \Delta^{\mathcal{I}}$ . The interpretation  $\cdot^{\mathcal{I}}$  is extended to complex roles and concepts via DL-constructors. An interpretation  $\mathcal{I}$  is a model of an ontology  $\mathcal{O}$  (written as  $\mathcal{I} \models \mathcal{O}$ ) if  $\mathcal{I}$  satisfies all axioms in  $\mathcal{O}$ . An ontology  $\mathcal{O}$  implies an axiom  $\alpha$  (written as  $\mathcal{O} \models \alpha$ ) if  $\mathcal{I} \models \alpha$  for every model  $\mathcal{I}$  of  $\mathcal{O}$ . The signature  $Sig(\alpha)$  of an axiom  $\alpha$  is the union of role, concept and individual symbols that occurring in  $\alpha$ . The  $Sig(\mathcal{O})$  of an ontology  $\mathcal{O}$  is defined analogously. Expression  $model(\mathcal{O})$  represents all models of the ontology  $\mathcal{O}$ .  $model(\alpha)$  is defined analogously for an axiom  $\alpha$ . Chapter 2 of [Baader et al. 2003] provides the detailed syntax and semantics of DL.

In this paper we focus on the weakly acyclic DL  $\mathcal{EL}^{++}$  [Baader et al. 2008], which provides the following main features: top concept  $\top$ , bottom concept  $\perp$ , nominal  $\{a\}$ , concept conjunction  $C \sqcap D$ , existential restriction  $\exists r.C$ , domain restriction  $dom(r) \sqsubseteq C$ , range restriction  $ran(r) \sqsubseteq C$ , general concept inclusion (GCIs)  $C \sqsubseteq D$ , role inclusions (RIs)  $r_1 \circ \dots \circ r_k \sqsubseteq r$ , concept assertion  $C(a)$  and role assertion  $r(a, b)$ .

An axiom is called cyclic iff there exists a concept or role in it directly uses itself. In  $\mathcal{EL}^{++}$  ontologies, only TBox and RBox allow cyclic axiom. Given an TBox  $C \sqsubseteq D$ , then  $C \sqsubseteq D$  is a cyclic axiom iff  $C$  and  $D$  contain same symbols; given a RBox  $r_1 \circ \dots \circ r_k \sqsubseteq r$ , it is a cyclic axiom iff  $\exists r_i = r, i \in \{1, \dots, k\}$ . An ontology is called weakly acyclic iff it does not contain cyclic axioms.

## 4 Axiom-based Module Extraction by Using Boundary

### 4.1 Axiom-based Module

**Definition 1 (Axiom-based Module)** Let  $\mathcal{O}$  be an ontology and  $\mathcal{O}_1 \subseteq \mathcal{O}$ . We say  $\mathcal{O}_1$  is a module for an axiom  $\alpha$  in ontology  $\mathcal{O}$  (or for short, an  $\alpha$ -module in  $\mathcal{O}$ ) if  $\mathcal{O}_1 \models \alpha$  iff  $\mathcal{O} \models \alpha$ . We denote by  $module(\alpha, \mathcal{O})$  the collection of all  $\alpha$ -module in  $\mathcal{O}$ .

**Definition 2 (Minimal Axiom-based Module)** Let  $\mathcal{O}_1$  be an  $\alpha$ -module in  $\mathcal{O}$ . We say that  $\mathcal{O}_1$  is a minimal module for an axiom  $\alpha$  in ontology  $\mathcal{O}$  (or for short, a minimal  $\alpha$ -module in  $\mathcal{O}$ ) iff there is no  $\alpha$ -module  $\mathcal{O}_2$  in  $\mathcal{O}$  such that  $\mathcal{O}_2 \subset \mathcal{O}_1$ .

The minimal  $\alpha$ -module in  $\mathcal{O}$  is sufficient to test the validity of  $\alpha$ . It is  $\emptyset$  when  $\mathcal{O} \not\models \alpha$ , and is not empty otherwise. The unification of all minimal  $\alpha$ -modules in  $\mathcal{O}$  is the set of axioms which provide all the necessary information in the reasoning process, which we name as *essential axiom-based module*.

**Definition 3 (Essential Axiom-based Module)** Let  $\mathcal{O}$  be an ontology and  $\alpha$  be an axiom, the essential axiom-based module for  $\alpha$  in  $\mathcal{O}$  (or for short, the essential  $\alpha$ -module in  $\mathcal{O}$ ) is the unification of all the minimal  $\alpha$ -modules in ontology  $\mathcal{O}$ , denoted by  $\mathcal{O}_e$ .

*Proof.* Since  $\mathcal{O}_1$  is an  $\alpha$ -module in  $\mathcal{O}$ , there exists a minimal  $\alpha$ -module  $\mathcal{O}_m$  which is included in  $\mathcal{O}_1$ . As  $\mathcal{O}'_e$  contains all minimal  $\alpha$ -modules in  $\mathcal{O}$ ,  $\mathcal{O}_m$  is also included in  $\mathcal{O}'_e$ ,  $\mathcal{O}_m \subseteq \mathcal{O}'_e$ . Thus,  $(\mathcal{O}'_e \cap \mathcal{O}_1) \in \text{module}(\alpha, \mathcal{O})$ .

## 4.2 Theory of Boundary

**Definition 4 (Available Interpretation of Symbols)** Let  $\mathcal{O}$  be an ontology,  $s$  be a symbol<sup>1</sup> in  $\mathcal{O}$ , i.e.,  $s \in \text{Sig}(\mathcal{O})$ . Let  $\mathfrak{M}$  be the set of all models of  $\mathcal{O}$ , a available interpretation of  $s$  is a function  $a_s^{\mathcal{O}} : \mathfrak{M} \rightarrow S$  where  $S$  is a set of sets, such that for any  $\mathcal{I} \in \mathfrak{M}$ , let  $\mathcal{I}'$  be a new interpretation obtained by letting  $s^{\mathcal{I}'} = X$  and keep interpretations of other symbols unchanged, then  $\mathcal{I}'$  is a model of  $\mathcal{O}$  iff  $X \in a_s^{\mathcal{O}}(\mathcal{I})$ . We call  $a_s^{\mathcal{O}}(\mathcal{I})$  the available interpretation of  $s$  in  $\mathcal{O}$ .

Example 1: let  $\mathcal{O}$  be  $\{C \sqsubseteq D\}$ , then  $a_C^{\mathcal{O}}(\mathcal{I}) = \{X | X \subseteq D^{\mathcal{I}}\}$  and  $a_D^{\mathcal{O}}(\mathcal{I}) = \{Y | Y \supseteq C^{\mathcal{I}}\}$ . Obviously, every symbol has a unique available interpretation.

**Proposition 1 (Existence of the Unique Available Interpretation)** Let  $\mathcal{O}$  be an ontology,  $s$  be a symbol in  $\mathcal{O}$ , then there must exist a unique  $a_s^{\mathcal{O}}$ .

*Proof.* We use two steps to prove the existence of unique  $a_s^{\mathcal{O}}$ .

1) For every axiom  $\alpha$  which contains symbol  $s$ , relationships between symbols in  $\alpha$  are determined, it can be represented by a unique correlation  $\mathfrak{R}(s_1^{\mathcal{I}}, \dots, s_k^{\mathcal{I}}), s_k \in \text{Sig}(\alpha)$ , which satisfies:  $\mathcal{I} \in \text{model}(\alpha)$  iff  $\mathcal{I}$  satisfies  $\mathfrak{R}$ .

For a given  $\mathcal{I}$ , we set interpretation of symbols in  $\text{Sig}(\alpha)/s$  unchanged, then  $\mathfrak{R}$  may be satisfied when changing  $s^{\mathcal{I}}$  into some value  $X$ , i.e., let  $\mathcal{I}'_X$  be a new interpretation which obtained by letting  $s^{\mathcal{I}'_X} = X$  and keep interpretation of other symbols unchanged,  $\mathcal{I}'_X$  satisfies  $\mathfrak{R}(s_1^{\mathcal{I}'_X}, \dots, s_k^{\mathcal{I}'_X})$ .  $a_s^{\mathcal{O}}$  is constructed by using the following

<sup>1</sup> In this paper, without loss of generality, we assume empty ABox,  $C(a) \Rightarrow \{a\} \sqsubseteq C$ ,  $r(a, b) \Rightarrow \{a\} \sqsubseteq \exists r.\{b\}$ . Please note that ABox assertions can be reduced to semantically equivalent TBox axioms. This change makes the theory foundation more concise yet assure the correctness.

method:  $a_s^\alpha(\mathcal{I}) = \{s^{\mathcal{I}'_X} \mid \mathcal{I}'_X \text{ satisfies } \mathfrak{R}\}$ . Since  $\mathfrak{R}$  is unique and existent,  $a_s^\alpha$  is unique and existent.

2)  $a_s^\mathcal{O}$  is the intersection of all  $a_s^{\alpha_i}$  in  $\mathcal{O}$ , where  $s \in \alpha_i$ . Since every  $a_s^{\alpha_i}$  is unique,  $a_s^\mathcal{O}$  is unique.

According to the above proof, available interpretation of a symbol in an axiom has the following properties:

**Lemma 1 (Properties of Available Interpretation in Axiom)** *Let  $\alpha$  be an axiom and  $s$  be a symbol in  $\alpha$ , i.e.,  $s \in \text{Sig}(\alpha)$ . For any  $\mathcal{I}$ , if  $a_s^\alpha(\mathcal{I})$  is nonempty, let  $X$  be an element in  $a_s^\alpha(\mathcal{I})$ ,  $\mathcal{I}'_X$  be a new interpretation which obtained by letting  $s^{\mathcal{I}'_X} = X$  and keep interpretation of other symbols unchanged, then  $\mathcal{I}'_X \in \text{model}(\alpha)$ .*

Based on the above theory, relationship between available interpretation and logical entailment is formalized as following:

**Proposition 2 (Relation Between Available Interpretation and Logical Entailment)**

*Let  $\mathcal{O}$  be an ontology,  $\alpha$  be an axiom and  $s$  be a symbol in  $\alpha$ , then  $\mathcal{O} \models \alpha$  if  $\forall \mathcal{I} \in \text{model}(\mathcal{O}), a_s^\mathcal{O}(\mathcal{I}) \subseteq a_s^\alpha(\mathcal{I})$ .*

*Proof.*  $\mathcal{O} \models \alpha \Leftarrow \forall \mathcal{I} \in \text{model}(\mathcal{O}), a_s^\mathcal{O}(\mathcal{I}) \subseteq a_s^\alpha(\mathcal{I})$ . for any model  $\mathcal{I}$  of  $\mathcal{O}$ ,  $a_s^\mathcal{O}(\mathcal{I}) \subseteq a_s^\alpha(\mathcal{I})$ . As  $s^\mathcal{I} \in a_s^\mathcal{O}(\mathcal{I})$ ,  $s^\mathcal{I} \in a_s^\alpha(\mathcal{I})$ , according to Lemma 1,  $\mathcal{I}$  is also model of  $\alpha$ . Thus,  $\text{model}(\mathcal{O}) \subseteq \text{model}(\alpha)$ ,  $\mathcal{O} \models \alpha$ .

According to the above proposition, axioms relevant to the available interpretation of one symbol in  $\alpha$  can provide all information to test  $\mathcal{O} \models \alpha$ . It can be partitioned using boundary of symbols. The sketch of theory of boundary is described as following:

- Available interpretation has boundaries. Available interpretation of a symbol in description logics is a set of sets, which has a lower and upper boundary in general. Lower boundary represents the minimal interpretation of the symbol, and upper boundary represents the maximal interpretation of the symbol. Boundary related definitions and propositions will be described in this subsection;
- *Boundary partition.* Using the notion of boundary, axioms relevant to interpretation of symbol can be separated into axioms relevant to lower boundary and axiom relevant to upper boundary. Axiom set relevant to the reasoning task is in general included in axiom set relevant to either lower boundary or upper boundary of the symbol. The process is called *boundary partition*, which will be described in proposition 4 of subsection 4.3;
- *Intersection operation.* As boundary relevant axiom set of every symbol in the testing axiom contains all information to executing the reasoning task, i.e., it contains essential axiom-based module, according to proposition 3, intersection of all axiom sets relevant to the boundaries of symbols in the testing axiom is also an exact

axiom-based module. The process is called *Intersection operation*, which will be described in proposition 5 of subsection 4.3.

**Definition 5 (Boundary of Symbols)** Let  $\mathcal{O}$  be an ontology and  $s$  be a symbol<sup>2</sup> in  $\mathcal{O}$ . Let  $\mathfrak{M}$  be the set of all models of  $\mathcal{O}$ . Boundary of  $s$  is a pair  $(l_s^\mathcal{O}, u_s^\mathcal{O})$ ,  $l_s^\mathcal{O}$  and  $u_s^\mathcal{O}$  are two functions:  $\mathfrak{M} \rightarrow (S_l, S_u)$  where  $S_l$  and  $S_u$  are two sets, such that (i) for any  $\mathcal{I} \in \mathfrak{M}$ ,  $S_l = l_s^\mathcal{O}(\mathcal{I}) \subseteq \Delta^\mathcal{I}$  or  $\Delta^\mathcal{I} \times \Delta^\mathcal{I}$ ,  $S_u = u_s^\mathcal{O}(\mathcal{I}) \subseteq \Delta^\mathcal{I}$  or  $\Delta^\mathcal{I} \times \Delta^{\mathcal{I}^3}$ ; (ii) For a given  $\mathcal{I}$  and  $X \subseteq \Delta^\mathcal{I}$ , let  $\mathcal{I}'$  be a new interpretation obtained from  $\mathcal{I}$  by letting  $s^{\mathcal{I}'} = X$  and keep other symbols interpretations unchanged, then  $\mathcal{I}' \in \text{model}(\mathcal{O})$  if  $l_s^\mathcal{O}(\mathcal{I}) \subseteq X \subseteq u_s^\mathcal{O}(\mathcal{I})$  and  $\mathcal{I}' \notin \text{model}(\mathcal{O})$  if  $X \subset l_s^\mathcal{O}(\mathcal{I})$  or  $X \supset u_s^\mathcal{O}(\mathcal{I})$ .

We call  $l_s^\mathcal{O}$  and  $u_s^\mathcal{O}$  the lower and upper boundary of  $s$  in  $\mathcal{O}^A$ . In  $\mathcal{O}$ , If  $s$  only has one lower or upper boundary, we say  $l_s^\mathcal{O}$  or  $u_s^\mathcal{O}$  is unique. Otherwise, it is nonunique,  $(l_s^\mathcal{O}[1], u_s^\mathcal{O}[1]), (l_s^\mathcal{O}[2], u_s^\mathcal{O}[2]), \dots$  are used to denote these boundaries.

Continuing with Example 1, for symbol  $C$ ,  $l_C^\mathcal{O} = \emptyset, u_C^\mathcal{O} = D^\mathcal{I}$ ; for  $D$ ,  $l_D^\mathcal{O} = C^\mathcal{I}, u_D^\mathcal{O} = \Delta^\mathcal{I}$ . Example 2: Let  $\mathcal{O}$  be  $\{C \sqsubseteq \exists r.D\}$ , for  $r$ ,  $u_r^\mathcal{O} = \Delta^\mathcal{I} \times \Delta^\mathcal{I}$ ,  $l_r^\mathcal{O}$  may be nonunique,  $l_r^\mathcal{O} = \{(x, y) | f(y) = x, x \in C^\mathcal{I}, y \in D^\mathcal{I}, f : D^\mathcal{I} \rightarrow C^\mathcal{I} \text{ is a minimal surjection}\}$ . We use a more concrete example to demonstrate the nonuniqueness. Let an interpretation  $\mathcal{I}$  of  $\mathcal{O}$  be  $\{\Delta^\mathcal{I} = \mathbb{N}, C^\mathcal{I} = \{1, 2\}, D^\mathcal{I} = \{3, 4\}, r^\mathcal{I} = \{(1, 3), (2, 3)\}\}$ , then  $r$  has four lower boundaries and only one upper boundaries,  $l_r^\mathcal{O}[1] = \{(1, 3), (2, 3)\}$ ,  $l_r^\mathcal{O}[2] = \{(1, 4), (2, 4)\}$ ,  $l_r^\mathcal{O}[3] = \{(1, 3), (2, 4)\}$ ,  $l_r^\mathcal{O}[4] = \{(1, 4), (2, 3)\}$  and  $u_r^\mathcal{O} = \{\mathbb{N} \times \mathbb{N}\}$ .

**Proposition 3 (Relationships between Boundary and Available Interpretation)** Let  $\mathcal{O}$  be a weakly acyclic  $\mathcal{EL}^{++}$  ontology<sup>5</sup> and  $s$  be a symbol in  $\mathcal{O}$ , then there must exist boundaries  $(l_s^\mathcal{O}[1], u_s^\mathcal{O}[1]), (l_s^\mathcal{O}[2], u_s^\mathcal{O}[2]), \dots$  which satisfies:  $X \in a_s^\mathcal{O}$  iff  $l_s^\mathcal{O}[1] \subseteq X \subseteq u_s^\mathcal{O}[1]$  or  $l_s^\mathcal{O}[2] \subseteq X \subseteq u_s^\mathcal{O}[2]$  or  $\dots$ , i.e.,  $a_s^\mathcal{O} = (l_s^\mathcal{O}[1], u_s^\mathcal{O}[1]) \cup (l_s^\mathcal{O}[2], u_s^\mathcal{O}[2]) \cup \dots$

*Proof.* We will firstly show every symbol in an axiom has a lower and a upper boundary, then prove the symbol also has lower and upper boundary in the ontology.

1. We use two steps to prove axiom  $\alpha$  has determined lower and upper boundaries.

1)  $a_s^\alpha(\mathcal{I})$  is continuous, which means there does not exist the following phenomena:  $\exists X, Y, Z, X \subset Y \subset Z \wedge X \in a_s^\alpha \wedge Y \notin a_s^\alpha \wedge Z \in a_s^\alpha$ . It can be proved by analyzing syntax of  $\mathcal{EL}^{++}$ : a)  $\alpha$  is one of the following type:  $C \sqsubseteq D, \text{dom}(r) \sqsubseteq C, \text{ran}(r) \sqsubseteq C, C(a)$  or  $r(a, b)$ , it is easy to see that  $a_s^\alpha$  is continuous, where  $s \in \text{Sig}(\alpha)$ ; b) In the above situation,  $C$  and  $D$  may be complex concepts, when  $C$  is  $\exists r.E$ , for  $r$  in  $\exists r.E \sqsubseteq D$ , if  $X \in a_r^\alpha$ , then  $\forall Y \subset X, Y \in a_r^\alpha$ , so  $a_r^\alpha$  is continuous; when  $C$  is  $E \sqcap F$ , for  $E$  in  $E \sqcap F \sqsubseteq D$ , if  $X \in a_E^\alpha$ , then  $\forall Y \subset X, Y \in a_E^\alpha$ , so  $a_E^\alpha$  is continuous, other situations

<sup>2</sup> By default, symbol  $s$  is not  $\top$  or  $\perp$  in this paper.

<sup>3</sup> If  $s$  is a concept symbol,  $S_l \subseteq \Delta^\mathcal{I}, S_u \subseteq \Delta^\mathcal{I}$ ; if  $s$  is a role symbol,  $S_l \subseteq \Delta^\mathcal{I} \times \Delta^\mathcal{I}, S_u \subseteq \Delta^\mathcal{I} \times \Delta^\mathcal{I}$

<sup>4</sup> We drop the superscript  $\mathcal{O}$  if it is clear from the context.

<sup>5</sup> In the rest part of this paper,  $\mathcal{O}$  is a weakly acyclic  $\mathcal{EL}^{++}$  ontology by default.

can be proved similarly; c) When  $\alpha$  is  $r_1 \circ \dots \circ r_k \sqsubseteq r_0$ , for  $r_1$ , if  $X \in a_{r_1}^\alpha$ , then  $\forall Y \subset X, Y \in a_{r_1}^\alpha$ , so  $a_{r_1}^\alpha$  is continuous, other situations can be proved analogically.

2) We give an construction method to compute boundaries from  $a_s^\alpha$ . a) In  $a_s^\alpha$ , we firstly find all minimal element  $l_i$  which satisfies  $\forall e \in a_s^\alpha \setminus \{l_i\}, e \not\subseteq l_i$ ; b) For every  $l_i$ , we find all the maximal super set of  $l_i$ , denoted by  $u_{ij}$  which satisfies  $l_i \subset u_{ij} \wedge \forall e \in a_s^\alpha \setminus \{u_{ij}\}, e \not\supseteq u_{ij}$ .  $(l_i, u_{ij})$  is a boundary of  $s$  in  $\alpha$ . Using this method, we can obtain all boundaries of  $s$  in  $\alpha$ .

2. Since every symbol  $s$  in an axiom has lower and upper boundary,  $l_s^\mathcal{O}$  and  $u_s^\mathcal{O}$  is the intersection of all lower and upper boundary in axioms which contain  $s$ ,  $l(u)_s^\mathcal{O} = \bigcap l(u)_s^\alpha, s \in \text{Sig}(\alpha), \alpha \in \mathcal{O}$ .

The above proposition shows that boundaries and available interpretation of a symbol in weakly acyclic  $\mathcal{EL}^{++}$  are mutual determined. For a symbol  $s$  in  $\mathcal{O}$ , boundary of  $s$  are determined by some axioms in  $\mathcal{O}$ . It can be formalized as following:

**Definition 6 (Relevance between Axiom and Symbol)** Let  $\mathcal{O}$  be an ontology,  $s$  be a symbol in  $\mathcal{O}$  and  $\alpha$  be an axiom.  $\mathcal{I}_\alpha$  is a model of  $\alpha$ ,  $\mathfrak{M}^{\mathcal{I}_\alpha}$  is all the model of  $\mathcal{O} \cup \{\alpha\}$  which set interpretation of every symbol  $t$  in  $\text{Sig}(\alpha)/s$  to  $t^{\mathcal{I}_\alpha}$ . If  $\exists \mathfrak{M}^{\mathcal{I}_\alpha}, \exists l(u)_s^\mathcal{O}[i], \forall l(u)_s^{\mathcal{O} \cup \{\alpha\}}[j], l(u)_s^\mathcal{O}[i](\mathcal{I}) \neq l(u)_s^{\mathcal{O} \cup \{\alpha\}}[j](\mathcal{I}^{\mathcal{I}_\alpha}), \mathcal{I} \in \mathfrak{M}, \mathcal{I}^{\mathcal{I}_\alpha} \in \mathfrak{M}^{\mathcal{I}_\alpha}, i, j = 1, 2, \dots$ , then we say axiom  $\alpha$  is relevant to the lower(upper) boundary of  $s$  through  $\mathcal{O}$ , denoted by  $\mathcal{L}(\mathcal{U})\mathcal{BR}(A, \mathcal{O}, \alpha) = 1$ ; else  $\alpha$  is irrelevant to the lower(upper) of  $s$  through  $\mathcal{O}$ , denoted by  $\mathcal{L}(\mathcal{U})\mathcal{BR}(s, \mathcal{O}, \alpha) = 0$ .

Example 3: Let  $\mathcal{O}$  be  $\{A \sqsubseteq B, C \sqsubseteq D\}$ , and axiom  $\alpha$  be  $B \sqsubseteq C$ . We set  $\mathcal{I}_\alpha$  to  $\{B^{\mathcal{I}_\alpha} = C^{\mathcal{I}_\alpha} = \emptyset\}$ , then  $\mathfrak{M}^{\mathcal{I}_\alpha}$  is  $\{A^{\mathcal{I}_\alpha} = B^{\mathcal{I}_\alpha} = C^{\mathcal{I}_\alpha} = \emptyset, D^{\mathcal{I}_\alpha} = \{X | X \subseteq \Delta^{\mathcal{I}_\alpha}\}$ . For symbol  $A$ , it is easy to see that  $u_A^{\mathcal{O} \cup \{\alpha\}}(\mathcal{I}^{\mathcal{I}_\alpha}) \neq u_A^\mathcal{O}(\mathcal{I})$ , so  $\mathcal{UBR}(s, \mathcal{O}, \alpha) = 1$ ; on the other hand,  $\forall \mathfrak{M}^{\mathcal{I}_\alpha}, l_A^{\mathcal{O} \cup \{\alpha\}}(\mathcal{I}^{\mathcal{I}_\alpha}) = l_A^\mathcal{O}(\mathcal{I}) = \emptyset$ , so  $\mathcal{LBR}(A, \mathcal{O}, \alpha) = 0$ .

**Definition 7 (Boundary Relevant Axiom (Set))** Let  $\mathcal{O}$  be an ontology,  $s$  be a symbol in  $\mathcal{O}$  and  $\alpha$  be an axiom.

1) **Boundary relevant axioms.** If  $\mathcal{L}(\mathcal{U})\mathcal{BR}(s, \emptyset, \alpha) = 1$ , then we say axiom  $\alpha$  is directly relevant to  $l_s(u_s)$ ,  $\mathcal{DL}(\mathcal{U})\mathcal{B}(s, \mathcal{O})$  is used to denote all these directly relevant axioms in  $\mathcal{O}$ ; If  $\mathcal{L}(\mathcal{U})\mathcal{BR}(s, \emptyset, \alpha) = 0$  and  $\mathcal{L}(\mathcal{U})\mathcal{BR}(s, \mathcal{O}, \alpha) = 1$ , then we say  $\alpha$  is indirectly relevant to  $l_s(u_s)$  through  $\mathcal{O}$ .  $\mathcal{IL}(\mathcal{U})\mathcal{B}(s, \mathcal{O})$  is used to denote all the axioms which are indirect relevant to the boundary of  $s$  through any nonempty subset of  $\mathcal{O}$ .

2) **Boundary relevant axiom set.** Axiom set relevant to  $l_s(u_s)$  in  $\mathcal{O}$  contains all axioms  $\alpha$  which are directly or indirectly relevant to  $l_s(u_s)$ , denoted by  $\mathcal{L}(\mathcal{U})\mathcal{B}(s, \mathcal{O})$ .

Example 4: Let  $\mathcal{O}$  be  $\{\alpha : A \sqsubseteq B, \beta : B \sqsubseteq C\}$ . For symbol  $A$ ,  $\alpha$  is directly relevant to  $u_A$ ,  $\mathcal{UBR}(A, \emptyset, \alpha) = 1$ ,  $\beta$  is not directly relevant to  $u_A$ ,  $\mathcal{LBR}(B, \emptyset, \beta) = 0$ , but it is indirectly relevant to  $u_A$  through  $\{\alpha\}$ ,  $\mathcal{LBR}(B, \{\alpha\}, \beta) = 1$ . According to the above analysis,  $\mathcal{DUB}(A, \mathcal{O}) = \{\alpha\}$ ,  $\mathcal{IUB}(A, \mathcal{O}) = \{\beta\}$ , and  $\mathcal{UB}(A, \mathcal{O}) = \{\alpha, \beta\}$ .

### 4.3 Boundary-based Module

In this section, relationship between boundary relevant axiom set and axiom-based module is given. we firstly use an example to illustrate their relationship. Example 5:  $\mathcal{O} \models C \sqsubseteq D$ . 1) For  $C$ ,  $\mathcal{O}$  entails  $C \sqsubseteq D$  because some axioms in  $\mathcal{O}$  influence the available interpretation of  $C$ , furthermore, these axioms influence the upper boundary of  $C$ . So axioms relevant to  $u_C$  in  $\mathcal{O}$  contain all the information for computing  $\mathcal{O} \models C \sqsubseteq D$ ,  $\mathcal{UB}(C, \mathcal{O}) \supseteq \mathcal{O}_e$ . 2) We can obtain  $\mathcal{LB}(D, \mathcal{O}) \supseteq \mathcal{O}_e$  using the similarly way. 3) According to properties of  $\mathcal{O}_e$ ,  $\mathcal{UB}(C, \mathcal{O}) \cap \mathcal{LB}(D, \mathcal{O})$  is an  $\alpha$ -module in  $\mathcal{O}$ .

**Proposition 4 (Boundary Partition)** *Let  $\mathcal{O} \models \alpha$  be an reasoning task, in which  $\mathcal{O}$  is an ontology and  $\alpha$  is an axiom,  $s$  is a symbol in  $\alpha$ .*

1) *If  $\mathcal{L}(\mathcal{UBR}(s, \emptyset, \alpha)) = 1$  and  $\mathcal{U}(\mathcal{LBR}(s, \emptyset, \alpha)) = 0$ , then axiom set relevant to  $l_s(u_s)$  in  $\mathcal{O}$  is the superset of essential  $\alpha$ -module in  $\mathcal{O}$ ,  $\mathcal{O}_e \subseteq \mathcal{L}(\mathcal{UR}(s, \mathcal{O}))$ ;*

2) *If  $\mathcal{LBR}(s, \emptyset, \alpha) = 1$  and  $\mathcal{UBR}(s, \emptyset, \alpha) = 1$ , then axiom set relevant to  $l_s$  or  $u_s$  in  $\mathcal{O}$  is the superset of essential  $\alpha$ -module in  $\mathcal{O}$ ,  $\mathcal{O}_e \subseteq \mathcal{LR}(s, \mathcal{O}) \cup \mathcal{UR}(s, \mathcal{O})$ .*

*$BMod(s, \alpha, \mathcal{O})$  is used to denote the above  $s$  boundary-based  $\alpha$ -module in  $\mathcal{O}$ .*

*Proof.*  $\mathcal{O} \models \alpha$  if  $\forall \mathcal{I} \in model(\mathcal{O}), a_s^\mathcal{O}(\mathcal{I}) \subseteq a_s^\alpha(\mathcal{I})$ . Based on the relationship between available interpretation and boundary, to test  $a_s^\mathcal{O}(\mathcal{I}) \subseteq a_s^\alpha(\mathcal{I})$ , we just need to test if boundary of  $s$  satisfies:  $\forall l_s^\mathcal{O}[i], u_s^\mathcal{O}[i], \exists l_s^\alpha[j], u_s^\alpha[j], l_s^\mathcal{O}[i] \supseteq l_s^\alpha[j] \wedge u_s^\mathcal{O}[i] \subseteq u_s^\alpha[j]$ , when  $\alpha$  is only relevant to the lower boundary of  $s$ ,  $u_s^\mathcal{O}[i] \subseteq u_s^\alpha[j]$  is always satisfied as  $u_s^\alpha = \Delta^{\mathcal{I}}$  or  $\Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}$ . So axioms which is relevant to the lower boundary of  $s$  in  $\mathcal{O}$  provide all the information to test if  $l_s^\mathcal{O}[i] \supseteq l_s^\alpha[j]$ . Hence, the lower boundary relevant axiom set includes  $\mathcal{O}_e$ ,  $\mathcal{UR}(s, \mathcal{O}) \supseteq \mathcal{O}_e$ . Other situation can be proved analogously.

Based on the above proposition, we compute a exact  $\alpha$ -module in  $\mathcal{O}$  by intersecting all boundary-based module of symbols in  $\alpha$ , it is formalized as following:

**Proposition 5 (Intersection Operation)** *Given a reasoning task  $\mathcal{O} \models \alpha$ , in which  $\mathcal{O}$  is an ontology and  $\alpha$  is an axiom, then intersection of all boundary-based module is an  $\alpha$ -module in  $\mathcal{O}$ ,  $\bigcap_{s \in Sig(\alpha)} BMod(s, \alpha, \mathcal{O}) \in module(\alpha, \mathcal{O})$ , we name it the intersection boundary-based  $\alpha$ -module in  $\mathcal{O}$ , denoted by  $IBMod(\alpha, \mathcal{O})$ .*

*Proof.* For every  $s \in Sig(\alpha)$ ,  $BMod(s, \alpha, \mathcal{O})$  contains essential axiom-based module for  $\alpha$  in  $\mathcal{O}$ . Based on the properties of essential axiom-based module, the intersection boundary-based  $\alpha$ -module in  $\mathcal{O}$  is  $\alpha$ -module in  $\mathcal{O}$ .

### 4.4 Calculation of the Boundary Relevant Axiom Set

Direct and indirect boundary relevance are used to calculate the boundary relevant axiom set in this subsection. We will firstly introduce the method for testing the direct boundary relevance between axioms and symbols, then show calculation of boundary relevant axiom set can be transformed into testing the direct boundary relevance.

**Proposition 6 (Testing Direct Boundary Relevance)** *Let  $\alpha$  be an axiom and  $s$  be a symbol in  $\alpha$ . Interpretation of  $s$  is set to the empty set (universe set) and  $\alpha$  is changed to  $\alpha^*$ . We test whether  $\alpha$  implies  $\alpha^*$ . If  $\alpha \models \alpha^*$ , then  $\alpha$  is not directly relevant to  $l_s(u_s)$ ; else  $\alpha$  is directly relevant to  $l_s(u_s)$ .*

*Proof.* We prove the correctness of testing the direct lower boundary relevance, and the upper situation can be proved using the similar way. If  $\alpha \models \alpha^*$ , then  $model(\alpha) \subseteq model(\alpha^*)$ , which means, for any model  $\mathcal{I}$  of  $\alpha$ ,  $\forall \mathcal{I} \in model(\alpha)$ , when all interpretation of other symbols in  $Sig(\alpha) \setminus s$  remain unchanged,  $s^{\mathcal{I}}$  can be the empty set,  $\emptyset \in a_s^\alpha(\mathcal{I})$ . Thus  $l_s$  is not changed,  $\mathcal{L}(\mathcal{U})\mathcal{BR}(s, \emptyset, \alpha) = 0$ . If  $\alpha \not\models \alpha^*$ , this means, there exists at least one model  $\mathcal{I}^*$  of  $\alpha$ ,  $\exists \mathcal{I}^* \in model(\alpha)$ , when interpretation of other symbols in  $Sig(\alpha) \setminus s$  is given a specific value,  $s^{\mathcal{I}^*}$  cannot be the empty set,  $\emptyset \notin a_s^\alpha(\mathcal{I}^*)$ . Hence  $\alpha$  is directly relevant to  $l_s$ .

A syntactical method for DL  $\mathcal{EL}^{++}$  is given as following:

**Lemma 2 (Syntactically Direct boundary relevance testing for  $\mathcal{EL}^{++}$ )** *Let  $\alpha$  be an  $\mathcal{EL}^{++}$  axiom, which has the following types:*

$C \sqsubseteq D, r_1 \circ \dots \circ r_k \sqsubseteq r, dom(r) \sqsubseteq C, ran(r) \sqsubseteq C, \{a\} \sqsubseteq C$  and  $\{a, b\} \sqsubseteq r^6$  in which  $C$  and  $D$  are concepts,  $r$  is a role,  $a$  and  $b$  are individuals. Let  $\alpha_L$  be all symbols in the left side of operator  $\sqsubseteq$  in  $\alpha$ ,  $\alpha_R$  be all symbols in the right side.

*Then  $\alpha$  is directly relevant to upper boundary of symbols in  $\alpha_L$ , and relevant to lower boundary of symbols in  $\alpha_R$ .*

Calculation of the axiom set relevant to the boundary of  $s$  can be divided into computation of direct and indirect boundary relevant axiom set. Firstly direct boundary relevant axiom set is computed using proposition 6; Secondly, for every axiom  $\alpha$  in directly boundary relevant axiom set, we calculate axioms which are indirectly relevant to the boundary of  $s$  by influencing available interpretation of symbols in  $\alpha$ .

Axioms indirectly relevant to the boundary of  $s$  by influencing available interpretation of symbols in  $\alpha$  are contained in the boundary relevant axiom set of symbols in  $Sig(\alpha)$ , we can analyze these axioms and remove those irrelevant to the boundary of  $s$ , the remains are considered as indirectly relevance to boundary of  $s$ , the process can be transformed into testing direct boundary relevance.

**Proposition 7 (Indirect Relevance Testing  $\Rightarrow$  Direct Relevance Testing)** *Let  $\alpha$  be an axiom,  $s, t$  be two symbols in  $\alpha$ , and  $\alpha$  is directly relevant to the boundary of  $s$ .*

1) *If  $\alpha$  is not directly relevant to  $l_t(u_t)$ , then axioms which are not relevant to  $l_t(u_t)$  are not indirectly relevant to the boundary of  $s$  by influencing  $a_t^\alpha$ .*

2) *If  $\alpha$  is directly relevant to the  $l_s(u_s)$  and  $l_s^\alpha(u_s^\alpha)$  is unique, then axioms which are relevant to the  $u_s(l_s)$  are not indirectly relevant to the  $l_s(u_s)$  by influencing  $a_s^\alpha$ .*

<sup>6</sup> We use  $\{a\} \sqsubseteq C$  and  $\{a, b\} \sqsubseteq r$  to denote  $C(a)$  and  $r(a, b)$ .

*Proof.* We prove the correctness of testing the indirect lower boundary relevance, and the upper situation can be proved using the similar way.

1) Axiom  $\alpha$  is not directly relevant to  $l_t$ , so for any model  $\mathcal{I}$  of  $\alpha$ , when change  $t^{\mathcal{I}}$  to the empty set, interpretation of other symbols can keep unchanged, and  $s^{\mathcal{I}}$  remain the same. And if an axiom  $\beta$  is not relevant to  $l_t$ , according to the definition of relevance between axiom and symbol, let  $\mathcal{O}$  be  $\{\alpha\}$ , then  $\forall \mathfrak{M}^{\mathcal{I}\beta}, t^{\mathcal{I}\beta}$  can be empty set. Since when  $t^{\mathcal{I}\beta} = \emptyset$ ,  $s^{\mathcal{I}\beta}$  can be  $s^{\mathcal{I}}$ . Thus,  $\forall \mathfrak{M}^{\mathcal{I}\beta}, \forall l(u)_s^{\mathcal{O}}[i], \exists l(u)_s^{\mathcal{O} \cup \{\beta\}}[j], l(u)_s^{\mathcal{O}}[i](\mathcal{I}) = l(u)_s^{\mathcal{O} \cup \{\beta\}}[j](\mathcal{I}^{\mathcal{I}\beta}), \mathcal{I} \in \mathfrak{M}, \mathcal{I}^{\mathcal{I}\beta} \in \mathfrak{M}^{\mathcal{I}\beta}, i, j = 1, 2, \dots$ , the axiom is not indirectly relevant to the boundary of  $s$  by influencing the  $a_t^\alpha$ .

2) Let  $\beta$  be an axiom which is relevant to  $u_s$ , if  $l_s^\alpha$  is unique, then  $l_s^\alpha \subseteq u_s^\beta$ , so  $\beta$  is not indirectly relevant to  $l_s$  by influencing  $a_s^\alpha$ .

If lower boundary of  $s$  is nonunique,  $\beta$  may influence some lower boundaries of  $s$ . Example 6: Let  $\alpha$  be  $C \sqsubseteq \exists r.D$ ,  $\beta$  be  $domain(r) \sqsubseteq E$  and an model  $\mathcal{I}$  of  $\alpha$  and  $\beta$ ,  $\mathcal{I} := \{\Delta^{\mathcal{I}} = \{1, 2, 3\}, C = \{1\}, D = \{2, 3\}, E = \{3\}, r = \{(1, 3)\}\}$ . It is easy to see  $\alpha$  only directly influences  $l_r$ , and  $\beta$  only directly influences the  $u_r$ . In  $\alpha$ ,  $l_r^\alpha(\mathcal{I}) = \{(1, 3)\}$  or  $\{(1, 2)\}$ , but in  $\{\alpha, \beta\}$ ,  $l_r^{\{\alpha, \beta\}}(\mathcal{I}) = \{(1, 3)\}$ . This is because  $l_r^\alpha$  is nonunique,  $\beta$  can influence  $l_r$  through  $\alpha$ .

According to the above proposition, calculation of boundary relevant axiom set is changed to an iterative process for testing direct boundary relevance, as described in algorithm 1. Note that we can firstly compute all the direct boundary relevance between symbols and axioms offline, then the boundary-based module can be fast obtained.

## 5 Implementation and Experiment

### 5.1 Implementation in DL $\mathcal{EL}^{++}$

We use Pellet<sup>7</sup> and OWLAPI<sup>8</sup> to implement the boundary-based module extraction method in a weakly acyclic DL  $\mathcal{EL}^{++}$ . As analyzed above, calculation for axiom-based module can be transformed into testing the direct boundary relevance and uniqueness. Given an axiom  $\alpha$ , and a symbol  $s$  in  $\alpha$ , lemma 2 is used to testing the direct boundary relevance. When testing the uniqueness, according to the semantic of  $\mathcal{EL}^{++}$  languages, only in axiom type  $C \sqsubseteq \exists r.D$ ,  $r$  and  $D$  have nonunique boundary. It is easy to observe that  $l_r$  and  $l_D$  are nonunique in  $C \sqsubseteq \exists r.D$ . If  $D$  is a complex boundary, the corresponding boundary of every symbol in  $Sig(D)$  is nonunique.

### 5.2 Evaluation

We compare *IBMod* with minimal axiom-based module (*mMod*) and essential axiom-based module (*eMod*)<sup>9</sup>. We select several real-world  $\mathcal{EL}^{++}$  ontologies that has been

<sup>7</sup> <http://pellet.owldl.com/>

<sup>8</sup> <http://owlapi.sourceforge.net/>

<sup>9</sup> *mMod* is a justification, *eMod* is the unification of all justifications. We use DefaultExplanationGenerator in Pellet to get the *mMod*, and implement *eMod* extraction based on *mMod*.



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**Algorithm 1:** Calculation of  $\mathcal{LR}(s, \mathcal{O})$  or  $\mathcal{UR}(s, \mathcal{O})$ :  $\text{calBR}(s, \mathcal{O}, b, \text{Rec})$

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**Input** :  $s$ : symbol;  
 $\mathcal{O}$ : ontology;  
 $b$ : boolean value, "0" and "1" denote lower or upper boundary;  
 $\text{Rec}$ : Records represent which symbol's boundary has been processed.

**Output:**  $R$ : Set which includes  $\mathcal{LR}(s, \mathcal{O})$  or  $\mathcal{UR}(s, \mathcal{O})$

```

1 begin
2   According to  $b$ , computing  $\mathcal{DLB}(s, \mathcal{O}) \rightarrow R$  or  $\mathcal{DUB}(s, \mathcal{O}) \rightarrow R$ ;
3   for every axiom  $\alpha$  in  $R$  do
4     if The current computing boundary of  $s$  is nonunique and  $(s, \neg b) \notin \text{Rec}$ 
5       then
6          $R = R \cup \text{calBR}(s, \mathcal{O}, \neg b, \text{Rec}), (s, \neg b) \rightarrow \text{Rec}$ ;
7       end
8       for every symbol  $t \in \text{Sig}(\alpha) \setminus \{s\}$  do
9         if  $\mathcal{UBR}(t, \emptyset, \alpha) = 1 \wedge (t, 0) \notin \text{Rec}$  then
10           $R = R \cup \text{calBR}(t, \mathcal{O}, 0, \text{Rec}), (t, 0) \rightarrow \text{Rec}$ ;
11        else if  $\mathcal{LBR}(t, \emptyset, \alpha) = 1 \wedge (t, 1) \notin \text{Rec}$  then
12           $R = R \cup \text{calBR}(t, \mathcal{O}, 1, \text{Rec}), (t, 1) \rightarrow \text{Rec}$ ;
13        end
14      end
15    end
16  return  $R$ ;
17 end

```

---

successfully applied in many applications, the test suite<sup>10</sup> comprises SUMO<sup>11</sup>, NCI<sup>12</sup>, and GO<sup>13</sup>. Axioms  $C \sqsubseteq D$  are generated from the above ontologies. All ontology classification axioms in SUMO is collected<sup>14</sup>. As NCI and GO contain too many  $C \sqsubseteq D$  axioms, we randomly generate 5000 entailed axioms and 500000 not entailed axioms. Entailment information is described in the second and third column of Table 1.

In Table 1, information of  $IBMod$  is illustrated in the fourth and fifth column, which includes number of not entailed axioms whose  $IBMod$  is not empty, which means it is not equal to  $mMod$  and  $eMod$ , plus the average size of those module; and average size of  $IBMod$  for entailed axioms. Average size of  $eMod$  and  $mMod$  for entailed axioms are described in the last two columns.

<sup>10</sup> SUMO and NCI are weakly acyclic ontologies, and there is only one cyclic axiom in GO ontology, which is a transitive role, we remove it from GO.

<sup>11</sup> <http://www.ontologyportal.org/>

<sup>12</sup> <http://www.mindswap.org/2003/CancerOntology/>

<sup>13</sup> <http://www.geneontology.org/index.shtml>

<sup>14</sup> Axioms which are already included in  $\mathcal{O}$  are eliminated.

Table 1: Comparison information between *IBMod* and optimal module on  $\mathcal{O} \models C \sqsubseteq D$ 

Ont.	entailment Inf.		<i>IBMod</i>		<i>eMod</i>	<i>mMod</i>
	Num of $\mathcal{O} \models \alpha$	Num of $\mathcal{O} \not\models \alpha$	$\mathcal{O} \not\models \alpha$ nonempty (Num./Avg. Size)	Avg. Size for $\mathcal{O} \models \alpha$	Avg. Size for $\mathcal{O} \models \alpha$	Avg. Size for $\mathcal{O} \models \alpha$
SUMO	3462	392112	0	4.92	4.92	4.20
NCI	5000	500000	242(0.048%)/33.43	12.20	7.93	4.51
GO	5000	500000	142(0.028%)/25.15	10.53	7.31	3.92

Results show that *IBMod* is very close to the *eMod*. *IBMod* is almost optimal for not entailed axioms, *IBMod* which is not empty only account for a very small proportion. For entailed axioms, *IBMod* is very close to the essential module. As our minimal minimal boundary-based module is an approximated approach for essential axiom-based module, the *IBMod* is not very close to the minimal module, however it is small enough for optimizing reasoning.

## 6 Conclusion and Future Work

In this paper, we described an exact and compact axiom-based approach extraction method by analyzing the relationship between axioms and boundaries of interpretations of symbols. In the future, we will extend our method to test more complex ontologies.

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## Rule Based Business Process Execution with BPEL+

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**Abstract:** While WS-BPEL addresses the industry's need for rich and standard service orchestration semantics it provide only limited expressiveness to describe (business) decision logic and conditional reaction logic. In this paper we propose a heterogeneous service-oriented integration of rules into BPEL to describe rule-based business processes and implement a distributed rule inference service middleware using rule engines which are deployed as distributed web-based inference services on an ESB. This declarative rule-based Semantic BPM (SBPM) approach aims at agile and adaptive business process execution via rules.

**Key Words:** BPM

**Category:** I.2, I.2.4, I.2.11

### 1 Introduction

Business Process Management (BPM) is considered as an effective approach to achieve business agility and flexibility. BPM solutions support simulating, modeling, executing, monitoring, and managing key business processes by abstracting the underneath IT infrastructure, IT service and application logic, and other aspects of IT. BPM can be realized in a top-down approach, where processes are first modeled and simulated and then deploy into the runtime environment. Or, in a bottom-up approach, as part of a Service-Oriented Architecture (SOA) transformation of the enterprize applications into modular business services, that can be easily integrated and reused in business processes - thereby creating a flexible, adaptable IT infrastructure. The explicitly modeled business processes can be reused, changed easily in response to new business requirements, and they enable real-time business activity monitoring.

Over the years, the Web Services Business Process Execution Language (WS-BPEL 2.0 or BPEL for short) has been broadly adopted as automated execution standard for the orchestration of Web Services into business processes. BPEL describes processes as activities performed by web services within a control flow which is orchestrated by the BPEL execution environment. However, typical business processes often include a number of decision points which effect the process flow; for example, a customers spending in the last year may determine whether he or she will get a discount or not. These decisions are evaluated based on certain events, conditions and facts, which may be internal or external to

the business process, and may be predefined company policies or business rules. BPEL's expressiveness for representing such conditional decision logic is rather limited to simple qualifying truth-valued conditions (without e.g. declarative rule chaining, variable binding, etc.).

In recent years we have seen the rise of a new type of software called business rule management systems (BRMS) which allow enterprise architects to easily define, manage, update and run the decision logic that directs enterprise applications in a Business rules engines (BRE) without needing to write code or change the business processes calling them. This addresses an urgent need businesses do have nowadays: to change their business rules in order to adapt to a rapidly business environment, and they contribute to agility in SOAs by enabling reduced time to automate, easier change, and easier maintenance for business policies and rules.

Early manifestations of BREs which have their roots in the realm of artificial intelligence and inference systems were complex, expensive to run and maintain and not very business-user friendly. New rule standards such as OMG SBVR, OMG PRR, W3C RIF / RuleML and improved technology providing enhanced usability, scalability and performance, as well as less costly maintenance and better understanding of the underlying semantics and inference systems makes the current generation of BREs and rules technology more usable. Business rules have been used extensively in enterprises, e.g., to implement credit risk assessment in the loan industry (what is the interest rate for my car loan?), yield management in the travel industry (what price to sell a ticket?), operations scheduling in manufacturing (what should we build today to maximize throughput and keep customers happy?), etc.

In this paper we describe a heterogeneous service-oriented combination of BPM technology and rule technology which incorporates BREs as inference / decision web services into the BPEL process logic (BPEL + Rules). While BPM enables automated and flexible business processes, declarative rules enable decision logic, reaction logic for processing complex events (CEP) and for reacting to them, and various types of constraints. While WS-BPEL addresses the industry's need for rich and standard service orchestration semantics, declarative rules address event-based, message driven, decentralized choreography semantics. The inference services, which run a BRE, are deployed on an enterprise service bus (ESB) and can be invoked by the BPEL process as semantic web services (SWS), using one of the many transport protocols supported by the ESB middleware.

This service-oriented rule-based approach has the potential to profoundly change the way IT services are used and collaborate in business processes. Akin to multi-agent systems (MAS) the rule-based logic inference layer which wraps the existing web services and data sources allows for semi-autonomous decisions and reactions to complex events detected by the rule-based event processing

logic. The combination of rules with ontologies gives precise semantics to used concepts such as processes, events, actions, tasks, state, time etc. Different rule inference services can communicate in (agent-based) conversations via messaging reaction rules, which enables them to build agent-based choreography workflows, that can be used as external subprocesses in the main orchestrated BPEL process. Potential application scenarios of BPEL+Rules for BPM are, e.g.:

- Dynamic processing
  - Intelligent routing
  - Validation of policies within process
  - Constraint checks
- Ad-hoc Workflows
  - Policy based task assignment
  - Various escalation policies
  - Load balancing of tasks
- Business Activity Monitoring
  - Alerts based on certain policies and complex event processing (rule-based CEP)
  - Dynamic processing based Key Performance Indicator (KPI) reasoning

In this paper we contribute with a declarative rule-based service-oriented business process execution approach exploiting WS-BPEL in combination with Corporate Semantic Web (CSW) technologies (semantic rules, ontologies and events/actions) and a scalable ESB middleware to operationalize such a distributed rule-based approach. Rule-based reaction logic for event processing and event messaging, and rule-based decision logic in combination with ontologies play a central role in connecting the various IT resources, human and knowledge resources, and Web-based services to agile business service networks. Ultimately, our novel rule-based design artifact might put the vision of highly flexible and adaptive Internet of Services supply chains / enterprise service networks into large scale practice and will lead to a highly flexible and agile BPM.

This combination of semantic technologies, i.e. declarative rules, ontologies and semantic event/action logics, with BPM, which leads to Semantic Business Process Management (SBPM) promises:

- enhanced automation in semantic discovery, configuration and composition of appropriate process components, information objects, and services (including human agents)

- automated mediation between different heterogeneous interfaces (e.g. semantic web services) and abstraction levels
- targeted complex queries on the process space and the process flow and state
- much more agile business process management via expressive rule-based decision and reaction logic

The key benefits of our approach are:

- use of complementary technologies: semantic technologies for representing rules, events, actions, state, etc. + BPM technologies
- standard-compliant use of WS-BPEL for orchestration of services as well as people and partners implemented as external semantic web services or semantic agents (having a precise meaning/semantics defined for their interfaces)
- clear separation of concerns:
  - BPEL is used for orchestration in the business process
  - rules for declarative specification of constantly changing business policies and regulations
  - rules focus on decision making, policies and rule-based event processing for building complex events of higher level of abstraction and relevance for the business process
  - rules can be used to integrate choreography sub-workflows in orchestrated BPEL processes
- enables business users to participate in business processes and in adapting business rules
- modify and apply new business rules without redeploying processes
- declarative semantics for processing events, actions, rules, state etc. (including logic for transactions, compensations etc.)

The rest of the paper is organized as follows: In section 2 we give an overview of the relevant concepts. In section 3 we discuss what is missing in BPM with respect to semantics and rules. In section 4 we introduce the heterogeneous service-oriented integration approach for adding rules to BPEL. In section 5 we implement this integration approach with a highly scalable and efficient rule-based inference ESB middleware. Section 6 concludes this paper and gives an outlook on our ongoing efforts to integrate humans by means of rule-based agents.

## **2 Background**

In this section we give an insight into the applied technologies and define relevant concepts and technologies.

### **2.1 Service Oriented Computing**

The computing paradigm that utilizes services for developing applications in open distributed environments such as the Web is known as Service Oriented Computing (SOC). The vision is to build large scale service supply chains (also known as enterprize services networks) which enable enterprizes to define and execute web services based transactions and business processes across multiple business entities and domain boundaries using standardized (web) protocols. Web services, which emerged in the last time as the prevailing technology for implementing IT services on the web, have received a great commitment from industry. A service-oriented architecture (SOA) expresses a perspective of software architecture that defines the use of loosely coupled software services to support the requirements of the business processes and software users. In a SOA environment, resources on a network are made available as independent services that can be accessed without knowledge of their underlying platform implementation. A SOA is not tied to a specific technology. It may be implemented using a wide range of technologies, including REST, DCOM, CORBA or Web Services. Service Component Architecture (SCA) is a set of specifications which describe a model for building applications and systems using a SOA. Recently, semantic web services (SWS), which provide an approach for semantically representing the functionality and interfaces of Web Services with the help of semantic technologies (ontologies and rules), attracted much attention from industry.

### **2.2 Complex Event Processing**

Complex Event Processing (CEP) allows real-time detection and processing of complex events from typically huge amounts of smaller (raw/atomic) events (e.g. from an event cloud or event stream). Rule-based CEP (aka intelligent CEP) exploits reaction rule technologies for event processing using, e.g., event algebras to describe the complex event types which trigger reaction rules (e.g. Event-Condition-Action (ECA) rules or event-driven production rules). Rule-based CEP often supports situation detection (detecting transitions in the universe that requires reaction either "reactive" or "proactive"), pre- and post-conditions, and (transactional) action logics (complex actions).

### **2.3 Declarative Rule Programming**

Rule systems have been investigated comprehensively in the realms of declarative programming and AI over the last two decades. Using declarative (inference) rules

has several advantages: reasoning with rules is based on a semantics of formal logic and it is relatively easy for the end user to write rules. The basic idea is that users employ rules to express *what* they want, the responsibility to interpret this and to decide on *how* to do it is delegated to an interpreter (e.g., an inference rule engine or a just in time rule compiler). There are different types of rules reaching from derivation rules, transformation rules to reaction rules and integrity rules / constraints.

## 2.4 Semantic Technologies

Semantic technologies aim at the formal representation of knowledge with clear, typically logic based semantics which allows for inference and reasoning, hence providing machine-readability and interpretability of data. The two major building blocks in semantic technologies are:

1. Ontologies which represent the conceptual knowledge of a domain and its meaning (semantics). Ontologies can be used, e.g. to represent business domain vocabularies, meta-models and meta-data
2. Rules which derive conclusions from given knowledge (derivation rules), which are logical constraints, or rules which process events/actions/state on the basis of a formal logic-based semantics

## 3 State of the Art in non-semantic BPM

Current BPM languages, such as BPMN 1.2 for modeling and WS-BPEL 2.0 for execution, are mostly syntactic process specification languages without a precise declarative formal logic semantics. This allows for ambiguities in the interpretation of models and specific functionalities such as compensations or exceptions. It hinders the integration of, e.g., rule inference services or humans via people link interactions. Modeling languages and models become incompatible and are no longer interchangeable. For instance, there are problems with model-to-model transformations and round-tripping, e.g. between BPMN and BPEL and vice versa. There is also a semantic gap between the business world and the IT world which use different vocabularies to describe the models and have different requirements on the abstraction level. The inner semantics of activities and their effects cannot be represented semantically in the current BPM approaches, which makes it hard to analyze and understand the business process behavior and the effects on the process states, beyond the pure functional description of the orchestration flow and the invoked web service interfaces. Agile business decisions in terms of business rules, complex event-driven behavior, and choreography interactions cannot be semantically integrated into BPEL.



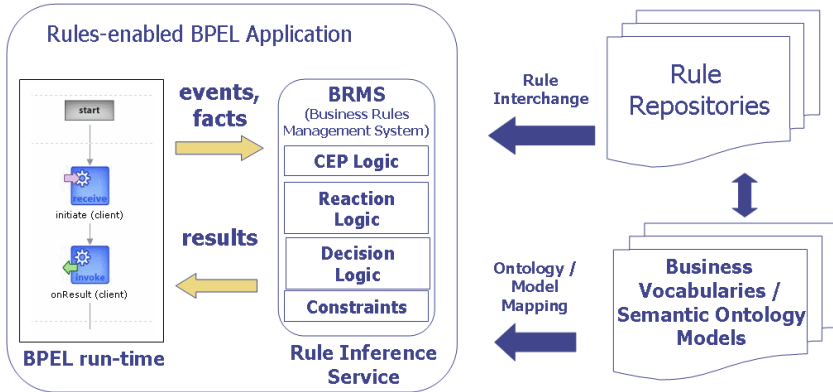


Figure 1: Heterogenous Integration of Rule Inference Services into BPEL Processes

What is missing for the semantic enrichment of BPM, i.e. for SBPM, is the integration of ontologies for events, processes, states, actions, and other concepts that relate e.g. to change over time into the BPEL definitions. With ontologies the processes and their causalities and roles would be precisely defined by logic. This would also make rules or logic that govern processes or react to events truly declarative knowledge which can be used in the processes for decisions and ad-hoc reactions. It would increase the ability to interchange semantic models across major BPM and BRMS vendors and would allow reusable, enterprise-relevant knowledge such as business policies and business vocabularies to be used in BPM models.

In this paper we will mainly focus on the heterogenous integration of rules technology with BPEL and will not specifically address ontologies for BPM and CEP which must relate processes, events, states, and actions, must include tense (past, present and future; perfected and progressive), time intervals with quantities (units, duration, composition, conversion and accuracy), etc.

#### 4 Integration of Rules in Business Processes Execution

In this section we describe a heterogenous integration approach of rules into service-oriented BPEL processes. Rules are integrated as external distributed rule inference services. This means they are not directly part of the BPEL process (homogenous integration), but are integrated by invoking the inference service (heterogenous integration) which runs a rule engine and executes the rule logic.

Figure 1 illustrates this integration approach. A BPEL decision activity invokes a rule inference service sending event or fact data (e.g. queries) to the rule engine. The rule engine processes the received data according to its internal

rule-based logic. The results might be, e.g. derived answers (e.g. decisions) on the queries of the BPEL process, or they might be actions which are triggered by the reaction rule-based processing of the events from the BPEL process.

The concrete steps in this approach are

1. Create a rule inference service with rule repository and define the semantic interface description of the inference service
2. Create a new inference service Partnerlink, choose a rule connection and choose an interaction pattern and the parameter bindings
3. Add a rules Activity which invokes the rule inference service; Bind BPEL variables to parameters of the Partnerlink

During the process execution the BPEL engine will invoke the rule inference service mapping the BPEL variables to the input facts / events and the result from the rule inference service. It is possible to implement different stateful and stateless interaction patterns between the BPEL process and the inference service.

## 5 Implementation of the BPEL+ Rules Approach

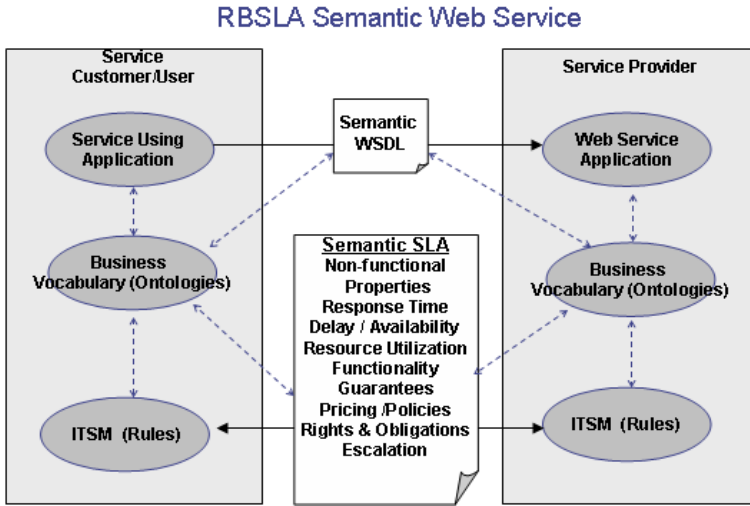
In this section we will implement the proposed heterogenous BPEL+Rules integration approach and describe the main technical components.

### 5.1 Rule-based Semantic Web Services

In order to use rules for BPEL a BRMS, which manages and executes the rule logic with an internal BRE, is provided as Semantic Web Services (SWS). A SWS is a Web Service which in addition to its syntactic interface description (WSDL) is extended with semantic information, for semantic discovery, selection, invocation and composition. SWSs have received quite a lot of attention in the last years and many different approaches exist, e.g. OWL-S (former DAML-S), WSDL-S, SAWSDL, SWWS / WSMF, WSMO / WSML, Meteor-S, SWSI, etc. In [Pas07] we have implemented a rule-based SWS approach which in addition to the semantic interface descriptions of the service allows representing non-functional properties of the service, in terms of a Rule-based Service Level Agreement (RBSLA) - see figure 2.

For instance, a rule set from a Service Level Agreement might define three different IT Service Level Management schedules (see ITIL ITSLM process):

```
if current time between 8am and 6pm then prime schedule.
if current time between 6pm and 8am then standard schedule.
if current time between 0am and 4am then optional maintenance schedule.
```



**Figure 2:** RBSLA Semantic Web Services

```

if prime schedule then the service level "average availability"
has a low value of 98%, a median of 99% and a high value of 100%
and a response time which must be below 4 seconds.
...
if standard schedule then the responsible role for service outages
is the second admin.

```

As shown in the RBSLA project [Pas07] such rule sets can be adequately represented as logic programs and easily extended with further rules, e.g. rules describing escalation levels and deontic norms such as certain obligations if service levels are missed.

The additional semantic information provided by RBSLA service descriptions is used for effectively invoking the inference services from the BPEL process, e.g. invoke a inference service which provides the requested decision functionality and the required quality of service (QoS).

## 5.2 Prova - A Semantic Rule Engine

Prova (<http://prova.ws>) [KPS06, Pas07] is both a Semantic Web rule language and a highly expressive distributed rule engine which supports declarative (backward reasoning) decision rules, complex reaction rule-based workflows, rule-based complex event processing (CEP), and dynamic access to external data sources such as databases, Web services, and Java APIs. It has a typed logic approach which allows to use external ontologies or Java class hierarchies as type system for the rules. Prova follows the spirit and design of the W3C Semantic

Web initiative and combines declarative rules, ontologies (vocabularies) and inference with dynamic object-oriented programming and access to external data sources via query languages such as SQL, SPARQL, and XQuery. One of the key advantages of Prova is its elegant separation of logic, data access, and computation as well as its tight integration of Java, Semantic Web and event processing technologies. It semantics draws on backward-reasoning logic programming (LP) concepts to formalize decision logic in terms of derivation rules and combines them with forward-directed messaging reaction rules for distributed event and action processing in order to exploit the benefits of both worlds.

Messaging reaction rules in Prova describe processes in terms of message-driven conversations between inference agents / services and represent their associated interactions via constructs for asynchronously sending and receiving event messages. Choreography interaction flows between distributed Prova inference agents/services are defined by the order of sending and receiving message constructs in messaging reaction rules. Messaging reaction rules maintain local conversation states which reflect the different activity flows and support performing them within in simultaneous conversation or sub-conversation branches.

The main language constructs of messaging reaction rules (as implemented in the rule engine Prova [KPS06]) are: *sendMsg* predicates to send outbound messages, reaction *rcvMsg* rules which react to inbound messages, and *rcvMsg* or *rcvMult* inline reactions in the body of messaging reaction rules to receive one or more context-dependent multiple inbound event messages:

```
sendMsg(XID,Protocol,Agent,Performative,Payload |Context)
rcvMsg(XID,Protocol,From,Performative,Paylod|Context)
rcvMult(XID,Protocol,From,Performative,Paylod|Context)
```

where *XID* is the conversation identifier (conversation-id) of the conversation to which the message will belong. *Protocol* defines the communication protocol such as JMS, HTTP, SOAP, Jade etc. *Agent* denotes the target party of the message. *Performative* describes the pragmatic context in which the message is send. A standard nomenclature of performatives is, e.g. the FIPA Agents Communication Language ACL or the BPEL activity vocabulary. *Payload* represents the message content sent in the message envelope. It can be a specific query or answer or a complex interchanged rule base (set of rules and facts).

For instance, the following messaging reaction rule waits for an inbound query which might come from the invoke request of a BPEL activity: (variables start with upper case letters)

```
% receive query and delegate it to another inference agent
rcvMsg(CID,esb,Requester,acl_query-ref,Query):-
... some conditions finding e.g. another inference agent ...,
sendMsg(Sub-CID,esb,Agent,acl_query-ref,Query),
```

```
rcvMsg(Sub-CID,esb,Agent,acl_inform-ref, Answer),  
... (other goals)...  
sendMsg(CID,esb,Requester,acl_inform-ref,Answer).
```

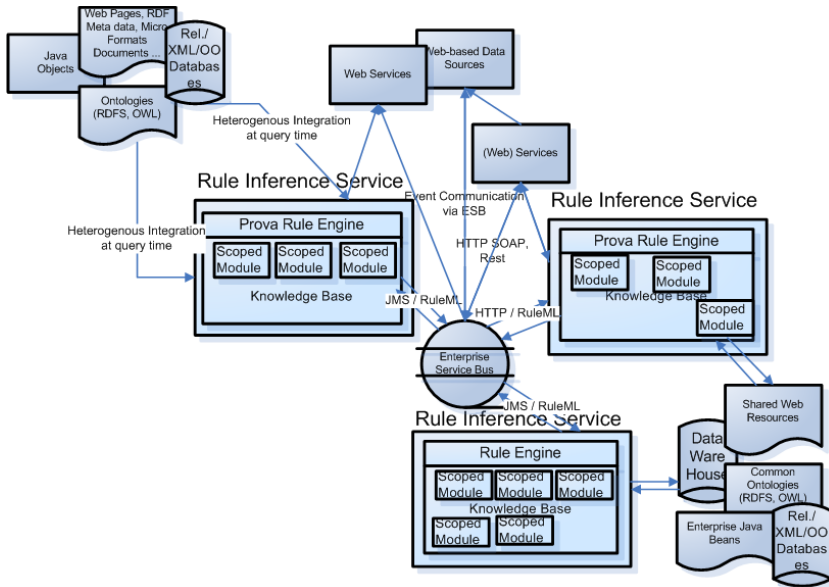
Via logical unification the data from the received inbound message is bound to variables and is used by the conditions in the body of the rule, which act as goals on other derivation rules in the local rule base (so called rule chaining). In the example the rule sends the query in a new sub-conversation (with the unique id Sub-CID) to another agent and waits for the answer. That is, the rule execution blocks at the `rcvMsg` condition in the body until an answer message is received in the inlined sub-conversation (or some timeout occurs), which activates the rule execution flow again, e.g., to prove further subsequent conditions (subgoals) of the rule or start other sub-conversations. Data from the received answers is bound to variables including backtracking to several variable bindings as usual in logic programming. Finally, in this example the rule sends back the answer to the original requesting party, which would be the BPEL process and terminates (finitely succeeds).

That is, the declarative rule-based approach provides an expressive and compact declarative programming language to represent complex event processing logic in arbitrary combination with conditional decision logic implemented in terms of derivation rules. Via sending and receiving event messages it is possible to implement choreography workflows that span several communicating (messaging) rule inference agents / services. With that approach it is possible to implement e.g. petri-net style conversation flows, and all complex event-based workflow patterns (as described, e.g. by Van der Aalst et al. [vdAtHKB03]) such as Join, Simple Merge, Cancel Activity, Multi-Choice, Structured Loop, Milestone can be implemented including also patterns like Deferred Choice which cannot be implemented by orchestration flows.

In summary, the major benefit of the described rule-based approach is the tight integration of standard derivation rules for implementing complex decision logic and messaging reaction rules for implementing behavioral event message based reaction logic, conversation-based interactions and choreography workflows. Complex (business) decision logic, such as business rules, can be implemented in a declarative way in terms of derivation rules (as logic programs) and used to prove conditional goals mixed in arbitrary combinations with send and receive message constructs in messaging reaction rules.

### 5.3 Enterprise Service Bus Middleware

To deploy and execute distributed rule-based inference agents as semantic web services an enterprise service bus middleware is used. We focus on the technical



**Figure 3:** Rule-based Middleware

aspects of the middleware and on the machine-to-machine communication between automated rule inference agents. Figure 3 illustrates the architecture of the ESB middleware.

Several Prova rule engines [KPS06] are deployed as distributed semantic web-based services. Each service runs a local rule base which implements the decision and reaction logic. The rules have access to local applications, data sources (e.g. web services, Java object representations such as EJBs, databases etc.), etc. and use them as local fact bases. The rule agents react to incoming events messages (requests) according to the defined rule-based execution logic. To communicate between the rule inference agents, Reaction RuleML [PKB<sup>+</sup>06] [Bol06], the current de-facto standard language for reactive web rules, is used as common rule interchange format. Translator services translate from Prova execution syntax into Reaction RuleML and vice versa.

To seamlessly handle asynchronous message-based interactions between the Prova rule inference services and with other applications and web-based services an enterprise service bus (ESB), the Mule open-source ESB [Mul06], is integrated as communication middleware. The ESB allows deploying the rule-based agents as distributed rule inference services installed as Web-based endpoints in the Mule object broker and supports the Reaction RuleML based communication via arbitrary transport protocols such as JMS, HTTP, SOAP (more than 30 protocols are supported) between them. That is, the ESB provides a highly

scalable and flexible event messaging framework to communicate synchronously but also asynchronously between services.

## 6 Conclusion

In this paper we have proposed a declarative rule-based approach for executable business processes descriptions in BPEL, where complex conditional decisions, complex event processing (CEP) logic, and choreography workflows are implemented in terms of rules. The rules are heterogeneously integrated into the BPEL process by invoking and executing them as semantic inference services. The rule based logic language combines derivation rules as means to represent conditional decision logic such as business rules with messaging reaction rules to describe conversation based process flow between agents. The conversational interactions take place via event messages. We have implemented a rule-based ESB middleware which deploys Prova rule engines as distributed inference services. At the platform-independent level it uses Reaction RuleML as a compact, extensible and standardized rule and event interchange format between the platform-specific Prova services. A highly scalable and efficient enterprise service bus is integrated as a communication middleware platform and web-based agent/service object broker. The realization of business processes by means of rules provides an expressive orchestration language which forms the technical foundation to integrate the business rules technology with the enterprise service and BPM technology. In summary the key benefits of our rule-based SBPM approach are:

- BPEL for orchestration of services , people and partners
- Rules focus on decision making and policies
- Rules can be used to integrate choreography sub-workflows in orchestrated BPEL processes
- Declarative specification of constantly changing business policies and regulations
- Enables business users to participate in business processes via adapting business rules
- Modify and apply new rules without redeploying processes

The agent model of our rule-based approach can be applied to human agents and provides promising means to integrate people into the BPEL process. In a next step we will implement user-friendly interfaces such as a semantic Process WIKI tool for the integration of humans. The users will communicate with the rule-based agents by adding knowledge-intensive information via the easy to

use WIKI interface, and the rule-based agents, which implement the particular agent role of the human user in the business process, will process and send this knowledge to the BPEL business processes.

### Acknowledgements

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## Towards a Corporate Semantic Web

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**Abstract:** Corporate Semantic Web aims at bringing semantic technologies to enterprises for gaining, managing, and utilizing knowledge as one of the critical resources for their success in a quickly changing and highly competitive world. It provides solutions in three main application areas for semantic technologies, namely semantic engineering, semantic search, and semantic collaboration in cooperations. It does not only address the technological aspects, but also the organizational and pragmatic aspect of actually using semantic technologies in enterprises, which includes learning and training aspects as well as economical considerations in the sense of entrepreneurial usages of Semantic Web technologies. This paper discusses the applications, objectives, challenges and realization of the vision of the Semantic Web in controlled environments of corporations.

**Key Words:** Corporate Semantic Web, Knowledge Management, Collaboration, Semantic Search, Ontology Engineering

**Category:** H.2, H.3.7, H.5.4

### 1 Introduction

Today, pure creation, storage and retrieval of information is no longer a challenge. With highly scalable and efficient Intranet solutions and Web information systems ideal infrastructures for distributed information management exist. Huge amounts of business data are accessible - at every time, distributed from any place, and via standardized service interfaces - however, not necessarily meaningful and pragmatically useful. Here the Semantic Web, which provides machine-readable meaning of information offers promising solutions for corporate knowledge management, but also poses new challenges.

Corporate Semantic Web (CSW) aims at establishing semantic technologies in enterprises. The expected results are an advantage in competition for enterprises. Focusing on the controlled environment in contrary to the global public Semantic Web it avoids facing unresolved problems of the Semantic Web like scalability, broader adoption of commonly shared ontologies, and trust issues.

Aiming at describing the work in progress of the CSW working group at the Free University Berlin<sup>1</sup> this paper is organized as follows. Section 2 introduces application scenarios and objectives we have identified in close cooperation with our industrial partners. Based on these we derived real world gaps (challenges)

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<sup>1</sup> (<http://www.corporate-semantic-web.de>)

towards the adoption of a Corporate Semantic Web in Section 3. In Section 4 the three research areas of CSW are introduced that aim at closing the identified challenges and bringing semantic technologies to enterprises. Finally, section 5 presents a conclusion and an outlook on our ongoing research.

## 2 Application Domains for a Corporate Semantic Web

Derived from interviews with our industrial cooperation partners we see two major application domains for corporate semantic technologies in the enterprise area:

### 1. Automated Semantic (Business) Processes Management

The assumption behind Business Process Management (BPM) is that the uniqueness of an enterprise lies in the way how it manages and executes its business processes. Accordingly, business processes are the most valuable asset of an enterprise. Modern BPM often directly builds IT Service Management (ITSM) which describes the change of information technology (IT) towards service and customer orientation, and IT Infrastructure Management (ITIM) which focuses on planning and efficient and effective delivering of IT services and products while meeting quality of service and security requirements. Corporate Semantic Web (CSW) technologies for semantic business process management (SBPM) provide scalable methods and tools for the machine-readable representation of knowledge, especially rules as a means for declaratively describing business rules and IT policies, and ontologies as a means of capturing a domain of discourse such as a business vocabulary which, for example, might be used in semantic business processes and Semantic Web Services (SWS).

### 2. Knowledge Management

In particular in the realm of corporate collaboration tools, Semantic Web technologies will support semi-automatic knowledge evolution and dynamic access to and integration of distributed, heterogeneous information sources and knowledge consolidation – for example, for trend, enterprise structure, and problem recognition. This will enable the mapping from corporate data and human expert information into explicit knowledge and finally into corporate wisdom stored e.g. in semantic organizational memories supporting e.g. sophisticated semantic search for organizational knowledge.

From our interviews we have identified the following common applications and objectives for the utilization of corporate semantic technologies:

- Intelligent Semantic Search  
Objectives:

- improved relevance of search results with higher precision and recall
  - processing of relations between different search results
  - determining of non explicit unknown correlations
  - automated navigation structures, e.g. for visual navigation of research results in the ontology graph
  - personalized and contextual semantic search
- Declarative Knowledge Representation
- Objectives:
- separation of concerns by separating content from meaning and presentation
  - declarative processing decoupled from the application logics
  - overcome problems of heterogeneous information integration
  - (automated) linking to other relevant information
  - (end) user control including personalization and customization
- Knowledge Transfer and Dissemination
- Objectives:
- right knowledge at the right time, at the right place / for the right person(s)
  - capture expert and organizational knowledge (organizational memory)
  - collaborative work supported by shared knowledge
  - detection of relevant information and situations and triggering of adequate reactions
  - reuse and utilization of knowledge (e.g. in departments, with partners, for customers)
- Advanced Agile Enterprise IT Service Management and Business Process Management
- Objectives:
- enhanced automation in discovery, configuration and composition of appropriate process components, information objects, and services
  - automated mediation between different heterogeneous interfaces and abstraction levels via business ontologies

- targeted complex queries on the process space and flow
- higher quality of service through improved semantic IT Service Management, e.g. by semantic web services and rule-based SLA monitoring
- much more agile business process management via (business) rules

While declarative knowledge representation technologies and tools, such as semantic tagging, wikis, blogs, and collaboration platforms, help collaborating and structuring shared distributed content, companies are also seeking more capable approaches for gaining, managing, and utilizing knowledge required for their agile business processes and dynamic enterprise service networks. Often this requires integration of knowledge-intensive workflows and human activities. Typically, this is problematic due to the purely syntactic functional interface descriptions. For instance, there is a semantic gap between the two worlds - human / knowledge representation vs. automated services and processes management. Corporate Semantic Web technologies allow discovering and transforming existing information into relevant knowledge of practical consequences, trigger automated reactions according to occurred complex events/situations, and derive answers and decisions from distributed information sources. Hence, these technologies are means to bridge between the two worlds.

### 3 Challenges for a Corporate Semantic Web

Early manifestations of Semantic Web technologies which have their roots in the realm of artificial intelligence and inference systems were complex, expensive to run and maintain and not very business-user friendly. Improved technology providing enhanced usability, scalability and performance, as well as less costly maintenance and better understanding of the underlying inference systems makes the current generation of Semantic Web technologies more usable for its application in enterprise settings. However, there are still a number of challenges that have to be taken into account when employing a semantic technologies.

In [Hepp 2007] four bottlenecks causing seldom use of ontologies on the web have been identified and [Delteil et al. 2007] describes several general “Semantic Web Business Gaps” which hinder the broad adoption of the Semantic Web. From our interviews we found out that the four major challenges for realizing the Corporate Semantic Web are:

(G1) Academic orientation gap: Ontologies are mainly considered as the background artifact of Semantic Web applications instead of flexible means for knowledge representation and data integration in processes. Tools for ontology creation only address developers with academic background, but rarely the usability needs of non-expert end-users. There are only few early adopters which

allow the construction of real-world use cases. But, lasting developments and advanced outreach to industry [Deteil et al. 2007] have not taken place, yet. This is partially caused by the lack of ongoing financial support after project funding periods, so that research results are not used in industrial innovation.

(G2) Application maturity gap: In consequence of G1 only very few tools reach a mature development state and become ready for productive use which explicitly address end-user requirements. Additionally, transparent benchmark standards with adequate evaluation criteria and comparability / compliance levels for mature tools are missing (see e.g. [Bizer and Schulz 2008]). This leads to reasonable suspiciousness against the computational performance of large-scale semantics applications in the enterprise world.

(G3) Engineering gap: Most current ontology engineering methodologies focus on ontologies developed for the public Web (e.g. [Sure and Studer 2002], [Pinto et al. 2005], [Fernandez-Lopez et al. 1997], [Surez-Figueroa et al. 2008]). They do not cover cost-effective creation and management of knowledge in small and mid-size companies and neglect the existing applications and organizational structures during ontology development. Agile engineering methodologies for ontologies and rule bases are needed which respect this existing enterprise landscaped, structures and software engineering processes. Several case studies try to prove the applicability of existing methodologies [Tempich et al. 2007] in general but do not specifically address problems in the corporate context.

(G4) Cost-benefit-estimation gap: There is a strong need for companies to estimate the cost-benefit-ratio of developing semantic-based enterprise information systems. Implementing such applications is a difficult time and resource consuming task since the necessary semantic knowledge such as ontologies and rules need to be engineered first. Building comprehensive enterprise ontologies for only one single application can hardly valorize the effort and decision makers need to be supported here by precise cost-benefit ratios.

## 4 Corporate Semantic Web

Corporate Semantic Web addresses both the consumer and the producer side, where consumers and producers might be humans as well as automated services, for example, in business processes and enterprise service networks. This also includes the adequate engineering, modeling, negotiation and controlling of the use of the (meta)data and meaning representations in a (collaborating) community of users or services in enterprise settings where the individual meanings as elements of the internal cognitive structures of the members become attuned to each others view in a communicative / interaction process. This allows dealing with issues like ambiguity of information and semantic choices, relevance of information, information overload, information hiding and strategic information

selection, as well as positive and negative consequences of actions (for example, in a decision making process).

Corporate Semantic Web has two intended meanings:

1. (Collaborative) workflows/processes, communication and knowledge management based on an infrastructure for enterprise networks which uses Semantic Web technologies.
2. Corporate = entrepreneurial usages of Semantic Web technologies (also with respect to total costs and return on investment)

Corporate Semantic Web aims at delivering innovative concepts and solutions for the management of knowledge in electronically organized enterprise environments. It focuses on the development and application of semantic technologies in controlled environments as well as the propagation of novel solutions for knowledge acquisition, provision, and management in corporate contexts (cf. Fig. 1).

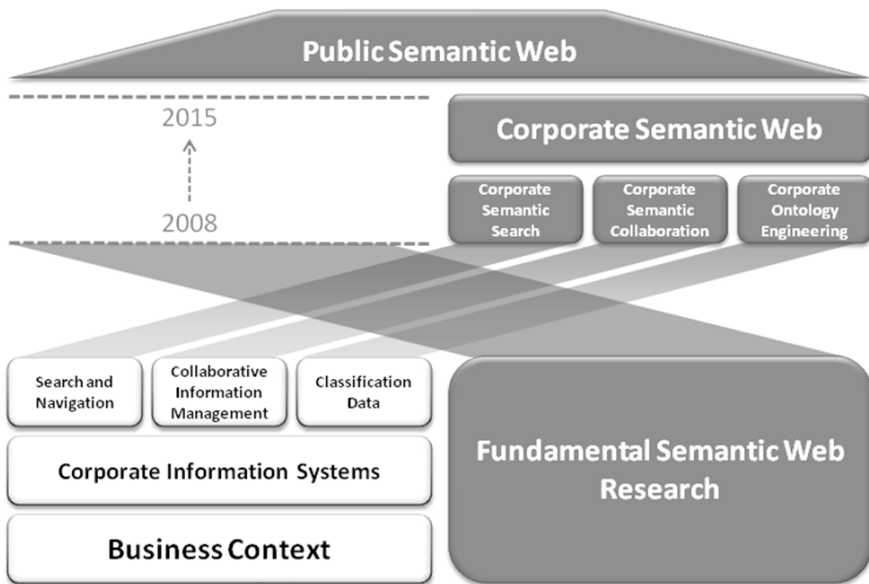


Figure 1: Evolution of the public Semantic Web based on results from Corporate Semantic Web research

The challenges (gaps) are addressed by three research areas:

1. Corporate semantic engineering improves the facilitation of agile ontology engineering to lessen the costs of ontology development and, especially, maintenance.
2. Corporate semantic collaboration focuses the human-centered aspects of knowledge management in corporate contexts.
3. Corporate semantic search is settled on the highest application level of the three research areas and at that point it is a representative for applications working on and with the appropriately represented and delivered background knowledge.

All three parts work together in an integrative Corporate Semantic Web life cycle loop where (1) semantic information is extracted from the existing corporate data (Semantic Search), (2) semantic knowledge such as corporate ontologies or business rules are engineered from this information and semantic-enriched information objects are created (Semantic engineering), and (3) used in collaborative processes and in knowledge-intensive decisions (Semantic Collaboration). These collaborative processes are again semantically analyzed to produce further information bits and in a new loop (1-2-3) are, for example, used to personalize the search and collaboration context.

*Corporate Ontology Engineering* aims on closing the gaps G3 and G4 by realizing ontology engineering in an evolutionary, aspect-oriented and cost-effective way which respects the agility and various aspects of the knowledge engineering and business processes. It comprises investigation on methodologies and tools regarding versioning, modularization and integration of ontologies and rule bases. While modular reuse and integration of existing ontologies reduce the cost and the time to deployment, efficient versioning allows for evolutionary improvement and refinement.

The goal of *Corporate Semantic Collaboration* is to close the gap G1 and G4 by extending the ontology engineering process to domain experts as well as knowledge managers. The evolution of ontologies is enabled by modeling knowledge in a collaborative way using easy-to-use collaborative modeling tools. Mining user activities additionally extends the corporate knowledge by observing users and deriving new knowledge from their workflows.

Finally, the third research area is *Corporate Semantic Search* which aims at closing gap 2. It investigates easy information discovery in both semantic as well as non-semantic data. Utilizing innovative semantic search techniques to facilitate deep analysis of available information by analyzing complex relationships in non-semantic data (i.e. trend mining) as well as providing users with personalized access to corporate information, results of this research will prepare the ground for various semantic-based applications.

## **5 Conclusion and Outlook**

Nowadays, companies seek more capable approaches for gaining, managing, and utilizing knowledge, and the Semantic Web offers promising solutions. While the global Semantic Web remains an unfulfilled vision for the present, the Corporate Semantic Web idea, which we presented in this paper, aims at bringing semantic technologies to enterprises. The expected results are an advantage in competition for enterprises using semantic technologies. In this paper we have discussed promising application domains of Semantic Web technologies in enterprises. In terms of a gap analysis we have introduced the main four challenges towards a Corporate Semantics Web and have identified the three corresponding research areas which address these challenges. Our ongoing research activities in this areas, focusing on the application of semantic technologies within controlled environments, contribute to the further maturing of Corporate Semantic Web technologies.

However, the Semantic Web technology has not arrived in the corporate world, yet. Incentives need to be provided to encourage in-house adoption and integration of these new Corporate Semantic Web technologies into the existing IT infrastructures, services and business processes. Decision makers on the operation, tactical and strategic IT management level need to understand the impact of this new technological approach and its adoption costs and return on investment.

Therefore, companies will have in mind the economical justifiability of the deployment of new technologies. One of the next steps in the Corporate Semantic Web project will be to develop methods for cost estimation of ontology development processes, ontology use, and ontology maintenance that are adaptable to different corporate environments.

Furthermore, methods for evaluating existing ontologies with regard to enterprise relevant usage criteria are needed. Early adopters deploying application-oriented solutions for improving their competitive advantages through enhanced knowledge management of semantically rich data will demonstrate incentives for further corporations to follow and thereby accelerate the realization of a global Semantic Web.

### **Acknowledgements**

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# Ontology Change Management

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**Abstract:** Ontologies evolve continuously throughout their lifecycle to respond to different change requirements. Handling ontology evolution is not a trivial task. In our work, we focus on issues related to ontology change management in a local context, particularly on consistency maintenance and we present in this paper, a pattern-oriented ontology change management approach. The modelled patterns correspond to the three dimensions *change*, *inconsistency* and *resolution alternative*. Based on these patterns and the links between them, we propose an automated process guiding and controlling change application while maintaining consistency of the evolved ontology.

Change management depends closely on the ontology representation model, we focus on OWL language and we consider change impact on logical consistency as specified in OWL DL layer.

**Keywords:** Ontology Evolution, Change Management, Consistency, OWL DL.

**Categories:** I.2.4, I.5.2, M.1, M.2, M.3, M.4

## 1 Introduction

Today, ontologies are finding their way into a wide variety of applications. They offer rich and explicit semantic conceptualizations and reasoning capabilities and facilitate query exploitation and system interoperability. However, just like any structure holding knowledge, they need to be updated as well. Change requirements could be initiated because of environment dynamics, the evolution of the modelled domain, the users' needs may change, adding new knowledge previously unknown or unavailable, correction and refinement of the conceptualization or ontology reuse for other applications.

In our work, we have defined an ontology evolution methodology **ONTO-EVO<sup>4L</sup>** (Ontology-Evolution-Evaluation) driven by a pattern-oriented modelling. The patterns model the three dimensions *change*, *inconsistency* and *resolution alternative*. Based on the modelled patterns and the link between them, we propose an automated process driving change application while maintaining consistency of the evolved ontology. In addition to pattern-oriented modelling, this methodology integrates an evaluation activity supported by an ontology quality model. The quality model is used to guide inconsistency resolution by evaluating the impact of resolution alternatives on ontology quality and choosing the alternative that preserves the quality of the evolved ontology.

The paper is organized as follows: in section 2, we detail the change management process and its different phases. A proposition of change management patterns is described and illustrated in section 3. Before concluding and discussing further developments of this work, we report on related work in section 4.

## 2 Change Management Process

The change management process is organized in four phases [Fig. 1]: change specification, change analysis, change resolution and change application.

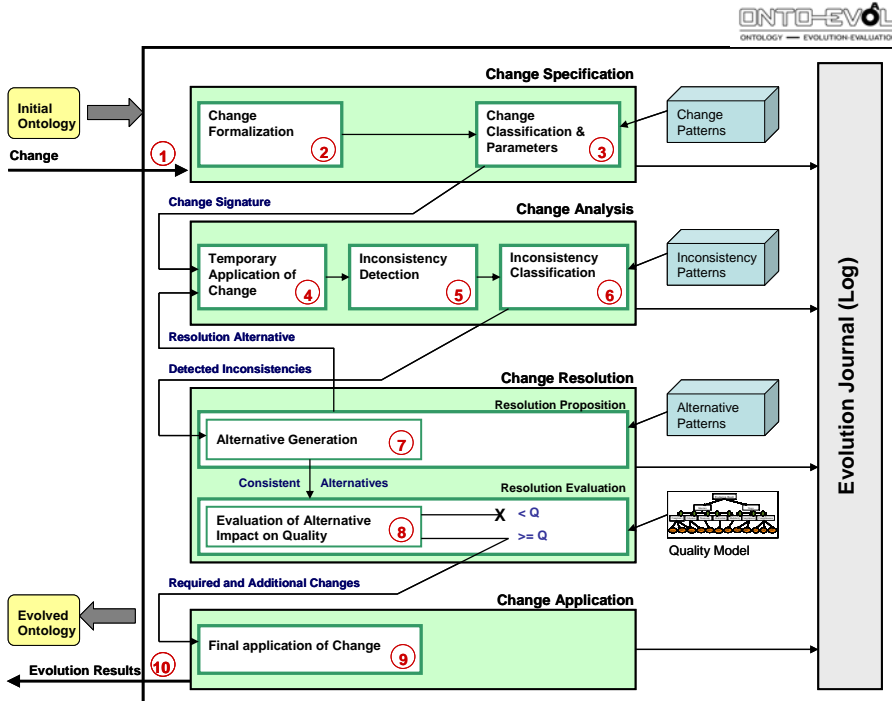


Figure 1: Pattern-oriented ontology change management

### 2.1 Change Specification

The specification phase is launched when a change request is initiated on an initial ontology, supposed to be consistent (1). The user formulates a change request through an ontology editor without worrying about how to apply it. He could ask for a simple or a composed change, without dealing with internal details of its application.

The specification phase has a larger role than a simple representation of the required change in an ontology language. It aims to explicit the change in a formal and comprehensive way to prepare analysis and resolution phases.

The change is firstly made explicit and formalized in OWL model (2). Then, it is classified according to predefined types of changes modelled by change patterns [section 3.1] and enriched by a set of arguments preparing the following phases (3).

The corresponding pattern is instantiated to the required change specificities (values, references of the involved entities, etc.). The whole specification derived constitutes the change signature.

## 2.2 Change Analysis

During the change analysis phase, the change formally specified is applied to a temporary version of the ontology so that its impacts can be analyzed (4). The following step aims to detect caused inconsistencies (5). Detected inconsistencies are then classified according to inconsistency patterns (6). The instantiation of inconsistency patterns prepare the resolution phase particularly through the link with corresponding alternative patterns [Fig. 2].

OWL DL is an axiom-oriented language. Classes and properties have structural descriptions specified through some defined constructors and; to each description, a semantic is associated based on domain interpretation [Horrocks and Patel-Schneider 04]. Satisfying ontology within an interpretation is constraint by the satisfaction of all ontology axioms. Two types of OWL consistency are distinguished: structural consistency and logical consistency. Structural consistency refers to syntactic conditions of OWL DL constructors and to the constraints specified on its elementary axioms and their combinations [Horrocks et al. 03]. Logical consistency refers to the formal semantic of the ontology and thus, to its satisfiability in the meaning that ontology is semantically correct and does not present any logical contradiction.

Only logical consistency is considered. Structural consistency is automatically verified at the beginning of the process. A change cannot be treated unless it is structurally consistent. We verify logical consistency by interfacing Pellet reasoner with our change management system. Pellet supports both terminological level *TBox* (classes and properties) and assertional level *ABox* (individuals) of OWL DL [Sirin et al. 07]. However, some logical inconsistencies particularly those referring to properties cannot be detected by Pellet and are supported by our system. Moreover, Pellet does not precise axioms that cause inconsistencies neither how to resolve the detected inconsistencies. Inconsistent axioms localization process is based on [Plessers and De Troyer 06].

## 2.3 Change Resolution

Change resolution includes two main activities: resolution proposition and resolution evaluation.

### 2.3.1 Resolution Proposition

Based on detected inconsistency instances and the links with inconsistency patterns [Fig. 2], alternative patterns are instantiated to generate potential resolution alternatives (7). Each alternative represents additional change operations resolving an inconsistency. However, an alternative should not cause other inconsistencies. Therefore, proposed alternatives are verified and resolved through a recursive mechanism and only consistent alternatives are accepted.

### 2.3.2 Resolution Evaluation

Several solutions can be proposed for resolving an inconsistency. Rather than presenting the different resolution alternatives to ontology engineer, we propose to guide the choice of the alternative to apply by evaluating the impact of each alternative on ontology quality (8). And thus, based on the evaluation results, the alternative that preserves ontology quality can be chosen automatically. The evaluation is based on a hierarchical quality model that we have defined. This model evaluates structural and usage features of ontology quality through a set of criteria and quantitative metrics. As the description of the quality model is not the subject of this paper, the reader can refer to [Djedidi and Aufaure 08]. Evaluating the impact on ontology quality helps automating the process by guiding resolution choices through evaluated and annotated alternatives.

## 2.4 Change Application

This phase corresponds to the final application of the change. It is optimized by applying quality evaluation techniques to guide inconsistency resolution and minimize reliance on user. Thus, if the resolutions preserve ontology quality, the required change and its derived changes are directly validated and applied (9) and the ontology evolves. In the case that all alternatives have negative effect on quality, the results of the different phases are presented to ontology engineer as a complement to his expertise so that he can decide about change (10). Beyond change management process automation, this phase provides a certain flexibility allowing user to control and decide about the change and its final validation.

All the process results are saved in the evolution journal which is a log structure used to keep ontology evolution historic and change management details as sequences of chronological information. This journal facilitates controlling ontology evolution, revoking a change or justifying it, ontology versioning and also in a future perspective, learning new change management patterns.

## 3 Proposition of Change Management Patterns

The term “pattern” derived from Middle Latin “*patronus*” means something proposed for imitation [Gangemi 05]. It is usually used to designate a model, a type, features observed repeatedly during a study. Many kinds of patterns were introduced in computer science such as *Architectural Patterns*, *Business Patterns* and *Design Patterns*. Design Patterns were introduced for shared guidelines that help to solve design problems and was also adopted in software and ontology engineering [Gangemi 05].

As the idea of modelling Design Patterns to build OWL ontologies [Gangemi et al. 07], *Change Management Patterns* (CMP) are proposed as a solution looking for invariances in change management, that repeatedly appear when evolving ontologies. CMP modelling brings out three categories of patterns: *Change Patterns*, *Inconsistency Patterns* and *Resolution Alternative Patterns*. The goal of this modelling is to offer different levels of abstraction, to establish links between these three categories of patterns determining inconsistencies that could be potentially

caused by a type of change and the alternatives that possibly resolve a kind of inconsistency and thus, to provide an automated change management process.

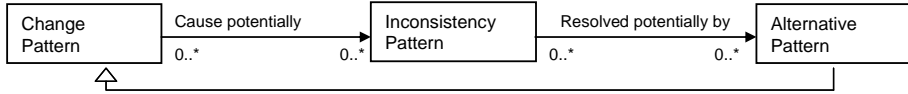


Figure 2: *Conceptual model of Change Management Patterns (CMP)*

### 3.1 Change Patterns

Change patterns are defined according to OWL DL model. They categorize changes, define formally their signification, their scope and their potential implications. Based on OWL meta-model, two categories of changes are distinguished [Klein 04]: basic changes and complex changes. Change patterns cover all OWL basic changes and a first core of complex changes.

Change pattern description includes:

- The type of involved entities corresponding to conceptual primitives of OWL (class, property, individual);
- A set of arguments including all necessary parameters to implement the change. Argument content varies depending on the type of the required change and the involved entities and may include among others:
  - References of concrete entities covered by the required change (their IDs in the ontology),
  - References (IDs) of intermediate entities implicated in change application (e.g. super-classes of a class to add),
  - Change values (e.g. cardinality restriction values),
- Constraints to verify when applying the change. They are preconditions that can be verified before change application. They help predicting inconsistencies that may be caused by a change. For a change adding an equivalence relation between two classes for example, the precondition is that the two classes are not disjoint within their respective hierarchies;

#### 3.1.1 Basic Change Patterns

Basic change patterns model simple and atomic OWL changes. They correspond to indivisible changes that can be specified by using the structure of the ontology only, and modify only one specific feature of the OWL knowledge model (e.g. add a class, delete a “is-a” relation, etc.).

*Example 1.* Let's consider a basic change pattern corresponding to adding a sub-class relation. This pattern is described as follow [Tab. 1]:

<b>Type</b>	<b>P_Chgt_Bas_Add_Sub_Class</b>
<b>Involved Entities</b>	Class, Class
<b>Arguments</b>	Sub_classID, Super_classID
<b>Constraints</b>	$\neg(\text{sub\_classID disjointWith Super\_classID})$
<b>OWL DL Axioms</b>	SubClassOf (Sub_classID, Super_classID)

Table 1: Basic change pattern example

To illustrate a possible instantiation of this pattern, let's take a simple example of an OWL ontology  $O$  defined by the following axioms: {Animal  $\sqsubseteq$  Fauna-Flora, Plant  $\sqsubseteq$  Fauna-Flora, Herbivore  $\sqsubseteq$  Animal, Carnivore  $\sqsubseteq$  Animal, Carnivorous-Plant  $\sqsubseteq$  Plant, Plant  $\sqsubseteq$   $\neg$ Animal}

And let's consider a required basic change  $Ch1$  defining *Carnivorous-Plant* class as a sub-class of class *Animal*. Instantiating the pattern  $P\_Bas\_Chg\_Add\_Sub\_Class$  [Tab. 1] by  $Ch1$  generates the following signature [Tab. 2]:

<b>Type</b>	<b>P_Chgt_Bas_Add_Sub_Class</b>
<b>Involved Entities</b>	Class, Class
<b>Arguments</b>	Carnivorous-Plant, Animal
<b>Constraints</b>	$\neg(\text{Carnivorous-Plant disjointWith Animal})$
<b>OWL DL Axioms</b>	SubClassOf (Carnivorous-Plant, Animal)

Table 2: Basic change pattern instantiation example

### 3.1.2 Complex Change Patterns

Complex change patterns correspond to composite and rich OWL changes grouping logical sequences of basic changes. Complex change patterns include more details as they describe a set of intermediate changes. If, for instance, a required change of adding a class specifies the class position in the hierarchy giving the list of its super-classes and / or defines a class union or intersection described by a set of restrictions; then, it is a complex change instantiating a complex change pattern itself described by a set of basic [Fig. 3] and / or complex change patterns.

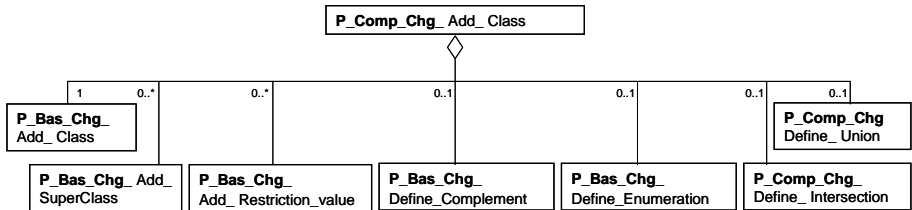


Figure 3: Conceptual model of a complex change pattern example

### 3.2 Inconsistency Patterns

During the change analysis phase, the system considers the constraints specified in the change signature, the links between the instantiated change pattern and inconsistency patterns that could be potentially caused [Fig. 2] and takes into account all the logical inconsistencies detected by Pellet reasoner. Identified inconsistencies are then classified according to inconsistency patterns to be resolved. The classification model focuses on the interpretation of Pellet results, axiom compositions and axiom dependencies to localize axioms causing inconsistencies.

Inconsistency pattern components vary from one inconsistency type to another, the main components are:

- The IDs of all –directly or indirectly– implicated entities. This information explains the inconsistency and facilitates its localization;
- The IDs of entities involved in the inconsistency. This information helps determining axioms causing the detected inconsistency and prepares resolution proposition activity;
- Axioms involved in the inconsistency.

*Example 2.* Let's take again the basic change example *Ch1* [Example 1], the instantiation of the corresponding disjointness inconsistency pattern is described as following [Tab. 3]:

Type	P_Incons_Disj
<b>Implicated Entities</b>	Animal, Carnivorous-Plant, Plant
<b>Involved Entities</b>	Animal, Plant
<b>Involved Axioms</b>	$(\text{Plant} \sqsubseteq \neg\text{Animal}) , (\text{Carnivorous-Plant} \sqsubseteq \text{Plant})$

Table 3: *Inconsistency pattern instantiation example*

### 3.3 Alternative Patterns

In change resolution phase, resolution proposition activity is based on the links between the instantiated inconsistency pattern and alternative patterns that could potentially resolve it [Fig. 2]. An alternative pattern represents an additional or substitutive change to apply so that a logical inconsistency can be resolved. It is described as a basic or complex change and it inherits change pattern properties [Fig. 2] which implies that it could cause itself inconsistencies. Other information can also enrich alternative pattern description such as preconditions to satisfy before choosing an alternative pattern as a resolution [Tab. 4].

*Example 3.* Let's reconsider the basic change *Ch1* example [Example 1]. Two possible resolution alternatives can resolve the inconsistency of disjointness caused by this change [Example 2]. Their patterns and corresponding instantiations are described as follow [Tab. 4, Fig. 4; Tab. 5, Fig. 5].



P_Alt_Disj_Bas_Chgt_Add_Sub_Class (a1)	
<b>Involved Entities</b>	Class, Class
<b>Arguments</b>	Sub_classID, Super_classID, Id1_cls_disj, Id2_cls_disj
<b>Preconditions</b>	$\text{SuperClass}(\text{Id1\_cls\_disj}) \cap \text{SuperClass}(\text{Id2\_cls\_disj}) = \text{Super\_classID}$
<b>Constraints</b>	$\neg(\text{Sub\_classID} \text{ disjointWith } \text{Super\_classID})$
<b>OWL DL Axioms</b>	$\text{SubClassOf}(\text{Sub\_classID}, \text{Super\_classID})$

Table 4: Alternative pattern example resolving a disjointness (a1)

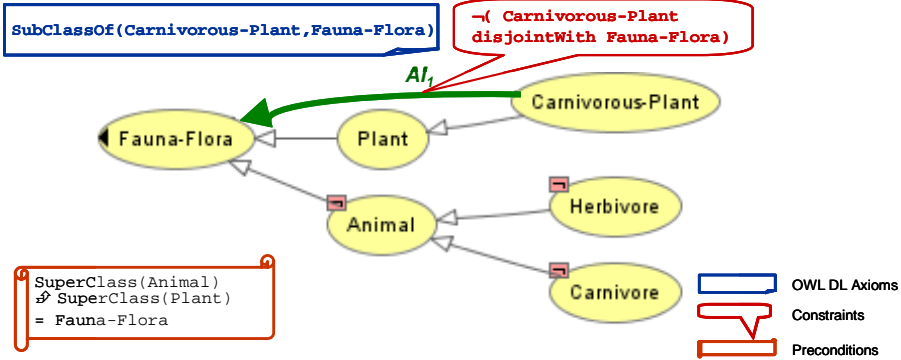


Figure 4: Instantiation of the alternative pattern a1

P_Alt_Disj_Comp_Chgt_HybridClass_Link (a2) (synthetic version)	
<b>Involved Entities</b>	Class, Class
<b>Arguments</b>	Id_HybridClass, Id_Sub-class, Id1_cls_disj, Id2_cls_disj
<b>Intermediate Components:</b>	$\text{Class}(\text{Id\_HybridClass}, \text{UnionOf}(\text{Id1\_cls\_disj}, \text{Id2\_cls\_disj}))$
<b>OWL DL Axioms</b>	$\text{SubClassOf}(\text{Sub\_classID}, \text{Id\_HybridClass})$

Table 5: Alternative pattern example resolving a disjointness (a2)

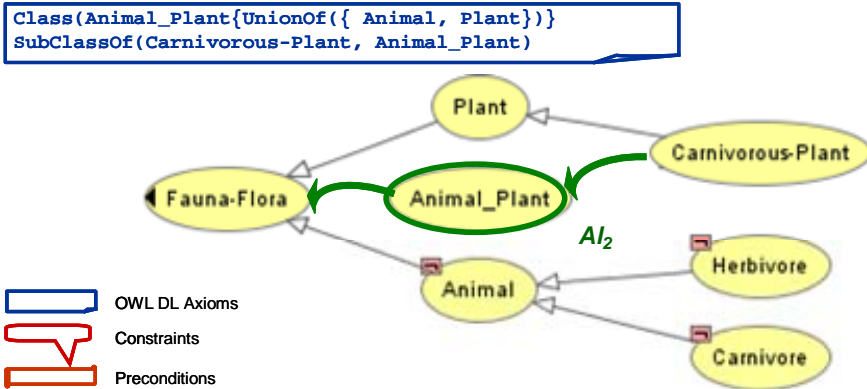


Figure 5: Instantiation of the alternative pattern  $al_2$

## 4 Discussion and Related Work

In the last few years, pattern modelling was adopted in web ontology design to propose guidelines and provide reusable ontological component catalogues. The notion of ontology design pattern has been mainly introduced by [Gangemi et al. 04], [Rector and Rogers 04], [Svatek 04]. In a theoretical point of view, *Change Management Patterns* CMP are close to *Ontology Design Patterns* ODP, particularly *Logical Ontology Patterns* LOP and *Content Ontology Patterns* COP [Presutti et al. 08]. Both CMP and ODP are applied in ontology engineering cycle. CMP and LOP are domain independent and could be applied more than once in an ontology to resolve an evolution (CMP) or a design (LOP) problem. CMP implementation and LOP formal expression are both derived from OWL DL model. In addition, *Change Patterns* of CMP can be considered as COP for ontology domain i.e. ontology design patterns solving modelling problems of the domain ‘ontology’. However, in a pragmatic point of view, they are different. CMP propose reusable solutions to guide change management in a local ontology evolution process. ODP are designed as reusable guidelines for a collaborative design context of networked ontologies and LOP represent compositions of logical constructions to resolve expressivity problems [Presutti et al. 08].

In related work in ontology evolution, we consider particularly those treating OWL ontologies, as change management depends closely on ontology representation model. In [Haase and Stojanovic 05], authors have introduced resolution strategies based on OWL Lite constraints. Inconsistency resolution is limited to the identification of the axioms causing inconsistencies and their presentation to the user as axioms that should be removed. In our approach, we tend to minimize axiom removing solutions by proposing resolution alternatives that merge, divide, generalize or specialize concepts and properties and redistribute instances to preserve existent knowledge. Moreover, we guide the choice of alternatives to apply by involving quality evaluation activity. In [Plessers et al. 06], authors have defined a change detection approach. Changes are expressed as temporal queries applied to a version

log. In [Plessers and De Troyer 06], authors have defined an algorithm localizing axioms causing inconsistencies in an OWL DL ontology. We have adopted this algorithm in the change analysis phase of our process. Another interesting approach has been applied in inconsistency resolution [Parsia et al. 05], [Wang et al. 05]: ontology debugging. The purpose is to provide more comprehensible explanations than standard reasoners' results. Two techniques are distinguished: *black-box* technique considering the reasoner as a black box and applying inferences to localize inconsistencies and; *glass-box* technique modifying the internal mechanism of the reasoner to explain inconsistencies and complete reasoners' results.

## 5 Conclusion and Future Work

In this paper, we present a pattern-oriented ontology change management process. The modelling of Change Management Patterns (CMP) defines and classifies types of *changes*, *inconsistencies* and *resolution alternatives* and brings out conceptual links between these three categories of patterns to guide and control change impact analysis and resolution. In addition, evaluating resolution alternatives' impact helps driving change management process and preserving ontology quality.

The defined patterns cover OWL DL basic changes and a sub-set of complex changes, a first core of logical inconsistencies and of alternatives that could resolve them. Currently, we work on completing and enriching these patterns, by developing a learning module and applying the approach to evolve a set of test ontologies. Indeed, it is not obvious to provide a complete change management system supporting all types of changes, specifying in advance potential inconsistencies and anticipating possible resolutions. The aim of our approach is to provide system capabilities that help driving ontology change management and to handle system scalability through a learning module enriching change management patterns.

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## SALERO Intelligent Media Annotation & Search

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**Abstract:** Currently the media production domain lacks efficient ways to organize and search for media assets. Ontology based applications have been identified as a viable solution to this problem, however, sometimes being too complex for non-experienced users. We present the *SALERO Intelligent Media Annotation & Search* system which provides an integrated view onto results retrieved from different search engines. Furthermore, it offers a powerful, yet user-friendly Web-based environment to organize and search for media assets.

**Key Words:** Information storage and retrieval, semantic media asset management

**Category:** H.3

### 1 Introduction

This paper presents the *Intelligent Media Annotation & Search*<sup>1</sup> (IMAS) system, an easy-to-use application based on the principles described in [Bürger 2008a], which is being developed within the European project SALERO<sup>2</sup>. The principles describe methodologies to support users in the process of manual semantic annotation including (i) selection of adequate ontology elements and (ii) extending

<sup>1</sup> <http://salero.joanneum.at/salero/>

<sup>2</sup> <http://www.salero.eu>

of ontologies during annotation time. An integral part of the work being done in SALERO is the management of media objects with semantic technologies which is addressed by the IMAS system by enabling their semantic annotation and retrieval. The use of semantic technologies reduces the problem of ambiguity in search by using existing, well-defined vocabularies, it allows us to do query expansions and to deal with multilinguality.

## 2 Related Work

The organisation, classification and retrieval of media objects is an ongoing challenge in games and media production. Semantic technologies have been identified as a viable solution to overcome some of the problems in this area [Bürger 2008]. A wide range of multimedia annotation tools [Obrenovic 2007, Simperl 2009] already offer functionality to attach ontological annotations to (parts) of the multimedia content and some offer reasoning services on top of them to semi-automatically create annotations based on existing annotations. The K-Space Annotation Tool [Saathoff 2008] provides a framework around the Core Ontology for Multimedia for efficient and rich semantic annotations of multimedia content. PhotoStuff [Halaschek-Wiener 2005] allows to use any ontology for the annotation of images and is available as a standalone desktop application. A web-based demonstrator for browsing and searching with very limited functionality is also available. Imagenotion [Walter 2007] already provides an integrated environment for the collaborative semantic annotation of images and image parts. User tests showed that the use of standard ontologies and tools is not generally suitable, which led to the development of a method where ontologies consist of imagenotions that graphically represent a semantic notion through an image.

As we experienced as well during prototypical iterations of our system, most paradigms applied in semantic annotation tools are not suitable for unexperienced users who are typically used to keyword-based tagging and suffer from information overload when confronted with complex interfaces.

## 3 System Description & Design Principles

The IMAS system architecture is shown in [Fig. 1]: The IMAS integrates two systems whose functionalities are offered as a set of Web services, i.e. the *Semantic Services* and the *Content-based Services*. The main aim of the IMAS is to allow easy annotation of media assets for later retrieval and reuse by users in media production. In order to support this, it has been built based on the following design principles:

1. **Designed for content creators.** The target users of the system are non-technically experienced content creators in the domain of media production.

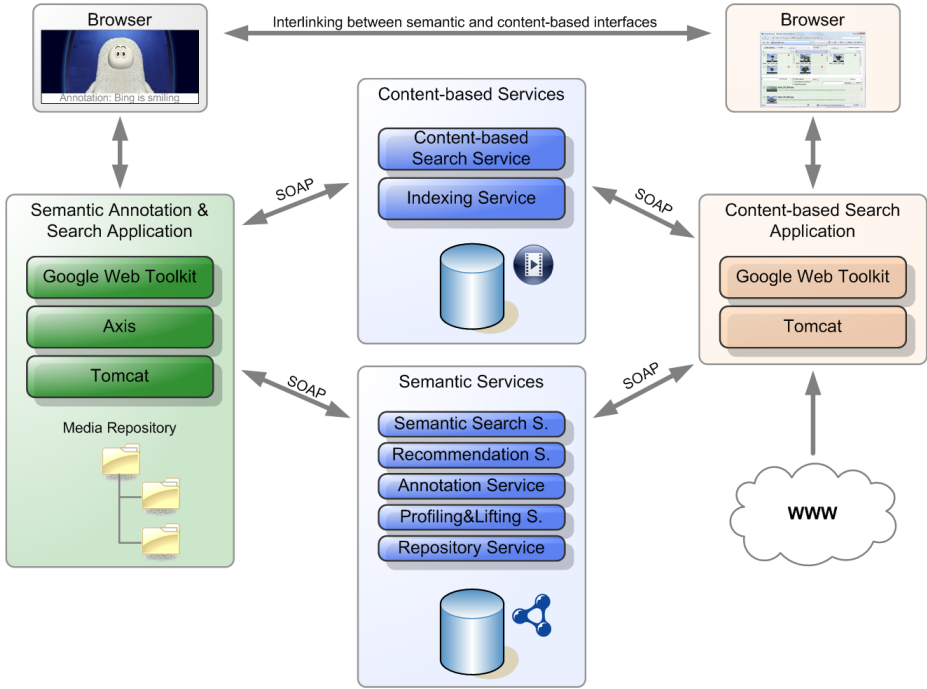


Figure 1: IMAS System Overview.

2. **Easy to use.** The interface provides Web 2.0 – based interaction mechanisms to make the annotation process as easy as possible.
3. **Global annotations.** To facilitate the annotation process, we only allow global annotations of media files instead of annotating parts of it.
4. **Statement-based annotation process.** We allow to create statements, which use ontological elements, to describe the content of media items.
5. **Ontology extension during use.** We allow users to easily extend the ontology during use based on principles described in [Bürger 2008a].
6. **Portability of the system.** In order to port the systems to other domains, only the underlying annotation ontology has to be adapted.
7. **Integration of semantic and content-based search.** The system provides an integrative view onto results from different search engines and by that provides a fallback solution which is able to retrieve objects without annotations too.

## 4 The Intelligent Media Annotation and Search Application

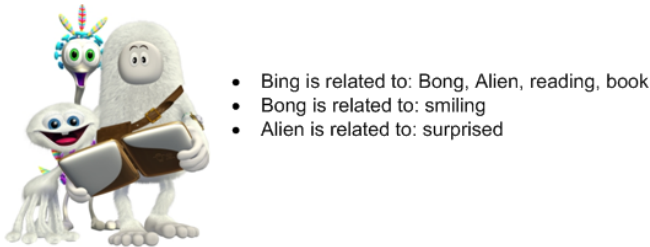
The IMAS end user application is an integrated Web-based application which can be used to annotate and search for media objects. As illustrated in [Fig. 1], it consumes functionality of (i) the *Semantic Services* which are used to add, update and delete semantic annotations as well as to search the annotation repository and (ii) the *Content-based Services* which are used to retrieve media items based on its intrinsic features such as colour, histograms or shapes.

### Usage:

The application allows to annotate any arbitrary files which are stored in pre-configurable media repositories. In order to ease the annotation process for our target user group media items are annotated globally instead of region- or segment-based. Additionally, media items are annotated by creating statements which contain semantic elements which are defined in an domain specific ontology. The annotation statements are formalized according to the ontology defined in [Bürger 2009] and can be seen as sentences about the content of the media item and are in the form of

$$\langle \textit{Resource isRelatedTo} \{ \textit{Concept}_1 \dots \textit{Concept}_n \} \rangle.$$

Using statements with semantic elements is a compromise in complexity between loose and fully semantically described annotations. [Fig. 2] illustrates statements with an example. To create such statements, three different input options are



**Figure 2:** Example of Annotation Statements.

available as shown in [Fig. 3]: (1) combining concepts via drag-and-drop, (2) selecting concepts consecutively and (3) using the text box as a command line interface in the spirit of [Raskin 2008] with auto-completion. Input option three is optimally suited for frequent users and input options one and two are ideal for users who rarely create annotations.



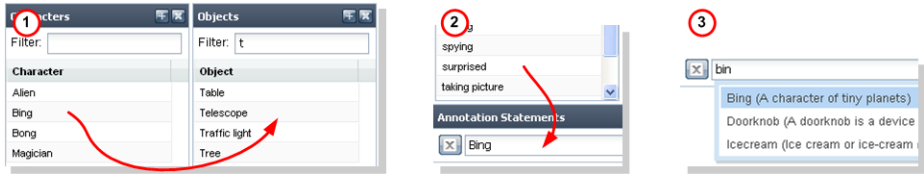


Figure 3: Creation of Annotation Statements.

#### 4.1 Semantic Services

IMAS is realized on top of the *SALERO Semantic Workbench* (cf. [Bürger 2008]) which not only offers a graphical user interface to engineer ontologies but also a set of services which provide ontology management functionality to other applications. The services offered by the semantic workbench include:

- **The Repository Service** which offers an API for the persistent storage of WSML<sup>3</sup> ontologies and their elements. It supports management of elements and the execution of SPARQL queries. The services are realized on top of the *Ontology Representation and Data Integration (ORDI)* – framework<sup>4</sup>.
- **The Annotation Service** is concerned with the management of semantic annotations and provides an API to manage and validate annotations against the ontologies stored in the repository.
- **The Semantic Search Service** offers an API to search for ontology elements and additionally offers keyword-based search for annotations which is expanded into full-text queries on a generated index and SPARQL queries.
- **The Recommendation Service** offers an API for retrieval of ontology elements which are prominently used for annotation and gives recommendations of related results during search.
- **The Profiling and Lifting Service** can be used to extract structural semantic information from existing MPEG-7<sup>5</sup> documents and for their semantic enrichment.

#### 4.2 Content-based Services

The *Content-based Services* offer functionality for the indexing and retrieval of image, video and textual information. The aim of the service is to complement

<sup>3</sup> <http://www.wsmo.org/wsml/wsml-syntax>

<sup>4</sup> <http://www.ontotext.com/ordi>

<sup>5</sup> <http://www.chiariglione.org/mpeg/standards/mpeg-7/mpeg-7.htm>

the semantic search services. As such their emphasis is on automatic indexing techniques, which can be used to retrieve images, text or video without manual annotation. This provides a fall-back system in the cases where material is not indexed by the semantic services, providing an alternative method of retrieval and bootstrapping. Architecturally, the content-based services are split into a backend indexing and retrieval system which provides a SOAP interface to other software components and a frontend search interface for end users. Textual information is indexed using standard Information Retrieval techniques (the Terrier system is used [Ounis 2006]); image and video data is indexed by extracting low-level visual features based on the MPEG-7 standard, as currently implemented in the ACE toolbox [O'Connor 2005]. Searches can be carried out on locally uploaded and indexed data or the system can also use third party Web services to search remote collections, such as Yahoo BOSS<sup>6</sup> or YouTube. Both local collections and remote services can be searched via the same search interface. The interface allows searching based on an optional textual query and zero or more image examples which may come from already indexed collections or be ad-hoc serialized images. The AspectBrowser [Villa 2009], a flexible environment for search and search result organisation, is the end user interface to the content-based services.

### 4.3 Search System

To search for media objects, the following input options are available to create a query: (i) free text, (ii) semantic concepts, (iii) statements, and (iv) images. Free text search is both executed in the *Semantic Services* and the *Content-based Services*. The concept-based search is expanded in the *Semantic Services*. Via the exemplary images a query is submitted to the *Content-based Services*. The results of both systems are merged based on the respective rank values being returned.

#### 4.3.1 Semantic Search Algorithm

The *Semantic Services* support two different types of queries: The first option are *concept-based* queries which are translated into SPARQL queries and which are evaluated via the *Repository Service* of the *Semantic Services* in the repository. The second option are *keyword-based* queries which are executed in a Lucene<sup>7</sup> index which is generated based on the ontologies and instance data in the repository. The Lucene index preserves the annotation triples and also stores subsumption information to enable efficient retrieval. Keyword and concept queries can be mixed to increase the precision of keyword-based querying in the system.

<sup>6</sup> <http://developer.yahoo.com/search/boss/>

<sup>7</sup> <http://lucene.apache.org>

Furthermore selected WordNet relations of the concepts can be expanded to increase the result set while preserving precision. Once the queries are answered, the results are ranked based on the semantics of the annotations attached to the returned results and their degree of match of the query. The ranking is based on the popular *tf/idf* measure which is customized for semantic annotations to take into account triples instead of just terms and the subsumption hierarchies.

### 4.3.2 Search Result Fusion

The core problem of generating the final list lies in devising a mechanism of combining the results from each system to produce effective results through the IMAS engine. The problem of combining results is widely studied, both by information retrieval communities as well as multimedia retrieval groups at various levels: combining results from many query examples, combining results originating from multiple features or results obtained from different search engines. Multimedia information retrieval communities refer to this as multimodal fusion (cf. [Mc Donald 2005], [Hoi 2008], [Qi 2005]) and querying with multiple examples (cf. [Westerveld 2004], [Kludas 2008]).

In our system a *round robin* mechanism combined with a *polling-based result fusion* mechanism is adopted to fuse results obtained from semantic and content-based search systems. A keyword-based search is employed to obtain the initial list of  $n$  results from the semantic search system. The top  $m \ll n$  results are then used by the content-based search to retrieve more visually similar images. Since it is also important to select the best feature or re-order the features according to their preference for the query examples favouring to obtain more diverse results, the knowledge embedded in queries are exploited by computing the correlation and *t*-distribution in the queries. The feature which has less correlation and high *t*-distribution is chosen as the most useful feature.

## 5 Conclusion and Outlook

In this paper we have presented the *Intelligent Media Annotation & Search*<sup>8</sup> system. The system is designed for the content creators in the realm of media production and uses a semantic enabled statement-based approach for fast and easy annotation of media files. The system also integrates semantic and content-based search to provide a fall-back and an alternative retrieval system. It is planned to explore a more sophisticated fusion mechanism with the automatic computation of the preference of the semantic system or the content-based system for a topic. A thematic browsing through the content, based on the ontologies, would also be feasible. Furthermore we are currently in the process of evaluating the integrated system; results are expected in the coming months.

<sup>8</sup> <http://salero.joanneum.at/salero/>

## Acknowledgements

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# Integrated Ontologies for the Semantic Web: Experiences from Modeling a Research Context Ontology

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**Abstract:** In the Semantic Web, ontologies play an important role as a means to enable the interlinking and the semantic integration of distributed Web data. These processes can be simplified if the underlying ontologies are modeled by integrating already existing Semantic Web ontologies. This paper describes strategies for building such integrated ontologies, summarizes some guidelines for this process and presents modeling experiences from a use case in which an integrated research context ontology is created.

**Keywords:** Semantic Web, Ontology Modeling, Semantic Integration, Ontology Reuse  
**Categories:** M.1, M.4, M.8

## 1 Introduction

While the amount of semantically annotated data on the Semantic Web is growing, the linking of this data is a current challenge [Berners-Lee 2006]. These linking processes can be simplified if the underlying ontologies are not created completely independently from one another but reuse and integrate existing ontologies instead [Shadbolt et al. 2006, Noy 2003, Sure et al. 2005].

Well-established methodologies for ontology modeling thus often identify the integration of existing ontologies as a distinct step in the modeling process [Uschold and King 1995, Fernández et al. 1997]. But they do not further elaborate on this integration process in detail.

While much research focuses on the processes of (semi-) automatic ontology matching and alignment [Euzenat and Shavaiko 2007, Ehrig 2007], more formal aspects of ontology integration in the sense of “building a new ontology reusing other available ontologies” [Pinto et al. 1999] are far less studied, such as the selection of suitable ontologies, their semantic integration and their specification or extension.

This topic is also addressed in the ExpertFinder project [Aleman-Meza et al. 2007]. It aims to reuse widely used vocabularies such as SIOC<sup>1</sup>, FOAF and SKOS for the annotation of expert related data, thereby defining best practices for standardisation in this area. Furthermore, tools like the Watson plugin support the process of identifying Semantic Web ontologies for reuse [d’Aquin et al. 2008].

Nevertheless, no formal guidelines are available yet to support ontology engineers in the process of modeling such integrated ontologies. The contribution of

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<sup>1</sup> <http://rdfs.org/sioc/ns>

this paper is to present strategies for modeling integrated ontologies [Section 2] and to delineate guidelines for ontology reuse and integration [Section 3], whose application is illustrated by a use case [Section 4]. The paper concludes with a brief summary of open research issues [Section 5].

## 2 Strategies for Modeling Integrated Ontologies

[Fig. 1] depicts two strategies for modeling integrated ontologies. It is loosely based on the ontology modeling methodology by [Uschold and King 1995] and adapted to the Semantic Web context in which the integration step (5) is of special importance.

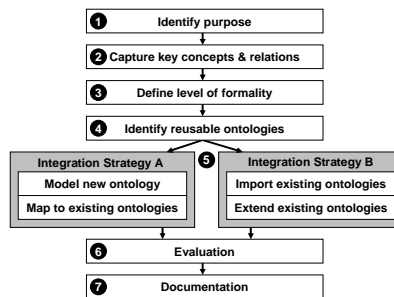


Figure 1: Strategies for modeling integrated ontologies

After identifying the purpose of the ontology (1), key concepts and relations need to be captured (2). In the next step, the level of formality of the ontology has to be defined (3), for example to select one of the Semantic Web standards that differ in their levels of expressiveness and formality. This step also influences the selection of potentially reusable ontologies (4). With the aim of integrating one's ontology into the Semantic Web, widely adapted ontologies should be identified for reuse.

As soon as reusable ontologies have been identified, the ontology engineer has to decide whether to follow a bottom-up or a top-down approach for modeling the integrated ontology. If the engineer starts with modeling the new ontology and afterwards maps it to other ontologies, the bottom-up approach is followed (A). The alternative top-down strategy (B) starts with importing the reusable ontologies, which are then specified and extended for one's own specific needs in the new ontology.

The next step in this model is the evaluation of the ontology, for example to assure its consistency and comprehensiveness (6). And finally, all ontology objects should be documented (7), which is especially important in the Semantic Web context where ontologies are intended to be reused by others.

In the domain of ontology modeling, both the top-down approach and the bottom-up approach often imply the reference to top-level ontologies such as Cyc, DOLCE or SUMO. A more pragmatic approach for the anarchical nature of the Semantic Web is the transfer of these strategies to other types of ontologies, such as widely adapted light-weight task or domain ontologies. While this practice does not allow to interpret all Semantic Web data in terms of one global ontology, it can assure that the newly created ontology is at least partly integrated into the Semantic Web by linking points

to widely adapted ontology schemata and to the respectively annotated data. Similarly to the DBpedia data set that serves as a nucleus to the Semantic Web on the data level [Auer et al. 2007], evolving standard ontologies such as FOAF and SKOS can serve as linking points to the Semantic Web on a schema level, thereby fostering the Semantic Web's semantic integration efforts.

### 3 Guidelines for Modeling Integrated Ontologies

Independent from the integration strategy, the question arises how to pursue the ontology integration process. It is important to note that ontology integration on the Semantic Web needs to follow the principle of not changing the imported or referenced ontologies. Only this way, interoperability can be guaranteed. Mappings, extensions or specializations therefore need to be defined in the new ontology.

The most intuitive strategy to integrate one's ontology with another one is to define equivalence relationships between classes and instances, for example by using OWL properties such as *owl:sameAs* or *owl:equivalentClass*. Similarly, *owl:equivalentProperty* can be used to express the equivalence between properties. Nevertheless, this strategy assumes that the meaning of the foreign ontology's properties and classes is well known and that they will be interpreted in the same way by all re-users. This also implies that one has to consider which inferences can be drawn on one's ontology after integrating it with other ontologies, due to the distributed nature of the Semantic Web.

Another strategy is the extension by refinement approach. This means that the properties and classes in one's own ontology are defined as subproperties or subclasses of properties and classes in existing ontologies. This strategy assures that reasoning over the own ontology is possible on an upper level, using the vocabulary of the top-level ontology.

Although no official guidelines exist yet on the integration of ontologies on the Semantic Web, the extension by refinement method can be considered as the best practice approach. For example, this strategy is recommended by [Miles 2005] and also applied by [Assem et al. 2006], in both cases in the context of converting thesauri into the SKOS standard and thereby extending the SKOS vocabulary, if necessary. It is further explained in a working draft<sup>2</sup> on how to extend the SKOS vocabulary.

### 4 Use Case: Modeling an Integrated Research Context Ontology

To further illustrate the above listed principles, this section describes modeling experiences from a use case in which an integrated research context ontology (RESCON) is created. While [Section 5.1] briefly delineates the distinct modeling steps, [Section 5.2.] goes into detail about modeling decisions in the integration step.

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<sup>2</sup> <http://isegserv.itd.rl.ac.uk/public/skos/drafts/appextensions.html>

### 4.1 Modeling steps

According to the model presented in [Section 2], the following steps were pursued:

**Identify purpose:** The ontology was designed for semantically integrating research context related data for the domain of educational research. The schema would then be instantiated and serve as background knowledge for the generation of query expansion terms in a domain-specific retrieval system.

**Capture key concepts and relations:** As the ontology was intended to represent research contexts, the key concepts *person*, *organization*, *project*, *concept* and *document* were identified. These were interrelated by properties expressing authorship, projects’ topics and persons’ interests, for example, as shown in [Fig. 2].

**Define level of formality:** OWL-DL was selected as the representation language for the ontology. In contrast to OWL Full, it is still determinable while offering several desirable language constructs such as inverse or symmetric properties.

**Identify reusable ontologies:** Three ontologies were identified for reuse because they are already widely applied in the Semantic Web. While the SWRC ontology [Sure et al. 2005] was suitable for modeling research contexts, the FOAF ontology was selected for modeling researcher related data. Furthermore, SKOS was applicable for modeling relationships between research topics, which were representable as *skos:Concepts*.

**Integration:** The integration of the selected ontologies was pursued following the top-down approach. Current versions of the selected ontologies were imported into the own ontology where they were further extended and specified.

**Evaluation and Documentation:** While the consistency of the ontology was tested with the help of a reasoner, the documentation still needs to be realized. For this purpose, the *rdfs:comment* annotation property will be used to describe the ontology’s classes and properties.

### 4.2 Modeling decisions

As the modeling process included the reuse of already existing Semantic Web ontologies, the resulting ontology schema [Fig. 2] comprises both objects from external ontologies and newly created objects in the RESCON namespace.

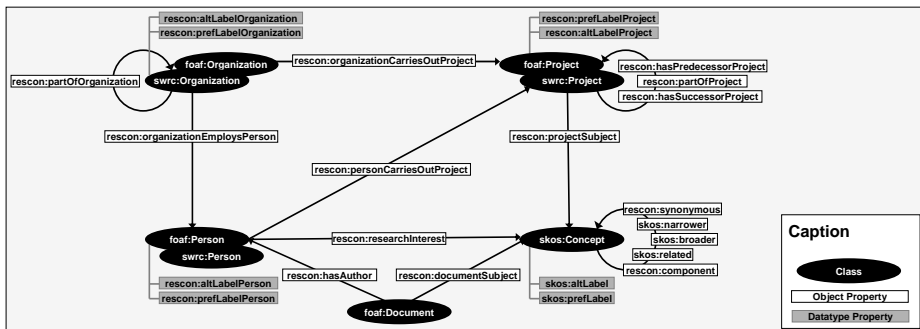


Figure 2: RESCON ontology schema



During the modeling process, the following decisions had to be made:

**Ontology languages:** Unfortunately, not all of the selected ontologies were available as OWL-DL versions. While the SWRC ontology completely relies on OWL-DL, the SKOS and FOAF ontologies partly comprise OWL Full language constructs. Consequently, they needed to be made OWL-DL compliant. To achieve this for the FOAF ontology, the suggestions on the Mindswap project website<sup>3</sup> were followed. For example, domain and range pointers to *rdf:Resource* were replaced by *owl:Thing* because *rdf:Resource* subsumes both classes and instances, turning the FOAF ontology into OWL Full. In the case of the SKOS ontology, an OWL-DL version<sup>4</sup> was available. This was selected for import although it was still experimental. In contrast to the original SKOS version, it does not contain OWL Full constructs. For example, properties are not allowed to be datatype and annotation properties at the same time in the DL version.

**Extension by refinement:** To suit the RESCON ontology's application- and domain-specific needs, the imported ontologies further needed to be extended and specified. In this use case, extensions or refinements on the class level were not necessary, but many specifications were realized on the property level. Domains and ranges of properties in the imported ontologies often needed to be specified because they were very broadly defined. For example, for defining a property that expresses authorship, *foaf:maker* was identified as a possible linking point in the imported ontologies. But *foaf:maker* refers to the domain *owl:Thing* and has no specified range. This led to the decision to define a new subproperty of *foaf:maker*, namely *rescon:hasAuthor* with the more specific domain *foaf:Document* and the range *foaf:Person*. Another example illustrates how the SKOS ontology was expanded in order to express synonymous relationships. According to the SKOS specification<sup>5</sup>, synonymous terms are to be represented by the annotation property *skos:altLabel*. But in the RESCON ontology, it was desirable to define synonymous relationships between certain instances of *skos:Concept* instead of representing synonyms as string annotations. This way, inverse synonymous relationships would be automatically inferable. This was achieved by defining the new property *rescon:synonymous* as a subproperty of *skos:semanticRelation* that already comprises other relationships between *skos:Concepts*, such as *skos:narrower*, *skos:broader* and *skos:related*. An overview of all properties and their specifications is given in [Fig. 3].

**Semantic overlappings:** Obviously, the imported ontologies showed semantic overlappings. Both SWRC and FOAF list the classes *person*, *project* and *organization*, for example. Nevertheless, it did not seem viable to define equivalence relationships between the respective classes because such statements would impact on all the data on the Semantic Web that is structured according to either one of these ontologies. For this reason, no integration of external ontologies was pursued.

**Instances versus classes:** As the RESCON ontology should incorporate domain-specific vocabulary terms from a thesaurus, a decision had to be taken whether to model these terms as classes or instances in the ontology. For example, each vocabulary term could have been represented as a subclass of *owl:Thing*. But in this

<sup>3</sup> [http://www.mindswap.org/2005/foaf\\_cleaner/](http://www.mindswap.org/2005/foaf_cleaner/) (not applicable to more recent FOAF versions)

<sup>4</sup> <http://www.w3.org/2004/02/skos/core/owl-dl/skos-core-owl-dl.owl>

<sup>5</sup> <http://www.w3.org/TR/skos-reference/> (W3C Working Draft 29 August 2008)

case, it would have been difficult to define sophisticated semantic relations between the classes. In accordance with best practices for transforming thesaurus vocabularies into SKOS [Miles 2005, Miles et al. 2005, Assem et al. 2006], the terms were finally modeled as instances of the class *skos:Concept*, which could then be interrelated by the *skos:semanticRelation* subproperties.

Property hierarchy	Domain	Range
<i>foaf:topic_interest</i> – <i>rescon:researchInterest</i>	<i>owl:Thing</i> <i>foaf:Person</i>	– <i>skos:Concept</i>
<i>rescon:label</i> – <i>rescon:alt_labelAll</i> – <i>skos:alt_label</i> – <i>rescon:alt_labelProject</i> – <i>rescon:alt_labelPerson</i> – <i>rescon:alt_labelOrganization</i> – <i>rescon:pref_labelAll</i> – <i>skos:pref_label</i> – <i>rescon:pref_labelProject</i> – <i>rescon:pref_labelPerson</i> – <i>rescon:pref_labelOrganization</i>	<i>swrc:foaf:Person</i> , <i>swrc:foaf:Organization</i> , <i>swrc:foaf:Project</i> , <i>skos:Concept</i> <i>swrc:foaf:Person</i> , <i>swrc:foaf:Organization</i> , <i>swrc:foaf:Project</i> , <i>skos:Concept</i> <i>skos:Concept</i> <i>swrc:foaf:Project</i> <i>swrc:foaf:Person</i> <i>swrc:foaf:Organization</i> <i>swrc:foaf:Person</i> , <i>swrc:foaf:Organization</i> , <i>swrc:foaf:Project</i> , <i>skos:Concept</i> <i>skos:Concept</i> <i>swrc:foaf:Project</i> <i>swrc:foaf:Person</i> <i>swrc:foaf:Organization</i>	String String String String String String String String String String
– <i>swrc:employs</i> – <i>rescon:organizationEmploysPerson</i>	<i>owl:Thing</i> <i>swrc:foaf:Organization</i>	<i>swrc:foaf:Person</i>
<i>swrc:carriesOut</i> – <i>rescon:personCarriesOutProject</i> – <i>rescon:organizationCarriesOutProject</i>	<i>owl:Thing</i> <i>swrc:foaf:Person</i> <i>swrc:foaf:Organization</i>	– <i>swrc:foaf:Project</i> <i>swrc:foaf:Project</i>
<i>skos:subject</i> – <i>rescon:projectSubject</i> – <i>foaf:documentSubject</i>	<i>owl:Thing</i> <i>swrc:foaf:Project</i> <i>foaf:Document</i>	<i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i>
<i>foaf:maker</i> – <i>rescon:hasAuthor</i>	<i>owl:Thing</i> <i>foaf:Document</i>	– <i>swrc:foaf:Person</i>
<i>skos:subject</i> – <i>rescon:projectSubject</i> – <i>rescon:documentSubject</i>	<i>owl:Thing</i> <i>swrc:foaf:Project</i> <i>foaf:Document</i>	<i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i>
<i>rescon:hasSuccessorProject</i>	<i>swrc:foaf:Project</i>	<i>swrc:foaf:Project</i>
<i>rescon:hasPredecessorProject</i>	<i>swrc:foaf:Project</i>	<i>swrc:foaf:Project</i>
<i>skos:semanticRelation</i> – <i>skos:narrower</i> – <i>skos:broader</i> – <i>skos:related</i> – <i>skos:synonymous</i>	<i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i>	<i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i> <i>skos:Concept</i>
<i>rescon:partOf</i> – <i>rescon:partOfProject</i> – <i>rescon:partOfOrganization</i>	<i>owl:Thing</i> <i>swrc:foaf:Project</i> <i>swrc:foaf:Organization</i>	– <i>swrc:foaf:Project</i> <i>swrc:foaf:Organization</i>

Figure 3: RESCON property specifications

**Integration of vocabularies:** But the subsequent integration of *skos:Concepts* with the ontology schema modeled around the *person*, *organization*, *project* and *document* classes was not trivial either. While the latter classes refer to real world-objects, the *skos:Concept* class represents concepts of such objects. On the one hand, the class *skos:Concept* could have been defined as a superclass of all other classes, which would have resulted in considering all ontology objects as *skos:Concepts*. On the other hand, a distinction could have been drawn in the ontology between concepts and real world-objects. As the *skos:Concept* class in the RESCON ontology was intended to represent only domain-specific conceptual terms (such as “education” or “cognitivism”), it could be defined as disjunct with the *person*, *organization*, *project* and *document* classes that refer to real world-objects. Consequently, *skos:Concept* was modeled as a sibling of the *person*, *organization*, *project* and *document* classes. This way, conceptual *skos:Concept* instances can be interrelated with the other classes’ real world-instances by properties such as *rescon:projectSubject*, which connects *foaf:Project* and *skos:Concept* instances, for example.

**Labels:** As the ontology was modeled to serve the generation of query expansion terms, the labelling of ontology objects played an important role. All ontology instances needed to be labelled, be they instances of the *person*, *project*, *organization*, *document* or *concept* classes. But originally, labels were only defined in the SKOS ontology, namely by the *skos:altLabel* and *skos:prefLabel* properties for the domain *skos:Concept*. Nevertheless, due to their representation as annotation properties, they cannot be used for reasoning, such as for inheriting property values. New labelling properties, that needed to be defined for the remaining classes, were therefore

specified as datatype properties with string ranges, such as *rescon:altLabelProject*, *rescon:prefLabelProject*, *rescon:altLabelPerson* and *rescon:prefLabelPerson* (see [Fig. 3]). Nevertheless, their similarity to the SKOS labelling properties should be expressed. This was realized by the new property *rescon:label* that comprises all these labelling properties as subproperties. This modeling design allows to either address the superproperty *rescon:label* to read out all label values of an ontology object or to address one of the more specific label properties, if needed.

## 5 Conclusion and Outlook

This paper has delineated strategies for creating integrated ontologies for the Semantic Web and exemplarily illustrated modeling decisions in this process. While the last two modeling aspects listed in [Section 4.2] are rather use case-specific (the integration of vocabularies and the use of labels), the other issues can be expected to occur in most integration projects. This applies to the handling of ontologies in different language variants, the extension of reused ontologies, the dealing with semantic overlappings and the decision whether to model certain ontology objects as instances or classes. This paper has shown possible modeling solutions for all these aspects, that may be of use in similar integration projects.

Moreover, the paper has identified current challenges, such as the integration of ontologies expressed in different language standards, the integration of terminological resources and ontologies, the semantic integration of already existing ontologies and the agreement on ontology integration guidelines, which may inspire further research.

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## Using iDocument for Document Categorization in Nepomuk Social Semantic Desktop

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**Abstract** On the Semantic Desktop users maintain their model of the world in a formal personal information model ontology. Concepts from this ontology are used to annotate documents from desktop, allowing efficient navigation and browsing of these. However, the mental overhead required for correctly classifying new incoming document is substantial. We present the integration of the ontology-based information extraction system iDocument into the Nepomuk Semantic Desktop for classifying documents within the personal information model. A comparison is done between iDocument and the original classification system Structure Recommender. It is based on real models and documents from five Nepomuk users. Results reveal evidences that iDocument's categorization proposals are rated with higher recall and precision values and show that iDocument's result ranking corresponds to user ratings.

**Key Words:** semantic desktop, ontology-based information extraction, text classification, personal information model

**Category:** H.3.1, I.2.7, M.0, M.5, M.8

### 1 Introduction

On the Semantic Desktop users maintain their model of the world in a formal personal information model ontology (PIMO, cf. [SvED07]). Concepts from PIMO are used to tag documents from desktop, allowing efficient navigation and browsing of these. The Nepomuk project [GHM<sup>+</sup>07] provided a Semantic Desktop implementation based on Semantic Web techniques (RDF/S). As the mental overhead required for correctly classifying new incoming document is substantial, Nepomuk offers a component called Drop-box. Users simply drop document from their desktop into the Drop-box and get recommended instances from PIMO as possible classification candidates. The current service generating these recommendations is Structure Recommender (StrucRec, cf. [TSJB08]). For each document, StrucRec generates a flat set of instance candidates. Unfortunately, these results are neither weighted nor ordered. Users cannot change the classification behavior to for example restrict recommendations on specific parts of their PIMO (e.g., just use instance about projects for classification purpose).

Therefore, we integrate the ontology-based information extraction (OBIE) system iDocument [AMD09] into Nepomuk. iDocument generates weighted document classification proposals. It also uses extraction templates that may be written in the RDF query language SPARQL<sup>1</sup> to define relevant patterns of PIMO instances for categorization purpose. In order to get evidence about the quality of iDocument's functionalities, we compare both systems with data from five mid-term to long-term Nepomuk users. Each user provided ten manually classified documents and rated the quality of recommended classification proposals from both systems.

The rest of this paper is structured as follows. At first, an overview of related and previous work is given. Nepomuk and its existing recommendation facilities are illustrated in Section 3. iDocument is explained in Section 4. Next section describes the comparison between iDocument and StrucRec. Finally, we conclude comparison and evaluation results and provide an outlook of future work.

## 2 Related Work

Ontology-based information extraction (OBIE) systems use ontologies and incorporated instance knowledge to extract information from unstructured text. Many OBIE approaches just extend standard IE systems as done in S-Cream [HSC02] or SOBA [BCR06]. Other approaches use ontologies for extraction purpose directly. Labsky et al. use specialized forms of extraction ontologies [LSN08]. GATE has been extended with ontology gazetteers for instance recognition tasks [BTMC04]. Compared to these, iDocument bases on GATE but provides additional extraction templates. These templates define patterns that describe relevant types of instances that should be extracted from text. As iDocument expects ontologies written in RDFS, templates are specified in SPARQL. Inside the Gnowsiss Semantic Desktop [SGK<sup>+</sup>06], the generation of tag recommendations was done with a system called ConTag [ASRB07]. ConTag used external Web Services for extracting named entities from documents. Privacy is an important issue, thus iDocument does not query external web services.

## 3 Document classification in Nepomuk

Nepomuk [GHM<sup>+</sup>07] provides a document classification component called Drop Box. Tag recommendations are generated each time the user drops a document into the Drop Box. Users may accept recommended instances as tags by clicking on them. In Nepomuk, StrucRec suggests PIMO things as tags (or document categories). StrucRec's<sup>2</sup> approach uses labels from PIMO instances matching

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<sup>1</sup> see <http://www.w3.org/TR/rdf-sparql-query>

<sup>2</sup> please inspect <http://www.alphaworks.ibm.com/tech/galaxy> for more information

them as parts of text passages. Next, it performs a spreading activation inside the PIMO for instance disambiguation purpose. Disadvantages of StrucRec are that it does not weight its results with confidence ratios and thus does not provide any ranking facilities. It is not user adaptable as users may not select specific parts of their PIMO for document classification purpose.

## 4 The OBIE system iDocument

iDocument takes an RDFS domain ontology, an extraction template in SPARQL (e.g., *SELECT \* WHERE { ?p rdf:type foaf:Person; foaf:member ?o. ?o rdf:type foaf:Organization }*), and a document as input and finally returns an RDF model with multiple named graphs. Each graph is a possible result (called scenario) for the given template. iDocument follows a pipeline of six extraction tasks (cf. [AMD09]). (i) Normalization extracts plain text and existing meta data from an underlying text document. (ii) Segmentation partitions incoming text to segmental units i.e., paragraphs, sentences, and tokens. (iii) Symbolization recognizes matches between phrases in text and literal values of data type properties of the domain ontology. Successful matches are called symbols. (iv) Instantiation resolves recognized symbols with candidates for possible instances. (v) Contextualization resolves recognized instances, recognized object properties, and existing fact knowledge for creating fact candidates that are valid for populating a template. (vi) Population populates extraction templates with multiple variants (called scenarios) of extracted facts. Each scenario, instance, and fact is weighted with a confidence value.

## 5 Evaluation

The comparison between iDocument and StrucRec was done on real PIMO data. Five Nepomuk users agreed to provide their PIMO model and ten already categorized documents. For each model, we logged statistics about the amount of overall PIMO instances. In addition, we marked those instances that were used as tags for each of the ten selected documents. These tag relations were deleted from the evaluation models. Based on these evaluation models, StrucRec and iDocument generated classification proposals. The Nepomuk users received two spreadsheets with results from iDocument and StrucRec about their documents. They did not know which of the recommendation system created which result. They rated each proposals by choosing one of the following three values:

- 1 The instance as such is invalid and should be deleted from PIMO. Some users had applied Nepomuk components that auto inserted noisy instances into their PIMO. Instances labeled with this value were ignored in this evaluation.

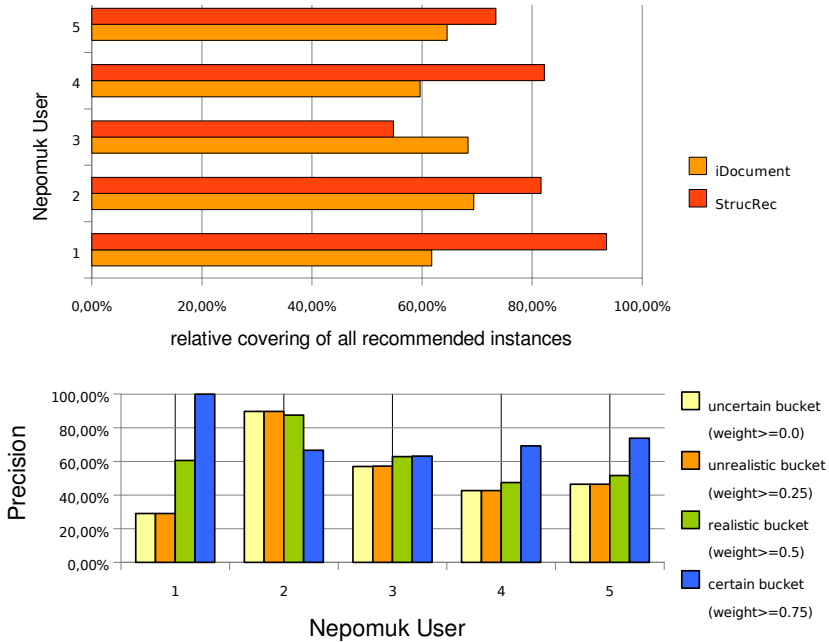


Figure 1: Upper chart: Relative amount of generated recommendations. Lower chart: Precision ratios about four ranges of iDocument’s ranked result list.

0 The instance is not a valid category for this document.

+1 The instance is a valid category for this document. Users could also use this values for instances they previously did not use for categorizing documents.

If users labeled identical categories different for the same document, these categories were ignored in the evaluation. The following table shows statistics about the amount of instances each of the five users maintained in his or her PIMO.

Nepomuk User	# Instances	User Type
1	1431	(long-term user)
2	189	(mid-term user)
3	19261	(long-term user)
4	8210	(long-term user)
5	649	(mid-term user)

The upper chart in Figure 1 shows the relative covering of recommended instances of both systems for each user. We observed that both systems generated 50% identical recommendations in general. In most cases, StrucRec generated more recommendations than iDocument.



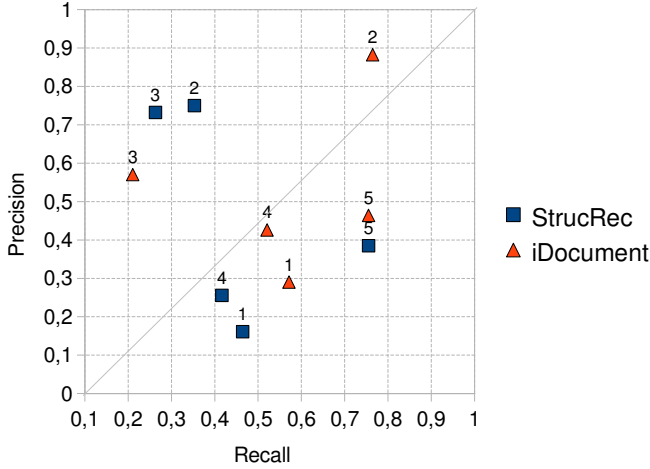


Figure 2: Recall and precision ratios

The calculation of recall was complicated as users did not know if they used all relevant PIMO instances for categorizing their documents. Thus, we could not assume users to rate over 1000 PIMO instances for each document. Therefore, we took those instances that were manually taken for categorization purpose as base line for relevant categories. We used this base line for estimating recall values about results from iDocument and StrucRec. Precision values were weighted by the amount of recommended instances each system made for each document. The distribution of precision ratios in Figure 2 shows that iDocument beats StrucRec for at least 14% except for User 3. Here StrucRec’s precision of results was 14% higher than iDocument’s. Analyzing recall values in Figure 2 shows that iDocument beats StrucRec for at least 10% except for User 3. Here StrucRec’s recall was 5% better than iDocument’s.

In contrast to StrucRec, iDocument generates confidence values for each recommendation (cf. [AD08]). We separated iDocument’s recommendations into four buckets with thresholds in steps of 0.25 from 0.0 to 1.0. Each bucket contained recommended instances if the confidence was greater than the buckets threshold. Then we analysed precision ratios for each bucket. The lower chart in Figure 1 reveals that four users accepted more recommendations in buckets with higher thresholds. This confirms the quality of iDocument’s result ranking.

## 6 Conclusion and Outlook

The comparison between StrucRec and iDocument yields that iDocument generates better recall and precision results than StrucRec for four of five users.

The user's PIMO model (User 3), where iDocument produced worse results than StrucRec, contained a huge amount of auto generated instances from other Nepomuk components. It was the largest PIMO model (19261 instances) and both systems' result were rated with poor recall values below 30%. The ranked result list of iDocument provided relevant results with high confidence weights for four of five users also. The PIMO model (User 4), where iDocument's result ranking did not fit, was the smallest of all (189 instances). As both systems generated about 50% identical recommendations, it is recommended to use both systems in Nepomuk. iDocument was executed with a standard IE template. In future work, user adaptable extraction templates are going to be evaluated. This work was financed by the BMBF project Perspecting (Grant 01IW08002).

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# GeoTemporal Reasoning for the Social Semantic Web

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**Abstract:** We demonstrate a Web 3.0 application that organizes social events for friends in the larger San Francisco Bay Area using real data from available web sources. We use a collection of techniques that will be at the heart of the next wave of applications on the web; entity extraction, querying federated databases, efficient spatial reasoning, temporal reasoning, practical RDFS++ reasoning, reasoning over preferences, social network analytics, activity planning and activity recognition.

**Keywords:** Geotemporal reasoning, social network analysis, knowledge management, RDFS

**Catagories:** H.1.2, H.2.8, H.4, I.2

## 1 Introduction

Tim Berners-Lee, James Hendler and Ora Lassila's Scientific American article [Berners-Lee et al., 2001] provides a compelling vision of the Semantic Web. The body of the article covered interesting use cases that showed what the Semantic Web will offer individual users.

Nearly all of the use cases are about helping people to organize their lives better, for example planning a visit to a doctor within the constraints of your working life and family life. In their use cases it is never about one person, but always about the person in a social context of family, circle of friends, work or service providers (like a doctor and his office). All use cases deal with events that happen at some point in time and at some particular place, where the agent must take into consideration that you have to travel between locations and be aware of traffic constraints. Finally, in many use cases it is clear that you have to deal with preferences of people.

We decided to test if the data on the web, and the currently available Semantic Web tools were sufficient to implement a typical use case, as mentioned above, on real scenarios using data available today.

The example we chose was an event-planning-agent for the San Francisco Bay area. The use case in the example is to organize an evening with your friends where you leave it up to the agent to determine a movie and restaurant, and then invite the right people and deal with the fact that they all have to come from different locations and will have different traveling times. Obviously the agent will also have to deal with the preferences that people have about food and movies.

### **1.1 Collected Data**

- **Restaurant Data.** We collected restaurant data from Yelp ([www.yelp.com](http://www.yelp.com)) since it is popular and fairly complete for restaurants in the Bay Area. We also used the Yelp classification scheme for type of food, price range, rating, and with the help of Google we can also accurately get the geospatial coordinates.
- **Movie Data.** We scraped part of the Internet Movie Database ([www.imdb.com](http://www.imdb.com)) to get movie titles, actors playing in movies, the rating for movies, the types of movies, reviews, etc.
- **Theater Data.** We used Yahoo's movie service to find all theaters in the Bay Area plus the current releases and their running times. We used the Google API again to find the geospatial coordinates
- **Transit Data.** We contacted the regional transit authority ([www.mtc.ca.gov](http://www.mtc.ca.gov)) and obtained transit data for all transportation modes in the greater Bay Area, in this case BART, MUNI, ferries, and local trains.

### **1.2 Simulated Data**

Due to privacy issues and data availability challenges we opted to simulate a large social network based on US Census Data (2000). We created a network of 5000 people; including names, frequency statistics, gender, age, work/study, a set of preferences for movies and type of food, a history for restaurants and movies visited, and relationships between people (school/lab/club mates, family, in love, etc).

## **2 Demonstration Scenarios**

1. There is a new major cinematic release this weekend and I want to see it with someone. Tell me which of my friends may be interested in this movie, the most convenient theater for our group, and determine a casual inexpensive restaurant location for after the movie. I need to be home by midnight.
2. I want to schedule a date with my girlfriend, but I don't want to drive a car. Tell me the most romantic and recent movie release she may like (if there are several choices, include those I may enjoy), include a quaint but not too expensive restaurant in the plans. The theater must be near the restaurant. I prefer that the transit fee for my girlfriend should be cheaper than mine, she has no wait time, and she can be home by her 11PM curfew.
3. Suddenly today's lecture is cancelled. Several of my classmates want to go see a movie but can't be late for their next lecture. Find the nearest theater available with movies starting soon (but we can be on time) and we can return back to our current location before the next lecture. If there are several choices, choose one the group will prefer on average.

4. I'd like to plan a dinner with some old school friends. I'd like to watch a movie with the largest number that have similar movie interests (not specific) before/after dinner, please suggest members, films, and theater nearest to the suggested restaurant. The location should be mutually inconvenient for everyone.

### **3 Summary of required reasoning capabilities of the Agent**

It falls outside the scope of this demo paper to explain in detail the inner workings of the agent. However, here are some things that the agent uses:

1. Geospatial computations. Both within the trip planner and for finding the right pairs of movie theaters and restaurants.
2. Temporal reasoning for all events. In the trip planner, finding the times between having dinner and going to the theater, etc.
3. Social network analysis. The agent needs to compute interest groups based on preferences and types of relationships between people
4. RDFS++ reasoning to reason over types of restaurants, types of movies, etc. RDF Schema is a W3C standard that adds semantics to RDF, essentially providing basic elements for the description of ontologies. The most important construct being that of classes and subclasses. RDFS++ refers to the fact that we also added some more advanced description logic features. We refer to [Allemang and Hendler, 2008] for an extensive description of RDFS++.
5. Federated querying. The restaurant data, the movie data, the theater data, the social networks and the transit data all reside in their own RDF triple stores. All the queries are done over a federated store that encompasses all these triple stores.
6. Trip planning. In this case is a well understood cost based planner that works directly on the RDF store (a type of A\* search [Dechter and Pearl, 1985]).





Figure 3: Transit Planning



Figure 4: Location Planning

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## **Semantic Web as Driver of Collaborative Demand Capacity Planning**

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**Abstract:** Supply Networks in the automotive industry are confronted with a lot of challenges - business and technical ones. One of the technical issues is the heterogeneous and different ICT platforms which are show-stopper to implement enterprise interoperability services. Besides other measures Semantic Web approaches could provide mitigation to solve this issue. Ontology is the basic problem which must be solved before the Semantic Web approaches could be applied. In the specific case of suppliers in automotive industry the so called Bill of Material (BOM) could be easily defined as a "slight" ontology. Especially the agreement on the ontology could be pushed by the leading partner of tier in the Supply Chain. That's why the two approaches namely Collaboration Agents and Semantic Annotation of Web Services will be pursued in the following paper. After having overcome the technical challenge on semantics the business oriented ones could be solved, which cover a fast shift in the portfolio of an OEM, where it must be taken into account that only 20% of parts of a car are produced directly in the plants of the OEM and the remaining overwhelming parts are delivered by suppliers in different tiers.

**Keywords:** Collaborative Demand Capacity Planning, Enterprise Interoperability, Semantic Web, Serious Gaming, SaaS (Software as a Service), Supply Networks

**Categories:** D.2.12, L.3.6, L.6.2, F.3.2



## 1 Introduction

One result of the current situation in the automotive industry is the insight that OEM's (Original Equipment Manufacturers) leeway for reactions are strongly limited due to the fact that only 20% of parts of a car are produced directly in the plants of the OEM and therefore about approximately 80% are delivered by suppliers in different tiers.

A typical supply chain for the production of a new car in the automotive industry encompass around 6 to 10 tiers and the supply network has around 3000-5000 partners (suppliers delivering components). Although OEM's may react very fast on changes in their portfolio driven by the market thanks to their flexible manufacturing, suppliers are lagging behind in producing their respective subparts. An important supply chain process covering all levels of supply is the "Collaborative Demand Capacity Planning (CDCP)". This process is in fact an exception/alert handling process when demands of the customer (OEM, 1st tier ff) don't match the planned capacity of the supplier (1st tier, 2nd tier ff). The process is a set of rules to handle such conflict in collaboration with partners in the supply chain. Also when this process is well defined and agreed by the partner the problem of handling the message flow due the heterogeneous and different ICT infrastructures is a show stopper to implement the process. CDCP is based on DCP (Demand Capacity Planning), which is an official VDA Verband der Automobilindustrie [VDA] recommendation. DCP is constraint to relations between OEM and 1st tier, respectively between (n) tier and (n+1) tier. To encounter this essential challenge not only one remedy will mitigate this issue but the combination of different ones.

In this paper especially the following remedies will be discussed, respectively a reference will be given where they are already explicitly referenced.

- Collaborative Demand Capacity Planning (CDCP)
- Enterprise Collaboration (EC) and Enterprise Interoperability (EI) Services
- Serious Gaming
- Semantic Web

EC/EI services which are based on Service Oriented Architecture (SOA), Ontology, and especially Semantic Web Services will originate from the EU funded project COIN [COIN, 08] and its forerunners such as ECOLEAD [ECOLEAD, 04] or ATHENA [ATHENA, 06] and should be selected and applied to solve the CDCP issues. To enable business interoperability, this paper addresses also semantic compatibility among different business processes. Especially in the automotive industry, the ontology models of business partner, for instance bill of materials, are not unified. But it's much easier to agree on a "slight" ontology for a Bill of Material (BOM). Experiences have shown that the agreement on ontology not only fails due to technical reasons but also due to political ones (at least within the automotive industry-see Odette). With the help of semantic web and its specific standards such as Resource Description Framework (RDF) and Web Ontology Language (OWL), on the one hand collaborative agents can solve some of the problems of horizontal business interoperability challenges and on the other hand semantic annotation of Web Services will facilitate these efforts. Moreover collaborative agents will be enabled to find much easier the requested portfolio within a tier when this portfolio is provided by RDF and OWL applying the ontology of BOM.

## **2 Theory**

To find an appropriate approach of solving the essential issues of CDCP, the above mentioned innovative methodologies must be applied on CDCP. Taking into account the first methodology – namely EC/EI services – the focus should be on EI services following the argumentation that in supply chains and supply networks the EC issues are not so relevant according to a very strong leading partner: the OEM. So the most important issues of EC services like the agreement on common business strategies, business models and primary modelling of common business processes are usually not really relevant as it's widely defined by the respective OEM and expect from their suppliers' to adhere to them. Important EC results are coming from the European project ECOLEAD but will not be explicitly considered in the context of CDCP.

Much more interesting are the results of the EU project ATHENA and especially the upcoming results of the ongoing EU funded project COIN. For solving the CDCP challenges the focus is put on innovative services for Business Process Interoperability, in order to fill the gap between Business and ICT (Information Communication Technology) in Business Process Management (BPM) in Supply Networks. These services will be provided by means of Serious Gaming in order to enable members of supply networks to learn how their own business processes can interoperate with the defined business processes of their partners and especially with the leading one i.e. OEM and higher tiers. The goal of such a game – and of course of the EI Services – is the solution of the CDCP issues. According on the experiences of Serious Gaming, members of supply networks will learn much faster compared to the application of conventional tools (e.g. [Baalsrud, 08]). On the last ICE 2008 conference [Withalm, 08] it was shown that the combination of Serious Gaming and CMMI assessment have the potential to improve on the one hand the collaboration behaviour of members of supply networks and on the other hand enabled the structuring of process areas of EC/EI. Afterwards the basic theories will be briefly introduced- namely Semantic Web, Ontology, and Business Interoperability Services.

### **2.1 Semantic Web**

The goal of the Semantic Web initiative is to create a universal medium for the exchange of data where data can be shared and processed by automated tools as well as by people. For the Web to scale, tomorrow's programs must be able to share and process data even when these programs have been designed totally independently. The Semantic Web will smoothly interconnect personal information management, enterprise application integration, and the global sharing of commercial, scientific and cultural data. Facilities to put machine-understandable data on the Web are quickly becoming a high priority for organisations, individuals and communities.

### **2.2 Ontology**

Authors have about ten years experience with ontology, semantic web and collaborative agents. First accomplishments were reached in establishing an ontology in tourism within the International Federation for Information Technology and Travel & Tourism (IFITT) workgroup "Reference Model Special Interest Group (RMSIG)" [RMSIG]. Together with Salzburg Research a joint scientific project was established,

funded by Austrian government, which is described in [Withalm, 00]. Further progress regarding ontology was reached in the EU projects Harmonize and Harmo-TEN [Werthner, 01]. Results of these projects were applied in the European Tourism Portal [ETD]. Moreover collaborative agents were primarily presented as early as in ENTER 2000 [Withalm, 00], which finally started the process of holding a patent [PAT A653/2001].

Ontology can enhance the functioning of the Web in many ways. They can be used in a simple fashion to improve the accuracy of Web searches - the search program can look for only those pages that refer to a precise concept instead of all the ones using ambiguous keywords. More advanced applications will use Ontology to relate the information on a page to the associated knowledge structures and inference rules as in our example above. In addition, Ontology makes it much easier to develop programs that can tackle complicated questions whose answers do not reside on a single Web page.

### **2.3 Business Interoperability Services**

Innovative Business Interoperability (BI) services for business process semantic annotation and mediation will be developed in order to allow an automatic reconciliation between internal processes and external public views and between these and the global cross-enterprise business process. The Enterprise Interoperability (EI) innovative services have been grouped into three classes: Information, Knowledge and Business Interoperability. A Cross Organizational Business Process (CBP) is the business process, which is modelled, defined and implemented by the leading partner of a supply network. A CBP approach combines two ideas and defines 8 technical requirements [COIN, 08].

## **3 Methodologies**

### **3.1 Collaboration Agents**

The most essential behaviours of Agents will be briefly described. Agents will roam through the portals of participating suppliers of the corresponding tier looking for partners who could deliver sub parts of the car model where such issues as availability, quality, prices, etc. are detailed specified according the bill of material (BOM). Agents will be programmed by the leading partner (i.e. OEM, 1st tier 2nd tier ff) in that way that they will find the most appropriate suppliers. On the other hand suppliers which are willing to propose their portfolio must implement their offers in form of RDF and OWL following the Ontology which is focused on the BOM of a specific car model. Therefore the collaborative agent must look for Semantic Web portals - they are characterized, that their contents are presented in RDF/OWL- for the desired sub parts of the car. Agents are now in the position roughly to look for appropriate suppliers.

As already outlined it seems feasible that the negotiation process of agents on the e-marketplace may be substituted by Semantic Web. In [ENTER, 04] these crucial problems of negotiation issues of agents were already discussed.

### **3.2 Semantic Annotation of Web Services**

CDCP's challenges could also be solved by Cross Organizational Business Processes (CBP). As already outlined one show stopper to implement these CBP Interoperability Services are heterogeneous and different ICT infrastructures. To overcome these problems SOA (Service Oriented Architecture) - basing on Web Services - was introduced. SOA's big benefits are on the one hand the direct mapping of business services on technical services (= Web Services) and on the other hand that Web Services are agnostic concerning ICT infrastructure and above all are available in the Internet.

## **4 Expected Results**

The organization ITA (Information Technology for the Automotive Industry) started already the project CDCP. ITA's way in handling such projects follows always the same approach. There must be at least one OEM or nth tier partner within the project who fosters it and who is willing to trial it. In the course of CDCP there is a German OEM who will promote this project. So all the results will be demonstrated in companion with this OEM and its suppliers which partly also participate in the project. Of course a further idea is that ICT partner within this project will later on implement respective ICT solutions which will be exploited on the one hand via the classical ISP model but on the other hand also via the most recent SaaS (Software as a Service) approach. Especially the EI service platform should be implemented with help of Semantic Web Services so it's well applicable also for other OEM's and their partners. A specific interest is paid to the implementation of a Serious Game, where existing platforms such as PRIME ([Duin, 07]) or SECONDS ([Hunecker, 08]) need to be adapted. Within the CDCP project of ITA a concrete tier in a supply chain will be selected and there the establishment of the "slight" ontology will be started. According the current discussion among collaborative agents and semantic annotation of web services a decision will come.

## **5 Conclusions**

Seamless implementation of CDCP along the supply chain is an urgent problem in the automotive industry which must be solved very fast especially in the case of the actual situation. There are some issues discussed in this paper which will substantially improve the acceleration of implementation and reaction of supply chain processes. CDCP has many stakeholders in the automotive industry that could benefit when meeting the goal of the CDCP project. The most important stakeholders are OEM's and their suppliers and ICT providers who will implement the recommended services and Serious Games.

Finally, the CDCP project is expected to deliver concepts of EI Services which might be implemented by the participating ICT partners during the time frame of the project. A serious game, which enables suppliers in the automotive industry to learn how EI services work, will support meeting the CDCP goals, i.e. on the one hand supplier learn to apply EI services and on the other hand it will help to reveal missing

EI services. One of the biggest challenges is the establishment of the “slight” ontology for BOM with a tier and then to find out which approach will be easier accepted by the suppliers: collaborative agents or semantic annotation of web services.

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# Applying Ontological Framework for Finding Links into the Future from Web

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**Abstract:** The tremendous growth in the size of Web has created a challenge to find context-specific information. After finding a specific content on the Web, users need to explicitly query search engines for the related information. In many cases, millions of generic hits are returned by general search engines which do not accomplish the users' intent. To cope with this scenario, same author has already implemented a feature called 'Links into the Future' within a digital journal. When a user is viewing a research paper, Links into the Future provides the user with most relevant papers that have been made available after the publication date of the focused paper. The users do not need to search the related papers instead the related papers are pushed into the users' local context. The same author has also proposed an ontological representation for this concept. However, the current work describes the complete system architecture and shows that how this ontological framework is applied to extend the notion for finding Links into the Future from Web documents. This work also shows that how the proposed ontological framework is instantiated and how individual ontology plays its role in finding the most related Links into the Future from Web documents.

**Keywords:** Links into the future, Ontologies, Ontological framework, Information extraction.

**Categories:** H.3.1, H.3.3, H.3.7

## 1 Introduction

The Web has become a major platform for sharing different kind of resources. However, with the evolution of Web, it has becomes very difficult to find task-related context-specific information. This is mainly because of the unstructured information on the Web. Furthermore, the user local context and task at hand is not considered for resource discovery [Heath et al 2005]. The Semantic Web, on the other hand, is struggling to structure the resources in a formal way which can further be interpreted and processed by machines intelligently.

Information supply paradigm as proposed by [Broder 2006] is about presenting users with the most relevant information by looking users 'local context. Inspiring from this paradigm, an idea of Links into the Future is proposed and implemented in this paper. This feature provides users with the most relevant information that has been made available on the Web after the publication date of the focused content. This feature can be realized in different contexts. For example when a user is reading a particular news article; Links into the Future provides the users with other relevant news articles that were published afterwards. The discovered articles may contain news resources indicating positive or negative sentiments about the news article in

focus. When a user is reading a book, Links into the Future provides user with links to related books or the books that are extended versions of the focused book. However, the scope of this paper is to apply this feature to find related papers from Web.

The idea of Links into the Future was originally proposed by [Maurer 2001]. An ontological representation for this idea was presented by the same author in [Afzal et al 2007a]. The same author also showed that how this feature can be implemented within a digital Journal in [Afzal et al 2007b]. Details of general rules to find future related papers from Web can be found in [Afzal 2009]. However, the current work is a follow up publication describing the complete system architecture to implement this idea for Web documents. This feature has been implemented in Journal of Universal Computer Science (J.UCS) [J.UCS 2009].

A future link from paper “a” to paper “b” (Future\_Link (a,b)) exists, if paper “b” is written by the same author/s as that of paper “a” and the topics of both papers are similar, as shown in equation (1).

$$\text{Authors (b)} \in \text{Authors (a)} \wedge \text{Topics (b)} \in \text{Topics (a)} \rightarrow \text{Future\_Link (a, b)} \quad (1)$$

The later sections of this work are divided as follows: Section 2 describes the underlying system architecture. Section 3 explains the working of ontological framework followed by the description of knowledge extraction module in section 4. Experimental results are discussed in section 5.

## 2 System architecture

This section presents the system architecture of the proposed system. Ontology based knowledge extraction from Web documents has been focused in project Artequakt [Alani et al 2003]. Alani et al. proposed an ontology-based knowledge extraction from text documents in artist domain. To extract some domain specific information from web documents is not a trivial issue. The proposed system can be seen in Figure 1. We are interested to find related future papers from different sources like Web, CiteSeer, DBLP. However, the focus of this paper is limited to find related papers from Web. There are mainly three modules of the system: knowledge extraction, ontology framework and visualization to the user. The details of these modules have been defined in the forthcoming sections.

## 3 Working of Ontological Framework to Represent Future Links

This section describes that how ontological framework defined in [Afzal et al 2007a] and shown in Figure 1 is applied for finding related documents from Web.

### 3.1 Author’s Publication

This ontology conceptualizes authors’ papers stored at different sources including J.UCS and Web. Initially, this ontology was populated from J. UCS authors (more than 2,100) and papers (more than 1,400) published by J.UCS. The newly discovered related papers from Web are linked in this ontology.



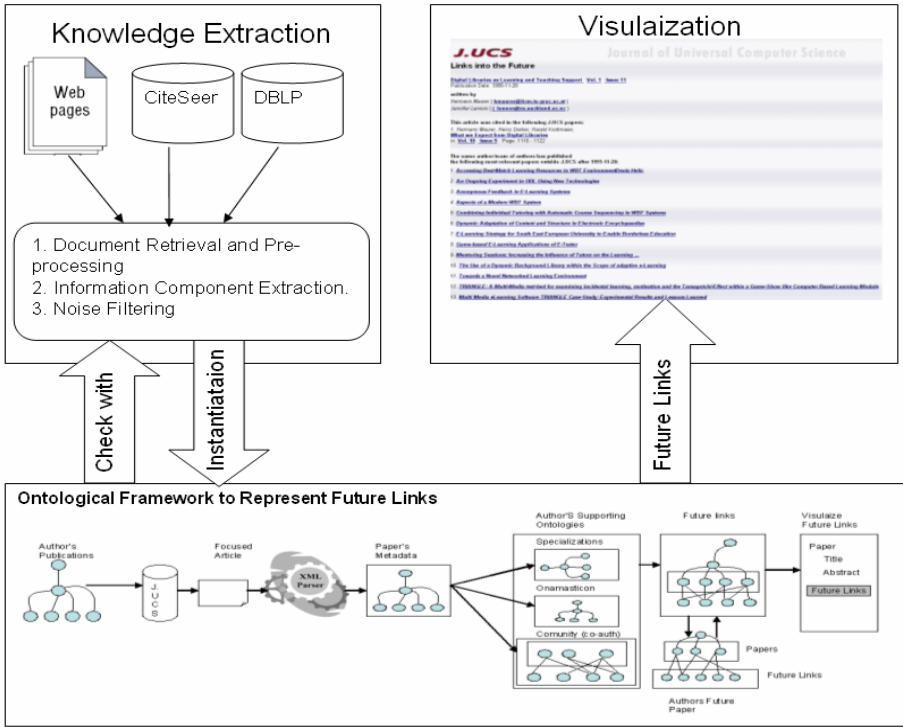


Figure 1: System Architecture

### 3.2 Paper’s metadata

When a paper is published by J.U.C.S, a detailed metadata file (including paper’s title, list of authors, ACM categories etc.) is generated. The paper’s metadata ontology was populated from metadata files [Afzal et al 2007a].

### 3.3 Author’s Onamasticon (Lexicon of author’s names)

Author disambiguation is an important task in finding related papers. The same author can be referred with different name variations. For example, “Full name”, “Initial., last name”, “Last name, initial.” Author’s Onamasticon ontology represents these name variations. The ontology was populated with the described set of variations for all authors. This ontology alone is not sufficient for authors’ disambiguation. For example searching papers written by author “H. Maurer” may result in some false positives like including papers written by “Henry Maurer” or so. This aspect has been solved by author’s specialization ontology discussed in section 3.4 along with some general rules as described in the section 4.

### **3.4 Author's Specialization**

When a paper is published by J.UCS, it is annotated with ACM categories by the authors of the paper. These categories are used to describe an author's specialization. This ontology was populated from the metadata files of J.UCS papers.

### **3.5 Future Links**

This ontology conceptualizes all candidate Links into the Future for all J.UCS papers. The same paper may be acquired from different sources which enhance its importance and used to rank accordingly.

### **3.6 Community (Co-Authors)**

This ontology conceptualizes the co-authors of a paper. If a paper is written by three authors, then all papers written by any of these three authors in the same area and published afterwards are considered as Links into the Future.

### **3.7 Author's Future Papers**

This ontology extends the concept of "author's publication ontology" where every paper is further linked with the future papers found from the Web. The newly discovered links from Web are dynamically incorporated. More than 500 Links into the Future were found for 250 unique papers within J. UCS.

## **4 Knowledge Extraction**

To find some specific information and relationship between documents from text/XML document stored at Web is a great challenge [Alani et al 2003]. But finding documents that are Links into the Future for a paper is a different task. We are interested in finding documents on the Web which were published by J.UCS authors. Knowledge extraction uses the ontology framework to extract related information from web. We have subdivided knowledge extraction module into three sub modules.

### **4.1 Document retrieval and pre-processing**

This module is responsible for filtering the documents retrieved from the Web. SOAP APIs of Google [Google API 2009], Yahoo [Yahoo API 2009], and Microsoft Live [MSN API 2009] were used to extract information from the Web. The query is designed to search particular formats (PDF, PS, and DOC) of documents. The query is formulated for searching papers from Web based on "author's publication", "Onomasticon" and "community" ontology. For example a typical query looks like {abstract references "Hermann Maurer" "H Maurer" "Maurer H" filetype: PDF}. This query formulation helped to reduce undesired information. Duplicate records are subsequently removed. Documents in PS and DOC file formats are first converted to PDF using MiKTeX [MiKTeX 2009] and Openoffice [Open Office 2009] respectively. Then pdfbox [PDFBox 2009], a Java library is used to convert PDF to plain text for further analysis.

## 4.2 Noise Filtering

Extracted dataset from 4.1 may contain documents other than research papers. The examples of these documents include CV, business card, publication list of authors etc. Two simple rules are devised to filter out only the papers: (1) Title of the paper followed by author name and abstract should exist in the same page. (need not be in the first page). Authors' full name is subsequently searched to disambiguate author/s names. (2) Word "reference" or "references" should exist, followed by proper sequence starting with any of the patterns: "[author]", "[1]", "1" and ()).

## 4.3 Information Component Extraction

This module uses the ontological framework (as described in section 3) to extract the relevant information. The list of authors is extracted and "author's publication ontology is populated". The papers discovered from Web are not annotated with ACM categories which might have been helpful to find their relatedness with JUCS papers (source papers). Relatedness is calculated based on similarity scores. To calculate similarity score we first removed papers' header and references to only focus on the paper's content. Then Yahoo term extractor [YahooTermExtractor 2009] was used to extract key terms. Similarity is calculated by taking a dot product of key terms extracted from source and candidates papers. All papers matching the defined threshold are filtered and considered as Links into the Future for the source paper. The newly discovered Links into the Future are updated in all relevant ontologies as described in section 3.

## 5 Experimental Results

We have manually checked the overall performance of the system for randomly selected authors as shown in Table 1. Columns in Table 1 represent result of filtering processes as described in section 4. We observed substantial amount of noise reduction in all phases. For example if user perform a query like {"Hermann Maurer"} in a search engine to find the papers written by the author. 168,000 results are returned. These results include video files, xml document, and other content which is not only the research papers. However, the formulated query defined in section 4.1 retrieved 112 documents. These documents further contain duplicate entries and after removing duplicates, we left with 75 unique results. However, these 75 documents may contain some research papers and some other related documents as discussed in section 4.2. The paper classification rules helped to filter only the research papers out of these documents and we left with 12 research papers only. The same process was done by using Yahoo and MSN searches. Then the universal set of all searches resulted in 23 unique papers. These 23 papers were considered candidate for similarity algorithm defined in section 4.3 which filtered out the 17 actual future links for the focused paper. The system has shown that it can reduce millions of generic hits returned by a general search engine to a few most relevant future related papers.

Author	Focused paper in J UCS	Search Engine	Formulated Query	After removal duplicate	Classified Papers	Unique paper	Actual Future Links
Maurer H.	Digital Libraries as Learning and Teaching Support vol. 1 Issue 11	Google	112	75	12	23	17
		Yahoo	495	86	19		
Abraham A.	A Novel Scheme for Secured Data Transfer Over Computer Networks Vol. 11 Issue 1	Google	148	62	13	33	22
		Yahoo	263	87	41		
Bulitko V	On Completeness of Pseudosimple Sets Vol.1 issue 2	Google	21	21	7	17	3
		Yahoo	45	28	13		
Shum S. B	Negotiating the Construction and Reconstruction of Organisational Memories Vol. 3 issue 8	Google	103	81	11	28	21
		Yahoo	546	104	26		
Abecker A.	Corporate Memories for Knowledge Management in Industrial Practice: Prospects and Challenges Vol. 3 Issue 8	Google	69	59	9	17	15
		Yahoo	335	65	14		

Table 1. Links into the Future results for selected authors

## 6 Conclusion

The working of ontological framework along with the role of individual ontology in finding Links into the Future from Web was explained in details. The results have shown that the system was able to find the most relevant Links into the Future from Web. The discovered Links into the Future are pushed to the user's local context. This has reduced the human effort to locate related papers from Web. This feature is available in J UCS (<http://www.jucs.org>) since 2007. We have received a number of emails from users of J.UCS who are finding this system extremely useful.

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# **The Management of the Knowledge Evolution by Using Text Mining Techniques**

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**Abstract:** The maintenance of the domain ontology or a knowledge model after the appearance of changes in the studied domain is an essential stage. Several studies provide methodologies for the maintenance of an ontology but only some of them deal with ontologies that are created from texts.

Text mining techniques provide good results when the processing of texts is done for the purpose of modelling or classification. The objective of our work is the use of text mining techniques for the maintenance of an ontology representing a dynamic domain, according to an analysis of textual changes and their effects on the corresponding ontology.

**Keywords:** knowledge, text mining, ontology

**Categories:** M.0, M.1

## **1 Introduction**

Currently there are many approaches for ontologies construction [Ontoweb 02]. However, only METHONTOLOGY [Fernandez 97] and ON-TO-Knowledge [Sure 04] consider the evolution process in the life cycle of an ontology, but they do not provide methods or recommendations to support it.

One of the problems encountered in evolving environments is the integration of new knowledge, which raises the problem of the modification of the initial ontology and its adaptation to the new needs.

In the state of the art, there are no theoretical complete studies or tools able to analyze the changes effects in the semantic relationship between ontological entities, or changes in the compatibility between the text corpus containing the domain knowledge and the ontology representing this domain [Stuckenschmidt 03].

The analysis of the main tools has highlighted the lack of very important functionalities to ensure the identification of the ontological changes [Delia 05].

Text mining techniques offer solutions to analyze texts for multiple purposes, classification, modelling, etc. Our work consists in using text mining techniques to extend the changes made on texts onto the ontology.

The paper is organized as follows: first, we present a state of the art of text mining techniques, then we present an analysis of the types of textual changes which can intervene and their effects on the ontology [ Najla 08]. Finally we present the text mining algorithms we have developed: a hierarchical clustering algorithm CAH, with a similarity measure, and the algorithm APRIORI with the measure of confidence. These two algorithms were modified in order to better adapt to our research problem: how to support the ontology evolution in a dynamic environment

## 2 State of the art

In this section we present an art state of the text mining techniques.

### 2.1 Learning lexico-syntactic patterns

Lexico-syntactic patterns are based on the study of the syntactical regularities between two given concepts. This is an observation of the realisation of a relationship in the corpus, in order to simplify the lexical and syntactical context. This simplification establishes a lexico-syntactic pattern. The advantage of this technique is to be targeted on the lexico-syntactic context. It remains effective on small-sized corpora. In [Zghal, 07] the experimental evaluation of a large number of patterns was made by using the CAMELEON tool.

### 2.2 Clustering techniques

The classification approach proposed by [Chagnoux, 08] consists in classifying documents in collections with respect to the sense of every word by using a labelled corpus such as WordNet. Then, for each of the formed collections, the words and their respective frequencies are extracted and compared with the other collections. The approach proposed by [Aussenac, 08], shows the construction of a domain ontology from textual documents by using two hierarchical classification algorithms.

### 2.3 Statistical techniques and associations rules

These techniques are based on the calculation of similarity measures. Association rules describe associations between certain elements. An association rule is an implication of the form:  $A \rightarrow B$ , where  $A = \{t_1, t_2, \dots, t_p\}$  and  $B = \{t_{p+1}, t_{p+2}, \dots, t_q\}$ .

A rule  $A \rightarrow B$  is interpreted as: a text containing the key terms  $\{t_1, t_2, \dots, t_p\}$  also tends to contain the key terms  $\{t_{p+1}, t_{p+2}, \dots, t_q\}$ , with some probability given by the *confidence* of the rule.

Several algorithms, e.g., Close and Pascal, implement the extracting rules process [Bastide, 02].

The measures of *support* and *confidence* cannot alone identify the rules which make sense. Therefore, other measures are also used, such as interest, belief, dependence, novelty and satisfaction [Cherfi, 04].

### 3 Ontological Evolution from a corpus of texts

Ontology evolution concerns the capacity to update an existing ontology following the emergence of new needs [Maedche, 03].

Ensuring the evolution in a dynamic environment where the actors are not all experts in ontology maintenance, requires the ability to specify the changes in a simple and understandable way [Noy, 03].

In the following, we present the types of changes according to two axes ; ontology and corpus.

#### 3.1 Analysis of ontological changes

The structure of an ontology is represented by a tuple:  $S := \{C, R, <, X\}$  where :

$C, R$  : are separated sets containing the concepts and no taxonomic relationships.

$<$  :  $CXC$  is a partial order on  $C$ , which defines the concept hierarchy.

$X$  :  $R \rightarrow CXC$  is the signature of an associative or taxonomic relationship.

The lexicon of the ontology is the tuple  $L := \{L_c, L_r, F, G\}$  where:

$L_c, L_r$  : are separated disjoint sets.

$F, G$  : are two references relationships.

The hierarchy of concepts is defined by a structure:  $S_0 := \{C, <\}$

The/A concept is defined by  $L_0 := \{L_c, F\}$ .

#### 3.2 Analysis of textual changes

Our text corpus is in French.

The corpus may be represented by the following vector :  $T = (t_1, t_2, \dots, t_n)$  where  $t_i$  : is the included term in the corpus, with the following conditions:

- The meaningless terms are removed (le, la, les, du ,..).
- All uppercase characters become lowercase.
- All conjugations are converted to the infinitive.
- The words with the same root and synonyms are considered as equivalent terms.

Let us detail these changes.

##### 3.2.1 Adding a new text

In this case, text mining techniques provide a hierarchical classification algorithm, which is most effective for our study case with a light modification to fit our needs.

The result of the algorithm is the classification of the concepts and the relationships in the ontology. This algorithm uses a similarity measure in order to group the concepts together.

##### 3.2.2 Deleting of a text fragment

In this case of evolution (text vs. ontology), we apply some text mining techniques, such as calculation of confidence and the algorithm APRIORI in order to update the ontology while preserving its coherence.

Let  $T$  be the initial corpus as:

$T = \{t_1, \dots, t_n\}$  where  $t_i$  : the corpus terms.



If  $T_2$  is the text to be removed; we work on the association rule  $T \rightarrow T_2$ , which means: the text which contains the terms of  $T$  also contains the terms of  $T_2$ .

### 3.2.3 Corpus update

The updating can be described as a deletion and an addition of a text fragment.

## 4 Algorithms

### 4.1 C.A.H Algorithm

1. **Input**
2.  $T = \{t_1, \dots, t_k\}$  : the initial corpus
3.  $T_n = \{t_1, \dots, t_n\}$  : the added text
4.  $O = (C, R, <, K)$  : the global ontology
5.  $C = \{C_1, \dots, C_n\}$  : all concepts of  $O$  with their vectors
6.  $\text{MatriSim}[n+m, n+m]$  : matrix of similarity with  $n$  number of concepts of the new text,  $m$  number of existing concepts in the ontology  $O$ .
7.  $S$  : the threshold of similarity
8. **Output**
9. the classes  $\text{Symi}$  of the synonymic concepts
10. **For**  $i=1, n+m$  **do**  $\text{Matrsim}[i, i] = \langle \rangle$
11. **for**  $i=1, n+m$  **do**
12. **for**  $j=1, n+m$  **do**
13. **if**  $\text{matrsim}[i, j] < \langle \rangle$  **then**  $\text{matrsim}[i, j] = X$
14. **endif**
15. **endfor**
16. **endfor**
17.  $\text{max} = 0$
18. **Repeat**
19. **for**  $i=1, n+m$  **do**
20. **for**  $j=1, n+m$  **do**
21. **if**  $\text{matrsim}[i, j] > \text{max}$  **then**
22.  $\text{max} := \text{matrsim}[i, j]$
23. **endif**
24. **endfor**
25. **endfor**
26. **if**  $\text{max} > \text{seuil}$  **then**  $m_i := m_{i-1} \cup C_i, C_j - C_i, C_j$
27.  $\text{matrsim}[i, j] := \langle \rangle$
28. **endif**
29. Update  $\text{Matrsim}$  by taking into account the new class
30. Make the inference by using the new relation **Until**  $\text{Gsim}(C_i, C_j) < \text{seuil}$
31. **endcah**

The algorithm continues until it ends the classification of all the concepts of  $C$ .

**APRIORI Algorithm**

1. **Input**
2.  $T_c = \{t_1, t_2, \dots, t_k\}$  : The set of the extracted words from the initial corpus
3.  $P_c = \{P_1, \dots, P_p\}$  : The set of the extracted transactions from the initial corpus (a transaction is a Sentence).
4.  $T_s = \{t_1, t_2, \dots, t_{kk}\}$  : The set of the extracted transactions from the text to be removed ( $kk \leq k$ ).
5.  $P_s = \{p_1, p_2, \dots, p_{kp}\}$  The set of extracted transaction from the texts to be removed ( $kp \leq p$ )
6. **Output**
7.  $C = \frac{T_c \cap T_s}{T_s}$  // calculate the confidence //
8. **if** ( $C=1$ ) **then** the total ontology is removed and we keep only the initial ontology.
9. **else For**  $i=1, kk$  **do**  $C_i = \frac{|\{t_i \in T_c\}|}{|\{t_i \in T_s\}|}$
10. **if**  $C_i=1$  **Then** remove the identifier  $t_i$  from the identifiers list
11. **else**  $i=i+1$  // go to the next  $t_i$
12. **Repeat until**  $i=k$
13. Cross the ontology in order to find a concept without identifier then remove.
14. **ENDAPRIORI**

**5 Ontology Maintenance**

The ontology maintenance is usually realized by taking into account at once the correspondence between the ontology and the real environment and the ontology expression quality. For example [Natalya, 02] proposes three criteria to measure the quality of an ontology:

- The accuracy of the modelling itself (clarity, standardization of the vocabulary, deletion of nearly anonymous concepts).
- The reliability of the ontology (completeness, consistency, scalability).
- The quality of the structuring (separation of classes using multiple inheritance, modularity).

In our case study we define two types of coherence:

- Internal Coherence: means the ontological coherence of the entities, for example: no cycle, no redundancy ...
- External coherence: means maintaining the dependency of the ontology in question with other ontologies (specific or generic).

**6 Conclusion**

Many works in text mining deal with how to manage huge number of texts. Most of these works deal with the problem from a statistical point of view without taking into account domain knowledge, and especially when this knowledge is included in texts corpora.

In this paper we called to text mining techniques by the two algorithms C.A.H and APRIORI in order to take into account the textual changes in the domain ontology.

The study of the changes which can intervene on texts as well as the formalism of representation that we adopted facilitate ontology maintenance.

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## Applying Ontology Modularization for Corporate Ontology Engineering

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**Abstract:** As an innovative approach for developing and maintaining continuously evolving ontologies in corporate context the Corporate Ontology Lifecycle Methodology aims at providing an intuitive understanding of rising costs per iteration. In this regard having a close look at ontology partitioning techniques as well as module extraction approaches is very promising, because modular reuse of ontologies as well as ontology composition of building blocks have a reducing impact on costs. In this paper we are discussing the modularization aspects of the Corporate Ontology Lifecycle Methodology and provide a first approach for applying ontology modularization techniques in corporate contexts.

**Key Words:** Corporate Semantic Web, Ontology Modularization

**Category:** H.2, H.5.4

### 1 Introduction

Fast creation of economic value out of knowledge is essential for modern companies. Therefore the ability to adopt new achievements into the business processes rapidly is very important. In this regard semantic technologies are very promising for the knowledge management within companies. Corporate Semantic Web<sup>1</sup> (CSW) is working on the adoption of semantic technologies in corporate contexts [Coskun et al. 2009]. Originated in this effort the Corporate Ontology Lifecycle Methodology [Luczak-Rösch and Heese 08] (COLM) is an innovative lifecycle model for continuously evolving ontologies in corporate contexts. The main intention is to provide an intuitive understanding of rising costs per iteration.

Thus having a close look at ontology modularization is very promising, because modular reuse of ontologies as well as ontology composition by building blocks have a significantly reducing impact on the rising costs for engineering as well as maintenance. In this paper we are discussing for which phases of COLM ontology modularization is beneficial and which aspects of ontology modularization are necessary in each phase.

The paper is organized in the following way. In Section 2 we present our understanding of ontology modularization. Afterwards, in Section 3 we provide a brief introduction to COLM and identify phases which can benefit in which

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<sup>1</sup> <http://www.corporate-semantic-web.de>

way from ontology modularization. In Section 4 we discuss how existing modularization mechanisms can be used in COLM, before finally closing this paper with a conclusion and an outlook in section 5.

## 2 Ontology Modularization

Component-based development of large and complex software systems by small well defined building blocks simplifies the understandability as well as the management and leads to reusable software modules and a scalable overall system. Accordingly, designing ontologies in a modular way is intuitively promising in order to benefit from the same advantages. However, modeling knowledge represented by ontologies is fundamentally different than software modules, which are mainly describing processes. The overall goals of modularization are ontology reuse, scalability, complexity management, understandability, and personalization. Due to different understandings of the term modularization in literature there is a need to clarify how this concept is understood in this work.

From an engineering perspective it is a design principle [d'Aquin et al. 2007] or an approach on developing ontologies. Similar to component-based software engineering it proposes to design ontologies by breaking down the complexity in smaller pieces and create small self-contained ontologies, called modules, which are used in order to compose more complex ontologies. On the other hand modularization is understood as a process which can be executed on ontologies to create smaller ontologies (e.g. within the NeOn Project<sup>2</sup>). This understanding is in turn divided into two categories. Partitioning ontologies is a process in which a bigger ontology is divided into smaller pieces like a puzzle. The second category, called module extraction, is more an application oriented activity which aims at extracting a particular part of an ontology mostly for a special use case. This means, that some content of the original ontology might be lost.

## 3 Modularization in COLM

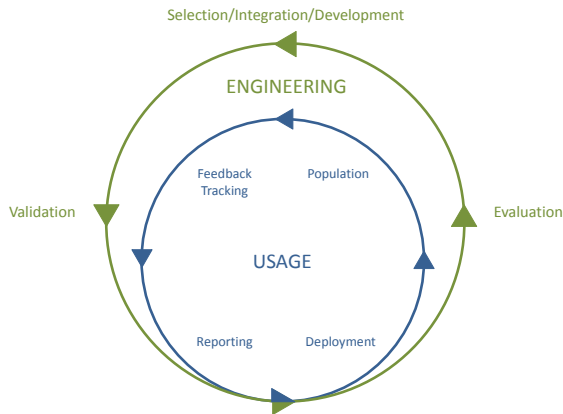
In this chapter we will give a brief introduction to COLM. Afterwards we will discuss how modularization can be applied to COLM and which requirements modularization mechanisms have to fulfil.

### 3.1 COLM

COLM (Figure 1) is an innovative lifecycle model for continuously evolving ontologies in corporate contexts. The main intention is to provide an intuitive understanding of raising costs per iteration and in dependence on the duration and effort spent in each process phase.

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<sup>2</sup> [www.neon-project.org](http://www.neon-project.org), NeOn Glossary of Activities to references



**Figure 1:** The Corporate Ontology Lifecycle

Starting the process at selection/development/integration means to start the knowledge acquisition and conceptualization, to re-use or re-engineer existing ontologies, or to commission a contractor to develop an ontology. The result of this phase is an ontology, which is validated against the objectives. At the intersection point between the engineering and the usage cycles the ontology engineers and the domain experts decide whether the ontology suites the requirements or not. If this is approved the ontology is deployed and in use by applications. Then the ontology is populated, which means that a process for instance generation from structured, semi-structured and unstructured data runs up. Throughout the whole feedback tracking phase, formal statements about users feedback and behavior are recorded. A reporting of this feedback log is performed at the end of the usage cycle. That means that all feedback information, which were collected until a decisive point, are analyzed respecting internal inconsistencies and their effects to the currently used ontology version. The usage cycle is left and the knowledge engineers evaluate the weaknesses of the current ontology with respect to the feedback log. This point may also be reached, when the validation shows that the new ontology is inappropriate to the specification. The lifecycle starts again with the implementation of the results of the evaluation.

### 3.2 Modularization Aspects of COLM

Modularization of ontologies is in different ways integrable into the lifecycle. As illustrated and mentioned previously COLM facilitates cost estimation in the run-up of cost-intensive evolution steps. The modularization and integration dimensions of COLM helps to decrease the capital expenditure (CAPEX) as

well as the operational expenditure (OPEX) and supports to realize ontology adoption to the corporate environment by keeping the incentives of a company in view.

At the very beginning of COLM during the selection and integration phases it is reasonable to look for existing ontologies for the sake of reusability, because developing ontologies from scratch is a very cumbersome and time-consuming task. Expecting candidate ontologies which perfectly fit into the targeted system is unrealistic, some customization will be necessary in order to adapt candidate ontologies and make them useful. At this point modularization is an important mechanism to allow reusability even if the candidate ontologies are not usable in their original form. The possibility of extracting only relevant parts of existing ontologies and integrate them in order to achieve a useful ontology decreases CAPEX drastically and makes ontology application realistic and really attractive for companies. In this regard, some kind of semi-automatic module extraction mechanism which is driven by ontology engineers together with domain experts is needed. By defining relevant parts of candidate ontologies, the mechanism is responsible for extracting a useful module, which can be customized in further steps.

Modularization during the lifetime of ontologies is also possible. This can be done based upon diverse aspects. In the feedback tracking and reporting phases, the closed and controlled corporate environment allows obtaining information as relevance of concepts and relationships regarding departments and application. It also enables to observe the evolution of the ontology and allows to identify vague parts which change very often and well-established parts which change less frequently. During the development phase it is possible to create modules based upon the mentioned observations. The possibility to identify modules according to the probability to change increases reliability, while the efficiency is improved by relevance based modularization. For that reason, a partitioning mechanism is necessary, that is automatically able to split the ontology into different building blocks, based upon the mentioned aspects.

Finally, in case of context-sensitive and ontology-based applications, which we expect to arise in future, an additional aspect of ontology modularization is possible. Those applications should be able to define their ontology requirements. During the deployment phase, while application need to load ontologies, they can feed fully automatic working module extraction mechanisms with user-specific and application requirements. Based upon these requirements, optimized modules regarding the application context, can be identified and extracted in real-time. This would lead to personalization and increased efficiency of the ontology usage, because loading needless parts and wasting storage as well as computing power can be avoided.

## 4 Applying Modularization to COLM

In this chapter we provide a brief discussion how three selected mechanisms meet the three modularization aspects of COLM.

As mentioned before the possibility to reuse existing ontologies is expected to have a reducing impact on the capital expenditure. Using the extraction for reuse mechanism presented in [Doran et al. 2007] is very promising for the selection and integration phase of COLM. The mechanism is designed following three module requirements: self-containment, concept centered, and consistency. Given a start concept it produces self-contained and consistent modules which can be used as a starting point and can be customized in further steps. Ontology engineers can extend it with new concepts and properties or integrate it with other modules extracted from different candidate ontologies.

Structure-based partitioning [Stuckenschmidt and Klein 2004] and its extensions in [Schlicht and Stuckenschmidt 2006, Schlicht and Stuckenschmidt 2007, Schlicht and Stuckenschmidt 2008] is a candidate for the second modularization aspect of COLM, that is for creating modules based on the observations during the usage phases. In this regard the second step of the mechanism needs a modification, because the original mechanism uses only social network analysis methods in order to determine the strength of the dependency. Obtained information about the relevance of concepts for certain users or departments as well as information about the probability to change has to be taken into consideration. The determined strength of dependency has to reflect these observations, so that personalized modules for departments and users as well as evolution based modules can be created.

Module extraction for knowledge selection [d'Aquin et al. 2006] is a method which is very promising for the third modularization aspect of COLM. It is strongly tight to a particular application and fulfills requirements as minimizing the user interaction, creating the smallest part of the original ontology still covering needed terms while implicit information should be contained in the extracted module. In this regard, modules are created which are very efficient and application-specific. This is done without the need for ontology engineers.

## 5 Conclusion and Outlook

COLM provides a cost sensitive methodology for adopting ontologies by keeping the corporate setting in view. In this regard, we state that modularization is very promising in order to reduce CAPEX through modular reuse and OPEX through simplified complexity management. Accordingly, we have discussed in this paper how three existing mechanisms can be applied to COLM. However, they might need some modifications in order to take the corporate setting and its conditions into account.



Through this paper it comes clear that further work in this direction is promising and necessary. Especially the chance of reducing investment costs through reusing existing ontologies in a modular way needs further investigation, because it would lessen the barrier for companies to adopt ontologies and Semantic Web technologies in general. Furthermore, well-sized modules which evolve independently during the usage would lead to increased quality and improved user experience which is very important for long-lasting application of Semantic Web technologies in companies.

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## A Proposed Ontology-based Algebra For Service Annotation, Discovery, and Composition

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**Abstract:** Service discovery and service composition are two crucial issues in the emerging area of Service-oriented Computing (SoC). The introduction of semantic annotations in Web service descriptions can support the discovery process of services and guide their composition into workflows. In this paper, we propose a *Structured Relationship Algebra* that extends existing frameworks for semantic service descriptions by a set of algebraic operators and allows to define in a uniform way formal semantic annotations regardless the framework adopted to describe service semantics. The proposed algebra is comprised by a set of three algebraic operators and allows to define new object properties at the ontology level called *derived properties*. Derived properties are used to describe the data transformation processed by a service by associating constraints on both properties and instances of the concepts and their related ontological relationships.

**Key Words:** Semantic Web services, ontology-based algebra, formal semantic annotations, service discovery, service composition.

**Categories:** H.3.5., I.2.4

### 1 Introduction

Service-oriented Computing (SoC) is emerging as a new, promising computing paradigm that centers on the notion of service as the fundamental element for accessing heterogeneous, rich and distributed resources in an interoperable way [PTDL07]. Web services are self-describing components that support a rapid and significant reuse of distributed applications. They are offered by service providers, which procure service implementation and maintenance, and supply service descriptions. On the other side, semantic annotations of Web services have several applications in the construction and management of service-oriented applications [MSZ01]. As well as assisting in the discovery of services [BHL<sup>+</sup>05], such annotations can be used to support the user in composing services into workflows [CS03]. Thus, several frameworks for semantic Web services has been proposed such as the OWL-S Semantic Markup for Web services [MBM<sup>+</sup>07], the Web Service Modeling Ontology (WSMO) [RKL<sup>+</sup>05], and the Semantic Annotations for WSDL (SAWSDL) [KVBF07]. These frameworks aim to create

semantic annotations to describe *functional* and *non-functional* properties of the service. In this paper, we present an algebra that extends existing frameworks for semantic service descriptions by a set of algebraic operators allowing to define in a uniform way formal annotations regardless the semantic framework adopted to describe service semantics. We present the *Structured Relationship Algebra* that is comprised by a set of three algebraic operators allowing to define new semantic relationships at the ontology level called *derived properties*. Using algebraic operators, *derived properties* are created by associating constraints on both properties and instances of the concepts participating to the relationships. We show how *derived properties* can be used to describe the relations that relate the inputs of a service to its outputs.

The remainder of this paper is organized as follows. Section 2 presents the preliminaries of the proposed approach. In Section 3, we describe the three algebraic operators and define their properties and their use to define semantic annotations. Finally, section 4 concludes the paper.

## 2 Preliminaries

In this section, we present some preliminaries of the proposed algebra. First, we introduce the notion of native ontology. A native ontology is a domain ontology described using an ontology definition language such as OWL<sup>1</sup>, RDF<sup>2</sup>, or RDF-S<sup>3</sup>. To simplify, we model ontologies as graphs of concepts linked by a set of directed relationships. The initial ontology graph is called a Native Ontology Graph (NOG), respectively defined with native concepts and relationships. The graph extended with derived properties is called Derived Ontology Graph (DOG).

**Definition 1 Native Ontology Graph.** A Native Ontology Graph is a directed labeled graph  $O=(T_C, T_R)$  where  $T_C$  is a finite set of labeled classes (nodes) and  $T_R$  is a finite set of labelled relationships (edges). A relationship  $r$  is written as  $(r, c_1, c_2)$  where  $\text{dom}(r)=c_1$ ,  $\text{range}(r)=c_2$ ,  $c_1$  and  $c_2 \in T_C$ , and  $r \in T_R$ .

*Example 1.* The figure 2 illustrates a fragment of a domain ontology. In a given regional area, we have different healthcare institutions or practitioner offices. Each institutions have his own medical files of their patients, stored as medical records. Each medical practitioner in the institution has a given role in the healthcare process of a patient. The role inside a given patient healthcare process specify the access rights to the patient information.

<sup>1</sup> <http://www.w3.org/TR/owl-ref/>

<sup>2</sup> <http://www.w3.org/RDF/>

<sup>3</sup> <http://www.w3.org/TR/rdf-schema/>

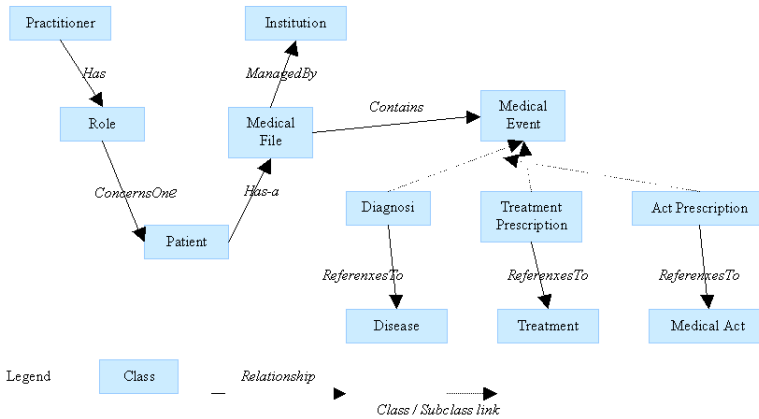


Figure 1: A Health Care Domain ontology

### 3 Our approach

The algebra defines two binary operators and one unary operator applied on relationships: composition, union, and restriction.

#### 3.1 Composition operator

The composition operator is a binary operator that allows to create a derived object property given two object properties. The operator is defined as follows and illustrated in Figure 2.

**Definition 2 Composition Operator.** Given two relationships  $R_1$  and  $R_2$  in  $T_R$ , such as  $dom(R_1)=C_{from1}$ ,  $range(R_1)=C_{to1}$ ,  $dom(R_2)=C_{from2}$ ,  $range(R_2)=C_{to2}$ , the composition  $R = R_1 \otimes R_2$  is defined by  $\langle R, x, z \rangle$  iff it exists an individual  $c$  belonging to both  $C_{to1}$  and  $C_{from2}$  such as  $\langle R_1, x, c \rangle$  AND  $\langle R_2, c, z \rangle$ ,  $x$ ,  $c$ , and  $z$  are respectively instances of  $C_{from1}$ ,  $C_{to1} \text{ MIN } C_{from2}$ , and  $C_{to2}$ .

If  $C_{to1}=C_{from2}$  then we get the classical operator of composition. If  $C_{to1} \text{ MIN } C_{from2} = \emptyset$  then  $R$  is the *null* relationship. The composition operator is not *commutative*. It is *associative* and it exists an identity element that is the *identity* relationship defined on the domain class  $Universal=\cup_i C_i$ ,  $C_i$  in  $T_C$  that corresponds to each individual itself such as  $\langle Identity, o, o \rangle$  for any individual  $o$ .

*Example 2.* Figure 2 depicts a fragment of a domain health care ontology. The fragment is extended with derived object properties that are the result of composing some relationships.

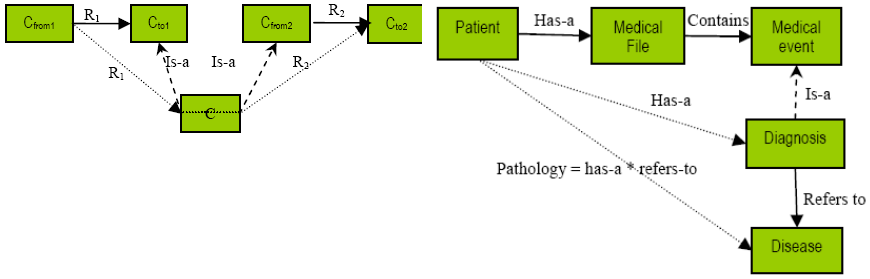


Figure 2: Illustration of the composition operator

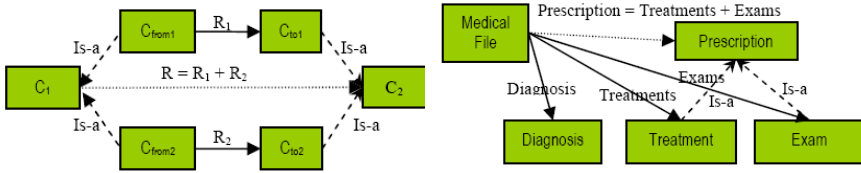


Figure 3: Illustration of the union operator

### 3.2 Union operator

The second operator of the algebra is the union operator denoted by  $\oplus$ , the union operator creates a derived object property by the union of two object properties as follows.

**Definition 3 Union Operator.** Given two relationships  $R_1$  and  $R_2$  such as such as  $\text{dom}(R_1) = C_{from1}$ ,  $\text{range}(R_1) = C_{to1}$ ,  $\text{dom}(R_2) = C_{from2}$ ,  $\text{range}(R_2) = C_{to2}$ , the union  $R = R_1 \oplus R_2$  is defined by  $\langle R, x, y \rangle$  iff  $\langle R_1, x, y \rangle$  OR  $\langle R_2, x, y \rangle$  such as  $\text{dom}(R_1 \oplus R_2) = C_{from1} \text{ MAX } C_{from2}$ , and  $\text{range}(R_1 \oplus R_2) = C_{to1} \text{ MAX } C_{to2}$ .

The union operator is *commutative* and *associative*. Note that the composition operator is *distributive* related to the Union operator. Finally, the *idempotence* property is that union of the same relationship is itself, i.e.,  $R = R \oplus R$ .

*Example 3.* Figure 3 illustrates the use of the union operator defining a new object property on the medical file concept, standing for all medical events corresponding to medical prescription that are either Treatment either exams.

### 3.3 Algebraic expression with composition and union operators

The composition and union operators defined above enable to write algebraic expressions, using a set of operands  $R_1, R_2, \dots, R_n$  that are native and/or de-

defined derived relationships. There is no restriction on possible composition and union, as these operations are always defined for any ordered pair of operand relationships. A composition or union operation with no meaning delivers an *EMPTY* relationship.

If we consider an algebraic expression  $R = \text{Expr}(R_1, \dots, R_n)$  where  $R_{i=1, \dots, n}$  are either native and/or derived relationships, this expression defines a new relationship  $R$ , with calculable domain and range thanks to the formal semantics of the union and composition operators. The expression becomes an expression of native relationships only, if we substitute each operand derived relationship by its definition in function of native relationships (iteratively in a finite number of times, as the number of definition is finite and as no recursion is possible in definitions).

This expression defines a multipath in the native ontology graph starting from an origin class  $C_{from}$  and ending at a destination class  $C_{to}$ . For a given individual  $o$ , it will be possible to calculate all the correspondents of  $o$  by  $R$  (i.e., all the individual  $o'$  such as  $\langle R, o, o' \rangle$ ) if we are able to determine all the correspondences for any relationship  $R_i$  in the expression of  $R$ . However, in practice, we may also need to follow a path in the graph starting from a concept  $C$ , but with an interest for a subset of instances of a class  $C'$  only. It is not possible to represent such a *restriction* with simple multipaths made of sequences (composition) and parallel (union) edges. To represent such restrictions, we define constraints on the properties instances of the corresponding range and domain concepts of a relationship.

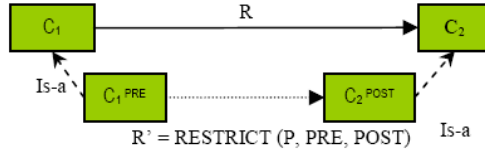
### 3.4 Restriction operator

In addition to the composition and union operators, we define the unary restriction operator that associates to any relationship  $R$  a derived relationship  $R'$  that has as a domain a sub-domain of  $R$ , and limiting the possible correspondence to a sub-range of  $R$ . Sub-domain and sub-range are defined by two restriction predicates, called PRE and POST conditions. This predicates being fixed, the restriction operator is considered as a unary operator applying on relationships.

**Definition 4.** Given two classes  $C_1$  and  $C_2$ , a relationship  $R$  such as  $\text{dom}(R) = C_1$  and  $\text{range}(R) = C_2$ , two predicates PRE and POST respectively defined on the properties of  $C$  and  $C'$ , the restriction operator defined by the 3-tuple  $(R, \text{PRE}, \text{POST})$  creates a new relationship  $R' = \text{RESTRICT}(R, \text{PRE}, \text{POST})$  such as  $\langle R', o, o' \rangle$  iff  $\langle R, o, o' \rangle$  AND PRE( $o$ ) is true AND POST( $o'$ ) is true.

The restricted relationship  $R'$  associates to an individual  $o$  from  $C$  its correspondent  $o'$  given by the relationship  $R$  iff the individual  $o$  verify the predicate PRE and the individual  $o'$  verify the predicate POST. If  $o$  does not belong to  $C^{PRE}$  (the set of instances of the class  $C$  that verify PRE), then it

has no correspondent and the restricted relationship  $R'$  is *empty*. If  $o$  belongs to  $C^{PRE}$ , but  $o'$  does not belong to  $C^{POST}$  (the set of instances of the class that verify POST), then  $o$  has no correspondent by the relationship  $R'$ . The result  $R' = \text{RESTRICT}(R, \text{PRE}, \text{POST})$  will be denoted  $R^{PRE,POST}$  such as  $\text{dom}(R^{PRE,POST}) = C^{PRE}$  and  $\text{range}(R^{PRE,POST}) = C^{POST}$ . The figure 7 below illustrates the restriction operator.



**Figure 4:** Illustration of the restriction operator

**Definition 5 Semantic Mapping Assertion.** Given a domain ontology  $O=(T_C, T_R)$  and a set of services  $S_i$ , For each  $S_i$ , a semantic assertion mapping is defined as 3-tuple  $\langle \text{MAP}, S_i, R^{PRE,POST} \rangle$  such as  $R$  is an algebraic expression over  $T_R$  constructed using the union, composition operators and PRE and POST are two logical predicates applied respectively on  $\text{dom}(R)$  and  $\text{range}(R)$  using the restriction operator.

*Example 4.* Let  $DS_1$  a Web service that delivers information about patients and their diagnosis information disease. The algebraic expression that express the service semantics is interpreted as follows:

$$E(DS_1) = \text{has}(\text{Patient}, \text{Medical\_File}) \otimes \text{contains}(\text{Medical\_File}, \text{Diagnosis}) \otimes \text{refers}(\text{Diagnosis}, \text{Disease}).$$

Let  $DS_2$  a Web service that delivers therapy prescription patients including medical acts. The algebraic expression that express the service semantics is interpreted as follows:

$$E(DS_2) = \text{has}(\text{Patient}, \text{Medical\_File}) \otimes [\text{contains}(\text{Medical\_File}, \text{Therapy\_Prescription}) \oplus \text{contains}(\text{Medical\_File}, \text{Act\_Prescription})].$$

## 4 Conclusions and Future Work

In this paper, we proposed the SRA algebra comprised by a set of algebraic operators. The SRA operators allow to define formal semantic annotations that capture the data transformation process performed by services. The composition and union operators allow to declare multipaths through a domain ontology

graph as a sequence or the union of several semantic relationships. The restriction operator allows to declare a new relationship by defining restrictions on the domain and range of an input one. As future work, we plan to define algorithms that deduces service composition plans given a query defined as an algebraic expression. Also, we plan to extend the proposed algebra with reasoning capabilities in order to enhance the composition and discovery process.

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# **ICPW 2009**

## **4<sup>th</sup> AIS SigPrag International Pragmatic Web Conference**

### **Editors**

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# **Knowledge Practices, Epistemic Technologies, and Pragmatic Web**

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**Abstract:** The purpose of the present article is to examine the implications of the pragmatic web for the research and development of educational technology. It is argued that, beyond knowledge acquisition and social participation, technology-mediated learning environments based on a semantic and pragmatic web have the potential for facilitating creation and advancement of knowledge. In order to capitalize on the increased information and social connectivity of the novel ICTs, it is essential to develop adaptive informatics that co-evolves with knowledge-laden social practices. The present arguments are grounded on a vision of “Metaweb” which is elaborated further from the perspective of social practice. Implications of the position presented concerning the research and development of technology-mediated learning environments are discussed.

**Keywords:** epistemic technology, knowledge practices, learning, dialogical inquiry, social media

**Categories:** L.1.4, L.2.3, L.3.0, L.3.6., L.6.2

## **1 Introduction**

The purpose of the present article is to examine the implications of the pragmatic web for computer-supported collaborative learning (CSCL). The present theoretically oriented elaborations emerged in the context of the Knowledge-Practices Laboratory ([www.kp-lab.org](http://www.kp-lab.org)); 22 organizations from 15 European countries take part in this integrated EC project focused on developing semantic-web- based technologies for supporting knowledge-creating learning in higher education and workplaces. While the semantic web has been the general foundation of the project, KP-Lab undertaking also have practice-based emphases extending mere semantic considerations and highlight the importance of examining the boundaries of the semantic and pragmatic webs.

In the background of the project are three metaphors of learning, i.e., the knowledge acquisition metaphor, the participation metaphor, and the knowledge-creation metaphor [compare Sfard, 98; Lave, 91, Figure 1]. The acquisition perspective examines knowledge as a characteristic of an individual mind and

considers an individual as the basic unit of knowing and learning. This cognitive view of learning relies on an assumption that the mind is a container of knowledge and learning is a process that fills the container, implanting knowledge there [Bereiter, 02]. An alternative approach is the participation metaphor of learning, according to which learning is an interactive process of participating in cultural practices and shared learning activities that structure and shape cognitive activity in many ways. Accordingly, learning is seen as a process of growing up and socializing to a community and acquiring the skills to communicate and act according to its socially negotiated norms. The situated nature of human knowledge and cognition is emphasized and examined social appropriation of community knowledge and adaptation to existing cultural practices.

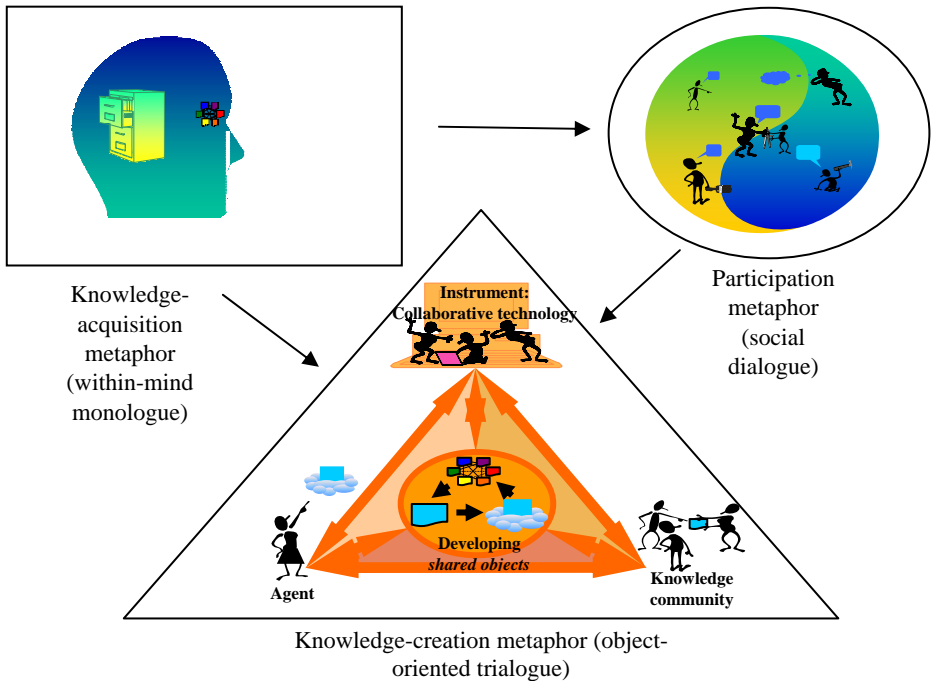


Figure 1: Three metaphors of learning

The division of two basic metaphors of learning is very fundamental. Neither of the above metaphors appears, however, to be sufficient when addressing processes of deliberately creating and advancing knowledge characteristic of an advanced knowledge society. The acquisition approach and the participation approach can both be developed so that they take innovative aspects into account, but this is not where these approaches appear to be at their best [Paavola, 04].

In order to overcome the dichotomy between the acquisition and participation metaphors, the present authors have proposed a third, knowledge-creation metaphor of learning [Paavola, 05; Hakkarainen, 04] drawing upon Yrjö Engeström’s [87] expansive learning theory based on the cultural-historical activity theory, and Carl

Bereiter's [02] knowledge-building theory. Within this framework, learning is understood as a process of innovative inquiry aimed at the progressive advancement of knowledge and deliberate transformation of social practices [Paavola, 04]. If the acquisition metaphor represents a "monological" (within-mind) and the participation metaphor a "dialogical" (interactive) view of learning, the knowledge-creation metaphor is "trialogical" because of its emphasis on transformative learning mediated by cultural artefacts and communities of people. Transformative learning radically broadens the shared objects by means of explicitly objectified and articulated novel tools, models, and concepts. It is characteristic of this kind of knowledge advancement that it takes place within epistemic communities rather than only within individuals (although individuals with heterogeneously distributed competencies have an important role, supported by cultural knowledge resources). Developing an object-centered view of human activity, characteristic of the triological approach, is a significant trend from philosophy [Davidson, 01; Clark, 03; Skagestad, 93; Sterelny, 04] to post-human social studies of science [Latour, 05; Knorr-Cetina, 99] and from organizational research [Engeström & Blackler, 2005; Law & Singleton, 2006] to psychology [Donald, 91; Gruber, 81; Hakkarainen, Lonka & Paavola, 04].

The metaphors of learning are associated with corresponding forms of ICTs, the knowledge-creation approach capitalizing on collaborative technologies that support sustained efforts of knowledge advancement (Figure 2). The challenge of the KP-Lab project is to integrate efforts of technological partners oriented to designing the semantic web, pedagogical partners aiming to facilitating transformative learning, and users collaborating through novel ICT tools in higher education and work environments. Collaborative conceptual tools are needed for processes of multi-voiced negotiations on meanings. The present paper focuses on examining some concepts and theories that have functioned as KP-Lab's reflective tools for co-designing collaborative learning technologies at the intersection of the semantic and pragmatic web. One tool of theoretical communication used by the KP-Lab project is Nova Spivack's vision of Metaweb.

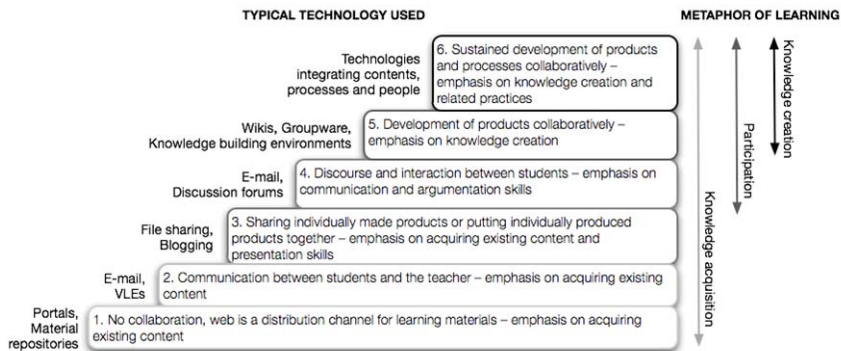


Figure 2: Epistemic technologies and metaphors of learning [Lakkala, in press]

## 2 From Metaweb representations to social practices

Nova Spivack has created a vision concerning Metaweb that arise from increased social (social software) and information connectivity (semantic web)<sup>1</sup>. Rather than merely capitalizing on accumulating information resources or social interaction, the central characteristic of Metaweb is to provide tools and practices that amplify social-collaboratively intelligent human pursuits. According to Spivack the Metaweb vision begins from representations of individual and group knowledge to connecting them together into knowledge representation of the whole Web<sup>2</sup>. Although Spivack's vision has gained much attention, there are certain shortcomings in the Metaweb that are familiar to semantic web technologies and visions in general. Ontology-based semantic information technologies are criticized to be hierarchical and authoritative [Pike, 07]. This is especially relevant when target is on systems that support knowledge work and knowledge creating tasks such as scientific exploration. Too strict and authoritative frameworks of knowledge (representations) cannot merge with demands of innovative knowledge work that is in need of constant re-evaluation and transformation of its concepts and practices. The issues of context and change are also noticed as relevant in future developments of semantic and pragmatic web technologies. Proposed developments in semantic services include pragmatic contextualization [Grobelnik et al, 08] and situated representations [Pike, 07]. It is suggested that ontologies should capture more specified domains of knowledge and integration of different domains should include integration of contextual information between contexts [Alani et al, 08].

Although sensitively developed Metaweb technologies can avoid some of the challenges and criticisms mentioned above, there are also other challenges taken up for the kinds of Semantic Social Software and Semantic Web technologies similar to the Metaweb [Schaffert, 08]. While the vision of Metaweb is very attractive, it appears essential to go beyond semantic-web based assumptions that privilege discursive (information exchange and social communication -related) processes and isolate information networks from social practices. In order to provide the collective intelligence with meaningful content, it should be embedded in the context of *social practices around shared objects and processes of technology use* rather than assumed to represent transcendental bodies of thought and ethereal interactions. From *syntax* (logical forms and symbolic structures) and *semantics* (meaning of symbols), the idea of the pragmatic web is to move toward *pragmatics* through addressing the contexts and practices of creating, using, and developing epistemic artifacts [de Moor, 02; Singh, 02]. This implies that users, their communities and network, as well as their evolving epistemic practices become essential in creating, interpreting, sharing, applying, and extending knowledge.

The notion of the pragmatic web guides one to consider Metaweb three-dimensionally in terms of social practices providing a topography or third dimension of the web's terrain. *Social practices* are assemblages of human activity that involve goal-directed sequences of actions using certain technology and rely on a socio-historically developed system of knowledge [Schatzki, 02; Scribner, 81]. By

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<sup>1</sup> See [http://novaspivack.typepad.com/nova\\_spivacks\\_weblog/2004/04%20new\\_version\\_of\\_.html](http://novaspivack.typepad.com/nova_spivacks_weblog/2004/04%20new_version_of_.html).

<sup>2</sup> [http://novaspivack.typepad.com/Minding\\_the\\_Planet\\_Article.pdf](http://novaspivack.typepad.com/Minding_the_Planet_Article.pdf)

*knowledge practice* [Hakkarainen, 09] the present investigators refer to personal and social practices related to working with knowledge; this should be interpreted broadly to involve pre-reflective implicit and tacit knowledge of expert work as well as shared routines and explicit procedures. Current theories of social practices highlight both the inseparability of knowing and doing and the creative and improvisational aspect of practice: “It is in practice, in fact, that knowledge comes to life, stays alive, and fades away. It is in practice that institutionalized, historically determined, and codified expertise acquires sense and becomes both a resource and a constraint for action” [Nicolini, Gherardi, & Yanow, 2004, p. 26]. Here the term “knowledge” is used in the broadest sense, to include explicit official discourses, implicit habits of expert working; and further yet to that which underlies the competencies of experts, for example, so called “procedural knowledge.” Knowledge practices, while sometimes just supporting routine learning, at their creative edge take place in dynamic and fluid settings designed to further innovation and knowledge. Targeting emphasis on social practices, and especially on knowledge practices, pragmatic web can move beyond offering just affordances and environments for social connectivity and emerging social practices.

As we see it, a central characteristic of Metaweb is provide tools and practices, dynamic and fluid in nature, that enable epistemic communities and networks to engage in coordinated, deliberate, and sustained efforts of knowledge advancement. The knowledge-advancement process focuses on developing shared epistemic objects; these epistemic “things” (artifacts) are incomplete, knowledge-laden, yet materially embodied, objects that have a capacity, in principle endlessly, to open up novel lines of inquiry [Knorr-Cetina, 01]. Investigators of the pragmatic web highlight the importance of co-evolution between collective knowledge networks, epistemic technologies, and social practices [Buckingham Shum, 06; DeMoor, 02]. It appears to us that knowledge-centered practices rely on material agency, based on reciprocal tuning of social, technical, and material aspects of activity [Pickering, 95]; knowledge advancement would not be possible without such merging of technologies and practices.

An essential factor in pragmatics is context. When the semantic level is dealt with in a context-free manner, investigators tend to focus on prototypical meanings. Resulting models consist of a set of entities and relations connecting those entities. In their actual use at the pragmatic level, meanings are imprecise and changing, biased at any moment by the particular social and external context. The contextual process of meaning attribution is simultaneously both socio-cultural and cognitively subjective [Honkela et al., 2008]. While the semantic web has been preoccupied with standardization of knowledge and systems of knowledge based on ontologies determined mainly by experts beforehand, the envisioned pragmatic web is oriented toward adapting to the special needs of customers and user communities. Rather than simply assimilating to already existing knowledge ontologies, the vision is to engage user communities in active negotiation and interpretation of meaning and to the development of knowledge structures grounded on their evolving practices and epistemic pursuits [de Moor, 02]. Toward that end, pursuit of centralized solutions is giving way to the co-development of services based on customer-provider negotiations and mass customization and co-configuration of products through reliance on long-term customer relations. As we see it, a central aspect of the

emerging pragmatic web should be to put change, transformation, and creation of knowledge and associated practices into the centre. This implies, for instance, pursuit of directed, ontology evolution so as to assist and guide knowledge-creation efforts.

A potentially highly useful extension of Metaweb is the use of adaptive informatics to build on the communally created, often not mutually compatible resources. If the semantic web involves efforts of top-down knowledge structure and system design, adaptive informatics corresponds to self-organizing processes of technologies that dynamically adapt to evolving requirements of social practices. By utilizing methods and techniques such as the self-organizing map (SOM), automated learning algorithms for discovering and analyzing complex patterns have been developed to support unsupervised and continuous machine learning from large amounts of new data [Kohonen, 01; Honkela, 05]. The SOM is dynamic, associative and consists of elements that can be called adaptive prototypes. The adaptation process in the SOM is based on the principle that what already exists in the system also influences the learning result [Kohonen, 01]. This coincides with the principles of constructive learning, unlike most other computerized models of memory and learning [Honkela, 00]. The SOM approach has been applied for pursuing data-driven analyses of textual contents. By relying on other kinds of adaptive technologies, it is also possible to simulate social practices [Lindqvist, 07] as well as support co-configuration of relationships between producers and users (see <http://www.cis.hut.fi/research/cog/pracsim/>).

### **3 Knowledge practices in between Semantic and Pragmatic Web**

In the context of the pragmatic web, creating, using, and developing knowledge rather than mere transmission of information or social exchange becomes the central concern. Thus far, discourses concerning the pragmatic web have, however, mainly addressed contextual aspects of using information by diverse communities of practice. Also highlighted have been various processes of negotiation of meaning which take place in the context of knowledge usage. Yet, the pragmatic web may elicit knowledge creation by 1) providing a technological infrastructure for augmenting the functioning of more or less distributed epistemic communities, 2) facilitating automated analysis and interpretation of large bodies of data generated by the users, and 3) adapting to and coevolving with human knowledge practices.

A foundational assumption of KP-Lab project has been that epistemic technologies become instruments of knowledge-creating learning only through transformed social practices [Hakkarainen, 06]. In order to facilitate expert-like practices of working creatively with knowledge in higher-education contexts, KP-Lab emphasizes courses where students solve complex problems for real customers coming from professional communities. Rather than eliciting inquiry learning within courses taking place at the prevailing institutional practices and pre-determined curricular boundaries, the project focuses on set-ups, arrangements, and patterns of interaction which elicit cross-fertilization of knowledge practices between educational and professional communities in close collaboration with professional communities. By breaking boundaries between communities, the participants may become reflectively aware of their own social practices.

The technologies and instruments supporting the kind of learning and knowledge creation described above require support to transform and reassess ways of representing and creating knowledge, i.e., support for cultivation of knowledge practices. While belief revision is easy, it is extremely hard for human being to transform their practices based on implicit and tacit knowledge and experience-based habitus. In order to overcome this limitation, the KP-Lab project aims at providing the participants tools for making visible, reflecting on, and deliberately transforming their knowledge practices. Examples of such tool-mediated transformation and cultivation processes of knowledge practices that have been explored and investigated in recent projects include *change-laboratory* methodology [Engeström, 96]. Change laboratory is an intervention method that involves sustained efforts in analyzing and transforming social practices. It comprises a series of workgroup meetings to reflect on current practices and envision future activities. Essential aspects of change laboratories are a) using videotaped practices as a “mirror” for assessing current activity, b) generating ideas and tools (e.g., charts) that help to assess past, present, and future activity, and c) modeling activity system embedded on present practices. Accordingly, the participants are guided to collect videotaped “mirror” material concerning practices of interest (either their own or those of a target community). Knowledge-Practices Environment (KPE) being developed involves Activity System Designer (ASD) tool that allows the participants to reflect, discuss, and annotate such video material, use activity-system triangles for modeling their activity, and envision and implement practical changes. Providing of participants tools and instruments that make them reflectively aware of various aspects of their activity and elicit transformations is a potentially significant aspect of pragmatic web. The proposed direction of development from Semantic web technologies and Metaweb to Pragmatic web is towards tools and systems that enable creation, maintenance, re-evaluation, and transformation of knowledge practices.

The KP-Lab project appears then to be in between semantic and pragmatic webs. Because the notion of pragmatic web had not yet gained momentum while the project was initiated, KP-Lab was framed around ideas and technologies emerging from the semantic web. Yet the very idea of “knowledge practice” interconnects KP-Lab with ideas and concerns of pragmatic web. While pursuing the project, it has been necessary to constantly renegotiate relations between semantic and pragmatic webs, for instance, in terms of highlighting users’ role of defining and transforming ontologies and formal models and using semantic services services (and not, for example, ontologies made by experts of the field). Due to KP-Lab’s position at the boundary between semantic and pragmatic web, it has sometimes been hard to introduce ideas concerning the project; it is much easier to talk about information than address practice-related issues. Overall, it appears essential to continue pursuing research and development of technology-mediated learning environments that focus on eliciting collaborative knowledge creation in parallel of addressing transformation of practice, essential from the perspective of the pragmatic web.

As Perez [2002] argued, however, technological and social innovations are interdependent. It appears that the technology as such does not determine the nature of its implementation but coevolves with gradually transforming institutional practices [Tuomi, 2002]. Our investigations, for more than a decade, indicate that meaningful technology-enhanced learning presupposes expansive learning



[Engeström, 87] processes in which novel technology-mediated practices of learning and instruction are iteratively developed. New technology-enhanced learning environments do not then automatically become instruments in teachers' and students' joint activities; transformation of their social practices is also called for. Such a developmental process involves adaptation and customization of the tool in parallel of cultivating social practices needed for its productive utilization. Before developing social practices in which the use of an instrument is embedded, all of its affordances cannot be productively utilized.

Only when ICT-based tools in general and collaborative technologies in particular have been fully merged or fused with social practices of participants, are their intellectual resources genuinely augmented and learning achievements correspondingly facilitated [Hakkarainen, 04]. Rather than addressing collaborative knowledge advancement efforts as its own sphere of activity, the present researchers understand it to be tightly coupled with evolving knowledge practices of the participants.

The KP-Lab concern is developing epistemic technologies that elicit deliberate collaborative knowledge creation. The project aims at conceptualizing a "triological" framework concerning pedagogical practices and models regarding computer-enhanced collaborative work around shared objects. The framework being developed is intended to be a 'boundary object' [Star, 89], to which various approaches can be compared regarding design of technologies for fostering shared efforts to create knowledge and transform practices. By developing and testing the knowledge-creating approach through a series of empirical studies, the KP-Lab project focuses on creating pedagogical models and guidelines for facilitating collaborative knowledge creation in polytechnics, universities, and professional communities. Neither students, teachers nor professionals should be considered as mere consumers of knowledge, but also as prospective creators of new knowledge and transformers of knowledge practices.

## **4 Conclusions**

One of the initial ideas behind the emergence and development of the semantic web has been the ability to represent and process meaningful content, not just strings of characters. It is now widely recognized that such aspirations have certain practical limitations, such as the contextual dependence of meaning and other semantic features of entities used in representations. One proposal for overcoming this issue is negotiation about ontologies and user-driven generation and definition of concepts and meaning. In the Metaweb vision and in discussions of social semantic software, the kind of user-centered perspective comes to highlight social participation and creation of shared meaning. As noted above, these issues have arisen in discussions in the initial writings on the Pragmatic web [Singh, 02]. When users participate in defining and generating concepts, they can create user-centered and contextually sensitive semantics in epistemic technologies they use.

The implications of the pragmatic web for computer-supported collaborative learning proposed here are intended to reach beyond ontology negotiation and affordances for social collaboration. Focusing on practices, and especially on knowledge practices, pragmatic web technologies have possibilities that do not just

provide affordances for social cooperation, but create technologies that support creation and maintenance of practices of collaboration. The advancement of pragmatic web for CSCL should offer not only means for negotiating of meaning, but a way to facilitate sustained collaborative efforts to advance shared artefacts and elicit other social practices relevant for creating and advancing knowledge.

The background of KP-Lab and discussions of this paper, extending to more general aspects of pragmatic web, knowledge practices and CSCL, relies on the three metaphors of learning, i.e., three paradigmatic ways that knowledge is generated and learned. All of these three ways of learning are relevant and usually serve different roles and functions in learning processes, as it has been previously argued. The first metaphor, acquisition metaphor, is representative of ‘monological’ way of learning. From the perspective of CSCL and the discussions above, these kinds of learning processes certainly benefit from well-structured and meaningful representations of knowledge. Well-defined and general ontologies of semantic web technologies can provide means for learners to acquire knowledge, perhaps as means for further collaborative processes. Here the traditional semantic web idea is seen to be more in terms with the first metaphor of learning, and the emergence of social semantic software can be seen to promote learning processes belonging to the second, dialogical, participation metaphor. In social semantic software, such as semantic wiki’s, users can participate in social practices of learning. For example in semantic wiki’s users can participate in social processes of creating wiki’s by applying knowledge models provided by the system.

The third metaphor of learning promotes collaboration practices that differ in certain respects from modes of participation in social semantic software. The main idea in the ‘trialogical’ knowledge creation metaphor is that knowledge creation is an object-centered process that calls for sustained and iterative collaborative efforts. While individual agents may have a crucial role in such a process, their actions take place upon the fertile ground of collective activity. Similar processes may also be present at the case of social semantic software. Working collaboratively for creating semantic wiki’s is naturally an object-centered collaborative process in respect of wiki being the object of learning. The practice-based perspective adopted here promotes the enhancement of the ways these collaborative processes are implemented: In our view it is crucial how long-standing collaborative knowledge advancement efforts and associated processes of individual learning and transformation of social practices are supported.

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# **An Interaction Design Perspective on the Pragmatic Web: Preliminary Thoughts**

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**Abstract:** Much research has been done and put into practice during the last years in order to increase usability and accessibility of digital artefacts. It can be observed that their usage is no longer limited to professional work contexts but diffuses into all areas of life. This introduces a new spectrum of users, who do not always act purposefully nor rationally. Some services offered in the Web are well adopted by users while others are not, especially those services that are intended to assist users the most, e.g. electronic government services. This paper draws on research literature to investigate how the vision of the Pragmatic Web can contribute to the interaction design of services that are accessible, intelligible and relevant, whereas – in contrast to the Semantic Web – the interaction happens primarily between human agents, especially those non-expert users of technology. Results of the investigation point out questions to be addressed in the interaction design within inclusive usage contexts.

**Keywords:** Pragmatic Web, Human Computer Interaction, Semiotics

**Categories:** H.1.2, H.4.3, H.5.2, H.5.3, H.5.4

## **1 Introduction**

During the last years, digital artefacts are being used in more and more diverse configurations. Within the context of this paper a “digital artefact” is anything created by humans and accessed via computerized technology (e.g. a word processing application running on a local PC, an electronic government service accessed via a mobile device, digital interactive television). Not only professionals are interacting with digital artefacts in a purposeful manner, but people are accessing services anywhere, anytime for different purposes, be it in a work context or simply for entertainment or other leisure related activities. [Bødker 2006] has coined the term “the third wave of HCI (Human-Computer Interaction)” to characterize this broadening and intermixing of use contexts and application types.

This third wave can be best described via juxtaposition with the second wave: the third wave is about non-work contexts, non-purposeful or non-rational actions, etc. It focuses on the cultural level and expands the view from mere cognitive to emotional aspects. This shift to the third wave in the HCI discipline – although leaving open still unsolved issues of the second wave – poses many new challenges and questions regarding interaction design.

We must not forget that a great number of potential users has difficulties to access those applications or services or has no access to them at all. Reasons for this are manifold: illiteracy, no experience in using digital artefacts, or special needs not attended by the service in question, only to name a few. In the context of Brazil for example, the Brazilian Computer Society has addressed this issue when defining the fourth of five “Grand Challenges in Computer Science Research in Brazil” as “Participative and Universal Access to Knowledge for the Brazilian Citizen” [SBC 2006].

The challenge refers to technological, educational, cultural, social and economical barriers to the access and the interaction with digital artefacts, whereas “access” is not only defined in the narrower sense of accessibility but in the more comprehensive sense of legibility, that addresses the problem of how to deliver information that makes sense and is relevant to users.

With regard to applications or services accessed via the Internet, today’s HTML-based so-called Syntactic Web does not offer many mechanisms to facilitate the understanding of content apart from content formatting and structuring. For example, the Wikipedia article on “Semantic Web” contains a thumbnail of the W3C’s Semantic Web logo ([http://en.wikipedia.org/wiki/Semantic\\_web](http://en.wikipedia.org/wiki/Semantic_web)), but apart from the logo caption, nothing indicates that the depicted image is the logo of a W3C activity related to the subject of the Wikipedia article. Furthermore, it is not clear, how the article and the activity are related (e.g. if the article is a summary of the activities key findings, if the activity is an example of an institution incidentally working on the same subject as the article’s authors, etc.)

The Semantic Web has been proposed as an extension to the current Web with the intent to introduce meaning to Web pages, processable by human or machine agents [Berners-Lee et al. 2001]. Currently, many languages exist (e.g. RDF Schema; <http://www.w3.org/TR/rdf-schema/>), or the Web Ontology Language (OWL; <http://www.w3.org/TR/owl-features/>), that allow for knowledge modelling and meaning sharing, and that provide a basis for semantic interoperability [Shadbolt et al. 2006]. However, the augmented semantic contents to a great extent remain inaccessible or unintelligible for human agents.

[Gandon 2005] illustrates some of the problems of retrieval of semantically annotated information and proposes a mechanism to facilitating the interpretation of query results. However, he does not treat questions related to interaction design. Despite this and other efforts having been made to make the Semantic Web intelligible for humans, according to [McCool 2005, p. 86] it will never achieve widespread adoption “because it’s a complex format and requires users to sacrifice expressivity and pay enormous costs in translation and maintenance”. However, [Singh 2002] claims that the vision of the Semantic Web can be implemented via Pragmatics, a branch of Semiotics that deals with context-based meaning. The purpose of this paper is thus to investigate how the vision of the Pragmatic Web can contribute to the interaction design of services that are accessible, intelligible and relevant, whereas – in contrast to the Semantic Web – the interaction happens primarily between human agents. The paper is organized as follows: [section 2] gives an overview of relevant literature in adjacent areas, [section 3] proposes an initial approach to conduct interaction design in the Pragmatic Web, and discusses the unveiled issues, [section 4] concludes.

## **2 Related Work –Pragmatic Research and the Pragmatic Web**

The challenges that arise with the third wave of HCI require a socio-technical view. Organizational Semiotics (OS) is a discipline that recognizes the need to approach the question of how to facilitate and promote access to digital artefacts in a way that considers technical as well as social issues [Stamper 2001]. It focuses on understanding the different properties of signs on various levels to analyse and design information systems in terms of three human information functions: expressing meanings, communicating intentions and creating knowledge.

The primary focus of this paper lies in the pragmatic aspects of digital artefacts, i.e. intentions, motivations, negotiations or, in other words, the different actions that are possible to be executed on a digital artefact and the question why and how actions are executed. Pragmatics deals with intentions, communications, conversations, negotiations, etc., i.e. with the purposeful use of signs. Important concepts with regard to Pragmatics are the “pragmatic information”, i.e. the personal knowledge and experience of each communicating partner, the shared knowledge (that is higher if the partners are from the same cultural community), and the context where the communication takes place, whereas the context is comprised of elements such as speaker, hearer, intention, purpose, theme, time, location, etc. [Liu 2000, chapter 3.2].

Besides Organizational Semiotics there exist other approaches that are suitable to investigate these questions of users acting in a broader organizational context, whereas organization is defined in a broader sense than for example the work context. [Cordeiro and Filipe 2003] compare the Language/Action Perspective (LAP), Organizational Semiotics (OS) and the Theory of Organized Activity (TOA) and propose an integration of the three approaches into a combined one.

[Cordeiro and Filipe 2003] and [Goldkuhl 2005] show that there still exist many open questions with regard to conceptualization, explanation and understanding with the help of different action oriented or pragmatic theories. Theories adapted from reference disciplines have different strengths and weaknesses. The Language/Action Perspective for example presumes that actions are purposeful, neglects tacit communication and has a focus on a professional work context [Winograd 2006].

The integration of LAP, OS and TOA proposed by [Cordeiro and Filipe 2003] starts from a TOA activity and is based on a vocabulary mapping and on drawing analogies between the respective key concepts. Within their integration model, the human within his social domain is acknowledged as the central concept. OS's information fields like family, religion or country expand the activity domain.

LAP, TOA and OS are often applied to business contexts that substantially differ from Bødker's third-wave HCI. In this context users that interact with each other might be influenced by entirely different information fields, thus in the worst case, the only implicit shared context that can be assumed is the URL accessed via the browser. Actions are not always rational; often the primary purpose of an action is entertainment or distraction.

Regarding the analysis of actions and action repertoires, depending on the theoretical frame of reference, different concepts exist. [Gibson 1977, p.177] defined, “the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or for ill”. An affordance is “something that refers to both the environment and the animal”. Affordances in the sense of Gibson are inherent



properties that simply exist. [Norman 2008] introduced the term into design in 1988, referring himself to “perceivable affordances”, i.e. properties that do not simply exist, but that have to be perceived. Since then, the term has been widely adopted by the HCI community, not always in the sense originally intended by Norman. In a later essay, he introduces the term “(social) signifier” that should replace the term “affordance”. The term “social signifier” reflects the social character of most actions that we perform and on the other hand allows accidental signifiers: “the perceivable part of an affordance is a signifier and if deliberately placed by a designer, it is a social signifier” [Norman 2008, p.19].

In OS, affordances are used in the original sense of Gibson: they are invariant repertoires of behaviour and as such constitute the perceivable reality of a human agent [Stamper 2001]. Thus, Norman’s “social signifiers” can be seen as an approximation to the affordances as defined in OS.

“Actability” is a similar concept that is concerned with social actions mediated by information systems. It has been defined as “an information system’s ability to perform actions, and to permit, promote and facilitate the performance of actions by users, both through the system and based on information from the system, in some business context” [Cronholm 1999, p. 1076]. [Goldkuhl 2008] provides a comparison of “actability” with “affordances” in Gibson’s sense.

From the perspective of interaction design, social signifiers, affordances and actability are concepts that are concerned with a pragmatically oriented action repertoire, i.e. the different actions a human agent can perform on a digital artefact. “Social signifiers” and “actability” seem to have a closer relation to the human-computer interface, whereas “affordances” in the OS sense emphasize the social context of the human agent. Furthermore, “affordances” exist independently of the digital artefact and thus seem to be an appropriate concept to be already considered in the phase of artefact creation.

Regarding the implementation of the Pragmatic Web vision using the theoretical constructs described above, examples from literature often refer to web services. A main difference of the approaches described below and our interaction design perspective is that web services often refer to electronic and not to human agents. However, many results below can be mapped or adapted to our case.

With relation to web services, [Singh 2002] identifies challenges that cannot be addressed by merely considering the Syntactic or Semantic Web, but that require a pragmatic view of the problem. For example, web services cannot be fully described by the methods they provide; instead, a model that permits the negotiation between service provider and consumer about if and how to interact with each other would be more adequate. [Singh 2002] lists three principles of pragmatic web service design: user before provider, process before data, and interaction before representation.

Although [Singh 2002] is concerned with web services provided and consumed by electronic agents, the challenges and principles he identified can be partly matched to human agents. E.g., the principle “interaction before representation” that refers to hiding “excess” semantics when describing the interaction specifications of services clearly applies to the modelling and implementation of (inter-)action repertoires in the human-computer interface.

Another milestone in the relatively recent history of the Pragmatic Web is the paper by [Schoop et al. 2006], in which the Pragmatic Web vision is defined as “to

augment human collaboration effectively by appropriate technologies, such as systems for ontology negotiations, for ontology-based business interactions, and for pragmatic ontology-building efforts in communities of practice” [Schoop et al. 2006, p.76]. Scientific contributions in the area reveal different understandings and accentuations of the term “Pragmatic Web”.

[De Moor and van den Heuvel 2004] adopt a semiotic perspective to examine how virtual communities can pragmatically select web services. Since the purpose of their work is theory construction, it has to be examined whether and how this methodology can be adopted to our usage scenario. On the other hand, it has to be questioned, if their approach can be adapted to be applicable by communities of “non-expert”/non-technical users. Furthermore, it is not clear, how the challenges identified by [Singh 2002] are addressed.

[Liu 2008] explores the context of pragmatic web services. He describes methods of how to construct, discover and rank pragmatic web services in order to be able to use the right service at the right time. Although the author works with computational agents, some of the concepts might be mapped to human agents. For example, a pragmatic web service can be interpreted as an element of the action repertoire. For a given user, alternative candidates may exist that all yield the desired result, but that may be more or less appropriate.

[De Moor 2005] addresses the problem of modelling context in the Pragmatic Web and proposes pragmatic patterns for the meaning negotiation processes. Meanings are assigned to syntactic resources and formalized in ontologies. Meaning alignment is concerned with the compatibility of ontologies. Ontologies are modelled on the semantic and used on the pragmatic layer: agents in the Pragmatic Web select meanings and meaning representations and negotiate meanings among each other.

In our approach, we adopt the conceptual model of the Web by [de Moor 2005] with semantic resources in the Semantic Web layer and a set of pragmatic contexts in the Pragmatic Web layer. The semantic resources exist mainly in the form of ontologies, i.e. we agree with [de Moor 2005] and use a mix of large, detailed, standard ontologies and independent, domain-specific micro-ontologies. These are supplemented by potentially large folksologies, i.e. ontologies that contain an unrestricted and non-stable set of entities and that are generated by amateur users in an uncoordinated way [Spyns et al. 2006].

### **3 A view on interaction design in the Pragmatic Web**

The previous section has shown that the Pragmatic Web is a still emerging area with different ideas and approaches, many of which build on the Syntactic Web and are concerned with (semi-)automated agents or expert human agents. The goal of this section is to explore how the concepts of the Pragmatic Web can be applied to the interaction of non-expert human agents and what design questions arise in this context. “Non-expert human agents” include users with special needs, low or no literacy skills and no or low computer skills.

Regarding non-expert human agents, the following questions arise: How can users select meanings from already existing ontologies? How can users create or adapt meanings? What are good meaning representations? How can users negotiate meanings with other users or non-human agents? These questions are interrelated and

have a common denominator: How can users benefit from more legible and more relevant information without having to worry about the conceptual aspects of the Pragmatic Web. For example, we cannot expect users to construct meanings querying and aligning different existing ontologies. End users should not be concerned with reading ontology diagrams or other representations. Required meaning negotiation processes should occur transparently to the user.

Under an actability perspective, the action repertoire of a system can be induced from the individual user's pragmatic context, i.e. it is the result of meaning selection and negotiation. In contrast to examples of actability related papers (see [Goldkuhl 2008] for further references), we cannot always presume a work-practice context and structured interaction among users. The action repertoire depends on the individual pragmatic context and can be different for different users. Moreover, the action repertoire cannot be exhaustively pre-defined and hence must be extensible to accommodate different meaning selection and negotiation processes and to enable novel ways of use. Finally, the action repertoire should not be defined on a per-system, but on a per-concept basis to ensure consistency of action repertoires for similar concepts in different systems.

### **3.1 An example and a preliminary case study**

The following example serves to illustrate our considerations and to indicate some of the arising questions. In contrast to scenarios often found in the Semantic Web literature (e.g. [Berners-Lee et al. 2001]), this example does not include electronic agents that automatically interpret or negotiate meanings but has a focus on pragmatic aspects of interaction between human agents.

A user of a social network service (SNS) like Facebook or MySpace is confronted with various pieces of information when moving around in the network. Depending on how the user interprets these pieces of information, different actions are afforded, all of which depend on the pragmatic context of the current user. Initially, meanings and action repertoires might be limited by the current service. For example, within the context of the SNS in question, a user is defined by a user name, an optional e-mail address and a personal page with a guest book. The action repertoire associated with a user and provided by the SNS is comprised of leaving a message in the guest book, adding a user's e-mail address to one's personal address book and sending synchronous or asynchronous messages to a user using tools provided by the SNS.

In this small example the repertoire of relevant actions could already differ for two distinct users: the e-mail address would be irrelevant to a digitally illiterate or semi-literate user without an e-mail account, and thus, the action "add to address book" would not be part of her/his personal action repertoire. On the other hand, a blind or illiterate user would opt to send and receive audio instead of text messages, whereas a deaf and literate user would prefer to send video messages in sign language to a user who accepts incoming video messages in sign language. A simple implicit meaning negotiation process between a literate and an illiterate user would yield the result that "send message" means "send an audio message".

Meanings and action repertoires can be extended if the user acts outside the SNS in other systems. For example, if the user is also a member of another SNS, he might be able to perform additional actions depending on whether other users (or any other

concept) reside in only one or both SNSs. If a user is also defined by a telephone number in the other SNS and the user in question has got a Voice over IP (VoIP) account from a third provider, s/he should be able to call telephone numbers of users in the SNS via her/his VoIP account. On the other hand, if two users already share a pragmatic context, they could also share meanings of further concepts and action repertoires associated with those concepts. For example if two users are part of the same SNS, have a shared pragmatic context with regard to the “user” concept, and similar action repertoires associated with that concept, user A could share a new communication method (e.g. “send SMS”) with user B.

The above examples are inspired by the e-Cidadania (engl.: e-Citizenship) project, the goal of which is to search for methods and system designs that provide access and make sense to the users' community, thus supporting the formation of a digital culture that respects the diversity in our society. Within this project, a SNS is being developed using OS as a frame of reference and following principles of Universal Design and Participatory Design (cf. [Neris et al. 2009] and <http://www.nied.unicamp.br/ecidadania>).

Many of the pilot users have no or almost no experience in the use of computers, the Internet and SNSs, some users have low literacy levels. The pilot users can be characterized as mainly belonging to the social class of the working poor and usually access the Internet at the local telecenter. Many of the pilot users own no e-mail account; most of them do not use instant messengers or other online communication tools.

The SNS implementation is based on an off-the-shelf content management system (CMS) that has been enhanced with additional functionalities. One of the core functionalities is the possibility to record video and audio messages as a complement to text. During activities with the pilot users, it became clear that the action “making a comment” does not necessarily mean to “write a comment and optionally add an audio or video message”, but could mean just to “leave an audio or video message”. As a result, the comment form has been changed to not requiring a text body as originally designed by the CMS provider.

An example to illustrate the different perspectives of actability and affordances is the area containing the list of online users. Regarding actability, clicking the user's name permits viewing his or her profile. Seeing a user's name in the list of online users affords to start a conversation even if the system does not permit it (yet). Hence, the actability perspective permits to detect e.g. a missing functionality during the analysis phase, whereas an analysis of affordances would have defined the need for this functionality during requirements specification.

### **3.2 Discussion**

The example and preliminary case study above and the approach to use Pragmatic Web techniques for direct interaction between human agents raise many questions. From the point of view of pragmatic interaction design, most of these questions are concerned with meanings, actions, and action repertoires. In order to structure the discussion, we use the organizational “onion” [Stamper 1993b], which describes an organization as consisting of three main layers of information systems: the informal, the formal and the technical information system (IS).

For each issue or question discussed, we indicate the implications on interaction design.

*Technical IS: Storing of meanings and action repertoires.* Meanings and actions should be shareable or reusable across system boundaries. Furthermore, a user potentially accesses Web based services via different channels in different environments. Thus, a purely local approach to storing would be infeasible. On the other hand, a remote centralized or distributed approach would have to be flexible and easy to use. Regarding interaction design, storing or accessing meanings and action repertoires should be as transparent as possible, and a user should not be bothered if storage is central or distributed.

*Technical IS: Interoperability.* The access to proposals of meanings or instantiations of action repertoires provided by different entities might require a prior registration. Thus, authentication and seamless, interoperable service execution are important aspects. E.g. two users who meet in a SNS and want to start a conversation using a tool outside the SNS they met in, should be able to do this transparently without needing to authenticate twice and without even leaving the SNS.

*Formal IS: Formal representation of meanings and action repertoires.* There exist various languages or notations to represent meanings. A representation of actions and action repertoires could be inspired by web service notations, bearing in mind the shortcomings described in [Section 2]. A great challenge for interaction design will be to translate the formalisms into user interfaces and processes that are meaningful to the user.

*Formal IS: Creation, adaptation, and sharing of meanings and action repertoires.* Based on the formal representations mentioned in the previous item, procedures have to be established to enable sharing and adaptation of meanings and action repertoires. The challenge for interaction design does not only lie in the translation of those procedures into meaningful interactions, but also in the impact this item has on the informal IS. E.g., privacy is an important issue here, since a user might want to share certain meanings only with certain users. One approach would be to share only meanings that are minimally required for the interaction with a current user. However, this approach could unnecessarily limit the evolution of other users.

*Informal IS: Meaning negotiation.* The example above has shown a simple case of implicit negotiation. However, if two users have to negotiate the meaning of concepts that either user selected from different semantic resources, mechanisms have to be provided that are compatible with the abilities of the end users. E.g. for a user with some digital literacy, “collaboratively creating a document” might mean “locally editing a document and sending it via e-mail to the collaborator”, whereas to a fully digitally literate user it might mean “using an online collaborating tool”. Conversation patterns like “Conversation for Possibilities” might provide a starting point for further investigations. Meaning negotiation can be complex. A challenge for interaction design is to enable meaning negotiation considering the different abilities and needs of users.

*Informal IS: Changing pragmatic contexts.* Users may move in different pragmatic contexts, for example work and private contexts. Meanings or actions relevant in one context might be irrelevant in other contexts or even differ. Depending on the current pragmatic context, it must be possible to select the adequate set of meanings and actions. Furthermore, different meanings and differences in the action

repertoire have to be accommodated by interaction design. E.g. compared to the work context, within the private context, an action “invite user to event” might propose a less formal invitation template and use a different channel for sending the invitation.

*All layers: Theory of interaction design.* The items above show that the Pragmatic Web affects interaction design on all three layers of information systems. We expect that “third-wave HCI” services that focus on concepts, meanings and associated actions pose other new requirements on interaction and interface design. Because of the greater diversity, we as HCI practitioners know our users and their use contexts less than ever. Regarding relevant meanings and action repertoires, it is not enough to rely on assumptions made by software engineers, interface designers and the like. Participation of end user representatives is crucial. Thus, we recommend an inclusive, universal and participatory approach in analogy to [Baranauskas et al 2008]. As to methods for defining meanings and action repertoires, the Semantic Analysis by [Stamper 1993a] seems promising, since ontology diagrams in this method already consider agents and affordances.

A problem that remains is the question of how to establish that connection between the formal and the informal. HCI theory has only recently begun to embrace the informal aspects of interaction design. Methods are emerging, but are not yet complete enough to analyse all phenomena, let alone design interaction comprehensively considering informal aspects.

## 4 Conclusion and Future Work

Based on the observation that the use of digital artefacts has significantly changed during the last years and that today users interact with those artefacts in different contexts, with different purposes and competencies, we investigated how the vision of the Pragmatic Web can contribute to the interaction design of services that must be accessible, intelligible and relevant.

Concepts currently being elaborated by the Pragmatic Web community, such as pragmatic patterns, pragmatic contexts, as well as methods and techniques from other areas, such as Organizational Semiotics, Language/Action Perspective or Socio-Instrumental Pragmatism provide promising starting points to define a frame of reference for analysing and designing accessible, intelligible and relevant services. The example and discussion from the previous section have posed many questions one of the more important ones in our research context being the question of designing interaction inclusively and universally.

Our next steps in this research include the formalization of a methodology to be adopted drawing on already existing methods from related areas. In parallel we envisage the participatory design and development of a prototype that explores our considerations from [section 3] regarding pragmatics in the inclusive usage of the Web.

### Acknowledgements

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# **Ethnomethodology as an Influence on Community-Centred Design**

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**Abstract:** Social norms are integral to the success of online communities. This success is predicated on social norms reinforcing accepted community behaviour, marshalling effective communication and, from a semiotic perspective, providing a foundation for the interpretation of signs. Accepting Stamper's ontological position, we propose ethnomethodology as a theoretical basis for community-centred design. Ethnomethodology is the study of social order and has over the last decade gained much currency as a precursor to technology innovation. The only assumption underlying ethnomethodology is that social order is concrete and observable. Thus, social visualisations, that draw inspiration from ethnomethodology, are proposed as means to render social order accountable. Through reflection, the community is enabled to observe ongoing social processes and activate policy decisions accordingly. This socio-technical framework conceives of the community and supporting infrastructure as a complete information system. Finally, we present the Community Management Framework (CMF), a system, which encourages self-management through ongoing reflection and community-based policy management (CBPM).

**Keywords:** ethnomethodology, social norms, self-organising communities, policy, organisational semiotics, community management framework, pragmatic web

**Categories:** H.4.3, H.5.3, J.4

## **1 Introduction**

Social norms play an integral role in the proliferation of self-organising online communities. Social norms not only marshal everyday social interaction but also coordinate and regulate ongoing group activity. In this context, the evolution of social norms has been acknowledged as a more successful approach to cooperation than the imposition of external rules [Ostrom, 2000]. This in turn suggests that the very genesis of effective, highly refined policy can be found in the emergence and continued evolution of social norms. Similarly, more formal, hierarchical organisations increasingly highlight the importance of social norms to help generate and sustain social capital. Social capital is central to effective communication and is crucial in the pursuit of knowledge sharing. This has led to calls for increased 'info-

culture analysis', which describes tacit knowledge embedded in social relationships surrounding work-related tasks, in addition to more traditional analyses such as info-structure (formal rules governing social interaction) and infra-structure (hardware and software tools that enable communication) [Huysman and Wulf, 2006]. In this regards, Stamper's semiotic ladder provides a framework to help determine knowledge and meaning within an organisation. The uppermost layers, semantic, pragmatic and social world, are concerned with signs and their corresponding meaning when situated within a social context [Stamper et al., 2000]. Stamper maintains norms and signs are inseparable. Social norms provide us with the foundation to interpret, understand and ultimately act on signs. Social norms are also emergent and temporally located – they are not external to the social context in which they develop and are bound to a period of existence.

It is from this perspective that we introduce ethnomethodology as an influence on the design of community-based software. Ethnomethodology is a method of social inquiry concerned with the study of indigenous social order [Livingstone, 1987: pg:13]. As a basis of investigation, ethnomethodology is founded on the single assumption that social order is concrete and observable. Over the last decade ethnomethodology has emerged as a popular method of research in technology related disciplines. Dourish and Button, for example, have coined the term 'Technomethodology' to describe their effort to incorporate an ethnomethodological perspective into the process of design [Dourish and Button, 1998][Dourish et al., 1996]. Our concern here, however, is more related to how ethnomethodology has emerged as a theoretical basis for innovations in social software. Much of this interest stems from the work of 'social translucent' systems, which endeavour to recreate characteristics of physical environments in the virtual domain. Other methods are influenced by the success of ethnomethodology as an approach to understanding indigenous work practice and have thus encouraged the adoption of *awareness* as a core aspect of collaboration in distributed teams. A central theme to this paper, one that is reflected in the origins of ethnomethodology, is that social order, while reinforced by social norms, is not regulated by social norms. This is a key distinction between some approaches to Language Action Perspective LAP, such as the Winograd and Flores' LAP system the Coordinator, that have attempted to imbue communication with meaning by the application of categories external to the actual communication. It is our position that meaning is created and recreated in a continued reflexive process of social negotiation. Norms, unlike rules, are not something external to social interaction. Norms, in contrast, are integral to social interaction.

Firstly, we introduce ethnomethodology. Focusing on the origins of the discipline, we discuss how insights from ethnomethodology may be adopted to help understand the emergence of indigenous social norms. Secondly, we discuss the importance of norms and the impact external policy can have on self-organising communities. To ensure group cohesion and effective communication, norms, over time, may evolve into more explicit policy rules. We discuss organisational semiotics, an approach to information systems that recognises the social orientation of signs and their related meaning. Computer mediated communication has been acknowledged as a 'lean medium' [Herring, 2003] – a medium that inhibits communication due to reduced social cues. From this perspective, we present related

work that has drawn influence from aspects of ethnomethodology and is concerned with recreating the experiences of physical interaction in the virtual domain. Finally, we discuss the Community Management Framework (CMF), an approach to supporting indigenous community practices by facilitating the emergence of norms and their evolution into policies. The CMF draws on much of the work presented in this paper and is founded on the Community Based Policy Management (CBPM) system [Feeney et al., 2004]. The CBPM is a novel technology that has been developed to support the collective management of resources and organisational structure using declarative policy rules.

## 2 The Ethnomethodological Input

Ethnomethodology is the study of ‘mundane methods that are used by people to produce and manage the common, everyday activities of the everyday social world’ [Livingstone, 1987: pg:10]. Everyday activities include simple greetings, taking turns in a conversation, reaching a verdict and the formation of a queue. Ethnomethodology emerged from a study carried out by the discipline’s founder Harold Garfinkel in 1954 and led to the publication of his seminal work *studies in ethnomethodology* in 1967 [Garfinkel, 1967]. Much of his early theorizing was developed in reaction to the work of Talcott Parson his supervisor in Harvard University. In short, Parson subscribed to the belief that society was effectively rule determined, and persons in pursuing their individual interest will do so in accordance with clear explicit rules. But Garfinkel rejected this theory for two fundamental reasons: Firstly, rule governed behaviour vastly underestimates the huge complexity evident in even the most basic of social actions. Secondly, many social situations, and the action that is practiced in those situations, are not analysable by reference to clear explicit rules. Rather, Garfinkel theorised that reasoning procedures, that drew form a vast area of background, common-sense knowledge, were in fact employed to accomplish social action in many different social settings [Heritage, 1984: pg128].

Over the last decade ethnomethodology has become a popular method of research in CSCW and to a lesser extent HCI. In part, as suggested by Dourish and Button, this is due to the publication of Lucy Suchman’s widely cited book: *Plans and Situated Actions*. Ultimately influenced by Garfinkel’s work and his approach to social action in local settings, Suchman illustrates her argument with several examples carried out in laboratory settings. Her book has become one of the seminal works in the HCI literature, and has helped propel ethnomethodology into the realm of HCI [Dourish and Button, 1998]. Indeed it was from an ethnomethodological standpoint that Suchman levelled criticisms on Winograd and Flores over their approach to the Coordinator - a system developed upon speech act theory. Persons communicating through the Coordinator had to categorise their communication before they began to interact. Suchman argued that meaning or intention cannot be categorised prior to the actual interaction because, citing conversation analysis, intention and meaning only emerged through continued social negotiation and unfolding social action [Suchman, 1993]. In this way ethnomethodology as a practice, or indeed influence on design, reflects Stamper’s ontology of actualism [Stamper, 2001]. Actors, specific to a situation, generate and regenerate meaning through an ongoing process of social negotiation.

### 3 Norms, Rules and Organisational Semiotics

Social norms marshal people's behaviour in everyday social situations. The organisation that is implicit in a simple queue, for example, emerges from a consensus regarding prevailing social norms. Stamper describes norms as 'a field of force that makes members of the community tend to behave or think in a certain way' [Stamper et al., 2000]. Norms are situated within a specific culture, have a lifespan independent of their actors and impact on varying degrees of social interaction. It has been found, for instance, that actors communicating across an IRC channel will typically strive towards an ideal message schema [Goutsos, 2005]. The notion of an ideal message schema is reinforced by norms that serve to compensate for the constraints of the medium. Similarly, conversation analysis, arguably ethnomethodology's greatest contribution, has been used to study the relationship between language and the traditional idea of community [Stommel, 2008]. Norms in this context emerged in the form of discursive identities. Discursive identities draw from the work of categorical identities or situational identities and refer to roles that people implicitly assume during talk to enable and further communication. Thus norms are not regulative but constitutive of social interaction. This helps to illustrate an important distinction between norms and rules. Norms are produced endogenously. Rules, in contrast, are explicit and imposed, often externally, to govern behaviour under specific circumstances. The emergence of web 2.0, and in particular self-organising online communities, has highlighted the importance of shared culture, social norms and, in cases where the community has expanded rapidly, clear and explicit policy rules. The Wikipedia case of the *biographies of living persons* as described in [Forte and Bruckman, 2008] demonstrates how norms, taken from the physical world and applied in the virtual domain, can evolve into guidelines and, eventually through a period of open discussion, debate and arbitration, emerge as Wikipedia policy. At the same time, the problems associated with reaching consensus have resulted in the proliferation of small decentralised groups that exhibit their own norms, rules and social structure.

From an organisational semiotics perspective, norms are integral to how organisations cohere. Stamper developed MEASUR as an approach to enable the identification of norms. The underlying assumption of MEASUR is that organisations are in themselves information systems and that the norm is an effective unit of specification [Liu, 2000]. Therefore MEASUR is mostly concerned with the upper three levels of the semiotic ladder, semantics, pragmatics and social world. In the social world, Stamper divides norms into four categories, perceptual (an agreed upon way of seeing the world), cognitive (beliefs and knowledge possessed by the group), evaluative (direct the group towards common goal) and behavioural (govern acceptable group behaviour). NORMA, the knowledge representation language, was developed to support the analyst encode norms and affordances in a set of conditional statements. This is the foundation for mapping the semiotic structure of an organisation. While we agree with the basis of the semiotic ladder, our position in regards to the application of a MEASUR is very different. We maintain that rendering social order *accountable* provides the community with an opportunity to reflect upon their ongoing communication processes. Through reflection, their

performance as a community, the effectiveness of current social norms and the communication model as whole is brought into sharp relief.

#### 4 Reflecting observable social action

The notion of the web as a lean medium has encouraged researchers to create systems that emulate the sorts of interactions that people engage in physical space. Kellogg's and Erickson's work on social translucent systems, for example, has sought to bridge the gap between interacting in physical space and communicating online. The approach is informed by ethnomethodology - highlighting the importance of *awareness* and *accountability* in unfolding social situations. The properties of physical space, or properties that help marshal successful interaction in physical space, are modelled on the metaphor of a door leading into a stairwell. The introduction of a small glass window presents each co-participant with the ability to sufficiently re-orientate their actions in accordance with each other. Thus, the small glass window renders their actions visible (to each other), accountable (to each other) and develops a collective sense of awareness (neither participant will slam the door in the other's face as such an action is not in accordance with behavioural norms). In their system, the small glass window is manifested as a social proxy - a visualisation that illustrates to those participating in a social situation the presence of others in their immediate environment [Erickson and Kellogg, 2000][Kellogg et al., 2006].

Social visualisations such as Coterie [Donath, 2002] and PeopleGarden [Xiong and Donath, 1999] present a more comprehensive view of social or indeed community-based processes. Coterie, developed at MIT, visualises discussion in Internet Relay Chat. Coterie's visualisation gives user's an immediate impression of the vitality of a conversation. PeopleGarden, in contrast, adopts the metaphor of a flowering garden to visualise user participation on a message board. History and identity are established by depicting users as flowers - the more petals a flower has indicates the number of posts and the longer the stem of a flower illustrates the length of time a participant has been involved. More recently, Communication Garden has augmented the visual metaphor of PeopleGarden with more sophisticated content and behavioural analysis [Zhu and Chen, 2008].

At the same time there have been several articles published addressing awareness in relation to collaborative work [McGrath and Munro, 2003][Lederer and Heer, 2004]. Work, and in particular work as a social undertaking, has preoccupied Garfinkel's later writing as he sought to bridge ethnomethodology with work related fields. He discussed this in terms of 'the shop floor problem' or how generic descriptions of work obfuscate the actual ongoing practice employed by the worker in the workplace, i.e. the shop floor. Studies have highlighted the discrepancy between work processes - the formal, exogenous procedure expected of those operating within a particular workflow for instance - and work practice - the informal, endogenous method employed by the worker to get the job done. One study carried out by researchers at Xerox Parc illustrated how employees working in the print industry used the 'ecology of the shop floor' - the line of sight between operatives and machines - combined with their knowledge of the print process, their knowledge of the machines and their knowledge of each other's work loads to support ad hoc cooperation [Bowers et al., 1995]. Distributed teams, however, do not share a

common work environment. And it is often the environment that provides the necessary social cues and other points of orientation crucial to efficient collaborative work. From this perspective, awareness in collaborative systems has focused on sharing social information and on highlighting the concept of shared cognition as part of collaboration. Shared cognition is important so that the user operating in a collaborative environment understands their position and corresponding relationships in context of a broader social system [Leinonen et al., 2005].

## 5 Discussion: The Community Management Framework

The Community Management Framework (CMF) is designed to support the progressive self-management of communities. The framework is founded on the principles of decentralised, self-management – management decision-making should be conducted in a collective, participative manner free of centralised control by a single member. For this to occur, however, we require a method for the community to reflect upon community-based processes, including the emergence of social norms, the creation and sharing of knowledge and the development of shared vocabularies, and to activate policy decisions according to an agreed upon consensus. This represents an approach to community management and the formation of policy that is participatory, evolutionary and non-prescriptive. The first image in Figure 1 illustrates a community feedback mechanism (as envisioned by the authors) that draws influence from the social visualisations discussed earlier. The second image is a screen-shot of policy formation in the Community Based Policy Management (CBPM) system a novel and functioning component of the CMF. CBPM was developed in reaction to rigid organisational models that adapt poorly to organisational change. The system enables management rules to be administered in a flexible group-based organisational model [Lewis et al., 2009].

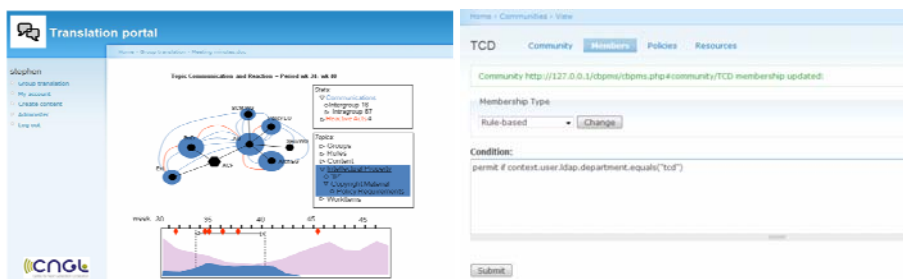


Figure 1: On the left is a mock-up illustrating topic formation and group activity in an online discussion group. The bottom visualisation depicts the relationship between conversation and related group activity on a temporal basis. On the right is a screen-shot illustrating rule formation in the CBPM system.

In accordance with semiotic theory, the CMF will treat policies as signals between decision makers and others in the community. This approach is self-reinforcing in that policies will provide the de facto model of norms which, when

combined with lightweight techniques for capturing community semantics and used in the semiotic analysis of self-reported problems, will increase the usefulness of, and thus the commitment to, explicit policy modelling by the community.

## 6 Conclusions

In this paper we presented ethnomethodology as an influence to the design of community based software. Ethnomethodology is concerned with the study of social order, however unlike other approaches to sociology, ethnomethodology does not prescribe to the notion of rule-governed behaviour. Thus, social order is indigenous, and norms are foundational, reflexive and endogenous. Stamper's semiotic ladder introduces norms as an embodiment of the organisation. They are emergent, often temporary yet provide a means to interpret and understand signs within a social context. In contrast, the imposition of external rules can have a negative consequence for online communities, often resulting in high attrition rates. In this context, we introduced the Community Management Framework. Drawing on ethnomethodology and semiotic theory, the CMF presents communities with a means to progressively self manage.

## 7 Future Work

There are several directions for future work. Firstly, we are extending the CMF platform with a set of novel self-management support services for progressively capturing community norms, operational rules and other organisational knowledge. This work presents an opportunity to assess the role of social visualisations on group decision-making, while also producing a need to operationalise social processes in a way that is conducive to quantitative analysis. Methods such as Social Network Analysis (SNA) may prove valuable in this respect. Secondly, the application of the CMF enables communities to *reflexively self-manage* as they observe their own management behaviour and generalise from previous outcomes to propose new theories for improving management strategies. This research involves designing appropriate mechanisms for reporting and analysing problems within a semiotic framework and assessing its effectiveness in supporting improvement in the operation of online communities. We intend to conduct several longitudinal studies to assess the impact of the CMF on community engagement, self-organisation and viability.

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# Value Modeling for the Pragmatic Web – the Case of Social Advertising

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**Abstract:** Social network sites have rapidly become very popular, but the business models behind them are still in their infancy. In this paper, a new combination of value modeling techniques is proposed to explore business models for the new web. In this approach, the business models are built up as overlays on social gratification models. The approach has been applied successfully to the case of social advertising in Facebook.

**Keywords:** e-business, value modeling, semantic web, social networks, uses and gratifications

**Categories:** H.1

## 1 Introduction

The Pragmatic Web [Schoop et al 2006] is the Internet as a platform of communication and coordination. How does the Internet effectively support social interaction? To answer this question we need to go beyond a data exchange view of communication. What do people try to achieve when they send messages or write notes? In order to model and, in the end, support these interactions effectively, we need modeling methods that consider both the goals and the means of communication and how the two are related. We can distinguish two levels of use for these modeling methods: first, they can be used off-line in thinking about the design of certain interactions, e.g. the interactions as part of a new business model. Secondly, these models, if sufficiently formalized, could be used by automated tools to support humans in their interactions, similar to the way workflow management tools support business processes within an organization. This paper is restricted to the first level and investigates the use of *value modeling*, a technique that does abstract from process details and focuses on the (economic) value that is exchanged. The technique was developed in the pre-Web 2.0 era. It does not explicitly deal with social aspects. In addition, its ontology reflects a Good-Dominant rather than a Service-Dominant logic [Vargo et al 2006], that is, it highlights value exchange rather than value co-creation [Weigand 2009]. So although it is one of the best rated value modeling methods known to date [Andersson et al 2006], it is not immediately clear whether it can be used for the Pragmatic Web and what extensions might be needed.

The objective of this paper is to develop a value modeling method for the Pragmatic Web by investigating how e3value, or an adapted version of it, can be used effectively in a Pragmatic Web context. This is done by means of an extensive case study of social advertisements in Facebook. Section 2 and 3 contain an introduction into the

value of social networks and value modeling, respectively. In section 4, the case study is introduced and more in particular, the notion of social advertising in Facebook. Section 5 is the e3-value analysis of the case. Section 6 contains the conclusions.

## 2 The value of the social web

The web is increasingly becoming a social place. To understand the value of virtual communities and social network sites, [Dholakia et al 2004] draw upon the well-established *uses and gratifications paradigm*, originally developed and employed by communications researchers to understand people's motivations for using different media [e.g., Flanagin and Metzger 2001; McQuail 1987; Bumgarner 2007]. This research assumes that individuals seek out media in a goal-directed fashion to fulfill a core set of motivations.

*Entertainment*, which may be of various kinds, is one motivation. Of special relevance from a marketing perspective, *informational value* is one that the participant derives from getting and sharing information in the group, and from knowing what others think. *Instrumental value* is derived from accomplishing specific tasks, such as solving a problem, generating an idea, influencing others regarding a pet issue or product, validating a decision already reached or buying a product, through online social interactions [McKenna and Barg 1999]. These objectives are all instrumental in the sense that they are usually defined prior to participation and facilitate achievement of specific end-state goals.

The next type of value, *self-discovery*, involves understanding and deepening salient aspects of one's self through social interactions. One aspect of self-discovery is to interact with others so as to obtain access to social resources and facilitate the attainment of one's future goals [McKenna and Bargh 1999]. Another aspect of self-discovery is that such interactions may help one to form, clearly define and elaborate on one's own preferences, tastes, and values. *Maintaining interpersonal connectivity* refers to the social benefits derived from establishing and maintaining contact with other people such as social support, friendship, and intimacy. *Social enhancement* is the value that a participant derives from gaining acceptance and approval of other members, and the enhancement of one's social status within the community on account of one's contributions to it.

Although traditionally, uses and gratifications is the dominant paradigm for explaining media exposure in communication science, the results of empirical validation have been rather disappointing. The problem is not with the motivations as such, but with the assumption that people actively seek out media in a goal-directed way [Palmgreen et al 1985]. For that reason, the original theory has been reformulated to take into account, not only the gratifications sought but also the gratifications obtained. According to [LaRose et al 2001], this redefined notion of uses and gratifications is moreless subsumed by the concept of *enactive learning* in social-cognitive theory [Bandura 1986]. Central to the social-cognitive theory is the focus on *outcome expectations* as providing the incentives as well as disincentives for enacting behavior. This broadens the scope of analysis beyond motivations. Factors such as self-efficacy – belief in one's capability to organize and execute a particular course of action – are considered relevant as well.

When applying uses and gratifications theory to medium choice, the usual assumption is that different media compete. However, according to [Dimmick et al 2000], a global comparison between the gratifications of each medium is not useful, as they often co-exist. It is important to identify the particular niche of a certain medium. Comparing personal e-mail and telephone, they found that a wider spectrum of needs is being served by the telephone, whereas e-mail provides greater gratification opportunities in its own niche.

### 3 Value Modeling

The e3value methodology models a network of enterprises and consumers creating, distributing, and consuming things of economic value [Gordijn and Akkermans 2003]. The main modeling constructs are:

- **Actor.** An actor is perceived by his or her environment as an economically independent entity.
- **Value object.** Actors exchange value objects. A value object is a service, good, money, or experience, which is of economic value to at least one actor.
- **Value port.** An actor uses a value port to provide or request value objects to or from other actors.
- **Value interface.** Actors have one or more value interfaces, grouping value ports and showing economic reciprocity. Actors will only offer objects to someone else if they receive adequate compensation in return
- **Value exchange.** A value exchange connects two value ports. It represents one or more potential trades of value objects.
- **Value activity.** An actor performs one or more value activities, which are assumed to yield a profit.
- **Dependency path.** Designers use a dependency path to reason about the number of value exchanges in an e3value model. A path consists of consumer needs, connections, dependency elements, and dependency boundaries. You satisfy a consumer need by exchanging value objects (via one or more interfaces). A *connection* relates a consumer need to an interface or relates an actor's various interfaces. A path can take complex forms, using AND/OR dependency elements taken from use case map scenarios [Buhr 1998]. A dependency boundary denotes the end of value exchanges on the path [Gordijn and Yu 2006].

A simple example illustrating the business model of Facebook from the advertisers' perspective is shown in [Fig. 1]. In this model, Facebook offers advertisement services against payment, very much like Google and other web companies. At the other side, Facebook offers users a social platform. Users don't pay, but their (massive) presence at Facebook is in itself of commercial value. One could add that the personal data they provide has a value in targeting the advertisements as well. Although illustrative, the model is ways too simplified as a real business model. "I don't think social networks can be monetized in the same way that search did", CEO Mark Zuckerberg recently said [Zuckerberg 2008].

E3-value has proven to be a useful instrument for developing business models; in addition it supports profitability analysis for each actor on the basis of net present value. However, e3-value originates from before the social web era. It does not explicitly consider actors (including consumers) as part of their social network. However, in the social web era the value proposition offered is not some resource that is consumed by customers to fulfill some “need”. Rather consumers are viewed as social actors that create value in their interactions, and the value proposition of a company is that it brings in certain resources that help these actors to create more value. Therefore we propose to extend e3-value with the following methodological guideline in order to make it an instrument of value modeling for the Pragmatic Web:

1. First, build a value model of the customer as part of his social network
2. Second, build a value model of the new service as an overlay of the first model

In order to assess the usefulness of this guideline, we apply it in this paper to a business model of social advertising in Facebook.

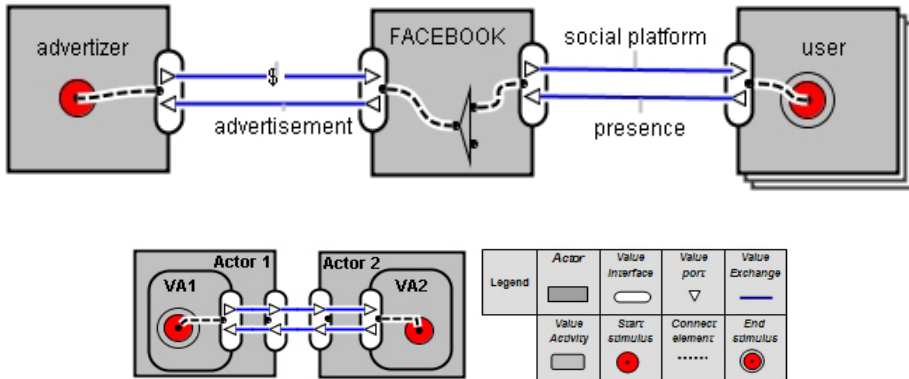


Fig. 1: Facebook from the perspective of the advertiser, and e3value legend

## 4 Advertisements in Facebook

Facebook started as a social network for college students for Harvard University students in February 2004. In hardly 4 years it has grown to one of world largest social network sites with more than 70 million users in 2008. As all social networks Facebook is searching for ways to monetize these users.

### 4.1 Social advertisement in Facebook

In finding ways to monetize this tremendous user database Facebook developed a so-called social advertisement platform. Social advertisement uses the nature of the relations and the motivation of people to use social network for selling products. We

explain three different advertisements used by the advertisement platform of Facebook:

### Social ads

Facebook describes social ads as:

*“Instead of creating an advertisement and hoping that it reaches the right customers, you can create a Facebook Social Ad and target it precisely to the audience you choose. The ads can also be shown to users whose friends have recently engaged with your Facebook Page or engaged with your website through Facebook Beacon. Social Ads are more likely to influence users when they appear next to a story about a friend's interaction with your business.”*

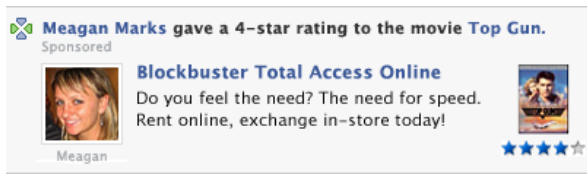


Fig. 2: Example social ad in Facebook

A typical example of a social ad is given in [Fig. 2]. Facebook is combining different pieces of information in this social ad: the picture of Meagan; the review of Meagan; the advertisement text of Blockbuster

### Pages

Facebook explains Pages as:

*“When your fans interact with your Facebook Page, the actions they take are automatically generated into social stories. These stories are published to News Feed, which friends may see the next time they log into Facebook (...) You can increase the viral distribution of your Facebook Page with Facebook Social Ads. Create an ad creative and attach it to stories in News Feed or in the left-hand Ad Space.”*

Facebook uses these Pages as input for their social ads. Besides that they automatically update the friend feed of your friend when you post a message or engage in another way with the brand.

### Beacon

Beacon is one of the latest and most controversial additions to the platform. Facebook describes Beacon as:

*“Simply determine which user actions you would like publish to Facebook and add a few lines of code to your web page. Facebook Beacon actions include purchasing a product, signing up for a service, adding an item to a wish list, and more... Stories of a user's engagement with your site may be displayed in his or her profile and in News Feed. These stories will act as a word-of-mouth promotion for your business and may be seen by friends who are also likely to be interested in your product.”*

The three advertisement forms explained above have two interesting properties. The advertisement is build with *combined* information of different sources and the platform uses the *Social Graph* to display the advertisement to potential target groups.

#### 4.2 Social and semantic advertisement

In the traditional meaning, social advertising is about applying marketing and advertising principles to promote health and social issues and bringing about positive behavior change. However, to cater for the Facebook' use of social ads, we need another definition. We propose the following general one:

*“Social advertisement is a form of advertisement that addresses people as part of a social network”*

It should be noted that the traditional meaning of social advertising and the social ad idea of Facebook are quite different at first sight, but perhaps not too remote after all. That is why we have suggested a broad definition. For example, to reach social network users, the sportswear company Converse included a social networking component to its "Open Gym" campaign. It organized real-world basketball competitions for inner-city youth and used Facebook as an online "meeting place" for participants.

Social advertising is to be distinguished from semantic advertising whose meaning is still evolving (most of the discussion is found in blogs on the web). Semantic advertising is a development in the evolution of contextual advertising, which simply means that advertisements are linked to pages based on a keyword match. In a certain sense, contextual advertising already occurred in traditional media like newspapers and TV as well, but not performed automatically. We define semantic advertising as follows:

*“Semantic advertisement actively combines information from different sources to enrich the context in which the advertisement is displayed. The information of the advertisement creates an added value for the content and is therefore part of it”*

Semantic advertising can make use of Semantic Web technology which gives many more opportunities than keyword matching. The matching can be improved in quality and also be made more dynamic. In the business field a few companies are pioneering the field of semantic advertisement. One of those companies is Radar Company that developed a product called Twine. Twine is social collaboration platform based on semantic technologies. Its business model is a combination of premium services and advertisement.

In this paper, we are not focusing on semantic advertising as such, but on a combination of social and semantic advertising, which has a very strong potential.

## 5 Analyzing Facebook

In order to analyze the business model behind Facebook's advertising, we should know which values are offered by whom to whom. We first model the social network, then the basic support Facebook offers and then the social advertising model.

## 5.1 Modeling the social network

Our modeling guidelines prescribe that in order to understand the value of a certain business model for the Web, one should start with a model of the social network of the customer. In this paper, we build up this model by means of the uses and gratifications paradigm. The result is pictured in [Fig. 3].

The model highlights self-discovery and social enhancement as the main value activities. Self-discovery motivates and is fed by personal disclosure and receiving interest from others. Also the social examples provided by others play a role. In addition, social relationships are maintained by gifts. We have linked this to the social enhancement. Note that subject and others are roles, representing the active and the passive side of the social relationship and taken up by the participants in a reciprocal way.

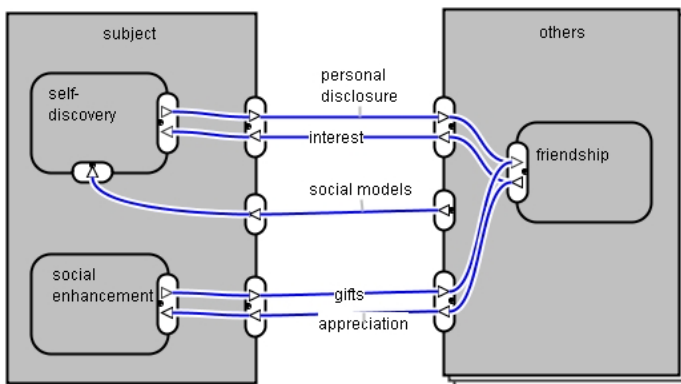


Fig. 3: e3-value model of the social network

## 5.2 The value of Facebook

Facebook is popular because it supports the motivations (like self-discovery, social enhancement and interpersonal connectivity) for people to join a social network. On the platform you can find new friends, send messages to them, give virtual gifts, share photos and music and show friends where in the world you have been. The value of Facebook with respect to the social network activities of people is shown in [Fig. 4]. In this figure, we make use of an extension of e3-value in the form of *value encounters*. A value encounter stands for the collaboration between multiple stakeholders where each party brings in certain resources [Weigand 2009]. Rather than viewing the collaboration as an exchange of value objects, it views it as a platform for co-creation of value. The advantage of the use of value encounters – pictured as dotted colored rectangles – is that it makes it possible to see where (and not only to whom) the actors contribute. They abstract from the way financial benefits are distributed. Value encounters can be related to each other by means of a positive or negative influence link. In [Fig. 4], the online communication value encounter and the friendship gifts value encounter exhibit a positive feedback loop.



The model in [Fig. 4] is not intended to be complete with respect to the Facebook business model. However, it makes very clear how Facebook by providing digital space and feedback functions (that can be related to its components, such as Wall, Status and Photos) enhances social network activities. Not included in the model is the space it offers for users to develop new software services for the community (Facebook Platform). This capitalizes on the social enhancement activity that aims at recognition and status on the basis of public contributions. Another component of Facebook called Gifts is targeting directly the value encounter of friendship gifts.

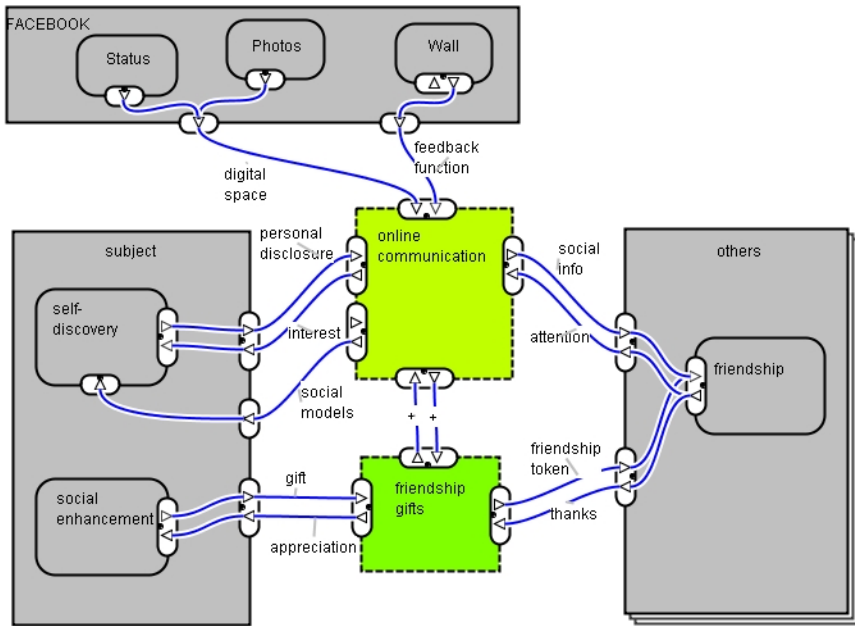


Fig. 4: Facebook value model overlaying the social network value model

### 5.3 Social advertisements in Facebook

Facebook earns money by selling advertisements to companies. They are able to provide a target audience and receive money instead. The goal of the advertisement is to great brand awareness at the user and increase selling of the products. Because Facebook is a private company no exact numbers about revenue and profit are known. The estimated revenue for 2007 is about \$150 million, which is a little bit more than \$2 per user. Most of their income is from advertisers who want to reach some of the 70 million users.

In the year 2008 this is a very common business model for a profitable web-service. However, the results were rather poor. The revenue of advertisements is measured with cost-per-million (CPM) or cost-per-click (CPC). The first measurement, CPM, means that the advertiser pays an amount for every time an advertisement is shown (viewed) to a visitor in units of a million. The second measurement means that the advertiser pays for every click on the advertisement.

Facebook generated a massive amount of impressions but a very low click thought rate: a typical click-through rate is between 0,1% and 0,2%. As already argued by Iskold in a blog [Iskold 2007], people are not coming to Facebook to click ads, they are coming to Facebook to see what there friends are up to. This situation is fundamentally different from a search engine like Google where users get to a web page based on a search that expresses at least a certain interest in an item or subject, often with an underlying intent to acquire something.

With the introduction of Social ads, Facebook made advertisement part of the content of the website to align it with the social interests. [Fig. 5] shows the contribution advertisers offer to the online communication, in return for publicity. This contribution enables subjects to extract model-based buying suggestions (“Meagan bought X and so may I”) and personalized buying suggestions (“Meagan celebrates her birthday and likes X”). These suggestions support self-discovery and buying behavior. That the advertiser is also a seller of the friendship gifts is not included but not unimportant of course. The contribution of Facebook is that it matches data and enriches the messages.

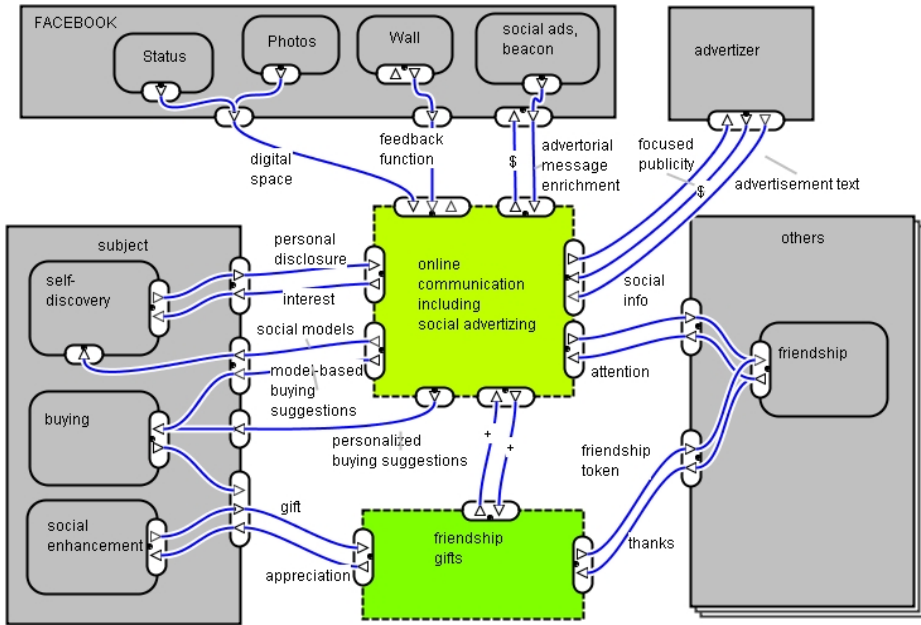


Fig. 5: Facebook advertisement model overlaying the Facebook value model

## 6 Conclusions

Social network sites stand in the tradition of online communities, but they also indicate a shift [Boyd and Ellison 2007]. While websites dedicated to communities of interest still exist and prosper, social network sites are primarily organized around people, not topics or interests. For online communities, a typical business model used

to be the affiliate or advertisement program, based on a match between the interests of the community and the products that the advertiser wants to promote. In order to find business models for social network sites, it is necessary to first identify the values that users derive from their presence. The more a business model is aligned with these values, the more successful it will be.

We have shown that the Facebook business model capitalizes on the social network, both in its basic form and when social advertisements are included. This demonstrates the value of the modeling guidelines given in section 3. A question is how this result can be generalized, as Facebook is clearly a special case. This is not only an issue of external validity. It may be the case the Facebook represents a trend, and the question is not just whether social models do underlie business models or not, but whether this is the way all business models should move, including traditional good-dominant models for consumer products like cars and food or tourist services.

In this paper, we have made basic usage of the uses and gratifications paradigm. As hinted at in section 2, social-cognitive theory may be a more comprehensive paradigm to base our social models on. One of the reasons is that this theory also considers disincentives. In the case of Facebook, a disincentive that has played a role is the privacy concern. When Beacon was launched in November 2007 it received a lot of criticism from MoveOn, a US privacy group. They accused Facebook of violation of user's privacy. Every site using Beacon send information to the Facebook servers of each user engagement and placed a cookie on the computer, independent if the user had an account on Facebook. When the user logged on to Facebook the user engagement of the website was added to the friend feed without prior notice of the user. This was on an opt-out base, which means that every user was automatically joining unless they opt-out. After the critique Facebook made it opt-in and notified the user that information about their activities was shared with other services.

Admittedly, the social model of Facebook [Fig. 3] developed in this paper is a rather crude one. We have introduced it here to illustrate the proposed value modeling approach. As a subject of future research, we suggest to extend and validate it on the basis of social-cognitive theory and empirical usage studies.

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## Reaching Semantic Agreements through Interaction

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**Abstract:** We address the complex problem of semantic heterogeneity in multiagent communication by looking at semantics related to interaction. Our approach takes the state of the interaction in which agents are engaged as the basis on which the semantic alignment rests. In this paper we describe an implementation of this technique and provide experimental results on interactions of varying complexity.

**Key Words:** interaction model, alignment protocol, alignment mechanism

**Category:** I.2.11, I.2.12

### 1 Introduction

We tackle the problem of semantic heterogeneity as it arises when combining separately engineered software entities in open and distributed environments. In particular, we focus on how to reach mutual understanding of the terminology that occurs in communicated messages during a multiagent interaction. Semantic heterogeneity is most commonly addressed either by having recourse to shared ontologies, or else by resolving terminological mismatches by ontology mapping [Kalfoglou and Schorlemmer 2003, Euzenat and Shvaiko 2007]. Ontologies may indeed be very useful for stable domains and closed communities, but the cost of guaranteeing global semantics increases quickly as the number of participants grows. Ontology mapping allows for more dynamism and openness, but current techniques compute semantic similarity in an interaction-independent fashion, for instance, by exploring the taxonomic structure of ontologies or by resorting to external sources such as WordNet, where semantic relations like synonymy, among others, were determined prior to interaction and independently from it. Hence, in general, these techniques do not address the fact that the meaning of a term is also relative to its use in the context of an interaction.

In this paper we aim at proving that this more pragmatic context may guide interacting agents in reaching a mutual understanding of their respective local terminologies. For this we make an empirical evaluation of an implementation of the Interaction-Situated Semantic Alignment (I-SSA) technique (Section 2), originally formalised in [Atencia and Schorlemmer 2008]. Our implementation of I-SSA lets two agents interact through communicative acts according to two separate interaction models locally managed by each agent. All terminological mismatches during communication are handled at a meta-level in the context of an alignment protocol. As interaction-modelling formalism we have initially

chosen finite-state automata (FSA), because they are the basis of more complex interaction-modelling formalisms such as Petri nets or electronic institutions [Arcos et al. 2005]. We set out to answer two Research Questions:

1. Is there a gain in communication accuracy —measured in the number of successful interactions, i.e., interactions reaching a final state— by repeated semantic alignment through a meta-level alignment interaction?
2. If so, how many repeated interactions between two agents are needed in order to get sufficiently good alignments —measured in the probability of a successful interaction?

The experimentation results (Section 3) give a positive answer to the first question and relate the number of interactions to the probability of a successful interaction on the basis of a collection of interaction models.

## 2 Interaction-Situated Semantic Alignment

We model a multiagent system as a set MAS of agents. Each agent in MAS has a unique identifier and may take one (or more) roles in the context of an interaction. Let *Role* be the set of roles and *Id* the set of agent identifiers. We write  $(id : r)$ , with  $r \in Role$  and  $id \in Id$ , for the agent in MAS with identifier *id* playing role *r*.

Each agent is able to communicate by sending messages from a set *M*, which is local to the agent. We assume that a set  $\mathcal{I}_P$  of *illocutionary particles* (such as “inform”, “ask”, “advertise”, etc.) is shared by all agents (see, for example, KQML [Labrou and Finin 1997] or FIPA ACL [O’Brien and Nicol 1998]).

**Definition 1.** Given a non-empty set *M* of messages, the set of *illocutions generated by M*, denoted by  $\mathcal{I}(M)$ , is the set of all tuples  $\langle \iota, (id : r), (id' : r'), m \rangle$  with  $\iota \in \mathcal{I}_P$ ,  $m \in M$ , and  $(id : r), (id' : r')$  agents such that  $id \neq id'$ . If  $i = \langle \iota, (id : r), (id' : r'), m \rangle$  is an illocution then  $(id : r)$  is the *sender* of *i* and  $(id' : r')$  is the *receiver* of *i*. In addition,  $\langle \iota, (id : r), (id' : r') \rangle$  and *m* are called the *head* and *content* of *i*, respectively.

In this work, we treat messages as propositions, i.e., as grounded atomic sentences, leaving the generalisation to first-order sentences for future work.

### 2.1 Interaction Models

We model an interaction model as a deterministic finite-state automaton whose transitions are labelled either with illocutions, or with special transitions such as, for instance, timeouts or null transitions (also  $\lambda$ -transitions):

**Definition 2.** An *interaction model* is a tuple  $IM = \langle Q, q^0, F, M, C, \delta \rangle$  where:

- $Q$  is a finite set of *states*,
- $q^0$  is a distinguished element of  $Q$  named the *initial state*,
- $F$  is a non-empty subset of  $Q$  which elements are called *final states*,
- $M$  is a finite non-empty set of *messages*,
- $C$  is a finite set of *special transitions*, and
- $\delta$  is a partial function from  $Q \times (\mathcal{J}(M) \cup C)$  to  $Q$  called the *transition function*.

Every interaction model is related with an automaton in a natural way. The notion of history associated to an interaction model presented below is very similar to a string accepted for an automaton. The clear difference is that the former one takes into account the states explicitly.

**Definition 3.** Let  $IM$  be an interaction model, where  $IM = \langle Q, q^0, F, M, C, \delta \rangle$ . An *IM-history* or *history* associated with  $IM$  is a finite sequence:

$$h = q^0, \sigma^1, q^1, \dots, q^{k-1}, \sigma^k, \dots, q^{n-1}, \sigma^n, q^n$$

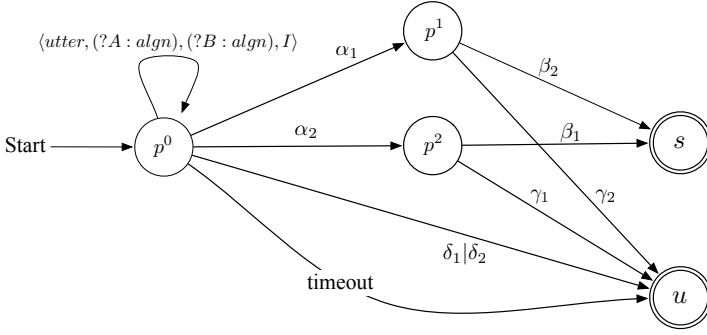
where  $q^n \in F$  and for each  $k$ :  $q^k \in Q$ ,  $\sigma^k \in \mathcal{J}(M) \cup C$  and  $\delta(q^{k-1}, \sigma^k) = q^k$ .

## 2.2 Alignment as Interaction

We study a scenario where two agents want to take part in an interaction, but with the thorny problem that the agents will follow different interaction models. So we have two agents  $A_1$  and  $A_2$  associated with interaction models  $IM_1$  and  $IM_2$ , respectively, and we assume that these interaction models are distinct but they are about the same kind of interaction (e.g., a sealed-bid auction, a travel reservation or a bargaining process).

With agents knowing that they may follow different interaction models and that semantic mismatches are likely to occur, communication requires to be processed in another level. For this reason, we define a meta-level *alignment protocol* (AP) (see Figure 1) that links interaction models: any communication act according to the object level interaction models becomes ineffective and has an effective counterpart according to the meta-level AP.

There are two final states by name of letters  $s$  and  $u$ . If the state  $s$  is reached, then the interaction is considered *successful*, otherwise it is considered *unsuccessful*. In this sense, we distinguish for the moment only two sorts of interactions. Regarding transitions, all of them are listed below the figure except one that has a special status. Notice that agents can adopt only one role, namely, the



$$\begin{aligned} \alpha_i &= \langle inform, (id_i : algn), (id_j : algn), final\_state \rangle \\ \beta_i &= \langle confirm, (id_i : algn), (id_j : algn), final\_state \rangle \\ \gamma_i &= \langle deny, (id_i : algn), (id_j : algn), final\_state \rangle \\ \delta_i &= \langle inform, (id_i : algn), (id_j : algn), failure \rangle \end{aligned}$$

Figure 1: The alignment protocol

‘aligner’ role, or *algn* in short. There are two kind of messages: **failure** and **final\_state**. Moreover, the former one can be tagged with the illocutionary particle *inform*, and the later one with *inform*, *confirm* and *deny*.

Each agent follows both AP and its own interaction model. When agents agree to initiate an interaction, both of them are in state  $p^0$  wrt AP. In addition, agent  $A_i$  is in state  $q_i^0$  wrt  $IM_i$  ( $i = 1, 2$ ). Imagine agent  $A_i$  is in state  $q_i$ , where  $q_i$  is an arbitrary element of  $Q_i$ . There can be several possibilities.

1.  $A_i$  decides to utter  $\mu = \langle \iota, (id_i : r), (id_j : r'), m \rangle$  in accord with  $IM_i$ , where  $\mu \in \delta_i(q_i, \cdot)$ .<sup>1</sup> The communication act must be carried out via AP so agent  $A_i$  sends illocution  $\langle utter, (id_i : algn), (id_j : algn), \mu \rangle$  to  $A_j$ . Therefore, the state remains the same in the AP context, whereas  $q_i$  turns to  $q_i' = \delta_i(q_i, \mu)$  in the  $IM_i$  context.
2.  $A_i$  prompts a state change by a special transition  $c_i \in C_i$  in the  $IM_i$  context. Thus  $q_i$  turns to  $q_i' = \delta_i(q_i, c_i)$ . This action is not reflected in AP since it does not entail any communication act.
3.  $A_i$  receives  $\langle utter, (id_j : algn), (id_i : algn), \mu \rangle$  where  $\mu = \langle \iota, (id_j : r), (id_i : r'), m \rangle$  with regard to AP. Recall that from  $A_i$ 's viewpoint,  $m$  is a foreign message so it is considered semantically different from all local messages. Consequently  **$m$  is to be mapped** with one of those messages that  $A_i$  expects to receive at state  $q_i$  in the  $IM_i$  context. Furthermore, we can make

<sup>1</sup>  $\delta_i(q_i, \cdot)$  is the function defined from  $\Sigma_i = \mathcal{J}(M_i) \cup C_i$  to  $Q_i$  in a natural way.



a selection and just consider those messages encased in illocutions which head is equal to that of  $\mu$ . In this way,  $A_i$  is to choose an element of the following set:

$$\mathcal{R} = \{a \mid \langle \iota, (id_j : r), (id_i : r'), a \rangle \in dom(\delta_i(q_i, \cdot))\}$$

There can be two possibilities:  $\mathcal{R}$  is empty or not.

- 3.1 As long as  $\mathcal{R}$  is not empty,  $A_i$  can select an element  $a$  of  $\mathcal{R}$  making use of the **alignment mechanism** (AM) explained further below. So  $q_i$  turns to  $q'_i = \delta_i(q_i, \nu)$  where  $\nu = \langle \iota, (id_j : r), (id_i : r'), a \rangle$ .
- 3.2 In case  $\mathcal{R}$  is empty, then no mapping is possible. The interaction is considered unsuccessful. In order to state it,  $A_i$  sends a failure message to  $A_j$  by uttering  $\delta_i = \langle inform, (id_i : align), (id_j : align), failure \rangle$ . Thus  $p_0$  turns to  $u$  in the AP context.
4. If  $q_i$  is a final state and  $A_i$  considers the interaction finished, it can send illocution  $\alpha_i = \langle inform, (id_i : align), (id_j : align), final\_state \rangle$  to  $A_j$ . In this case,  $p_0$  turns to  $p_i$  and  $A_i$  expects to receive illocutions  $\beta_j$  or  $\gamma_j$  ( $j \neq i$ ), either confirming or denying the interaction end, respectively. If it receives  $\beta_j$ , then  $p_i$  turns to  $s$  and the interaction is considered successful; if it receives  $\gamma_j$ ,  $p_i$  turns to  $u$  and the interaction is considered unsuccessful.
5. Finally, we have to take into account the possibility of a deadlock. This is the case when, for example, successive mappings have led the agents to states where both of them only can receive. In order to avoid deadlocks, the special transition *timeout* is linked to the initial state  $p_0$  in AP. When a specific period of time is exceeded, this transition leads agents to finish the interaction considered unsuccessful.

The alignment mechanism associates every foreign message with a categorical variable ranging over local messages, such that a variable assignment represents a mapping element. The mechanism further computes frequency distributions of all these variables on the basis of past successful interactions. Agents mapping choices are determined by virtue of these distributions.

Assume agent  $A_i$  tackles a situation like the one described above in case 3.1. Message  $m$  is associated with a variable  $X$  that takes values in  $M_i$ . The equality  $X = a$  represents a *mapping element* (the fact that  $m$  is mapped to  $a$ ), also written  $[m/a]$ . If there is no past experience,  $[m/a]$  is chosen with probability

$$p = \frac{1}{n}$$

where  $n$  is the cardinality of  $\mathcal{R}$ .

Now, things are different as long as agents have interacted successfully in the past. In order to reason about past experiences, agents have to keep track of these ones. A *history* is a sequence of the form:

$$h = q_i^0, \sigma_i^1, q_i^1, \dots, q_i^{k-1}, \sigma_i^k, \dots, q_i^{n-1}, \sigma_i^n, q_i^n$$

computed recursively as follows:

- $q_i^0$  is the initial state of  $IM_i$ , and
- if  $A_i$  is in case 1, then  $[\iota, q_i^l]$  is queued in  $h$ ,
- if  $A_i$  is in case 2, then  $[c_i, q_i^l]$  is queued in  $h$ ,
- if  $A_i$  is in case 3.1,  $[\langle \iota, (id_j : r), (id_i : r'), [m/a] \rangle, q_i^l]$  is then queued in  $h$ ,
- $q_i^n$  is a final state of  $IM_i$ .

Notice that unsuccessful interactions are not considered.

Agents resort to all past histories in order to calculate the frequency distributions. Remember foreign messages do not occur in isolation: each message is the content of a specific illocution which is received at a particular state. To capture this dependency two more variables are considered:  $Q$  and  $H$ .  $Q$  takes values in the set of states  $Q_i$  and  $H$  can be instantiated with heads of illocutions.

So coming back to a situation like the one described in 3.1, agent  $A_i$  wonders whether  $X = a$ , where  $a$  varies in  $M_i$ , given that  $m$  is the content of an illocution with head  $H = \langle \iota, (id_j : r), (id_j : r') \rangle$  that has been received at state  $Q = q_i$ . Using the corresponding frequency distribution:

$$f_r[X = a \mid Q = q_i, H = \langle \iota, (id_i : r), (id_j : r') \rangle] = \frac{v}{w} \in \mathbb{Q}$$

and  $[m/a]$  is chosen with probability

$$p = \frac{v}{w}$$

Note that this option prevents agents from discovering new mapping elements. Alternatively, we can “contaminate” this distribution probability with the uniform distribution over  $[1, \dots, N_0]$ , where  $N_0$  is the number of zeros of the former frequency distribution. In this case,  $[m/a]$  is chosen with probability

$$p = q \frac{v}{w} + (1 - q) \frac{1}{N_0}$$

where  $q$  is a number close to 1.

### 3 Experimentation

#### 3.1 Design

In this section we will explain our experiment design. The alignment protocol and mechanism are implemented in Sicstus Prolog and all random operations were executed with the Sicstus Prolog random library.

In our simulations only two agents are considered. This assumption is by no means very restrictive, since it is always possible to split an interaction among several agents into several interactions between two agents.

To overcome the lack of sufficiently complex examples with which to run our implementation and experiments, we have used the FSA Utilities toolbox [van Noord 1996] as follows. First, an abstract alphabet made up of arbitrary illocutions and special transitions is generated. Second, a regular expression is built upon this alphabet and prefixed numbers of Kleene star, concatenation and alternation operators. Finally, the regular expression is compiled into an automaton using the FSA library. Table 1 shows all variables considered in this process and the range of values they may take.

Name	Variable	Range
Number of illocutions	$N_{ill}$	$\mathbb{N}^*$
Number of illocutionary particles	$N_{ip}$	$\mathbb{N}^*$
Number of roles	$N_{role}$	$\mathbb{N}^*$
Number of messages	$N_{msg}$	$\mathbb{N}^*$
Number of special transitions	$N_{spt}$	$\mathbb{N}$
Number of Kleene star operators	$N_{star}$	$\mathbb{N}$
Number of concatenation operators	$N_{con}$	$\mathbb{N}$
Number of alternation operators	$N_{alt}$	$\mathbb{N}$

**Table 1:** Simulation variables

In practice, the ranges of these variables are bounded. One expects  $N_{ip}$  not to be much greater than 30 (KQML performatives, for instance, do not exceed this value). A reasonable upper bound for  $N_{role}$  is 20, and our recent experience within the OpenKnowledge project has confirmed this (see, for example, [Marchese et al. 2008], where an eResponse interaction model with no more than 10 roles is defined).<sup>2</sup> Likewise the number of special transitions is no likely to be greater than 5. Though ontologies vary in size from a few hundred terms to

<sup>2</sup> <http://www.openk.org>.

hundreds to tens of thousands of terms, these amounts reduce when limited to appear in specific interactions. For this reason, interaction models with more than 100 messages are not considered. Now, operators measure the complexity of the interaction model. Again, experience within the Openknowledge project has shown that interaction model complexity do not go over the complexity entailed by a few hundreds of operators. Finally, the number of illocutions  $N_{ill}$  is bounded by the following inequalities which must hold to ensure that all symbols considered so far appear in the resulting interaction model:

$$N_{ill} \geq \max \left\{ N_{ip}, N_{msg}, \left[ \frac{N_{role}}{2} \right] + 1 \right\} \quad (1)$$

$$N_{ill} + N_{spt} \leq N_{con} + N_{alt} + 1 \quad (2)$$

We generated five interaction models corresponding with the variable groundings of Table 2 (with the same variable order as in Table 1).

<b>Interaction model</b>	<b>Variable instantiations</b>
imodel1	15, 1, 1, 5, 0, 2, 10, 15
imodel2	20, 1, 2, 10, 0, 5, 15, 10
imodel3	30, 2, 3, 15, 2, 10, 20, 25
imodel4	50, 1, 1, 40, 0, 15, 30, 25
imodel5	100, 4, 5, 80, 2, 20, 50, 80

**Table 2:** Interaction models

### 3.2 Execution and Evaluation

Remember that in our model agents consider all foreign messages semantically different, even when they match syntactically with any local ones. This fact justifies our decision to let agents follow the same interaction model, since agents will deal the situation as if they conform to disparate models.

In total three experiments were performed. In the first one, we simulated two agents interacting through the alignment protocol and taking advantage of the alignment mechanism. In the second one, agents only made use of the alignment protocol and no update alignment was carried out ever. Now, some series of interactions were simulated. Specifically, we ran both implementations with all interaction models in series of  $N = 2^n$  interactions, where  $n = 1, 2, \dots, 12$  (thus we let agents interact at most 4096 times). Each batch of interactions was performed 50 times recording the average of failures  $F(N)$  (or  $F$ ). In order to compare both experiments we computed the ratio of failures to interactions,

that is,  $R = \frac{F}{N}$ . Figure 2 exposes the results corresponding to imodel4. It is straightforward to check that when using the alignment mechanism the number of failures decreases considerably, while the alignment protocol alone yields a higher and almost constant number of failures. Similar results were obtained with the rest of interaction models (Figure 3). This answers positively Research Question 1 stated in the Introduction.

In the third experiment, we first let agents interact as in the first experiment so as to compute an alignment, again in series of  $N = 2^n$  interactions, where  $n = 1, 2, \dots, 12$ . This alignment was then used by the agents to interact 50 times without using the alignment mechanism. We recorded this time the ratio of successes to interactions, that is,  $R = \frac{S}{50}$ . Figure 4 shows the results with the five interaction models. In all cases  $R$  approaches 1. Actually, no more than 256 interactions are needed to achieve an alignment that ensures a probability close to 0.8 to interact successfully. This answers Research Question 2.

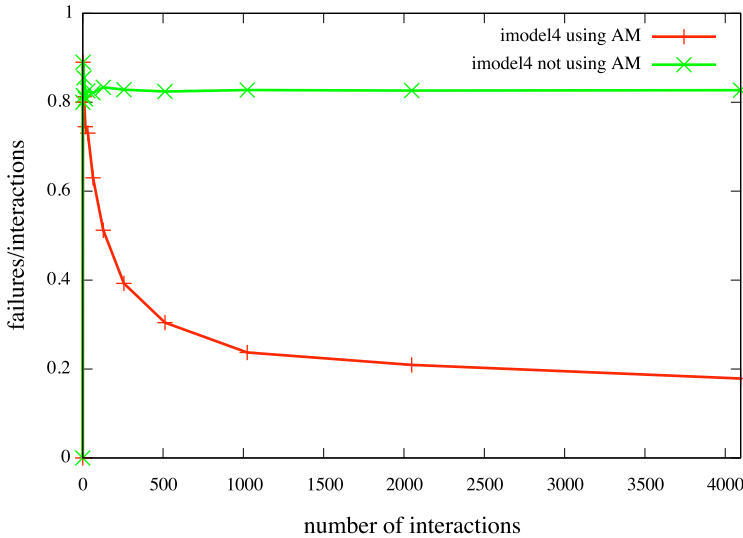


Figure 2: Experiments 1 and 2 with imodel4

### 4 Conclusions and Further Work

We have shown that, by guiding the interaction of agents that employ different terminologies by means of a meta-level alignment protocol, interacting agents are capable of significantly increasing their communication accuracy by repeated interactions. This meta-level alignment protocol takes the state into account when establishing semantic relationships between mismatching terminology.

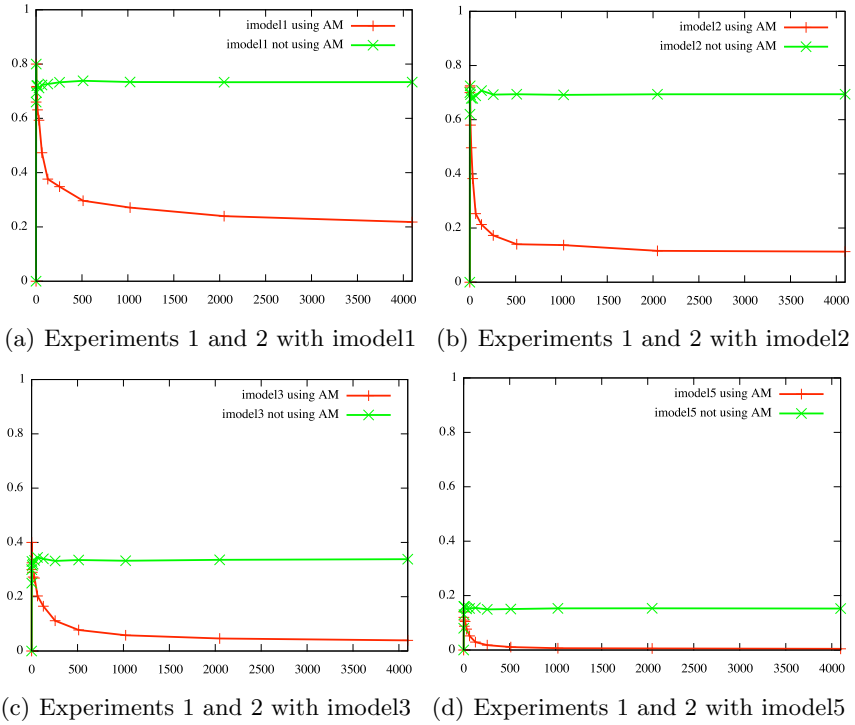


Figure 3: Experimentation results

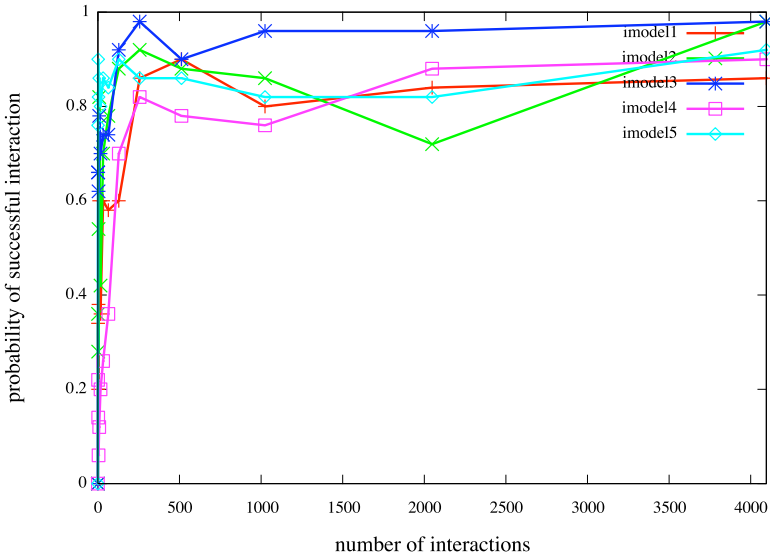


Figure 4: Experiment 3 with all interaction models

The alignment accuracy that agents are capable to achieve by resorting only to the interaction context as captured in the alignment protocol is relative to the expressiveness of the interaction-modelling language. For the case of simple FSA-based interaction models as those considered in this paper, semantic alignment is bounded by the mathematical product of interaction models as defined in [Atencia and Schorlemmer 2008]. In order to get more accurate interaction-situated semantic alignments we plan to extend our initial approach to more expressive interaction-modelling formalisms and richer communication languages.

Concerning the experimentation, we plan to test the significant relationship among the independent variables ( $N_{ill}$ ,  $N_{ip}$ ,  $N_{role}$ ,  $N_{msg}$ ,  $N_{spt}$ ,  $N_{star}$ ,  $N_{con}$ ,  $N_{alt}$ ) and the dependent variables (both ratios above). This will give us information about the kind of interaction models specially suitable for our approach.

## 5 Related Work

Other approaches share with ours the insight that semantics is often interaction-specific. In [Besana and Robertson 2007] the authors opt to attach probabilities to meanings of terms that are determined by earlier, similar interactions, and these probabilities are used to predict the set of possible meanings of a message. Meaning is also defined relative to a particular interaction, but the authors aim at reducing the search space of possible a priori mappings (in a classical sense), namely by assessing those ones with highest probability in the context of an interaction.

In [Rovatsos 2007] a dynamic semantics for agent communication languages (ACLs) is proposed. With the same spirit, Rovatsos bases his notion of dynamic semantics on the idea of defining alternatives for the meaning of individual speech acts in an ACL semantics specification, and transition rules between semantic states (collections of variants for different speech acts) that describe the current meaning of the ACL. One of our initial premises leads to an ACL to be shared by all agents. We believe that to agree on a pre-defined ACL is not a big assumption that can significantly help to solve the semantic heterogeneity brought by the existence of different agent content languages.

In tune with the previous work, Bravo and Velázquez present an approach for discovering pragmatic similarity relations among agent interaction protocols [Bravo and Velázquez 2008]. Besides the objection already explained above, the authors do not take into account state histories when measuring their notion of pragmatic similarity, but separate state transitions. This certainly leaves out relations among messages that may be crucial in certain scenarios.

## Acknowledgments

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## A Semiotic Framework for Ontology Development

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**Abstract:** We address the issue of ontology construction and reuse, and regard such processes as collaborative negotiations among stakeholders. A semiotic framework is proposed to model the communication environment. Accordingly, content and expression of an ontology have been clearly distinguished, and formalized independently. A twofold model is proposed: at an operational level, two stakeholders – such as designer and user – negotiate by proposing and modifying ontology fragments. At a reflexive level, the negotiation involves interpretations, until a set of shared meanings is reached; the process can be described adopting a narrative approach.

**Key Words:** Semiotics, Semantic Web, Pragmatic Web, Ontologies, Engineering

**Category:** M.4, M.8, I.2.4

### 1 Introduction

Ontologies are artifacts, i.e., artificial systems that are intentionally designed for specified purposes [Gruber 2004], and several development methodologies have been proposed [Fernandez Lopez 1999]. In the field of ontology engineering, another issue is the reuse of existing artifacts. Development and reuse are still open problems. The latter, for example, cannot be regarded as a matter of importing a structure valid in any case, and so immediately applicable. The current techniques [Paslaru-Bontas 2007] do not go beyond empirical mechanisms of adaptation of imported pieces of knowledge. As matter of fact, contexts are likely to be different: basic assumptions, perspectives, goals, intentions, . . . . and by no means semantic consistency is ensured to the fragments once they have been assembled.

In a previous paper [Toppano et al. 2008] we stressed that the development of an ontology is a collaborative work within a community of stakeholders. This lead us to regard it as a semantically-effective communication problem, in the realm of the Pragmatic web [Verschueren 2003].

In this paper we argue that design and reuse of an ontology obey essentially to the same process. A semiotic approach offers an adequate framework, involving the stakeholders and their operational contexts. The ontology is a semiotic object (text). The dialogue is a negotiation leading to a contract, and binding the stakeholders to a shared semantics. We propose a twofold model of the development process, which involves the use and the negotiation of meanings.

The next section of the paper contains the main ideas borrowed from Semiotics; Section 3 presents our model; Section 4 contains our conclusions.

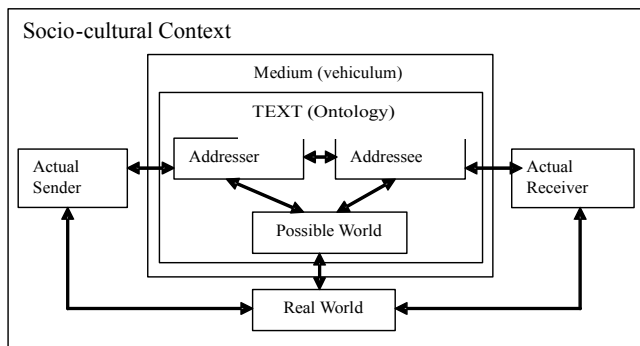
## 2 A semiotic framework

### 2.1 The ontology as a text

As a semiotic object, according to the model by [Hjemslev 1961], the ontology has a content and an expression. The former is the underlying conceptualization; the latter, a formal description. Other groups have applied such a distinction. [Hartmann et al. 2005] individuate the ontology base and the document — its specific realization. However, only the formal expression is reified by symbolic artifacts. We argue that the content is to be represented too, which allows to make semantics clear and simplify the reuse. On the contrary, when the conceptualization is left implicit it should be anyhow extracted for the sake of sharability.

### 2.2 A communication framework

The scheme in Figure 1 generalizes the model by [Jakobson 2002]. The ontology (text) includes an addresser and an addressee, i.e., the imprints of the actual sender — e.g., the designer — and the receiver (the user), respectively. They are connected by means of an instrumental medium — e.g., a PC connected to a network — enabling the circulation of the text within a socio-cultural context. They establish a direct relationship with a possible world, i.e. an implicit conceptualization of the ontology.



**Figure 1:** The communication framework.

The ontology is not only a text about the domain, but also an example of how a domain can be represented according to the assumptions. An agreement is required: an addressee who agrees on a conceptualization can get concrete results: achieve goals; share meanings . . . . . ultimately, become a member of a community! Therefore, the agreement is to be made explicit, namely: the conceptualization; its purposes; the preconditions; the expected effects; the point of view; the

assumptions and abstraction levels. All of this may be expressed by another artifact describing the context [Benerecetti et al. 2000],[Gangemi et al. 2006], which is, in turn, a text. The framework in Figure 1 can be applied again. Information like metadata — mainly static and oversimplified — do not tell anything about the way consensus has been reached.

### 3 Ontology development: a twofold model

We propose a model that makes explicit the negotiation, and is grounded on the triadic model by Peirce [Peirce 1931]. A generic sign (a text) is decomposed into three elements: *representamen*, *interpretant* and *object*. The first one is the form taken by the sign; the second is the sense made of it; the object is what the sign stands for (the *referent*).

Building a conceptualization is a situated, collaborative synthesis of knowledge. 'Situated' means that the decisions taken by the stakeholders depend on their status at a given time, which includes, as in [Gero and Kannengiesser 2002], the ideas and expectations of the designer, as well as the external status of the ontology. The scenario is sketched in Figure 2.

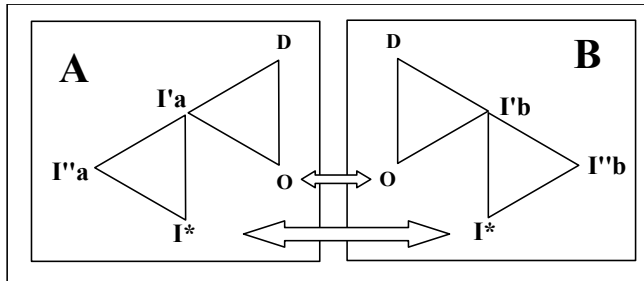


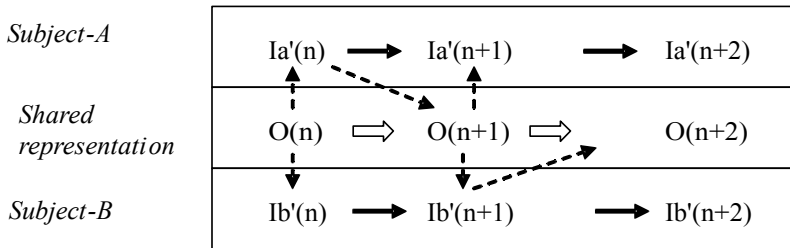
Figure 2: The triadic model of Peirce applied to domain and interpretation.

Two agents *A, B* model the domain of discourse *D*, – object, in the triadic model – and produce two symbolic models: the conceptualization *O*, – representamen – and the interpretation *I\**, – representamen, also – i.e., concepts and relations in the underlying conceptualization *I'*. The triangles *D – O – I'* and *I' – I\* – I''* are instantiations of the triadic model. Both the individual and common contexts of *A* and *B* are sketched as rectangular boxes. Giving the interpretation an explicit form is a precondition for the negotiation to take place. The development occurs at two distinct levels. The operational one concerns the conceptualization *O*. a process that generates, combines and transforms ontology fragments. The reflexive level concerns the shared interpretation *I\**. This

level addresses the dynamics of comprehension of the ontology: for example, addressing questions like: "...What do you mean with ...?"; "...I think that by X you mean Y. Is it true?" "...What question can you answer with ...?."

### 3.1 The operational level

The activities can be sketched as in Figure 3 Each actor interprets the state of



**Figure 3:** Activities at the operational level.

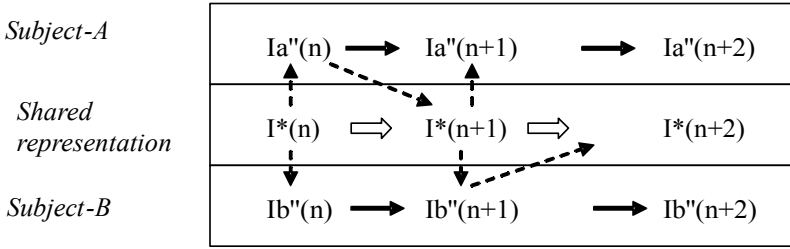
the conceptualization and eventually proposes to modify it. Three processes are at work: the conceptualization  $O(n)$ ; the interpretation by A and B, namely  $Ia'(n)$  and  $Ib'(n)$ . The actors can use different perspectives which may not be aligned. Being such perspectives left implicit, there is no way to discuss and eventually align them.

### 3.2 The reflexive level

As in Figure 4, the agents collaborate to construct a shared interpretation  $I$  of the domain. Since the meanings associated to the ontology depend on the current context, misunderstandings can occur. For this reason, reflections are necessary, being the only way to detect inconsistencies. The interpretation is expected to converge to a shared meaning. At the operational level, such a meaning may be adopted even without sharing it.

### 3.3 The rôle of negotiation

Both the operational and reflexive levels require negotiation. The former seeks for solutions proposed by the participants: for example, adding or deleting concept



**Figure 4:** Activities at the reflexive level.

fragments; a distributed mechanism may be adopted, for example based on voting. At the reflexive level, an integrative approach is appropriate [Kersten 2001]. As a matter of fact, negotiating meanings is a matter of constructing an interpretation not necessarily available beforehand [Stahl and Herrmann 1999].

Semiotics suggests solutions. A narrative model [Floch 1985] can support the discussion effectively, since it captures the variability of the process. Narratives convey information about what happens – who, what, when, where and how – but also basic values and judgments.

### 4 Conclusions

We have addressed the issue of ontology development, assuming that consists of a collaborative negotiation among stakeholders. Our viewpoint allows for a unified approach to building an ontology from scratch and reusing an existing one. Novel contribution is the application of a semiotic framework to model the communication processes. The ontology is regarded as a semiotic object made of content and expression: both are considered as texts to be explicitly represented. The communication framework inscribes stakeholders and context within the texts, which become the mediators (media) of the negotiation. The triadic model by Peirce details a mechanism of interpretation and reification.

We propose the negotiation to occur at two distinct levels: operational and reflexive. The former concerns the ontology as a document, that is incrementally put forward and detailed; the underlying interpretation remains implicit. The context may be explicated by metadata, for the sake of an effective use of the ontology itself. However, if the conceptualization is to be truly shared, an upper, reflexive level of negotiation is to be activated. The main concern is

semantics, the interpretation of the concepts adopted at the operational level. We have proposed to represent the communication by narrative techniques, that would better account for the time evolution of the negotiation and enrich the articulation of contexts.

The importance of communication processes within the development of ontologies cannot be overlooked; a semiotic framework offers solutions that appear profound and effective, and deserve systematic experiments. Design choices are also communicative choices — which is a pragmatic perspective — and Semiotics is helpful to the study of mechanisms underlying the choices of a community of developers. We are currently working along this direction.

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## Web 2.010 - Social Network “Make Difference Together” with Pragmatic Description of Projects in the Standard of European Commission’s Framework Programme

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**Abstract:** The article outlines the social network aiming to join participants, who are looking for partners in some social project rather than partners for simple chatting or for any other forms of informal communication. Standard semiformal language with formal syntax and informal unlimited vocabulary for the pragmatic description of the projects in such social network, is proposed. This language is elaborated on base of Seventh Framework Programme (FP7) standards of preparing proposals.

**Keywords:** FP7, Social networks, Pragmatic Web, W2.0, Language of presentation of pragmatic description

**Categories:** H.1.0, H.4.3, H.5.2, H.5.3

### 1 Introduction: Social Communication and Social Doing

Almost all modern popular social networks aims first facilitating social *communication* and exchange of information; and only few of them (e.g. The Point, <http://www.thepoint.com/>) have as their primary aim facilitating common *action*. Of course, sometimes (as, for example, in case of Wikipedia) the exchange of information results in the production of new valuable product. However, besides specialized open source networks, which realize specific project, there are almost no Social Networks focusing on networking of collaborators and organizing the teams, which will realize the ideas of participants. Nevertheless, such networks will inevitably appear.

The logics of development of Internet consists in the creation on base of humankind the huge social being with the system of informational processes, which may be called “a collective mind”. In course of development, this mind becomes more and more powerful creating more and more mental abilities. The ability to operate with the meaning (Semantic Web) is one of the steps in this development. The ability to act purposefully is another step, not less important. In fact, many groups in Social Networks want to act in cooperative manner facilitating individual abilities of group’s members, but the lack of techniques of operationalization of common activity effectively frustrates this need. Moreover, perhaps it is difficult to name the social network, which does not need this kind of instruments and which would reject to implement them. Sta.rUp.biz (<http://sta.rtup.biz/>), E.Factor (<http://www.efactor.com/>), LinkedIn (<http://www.linkedin.com/>) are just some names from this list of potential users of this technology.

Thus, we need today the instruments, which allow organize a collective activity in the framework of Internet. Elaboration of such instruments will designate the emergence of social networks of next generations – the ones, which allow to join effectively the efforts of many potential collaborators with common interests and to supplement mutually their competences. The demand in this sort of social networks is quite obvious not only from both people and organisations, which are looking for partners, but also from funding agencies that are looking for best investment opportunities.

I called this kind of “acting social networks” “Web 2.010”, or “Make Difference Together” (MDT). This paper outlines the main features of MDT and sketches some principles of their realization.

## **2 The Place of MDT among Other Approaches to the Description of Activity**

One of the central tasks of MDTs is the transformation of the “pure idea” into the detailed project that may be practically realized. Too often, an initiator of some project limits himself by the very brief elaboration of his idea only omitting many crucially important moments and creating impression of rawness that diminishes the number of his potential collaborators. Such briefness is quite natural because an elaborated description even of middle-scale project may easily reach the size of hundred pages and demands many months of efforts to prepare. However, the participation even of rather few collaborators, who cooperates one with others for example in a wiki-styled manner may reduce this figure crucially. MDT aims to create the infrastructure for such collaboration, which must initiate the cooperation in the realization of project. The principles of interaction in course of such collaboration are described in the section of 3.2.

The means of detailed description of project, which includes, for example, the working plan, the team of participants with their competences and responsibilities, the management system, the resources that must be attracted and so on, constitute the essential part of MDT’s instruments. The principles of MDT’s “ontology” of description of project occupies the intermediate position between the two current approaches to the describing project, represented by already mentioned “The Point”, on the one hand, and “Description of Project” (DOAP, <http://trac.usefulinc.com/doap>), on the other. The ontology of DOAP that deals with description of open source projects provide an example of formal system, which focuses on machine-readable data and hence intends to construct completely formal descriptions in RDF. Thus, DOAP limits itself by rather fragmentary descriptions of the whole entity as any open source project is. In other words, DOAP reflects only relatively small part of complete description of open source project, which may be easily formalized, leaving the rest (“un-formalized”) part of description out of own framework. The descriptions of the projects in the system like “The Point”, on the contrary, describe projects in completely informal manner. Such descriptions are enough for many projects, but not for the projects with the complex structure, including elaborating plan. MDT aims to bridge these two approaches basing on semiformal description of complex projects, which originates the scopes of



organization development, project management or virtual organisation integration (for example, [Putnik, 06]). In particular, good example of such semiformal structure of description of projects may be found in the documents of European Commission's Framework Program (e.g. [CORDIS-a, n.d.]). And although MDT relates to the broader class of collective activities than ones described in Framework Program, the general structure of description may be represented on this example.

### 3 Architecture of MDT

An "atom" of MDT is the record describing the project consisting of two parts: (a) general information about the status of project, and (b) template of the Proposal of Project (PP).

General information about the status of project includes the fields like: (a) the language of PP, (b) the name of author-owner (AO) of project, ID, password, the means of contact, (c) the state of verification of data; (d) the number of participants of different legal status and different levels of involvement, (e) source(s) of funding, (f) state of development of project, (g) levels of confidentiality, etc. Information in these fields may be changed by AO and/or by MDT itself (automatically) and/or Administrator of MDT.

PP is a structured multilevel record - a complex word in special language of pragmatic description (LPD). Multilevel syntax-semantic structure is natural for the human mode of processing information. LPD differs from the completely formal programming languages like Java or markup languages like HTML, since the only upper part of its syntax categories is strictly formalized while the lower levels allow arbitrary "records" including ones without limited "alphabet", e.g. scheme, drawings etc. Thus, from the semiotic point of view the LPD covers several levels of description - from syntax to pragmatic ones. This explains the name "meta-syntax".

#### 3.1 Meta-syntax of LPD

Like most of large texts, PP has multilevel, hierarchical structure, in which the large parts of upper hierarchical levels consist of smaller parts of lower levels, which, in their turn, consists of even smaller parts and so on. Thus, one may see the whole hierarchy of syntax categories, where the categories of lower level disclose the category of upper level. I name such multilayer syntax structure *meta-syntax*. Below I explicate this structure basing mainly on European Commission FP7 standards [Guide, 08].

In accordance with the rules of FP7, the categories of upper level may be introduced as follows:(a) Concept, objectives, methods, (b) Work plan (c) Participants, (d) Organizational structure and Management, (e) Budget, (f) Legal and Ethical Issues

I represent the overall syntax structure in the other article [Zelitchenko, 09]. The following small fragment of syntax tree illustrates the general approach.

```
<2.WORK PLAN> → <2.1.OVERALL STRATEGY><2.2.WORK PACKAGES
(WP) AND DELIVERABLES><risks>
```

<2.1.OVERALL STRATEGY> → <2.1.1.PRODUCTION>  
     <2.1.2.DISSEMINATION>  
     <2.1.1.PRODUCTION>→<schedule><methodology/technology>  
     <2.1.2.DISSEMINATION>→<2.1.2.1.EXPECTED IMPACTS><how to bring  
         about these impacts><2.1.2.2.SYNERGY WITH OTHER  
         PROJECTS><management of intellectual property>  
     <2.1.2.1.EXPECTED IMPACTS>→ (<t>)  
     <2.1.2.2.SYNERGY WITH OTHER PROJECTS>→ (<t>) | [(code project)]

### 3.2 Principles of partners' collaboration

There are two categories users in MDT: (a) the participants of project with different levels of authority to edit PP, and (b) searchers for project to join. In first category there is sub-category of AOs (or administrators), who originate PP, manage membership in the consortium that realize the project, and grant the different rights to edit PP.

MDT provides options for AOs to create PP, to edit PP personally and to grant to the people of AO's choice the different authorities to edit PP. Thus, in course of realization of the project, PP is transformed from the "pure" proposal into the Announcement of News.

The system of flexible control of confidentiality is absolutely a must for MDT. AO must get option to determine the different levels of acceptability of different parts of PP – from the limited part of participants of project, say, "Management Team only" to everybody. In the same way, the AO grants the different degrees of authority to edit PP.

For the searchers, MDT gives the possibility to see (and to search after the size of MDT become large enough to stop being easily observable) the PPs and to establish the first contact with AOs.

All other interactions between the users come out of the framework of MDT.

## 4 Issues of Implementation: Security and Legal Issues

MDT cannot be responsible for content of PP and provides information for the users "as it is", but in the case the AO provide verification on the parts information in PP, these parts of information may be marked by the sign of verification.

MDT grants users with different status depending on both their experience of work with MDT and the level of verification the users wanted to provide for MDT. This status may be used by AOs to grant users with different right to access information in PP and to make decision about collaboration with the user. Thus, each user of MDT has the option to reach that level of compromise between confidentiality and attractiveness for other users, which is comfortable for him.

Essential part of MDT is the user agreement, which stipulates the aims of MDT, rights, obligations and potential risks of users, ethical code, legal issues, including the rights on intellectual properties, and so on.

However, both legal matters and security ones cannot be absolutized or even simply overestimated. There are many social networks (e.g. New Civilization Network, <http://www.newciv.org/>), where the users aim first to find co-thinkers and

co-workers for social projects that propose making social benefits rather than personal ones like a money or a fame. The legal status of the projects in such networks is quite different from one in commercial ones. However, the general structure of their projects is the same. Thus, for different applied scopes the different MDTs with different requirements to security matters must be elaborated.

## 5 Scopes of Applications and Potential Customers

The crucial aspect to evaluate the business potential of any enterprise is the estimation of demand. In case of MDT this demand is quite obvious. For example, today the portal of European Commission FP7 Program CORDIS provides the services "Preparation and Submission of Proposals" [CORDIS-a, n.d.], "Find Project Partners" [CORDIS-b, n.d.] and "Find a Project" [CORDIS-c, n.d.]. MDT is in line with this direction of applied software development providing it with new functionalities. Thus, the first group of potential customers of the systems like MDT is the funding agencies - from transnational agencies like FP7 to local venture capital firms.

The other huge groups of potential customers are social networks and – what is even more important – their participants, which do not find in the present social networks what they are looking for, the partners. The "altruistic" or "philanthropic" networks, which were mentioned in previous section, constitute the important part of potential users of MDT-technology.

## 6 Conclusion: the Lines of Development

At the present, the idea of MDT is still a "pure idea", which expects the team of collaborators who fill it with "blood and flesh" and initiates the that way of transformation an idea into a project, which MDT itself aims to facilitate. Thus, the present paper is just an announce of idea. Nevertheless, I would like to designate some directions of further development which seems important.

Although the first stages of development of MDT, when the number of projects in MDT do not become unobservable yet, do not demand a powerful searcher, in course of development of MDT, the powerful search system, which allows searching for the ideas/projects in different stage of development and in different fields will become more and more important part of the MDT

There are many other possible lines of development of MDT; all of them are related with introducing new functions. For example, it is possible to add the function of hosting projects' websites and such web services as project's blog, discussion forum etc. However, the most obvious direction of development is the development of LPD itself.

The first, most obvious line of such development is the development of the tree of syntax categories. In presented here version of LPD there are many categories, which may be further structured. For example, it is easy to specify what specific tables must be included in category <5.3.DETAILED BUDGET> in FP7. However, in such development of formal structure of project, the compromise between "external" implementation of structure as it is seen optimal for architect of system, on the one hand, and its "internal" self-development resulted from the system of categories that

were introduced by the users, on the other, must be reached. For example, in different types of MDT, the contents of pre-terminal category <description of relationships between  $i$ -th and  $j$ -th organisation's bodies> (4.2) may be quite different: in commercial structures they are naturally much more formal, than between the partners in some philanthropic project.

Thus, instead of elaborating the huge conceptual trees with very specific categories, in some applications is more purposeful to elaborate the special statistical techniques in spirit of content analysis [Holsti, 69] that allow to disclose the system of lower-level constructs in users' free descriptions of the relatively few broad high-level categories, which are determined by the relatively general conceptual tree like one represented in this article.

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# **Toward Pragmatic Dimensions of Knowledge Reuse and Learning on the Web**

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**Abstract:** Web based technologies have been promising to boost the Knowledge Management practice, by exploding the potential of knowledge Reuse and Learning. In assessing state of the art of this area of research, and in attempting to locate the boundaries for knowledge transformation and 'emergence', a pragmatic dimension surfaces. This paper contributes a novel perspective on knowledge reuse in the light of a 'pragmatic web' context, and prompts a line of inquiry in the exploration of this novel interdisciplinary domain of study and practice.

**Keywords:** Knowledge Reuse, Semantic Web, Systems and Software

**Categories:** M.3, M.8, H.1.1, L.1.0, L.1.1, L.1.3, L.2.3, L.2.4

## **1 Introduction, Scope, Intended Contribution**

The state of the art of 'Knowledge Reuse and Learning' can be captured at least in part by tracking its chronological evolution, which goes back over twenty years. [Smith, Duffy, 2001]. Much transformation and changes are happening thanks to current advances in web technologies, despite chaotic growth unfolding in real time across several overlapping and loosely specified paradigms, such as 'web 2.0' versus 'web 3.0', for example. While changes happen thanks to technological innovation, essentially they transform and impact the fabric of organisations and society at large. This position paper introduces the rationale for aligning traditional 'knowledge reuse' (KR) practices as studied in classical Knowledge Management (KM), to the latest paradigm of web research, here identified as 'pragmatic web'. The scope of this research to date is exploratory and aimed at identifying knowledge reuse and learning in practice, and taking into account a wider interdisciplinary context, the boundaries of which are yet to be defined. To the author's knowledge at the time of writing, it is the first time that knowledge reuse and learning are studied in relation to the pragmatic web framework. The identification of new pragmatic web boundaries of knowledge reuse, and the formulation of corresponding hypotheses aim to be the main contribution of this paper. Expected outcomes of this research are improved understanding of knowledge reuse dynamics and their impact in open networked knowledge exchanged environments, to guide the development of suitable practices, tools and systems.

## 1.1 Paper Organisation

This paper is organised roughly into four main sections as follows: section 2 provides a summary of literature review and a problem statement, section 3 discusses KR in relation to evolving web paradigms, section 4 discusses KR research open questions in the light of Pragmatic Web research, presenting and justifying the rationale for a non linear, chaotic and interdisciplinary approach to addressing the complexity of open KR questions.

## 2 Literature review

The emphasis of information management practice in recent decades, has shifted from revolving around data management (DM) to knowledge management (KM), whereby knowledge results from the combination of data, information, skills, know how, experience, intelligence, ability, and includes more subjective factors such as insights, intuition and ambitions of individuals and resources that are the foundation of knowledge networks. [Nonaka, 1995].

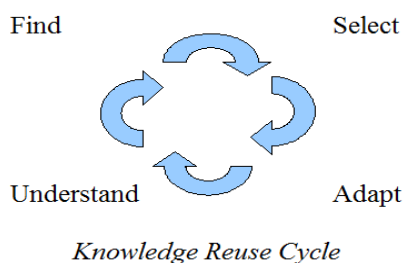


Figure 1: Adapted from Dusink and Katwijk

A typical 'knowledge management lifecycle' breaks down the KM process into activity sets, for example discovery, organisation, sharing and application (use, reuse). Modelling such KM activities as discrete functions however is arbitrary, as in reality they are interdependent, blend together and often take place simultaneously. Knowledge 'Reuse' (KR) which within the classical knowledge management lifecycle is considered a 'phase' [Tao et al., 2005], actually is an underlying function of most other KM activities, and should be modelled as such. Loosely adapted from the software domain [Dusink and Katwijk, 1995], the notion of 'reuse' can be defined as the systematic application of existing artifacts, or the physical incorporation of existing artifacts, during the process of building a new system, whereby artifacts are identified as pieces of formalized knowledge that can contribute to an engineering process, such as designs, transformation rules, as well as e.g. descriptions of how to detect abstract data types. A typical Knowledge Reuse cycle consists of steps such as find, select, understand, adapt/adopt (Figure 1). Although 'tacit' knowledge is also a contributing factor to KR [Harsh, 2008], for the purpose of this research we focus on knowledge reuse that takes place mainly through 'explicit' knowledge, and that as

such is codified via explicit 'knowledge representation' formalisms and artifacts. In a Theory of Knowledge Reuse, Lynn [Lynn, 2001] characterizes four distinct typologies of situations: shared work producers, who produce knowledge they later reuse; shared work practitioners, who reuse each other's knowledge contributions; expertise-seeking novices; and secondary knowledge miners bringing to light the importance of distinguishing 'context' to all aspects of KR. More recently, Carlile [Carlile, 2003] considers reuse part of a 'knowledge transformation' process, which bears even more direct implications to the pragmatic view of the web. Knowledge Reuse is viewed by Carlile as a cycle, he also proposes an 'integrated framework' incorporating syntactic, semantic, pragmatic dimensions of knowledge transformation as a strategic and tactical approach to knowledge integration across disciplinary boundaries.

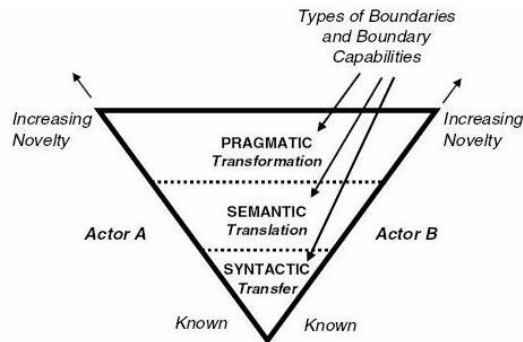


Figure 2: Knowledge transformation, Carlile 2003

Research into the pragmatic dimensions of knowledge reuse has already started, and constitutes one of the points of departure for the work ahead. Particularly important is the notion of 'context'. An analysis of context awareness and context codification [Chai and Nebus, 2006], identifies different dimensions for context, and corresponding mechanisms for overcoming such barriers are suggested by the same authors. The separation of 'semantic' and 'conceptual' layers for knowledge and its representation is already an established concept in the domain of operational simulations [Tolk, 2003]. Knowledge Transformers as a connecting link between learning and creativity were identified by Sim and Duffy [Sim and Duffy, 2004]. Future research may be desirable in understanding the role of knowledge transformer to the practice of knowledge reuse.

Knowledge Transformers	Description of how knowledge is transformed
Abstraction/ Detailing	Abstraction generates a new version of the knowledge with less detail than the original through the use of representation of abstract concepts or operators. Detailing is the opposite, in which the new knowledge is generated with more details.
Association/ Disassociation	Association determines a dependency between given entities or descriptions based on some logical, causal or statistical relationships. The opposite is disassociation, which asserts a lack of dependency.
Derivations (Reformulation)/ Randomisation	Derivations are transformations that derive one knowledge from another piece of knowledge (based on some dependency between them). Randomisation transforms one knowledge segment into another by making random changes.
Explanation/ Discovery	Explanation derives additional knowledge based on domain knowledge. Discovery derives new knowledge without an underlying domain knowledge.
Group Rationalisation (or Clustering)/ Decomposition	Group rationalisation involves the grouping of past designs according to their similarities when considering particular perspective(s) or criteria. Decomposition removes the groupings.
Generalisation/ Specialisation	Generalisation generates a description that characterises all of the concept based on a conjunction of all the specialisations of that concept. Typically, the underlying inference is inductive. Specialisation increases the specificity of the description.
Similarity comparison/ Dissimilarity comparison	Similarity comparison derives new knowledge about a design on the basis of similarity between the design and similar past design(s). The similarity comparison is based on analogical inference. The opposite is dissimilarity comparison, which derives the new knowledge on the basis of lack of similarity between the two or more past designs.

Figure 3: Knowledge Transformers, Sim and Duffy, 2004

### 2.1 Problem Statement

Despite increasing quantities of valuable ‘knowledge’ being produced everyday in all fields of research and practice, the ability of systems and personnel to manage and apply existing knowledge to decision making and problem solving, is not easily qualified nor quantified, and limited one the one hand by the physical, psychological and cognitive capacity (of human and machine), on the other hand by the configuration of the information systems and social and organisational infrastructures in place which directly or indirectly regulate the knowledge flows. The proliferation of talks, papers, studies, findings, surveys, theses, paradigms on knowledge reuse notwithstanding, limited measures are in place to assess its more ‘pragmatic’ aspects for example a) how knowledge is reused in practice, b) the effect of knowledge reuse on the organisational environment, c) the impact of research on the actual practice, d) the impact of knowledge reuse on the transformation of organisations and society at large. The answers to such questions are likely to require investigation methods adequate to their complexity of the domain. A preliminary analysis of literature review points to a state of the art in knowledge reuse and learning riddled with paradoxes and challenges, partly summarised as follows:

1. Essentially a multidisciplinary question, the more generalised aspects of knowledge reuse practice require a multidisciplinary framework that can address KR requirements from an integrated perspective, while the more specific aspects of knowledge reuse are still heavily domain dependent.
2. Increased proliferation of knowledge results in increased reuse challenges, whereby the reuse capability must imply the ability to filter applicable knowledge and apply it contextually. Semantic web technologies under development address this challenge only in part. Pragmatic web practices are expected to support knowledge in context, and operational and process aspects of knowledge reuse.



3. Limited instruments and tools exist to measure the impact of KR research on productivity and on the overall evolution of organisational processes and structures

## **2.2 KR and Learning and Organisational Transformation**

KM research and practice to date, offer only partial insights into the relationship between knowledge reuse and productivity, and ongoing patterns of organisational transformation. Even more limited insights exist with respect to the organisational transformations triggered by chaotic and distributed (networked) knowledge exchange environments, which are characterized by increased and virtually unbounded knowledge exchange patterns. In this context, the role of 'open' and 'web based' information environments, which are at the base of exponential knowledge exchange patterns, is becoming central to the notion of knowledge reuse. Among some of the factors that warrant this line of enquiry are:

- a) the increased adoption of distributed and networked organisational models [Borgatti, 2003]
- b) the emergence of the 'extended enterprise', whereby organisations externalise part of their production processes (product or services) which become shared across the supply chain

## **3 Knowledge Reuse and Web Paradigms**

New technologies, in particular web based technologies, open up new prospects for knowledge management, especially reuse and learning: virtual environments, characterized by the lack of time/space boundaries, dissolve the physical barriers to knowledge transfer, therefore supposedly facilitating pervasive knowledge access, reuse and transformation. In practice however other challenges come into being :

- while physical barriers to knowledge access may be reduced by the pervasiveness of the web, cognitive barriers still exist, and potentially become greater as the amount and degree of reliability of knowledge increases. It is expected that knowledge exchanges through web based social knowledge networks should address cognitive barriers with suitable propaedeutics (knowledge necessary for learning).
- the inherent nature of web based technologies, and the chaotic and virtually unbounded environments such as the web, constrain further the 'usability', hence the 'utility' of knowledge published on the web by increasing the complex challenge of sorting and retrieving meaningful, accurate and up to date data which is relevant to our queries, and to keep up and filter 'intelligence' from the vast amount of data that is being produced.

Additional obstacles to effective knowledge reuse may be partly due to inherent limitations of existing technologies and technology development patterns, and partly by non technical factors, such as organisational and social structures.

### **3.1 The Semantic Web**

In order to address these, and other challenges, the 'semantic web' was invented [Berners-Lee, Hendler, Lassila, 2001]. Semantic web technologies have been in development for over a decade, with the aim to support and leverage the logical relations that underlie knowledge represented in non structured form. The semantic web technology corpus, which includes knowledge, techniques and tools, is devised directly or indirectly with the intent to maximise knowledge reuse. It consist essentially of artifacts, such as vocabularies explicitly coded to represent relations, properties, hierarchies and classes, represented and exposed in such a way that they aim to be accessible and reusable. Formalised vocabularies are in fact considered the equivalent of 'simple ontologies'. Ontologies, in various degrees of formalization, can be used to support knowledge management functions [Mizoguchi et al]. Semantic web frameworks in support of Knowledge Reuse have been explored to some extent [Stojanovic and Handschuh, 2002]. But 'semantic knowledge management' to date is still purely notional. Current 'semantic web' standards issued by the governing consortium W3C are prescribed in the form of RDF, OWL which are respectively the recommended formats for vocabularies and ontologies, and SPARQL the corresponding query language. These recommendations represent 'attempts' to standardize novel approaches to semantic web, although they may not be the only way of supporting semantic capabilities on the web. Semantic technologies have been in development for some years, yet limited measurements of advances in terms of their impact on knowledge reuse are available, as much of the current efforts are devoted to overcome core infrastructural challenges ('plumbing'). This further supports and justifies the investigation into how pragmatic dimension contribute to the development of web based technologies in relation to KR. The more the semantic web takes shape, the more the lack of adequate instruments to capture and represent social and human dimensions, and practical context, become evident. The role and impact of human factors in the development of the semantic web, are still largely out of the scope of current SW research, prompting central questions that are often overlooked in technical debates.

### **3.2 The Pragmatic Web**

A 'pragmatic web' (PW) approach appears to prioritise a different set of challenges and an entirely new perspective, in comparison to the current semantic web (SW) research. Although at 'physical' level there is only one web (that we know of) - the open 'network of networks' that links computers via http and uses IP protocols and hypertext (HTML) - the 'pragmatic web' approach, as described in literature, [Schoop, De Moor, Dietz, 2008] focuses on the intent to explicitly research, support, interpret and model 'context' to knowledge on the web. Technically, and with some limitations, 'contextual' information can be represented on web with current SW artifacts and techniques [Tazari, 2003] and [Guha, McCool, Fikes, 2004]. Pragmatically, however, challenges to knowledge reuse, and relevant contextual dependencies, are not merely technical, but belong to the realm of social and organisational systems design and management, and extend well into the boundaries of what is designated as 'policy' management. Although it is impossible to pinpoint exactly where the semantic and pragmatic web overlap and where they actually differ,

in the sense that semantic web research is increasingly adopting a stronger 'user centric' approach, the focus of the PW as envisaged so far seems to emphasise:

1. placing the human-human interaction, together with its social and behavioural complexity at the heart of web based systems design and development
2. the exploration of alternative frameworks and assumptions that can more adequately capture such complexities, and that are not restricted to RDF/OWL as they are known today.

The distinction between syntactic, semantic and pragmatic 'dimensions' initially part of the linguistic and communication theory, credited to Charles Morris [Morris, 1946]. Morris defined pragmatics as "dealing with the origins, uses, and effects of signs within the total behaviour of the interpreters of signs"; semantics as "the relations between signs and the objects they signify", narrowing semiotic study to the strict literal meaning of signs and propositions. Syntactic "concerns the formal relations between signs themselves, further narrowing semiotic study to the logical and grammatical rules that govern sign use." Morris based much of his work on earlier studies of semiotics by Charles Pierce, and the 'social behaviourism' of Dewey and Mead. When considering the web as a virtually unbounded and chaotic information environment, structure and meaning acquire relevance mainly thanks to 'context', which is defined as the dynamic combination of factors and conditions that surround and affect an object or an event. On this premise, the pragmatic dimension is critical to information communication in that it allows the understanding and modelling of 'behaviours' and human 'experience', which in turn affect systems functionality and design. The complementarity of the 'pragmatic approach' to the 'semantic web' is consolidating around a small and diverse community of interest, with the intent to develop environments and infrastructures designed primarily to support the automation of human-human web based knowledge exchange, with particular emphasis on rule based reasoning and intelligent applications based on natural language. While much of the 'semantic web' is still under construction, the pragmatic web is pointing to a further shift toward adaptive and context sensitive real time communication environment capable of supporting intelligent and dynamic applications.

#### **4 Open Questions in Knowledge Reuse, role of a Pragmatic Web**

Web mediated human to human interaction is one of the purposes of pragmatic web research. Human to human interaction has so far been envisaged as essential to knowledge reuse. In a study carried out at NASA Jet Propulsion Laboratory, [Majchrzak, 2001] all six case analyses of reuse for innovation, primarily rely on human-to-human contact for learning to occur - to find the right individuals with the right solutions, to query the individuals to assess the applicability and limitation of the solution, and to physically manipulate the solutions to personally assess their appropriateness. The importance of 'social knowledge networks' in KR in the context of architecture/engineering/construction industry has already been studied to some extent [Demian and Fruchter, 2006]. One of the important issues emerging from

research is that ‘internal’ knowledge – knowledge existing within a role or within an organisation – is usually complementary and necessary to make use of to ‘external’ knowledge – knowledge stored in some repository:

“ [...] *The term knowledge in context has been used by Finger (1998) in a similar sense. She notes that designers must seek out previous designs in the context of a design problem. Design is a process of constructing a theory of the artifact, not merely constructing a manufacturable description. This artifact theory is a contextual theory that provides knowledge for describing and analyzing an artifact and for explaining and predicting the nature of the artefact*”.

Since the web is the largest knowledge repository ever existed, to create support for knowledge reuse in practice, taking into account the social knowledge networks dynamics already under study, points to new requirements to guide the development of web technologies and infrastructures. A preliminary conclusion from analysis of existing work in this area points to the need for artifacts capable of extending the capability of the web from an instrument to disseminate and expose data and information, to an instrument capable of disseminating knowledge, know how, and intelligence that are applicable to the evolution and advancement of society at large. Additionally, a gap is identified between theoretical research and in practice. (Skinner, 2007).

#### Stages/Standards of Knowledge Utilization

Stage	Category	Description
1	Reception	Receiving information/information <sup>a</sup> is within reach
2	Cognition	Read, digest, and understand information
3	Discussion	Altering frames of reference to the new information
4	Reference	Information influences action/adoption of information
5	Adoption	Influences outcomes and results/effort to favour information
6	Implementation	Adopted information becomes practice
7	Impact	Tangible benefits of information

*Note.* Summarized from Knott and Wildavsky (1980).

<sup>a</sup>The term “information” could be substituted by project, program, intervention, innovation, practice, policy, research, knowledge, document, evaluation, etc.

*Figure 4: Seven Standards of Utilization (Knott & Wildavsky, 1980)*

Open questions in Knowledge Reuse research to date include actual measurement of KM practices, and the impact and implication of networked Knowledge Reuse and Learning onto Organisational structures.

Starting from the seven Standards of Utilization Model (fig above) in our work we aim to measure Impact into more granular parameters, an initial outline of additional granularity below below:

1	Productivity	Efficiency of resources
2	Quality/experience	Experience (user, producer)
3	Model/Process Evolution	Process/model
4	Organisational Evolution	Organisational structure and dynamics
5	Contribution to Public Knowledge	Knowledge in the public domain
6	Contribution to Organisational Memory	Knowledge in the organisation

*Figure 5: Breaking down Impact/tangible benefits of Knowledge Reuse into further factors*

#### 4.1 Emerging Hypotheses

It is part of the underlying overall hypothesis supported by this paper that exploration of pragmatic aspects of the semantic web could lead to results applicable in the knowledge reuse and learning research and practice. The main motive for this paper and its underlying investigation is that KR remains limited and largely not understood nor justified, despite vast amounts resources being devoted to KR and semantic web technologies research and technologies. In the course of literature review, and in the attempt to understand the problem, and to better define the research question and corresponding method of inquiry, the following hypotheses emerge:

- 1) the practice of maximisation of KR, as a factor of knowledge exchange currently depends on the ability of individuals and organisations to accept the shift toward open and participatory paradigms, such as social networking. The benefits versus the risks of incorporating emergent organisational paradigms into traditional organisational structures remains to be weighted and tested.
- 2) the development of semantic web technologies, tools, platforms, environment and standards must be guided by the requirements of knowledge reuse in practice, which in turn must be guided by measurements of benefit parameters at different levels of granularity.
- 3) suitable multidisciplinary methods of enquiry must be developed for emergent dimensions of KR to be studied and applied

#### 4.2 An Interdisciplinary Approach to Complexity in Knowledge Reuse

Knowledge reuse can be viewed from different disciplinary perspectives, for example:

- a) A set of principles that can guide design [Duffy and Duffy, 1996]
- b) A desirable quality of any KM activity [Majchrzak, 2001]
- c) An essential component of learning processes [various]
- d) As a criteria to evaluate one quality factor of KM activities and tools [various]

Taking the above into account, knowledge reuse in distributed networked organisations which operate at least in part on the web, acquires exponential dimensions and becomes far more complex than originally thought of. On the one hand we observe more frequent and more rapid human to human interactions, where the knowledge flows virtually unbounded, and follows chaotic self directed patterns, on the other hand organisational structures, hierarchies, bureaucracies, protocols, rules

constrain such self directed knowledge flows, and more importantly regulate and influence the way this virtually unbounded knowledge flow is actually used, applied and internalised by the organisation. Most challenging, and interestingly, it's the study of the impact of 'networked' knowledge reuse on the transformation of organisational and social structures themselves (fig 6, Implications of Knowledge Reuse). In order for research to meaningfully investigate the depth and impact of knowledge reuse in complex information systems environments, a suitably multidimensional conceptual framework should be devised, a preliminary analysis of which is sketched below in section 4.3.

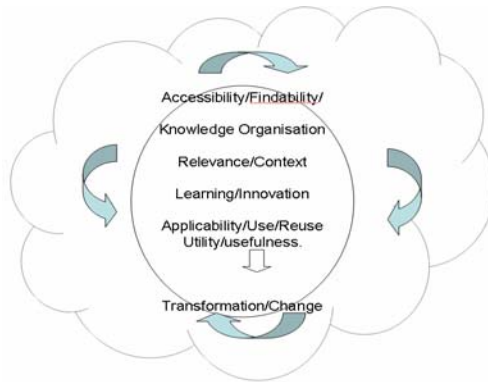


Figure 6: Implications of Knowledge Reuse

### 4.3 Crossing Domain Boundaries

The state of the art in Knowledge Exchange is characterized by a chaotic landscape of sometimes conflicting disciplines, a lot of theoretical research with limited practical applications, and limited instruments to assess the impact of research to understand and solve “real world“ issues. Evolutionary patterns of knowledge in design teams have already been investigated [Wu and Duffy, 2002], our work in this space extends previous model to the study of ‘knowledge reuse dynamics in practice’ with particular interest in co-evolution and reuse in networked enabled environments, and with a view to bridging the gap between theory and practice. Analysing the co-evolution factors and dynamics of knowledge reuse and organisational transformation starts drifting towards *complex systems sciences*, calling for sound yet extensible multidisciplinary methodological approaches and adequate frameworks for investigation and practice. A model for indertdisciplinary investigation which is inspiring our progress is provided by Tomiyama et al [Tomiyama et al., 2007] in Complexity of Multi-Disciplinary Design, which looks for crossdisciplinary solutions to cross disciplinary problems. The first research question there is whether inter-intra- multi- trans- or cross- disciplinary approach, or any combination thereof, is best suited to the problem ( currently still an open question). A preliminary outline of an integral domain approach in knowledge reuse is sketched in figure below.

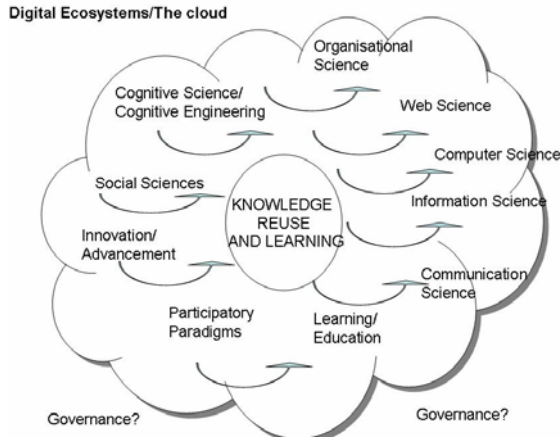


Figure 7: Knowledge Reuse in the Cloud

In addition to the research areas identified above (see Image 7) other emerging domains that add a perspective to KR and that should be taken into account into a knowledge framework are:

- **Neuroscience/Brain Informatics:** The paper ‘The Fallacy of KR’ advocates that neuroscience provides the key to understand the mechanism of KR, and introduces the notion of knowledge mobilization and knowledge sustainability [Bennet and Bennet, 2008]
- **Digital Ecosystems** ‘Knowledge as Ecosystem’ considers knowledge exchange and reuse as a natural synergy taking place given favourable environmental conditions.
- **Knowledge Hubs and Knowledge Clusters:** The flow of knowledge can be helped by appropriate organisational configuration, however the flow dynamics need to be mapped and considered at organisational and system structures. The emergence of Knowledge Hubs and Knowledge Clusters should be studied [Evers, 2008]
- **Social Network Analysis:** The next frontier for knowledge reuse is the study of ‘Knowledge Networks Analysis’, whereby thanks to the support of suitable informatics tools, it is possible to analyze large volume knowledge exchange data and patterns, and how they occur in social networks. [various]

#### 4.4 Conclusions and Future Work

The web is the most pervasive, extensive and rapidly growing knowledge base ever existed. Its potential for optimising Knowledge Reuse is unlimited, but it is dependent on the availability of technologies capable of supporting KR needs in very fast changing worlds. Semantic Web capabilities (tools, platforms) must be developed taking into account applied usage and the rapid patterns of transformation that are taking place in all domains thanks to web based interactions. Last but not least, technologies should be developed to provide intended benefits for participating individuals, organisations and for the advancement of society at large. By analysing current literature, state of the art research in related fields and domain alignment to

provide an integrated perspective, this paper positions Knowledge Reuse in Practice in the context of the an evolving Web, given its complexity and multidisciplinary. As our research borders with the realm of complex systems science, non linear and at times chaotic methodological pattern of inquiry are hopefully justified.

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# Defining a Pragmatic Based Web-service Discovery Mechanism

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**Abstract:** The discovery of contextually relevant web services is crucial to business organisations. Pragmatics (in terms of communication acts) and semiotics (the understanding of signs), intersect at an important point in relation to textual entities. The intersection of pragmatics and semiotics provides the fabric essential to model the interaction between humans and norm-based agents by moving beyond the traditional two-role communication loop model found in the Language/Action Perspective to a proposed multi-responsive model to discover appropriate web services in Service Oriented Architecture contexts.

**Keywords:** Pragmatics, Semiotics, Communication Acts, Norms, Service Oriented Architecture

**Categories:** H.1.0, H.1.1, H.1.2, H.4.0

## 1 Introduction

A function that pragmatics (*interpretation of communicative acts*) and semiotics (*the understanding of signs*) can have with the discovery of web services in a Service Oriented Architecture (SOA) context is reported in this paper. SOA is an approach to leveraging existing software systems to fulfil business processes. SOA, established as a mainstream software development paradigm is tightly coupled with the concept of web services. Web services follow the principle of building software that can be accessed across organisational boundaries, in a collaborative manner, between service consumers and service providers. Using web services as a way of implementing a SOA, is based upon the notion of identifying predefined capabilities that characterise what a web service can functionally achieve. Should a business organisation wish to use a web service, it would need to take into account the issues associated with web service discovery. For example, [Crasso et al, 08; Atkinson et al; 07; Huang et al, 08; Li et al, 07; Pastore, 08; Diamadopoulou et al, 08] all highlight the concerns surrounding web service discovery. They claim that web service discovery is the weak component of the tri-themed web service model (service requestor, service consumer and service discovery).

An example SOA framework by [OASIS, 08] stresses the importance of considering the organisational issues linked to SOA implementations. For example, recognised in the OASIS framework is the socially orientated nature of SOA resulting in an assembly of various types of models, such as the '*social structure*' [OASIS, 08]. Within the social structure, 'norms' emerge as a mix of constituents, for example

human agents, software agents (norm-based) and various SOA resources, of the social model interact. Various communicative acts are produced as a result of the different models interacting within the SOA framework. Pragmatics and semiotics outlined in this paper are amenable to the challenges of specifying a ‘communication act’ approach to initiate the discovery of web services. In diverse business organisation settings, pragmatics and semiotics can be used to take into account a multitude of different factors that need to be communicated prior to web service discovery and selection.

## 2 Pragmatics

Pragmatics in the linguistic domain is used to describe what ‘conversational partners’ in different contexts (taken as culture, language, time and place) communicate. Pragmatics in this sense is used to analyse the intentions contained in communicative acts between speakers and hearers. Pragmaticians converge on the analysis of different kinds of utterances and their associated meanings in human to human communication patterns. However, regarding the computational realm, the resolution of many computer scientists is to place computing as close to the human sphere as possible. Varied notations are used to describe the functioning of systems behaviour. Notations share a common theme, however, to specify processes that enable humans to interact with each other and with computers in meaningful ways. One route to achieve such as move is to simulate human to human communication acts between humans and computers. An established body of work exists which promotes such an interaction, the Language/Action Perspective (LAP). LAP provides the means to facilitate human to computer interaction in terms of web service discovery processes within a SOA framework.

### 2.1 Language/Action Perspective

The Language/Action Perspective (LAP) focuses upon ‘face-to-face’ communication acts to orchestrate activity between humans supported by computers to achieve business objectives [Weigand, 06]. LAP amplifies typical business process modelling notation with Speech Act Theory (SAT) so that actions can be defined in accord with responses to speech acts [Weigand, 06]. The basis upon which LAP was founded relates to ‘communication loops’ [Goldkuhl, 07] created originally by [Winograd & Flores, 86; Medina-Mora et al, 92; Dietz, 99]. They all share a common communication pattern – requester and performer.

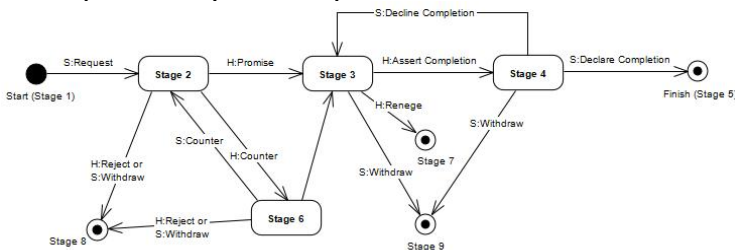


Figure 1: Communication loop

Implicit in figure 1 is a communication loop: request an action, agree to do an action, do the requested action, and report on the completion of the action. LAP therefore is based upon the analysis of communication patterns and the causal actions that people carry out in response to communicative acts. An example application from the LAP domain that closely relates to the objectives in this paper includes ‘Negoisst’ an e-negotiating system based upon control loop theory [Schoop, 05]. The foundational work by [Winograd & Flores, 86; Medina-Mora et al, 92; Dietz, 99] and the example system by [Schoop, 05] all use SAT as an intrinsic component.

## 2.2 Speech Act Theory

Speech acts are composed of *illocutionary acts*, *illocutionary points*, *illocutionary force*, and *propositional content*. An illocutionary act, described by [Austin, 62], captures a speaker’s intention in a communication act between a speaker (requester) and a hearer (performer). To strengthen an illocutionary act, [Searle, 69] adds to Austin’s [Austin, 62] theory illocutionary points which are classified as: *assertive*: commit the speaker (in varying degrees) to something being the case, or to the truth of the expressed proposition; *directive*: attempt (in varying degrees) to request the hearer to do something. These include both questions (which can direct the hearer to make an assertive speech act in response) and commands (which direct the hearer to carry out some linguistic or non-linguistic act); *commissive*: commit the speaker (in varying degrees) to promise to do some future course of action; *declaration*: bring about the correspondence between the propositional content of the speech act and reality; *expressive*: express a psychological state about a state of affairs (for example thanking). Illocutionary force expresses the strength of the illocutionary point by using vocabulary that details the intentions of a speaker. Propositional content carries the information or data in the illocutionary act. Hence the four elements of speech acts: *illocutionary act*, *illocutionary point*, *illocutionary force*, and *propositional content*, form a communicative act.

In summary, the term ‘communicative act’ refers to conversations that are used to capture intentions and to provide a negotiation procedure [Stamper, 96] resulting in an action. The action is often determined by a meaning making process attributed to Peircean semiotics – semiosis [Stamper 96; Liu 00; Liu 08].

## 3 Semiotics

Semiotics is based upon two positions related to [Saussure, 83] and [Peirce, 31-58] where both adhere to a subjective element to understanding signs. Signs can have different meanings across various cultural or social settings. Peirce’s view of semiotics is used in this paper due to its triadic grounding of semiosis. To shape understanding of a sign Peirce defined the term semiosis, the interplay between three unified parts: a sign, an object and an interpretant. A sign can take on various formats: symbolic, iconic and indexical. Symbolic signs are typically words, iconic signs are pictures, and indexical signs are signs that ‘naturally’ occur and have causal links to meaning. Each sign classification has an order of ‘agreed rules’ associated with them to make them work. For example, indexical signs are highly subjective and symbolic signs such as words are not so subjective.

Regarding semiosis the sign refers to an object, and the object verifies its sign. For example, smoke (the sign) may signify fire (the object), if a fire is discovered the fire verifies the sign – smoke. The link between the sign and the object is known as the sign/object relation. The sign/interpretant relation enhances the meaning of the sign/object relation in the mind of someone, for example, if fire is seen it may mean danger depending upon its location, hence the role of semiosis creates an improved meaning of the sign/object relation. The interpretant therefore is an enhanced sign created from the sign/object relation; it includes the contextual meaning given to a sign. To crystallise the meaning making process (semiosis) of a sign, Morris [Morris, 38] devised three levels: syntactic: recognition of the sign in relation to other signs; semantic: comprehension of the intended meaning of the sign; and pragmatic: contextual meaning added to the sign. In terms of semiosis and communicative acts ‘emergent properties’ (the deontic operators obligation, permission and forbiddance) materialise that expose a semiotic response to a communication act. Normative actions such as carrying out a task without coercion (obligation), being persuaded into doing a task (permission), and absolute refusal to do a task (forbidden) by a recipient of a message in a communication act, are responses to the pragmatic meaning of a sign [Stamper, 96; Liu, 00].

### 3.1 Norms and Norm-based Agents

According to [Boella et al, 06] social norms “exist where models of human activity are normatively regulated”. Essentially social norms provide a mechanism by which human agents through consensus, recognise and adhere to. Social norms also introduce unpredictable behaviour [Young, 08]. Social norms are ‘enforced’ by coordination motives. Coordination motives are social phenomena as they are shared expectations about a solution to a given problem, essential in a negotiation framework such as a SOA. Rigid enforcement is therefore not required [Young, 08]. Social norms are governed by expected patterns of behaviour; ‘legal’ norms however require a different form of control. Legal norms are sustained by social disapproval or a form of punishment for norm violation. Legal based norms are an expression of obligations and rights that an individual human agent (or a machine-based agent) has within a social system [Boella et al, 06; Liu, 00]. Typically legal norms are supported by a consenting mechanism. Should a machine (norm-based) agent ‘own’ a legal norm, or a set of legal norms, consent for action is implied. Legal and social norms can be used to ensure that web service selection is compliant within a SOA.

Norm-based agents, according to [Boella et al, 08], can communicate, distribute, detect, create, modify and enforce norms in a Multi-Agent System (MAS). Norm-based agents in a normative business organisational system (which includes a SOA) interact with the system in various ways. Norm-based agents (human and software based) are expected to communicate with other norm-based agents [Boella et al, 08]. Business organisations that implement a SOA are in fact implementing a normative system. The exemplar [OASIS, 08] as previously described ‘is’ a normative SOA framework.

## 4 Research Challenge

The foundational elements of the LAP domain provide a suitable mechanism to coordinate communication between humans and norm-based (software) agents to discover web services from within a SOA context. The typical two-role communication [Goldkuhl, 07] exchange pattern, evidenced in work by [Winograd & Flores, 86; Medina-Mora et al, 92; Dietz, 99; Schoop, 05] as previously shown in figure 1, demonstrates that ‘S’ the speaker makes a request, ‘H’ the hearer promises to do the request, or counters the request and so on. This approach however appears to be prohibitive in terms of business process modelling in a normative SOA context, for example:

*The communication loop (with its two roles) is used in business process modelling as a generic template. As I conceive it to be an over-simplification of business processes, it can deceive people to perform such a restricted analysis [Goldkuhl, 07].*

With regard to business process modelling notations, such as Unified Modelling Language (UML) Activity Diagrams [UML, 08] and its range of available semantics, mechanisms are available that facilitate what [Goldkuhl, 07] calls ‘multi-responsive’ actions. The orchestration of web service discovery in SOA contexts rely on business process modelling techniques that have multi-responsive communication patterns, hence there appears to be a mismatch between what is required as business process modelling in SOA contexts and the foundational aspects of LAP. As such, the general mismatch between the two is pointed out by [Goldkuhl, 07]. Hence, it is fair to say that the traditional speaker-hearer schema bars securing appropriate ‘pragmatic’ decision making in a normative SOA context. There is a need to move from the traditional communication-loop pattern exhibited in [Winograd & Flores, 86; Medina-Mora et al, 92; Dietz, 99] to provide a richer communication act pattern and decision making process to build a truly pragmatic negotiation mechanism within a SOA framework.

The research challenge in this paper focuses on defining a pragmatic (normative SOA based) web service discovery mechanism based upon a multi-responsive communication pattern. The motive behind this research challenge is based upon the required use of norm-based agents (typically machine orientated but also includes humans) [OASIS, 08] to discover relevant web services. To achieve such a move semiotics (semiosis) provides a route to coordinate actions of agents (human and machine-based) and have agency (such as intentions) communicated non-verbally by norm-based agents.

The intersection of semiotics and pragmatics as advocated by [Cooren, 08] where ‘agency’ can be attributed to textual entities is built upon as a pivotal theme in this research challenge. Cooren shows that agency can be attributed, not only to the person who created a non-verbalised speech act, but also to the resultant textual entity. The notion of agency credited to textual entities opens up the traditional speaker-hearer schema that generates communication loops originating from within the LAP domain. This notion allows norm-based agents to make and respond to communicative acts whilst carrying out duties in a SOA based implementation.

## 5 Defining a Multi-responsive Communication Pattern

Based upon figure 2, the web service discovery communication pattern consists of a sign (content of a communication act) that embodies some form of agency, in this case ‘intentions’. Human semiosis is very much a part of the communication model, as human semiosis is used to guide, through negotiation, norm-based agent behaviour. The model however allows norm-based agents to confer with other norm-based agents and other humans. Norm-based agents have access to a norm base ‘shared’ with human agents, and hence invoke communicative acts. Evidently, humans make meanings of signs contained in the sign/interpretant relation using a range of faculties that machines do not have. To capture this aspect [Benfell and Liu, 09] proposed that human agents, through semiosis, should be an integral element of a web service discovery process in a normative SOA framework.

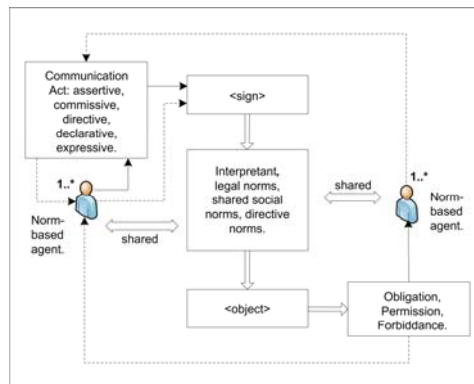


Figure 2: *Multi-responsive communication and semiosis*

To formalise the multi-responsive communication pattern various message types based upon SAT are used to communicate with norm-based agents. Normative behaviour is governed by the process of semiosis whereby emergent deontic states indicate actions to be carried out (or not to be carried out) according to the content of the communication act a norm-based agent receives.

### 5.1 Setting the Multi-responsive Communication Pattern in a SOA Context

Norms are used in this paper as an interleaving mechanism to assist business modelling. Norms, therefore, are central to modelling a business (in this solution) by identifying ‘directive’ (pragmatic high-level contextual norms) to guide the behaviour of norm-based agents. The term ‘directive norm’ is unique to the approach devised here. Business modelling is achieved through various modes of describing directive norms thus enabling norm modelling to traverse through a SOA framework. Two such approaches that fulfil norm modelling are the Business Motivation Model [BMM, 08] and the UML [UML, 08].

## 5.2 Achieving Pragmatic Web Service Discovery in a SOA Context

BMM promotes a range of core features that are applicable to structuring business organisation objectives. The ones used here are *Mission*, *Strategy*, *Tactic* and *Directives*. Each is used to provide input, in increasing detail, from *Mission* to *Strategy*, *Strategy* to *Tactic*, and *Tactic* to *Directives*. The *Directive* component is used to contain the pragmatic high-level directive norms to guide the modelling of business objectives within the multi-responsive communication pattern.

Taking into account directive norms as an approach to contextual web service discovery, a SOA representation is formulated next. With reference to figure 3, the package *Business Organisation Model* is made up of three ‘packages’, *Social Structure*, *Stakeholder and Participants*, and *Needs and Capabilities*. These are taken directly from the OASIS SOA framework [OASIS, 08]. The *Social Structure* defines the power relationships amongst a set of participants that belong to a business organisation. The *Stakeholders and Participants* package sets out the major actors that relate to SOA implementations. The *Needs and Capability* package is linked to the fulfilment of business objectives, and to achieve this, the model uses four elements taken from the BMM, *Mission*, *Strategy*, *Tactics* and *Directives*. In the SOA model, the crucial element is *Directive*, as this holds directive norms that are communicated by all agents.

To validate the use of directive norms, an example application based upon a hypothetical on-line journal subscription business organisation called, Journals on-Line (JOL), who wish to use web services as their implementation strategy, is shown. For the communication of directive norms to occur and to demonstrate the actions taken by norm-based agents, appropriate packages (figure 3) are selected from the *Business Organisation Model* and the *SOA Specification Model*. First business objectives are described using *Mission*, *Strategy*, *Tactics* and *Directives* to set directive (high-level) norms.

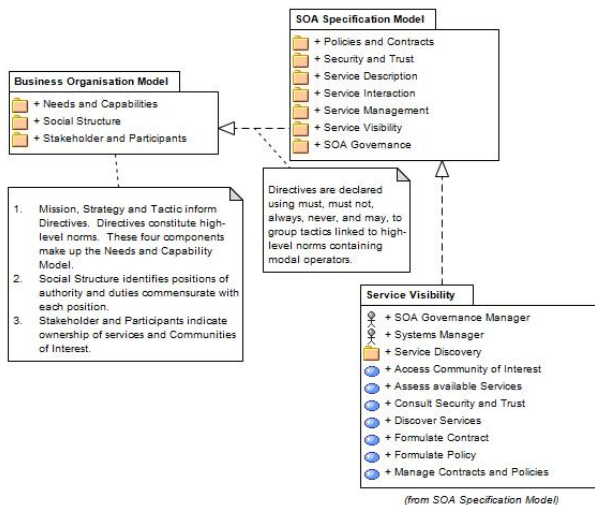


Figure 3: Organisational Models



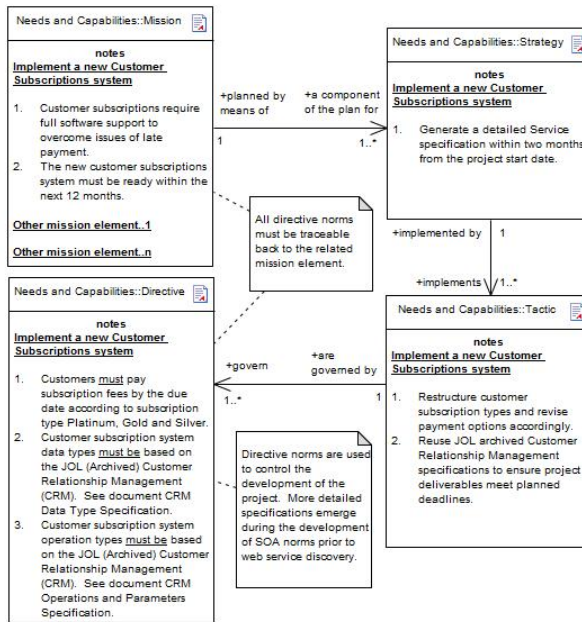


Figure 4: Needs and Capabilities

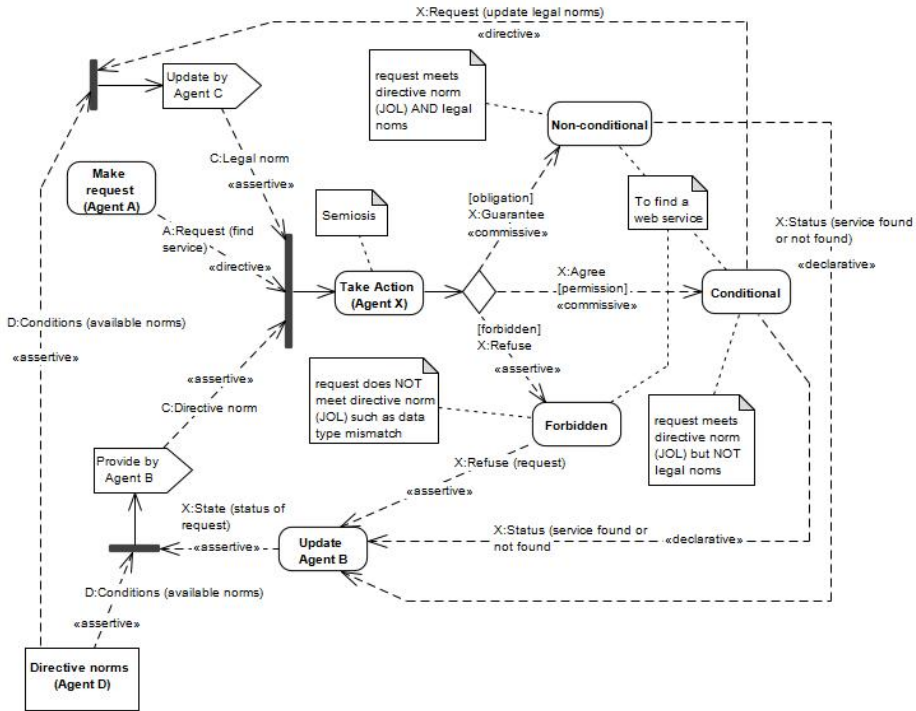
Using the *Needs and Capabilities* package (figure 4), a selection of directive norms that are pertinent to web service discovery are identified so that they can be communicated by norm-based agents. In a real case scenario this list would be much greater. The multi-responsive communication pattern in figure 5 below is discussed next.

### 5.3 The Multi-responsive Communication Pattern – a discussion

With reference to figure 5 should the ‘present situation’ be modelled only, where Agent A makes an initial request, Agent X infers through semiosis if it is obliged, permitted, or forbidden to carry out the request and so on, indicative of the original communication loop, proves its worth in this case. However, the following observations can be made:

- (i) It is a very narrow modelling scenario as there are other background features that should be solicited in this situation to fully capture an appropriate analysis. Shown in figure 5 are three occurrences of multi-responsiveness (indicated using UML Activity Diagram fork and join notation – heavy emboldened lines) representing background features to the present case;
- (ii) Regarding multi-responsiveness (where there is a response to several earlier actions) Agent X in figure 5 receives a number of ‘trans-situational grounds’ (Goldkuhl, 07] as communicative acts. Agents D and B generate communicative acts based upon directive norms (a textual entity exhibiting

agency) that are communicated to Agent X at ‘some point in time’. Goldkuhl refers to this as ‘memory traces’ and cites [Giddens, 84]. Modelling trans-situational grounds facilitates the specification of a MAS in accord with the specification of norm-based agents by [Boella et al, 08]. Should a typical communication loop construct be used to model the example scenario only, this information is unlikely to be present. This could have severe ramifications for the quality of an Information System, as it prohibits the identification of other norm-based agents and their role in this particular (and any) scenario;



- (iii) Inferences that can be made from a model devised using the traditional communication loop would suggest that Agent X would be responsible for updating its own legal norms and taking ownership of directive norms – opposite to the requirements laid out in the OASIS SOA framework for software-based agents;
- (iv) Directive norms are owned by a business organisation, and by nature, are independent of any one stakeholder. They are also documented as textual entities that according to [Cooren, 08] can exhibit agency. This promotes the need for them to be modelled accurately, and therefore, communicated (as a communication act) in a normative SOA framework implementation.
- (v) The multi-responsive pattern of communication acts also strengthens the notion of pragmatic web service discovery by identifying more clearly the origin of relevant norms belonging to the ‘present situation’.

## 6 Conclusions and Future Work

The web service discovery mechanism (devised here) driven by a normative SOA framework uses the linkage of pragmatics and semiotics to make possible the contextual discovery of web services using a multi-responsive communication pattern. The assertion that a textual entity can demonstrate ‘agency’ normally attributed to human agents [Cooren, 08], was used as the foundation for this hypothesis. Additionally, the web service discovery mechanism manages the interface between agents (human and machine-based). The purpose of capturing communication acts and applying semiosis to the related symbolic signs provides a means to capture intentions and have norm-based agents act upon them.

Three areas require further exploratory work to ensure that the web service discovery mechanism is consistent with the purpose of using pragmatics and semiotics as a method to overcome the limitations of traditional communication loop modelling, and to further enhance the pragmatic nature of discovering web services in diverse business organisation settings:

- (i) Further exploration of notation, for example UML, that can more accurately specify triggers for actions as opposed to a mix of modelling triggers and background initiatives. Also identified by [Goldkuhl, 07];
- (ii) Translation of directive norms into ‘executable’ norms that govern the actions of norm-based agents to derive semantic and syntactic specifications of web services prior to discovery;
- (iii) Specification of norm-based agents to include their aggregated elements and specialised roles within a normative SOA framework.

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# Intention Broadcasting

## A Model for Computer-Mediated Intention Sharing and Coordination

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**Abstract:** Social media innovations, together with rapidly improving data sharing methodologies, are enabling individuals and groups to instantly disseminate, or “broadcast”, messages across many diverse networks. This phenomenon, combined with the growing use of social media services for sharing and coordinating intentions, led me to develop the concept of “intention broadcasting”. In this paper I present a model for computer-mediated intention sharing and coordination. It was created to help guide web practitioners in the development of intention-broadcasting related systems.

**Keywords:** intention broadcasting, intentions, pragmatic web, context, coordination

**Categories:** A.0, C.0, C.2.0, C.3, J.0, J.4

## 1 Introduction

Cognitive science recognizes that a high-level ability to share and coordinate intentions is a uniquely human attribute, which has helped us to develop cultures and build civilizations [Tomasello et al., 2005]. This ability is far from perfect, however, and many problems arise when we are ineffective in sharing our intentions. If it were possible to improve our abilities to share and coordinate intentions, the positive impact on our lives would be profound.

The ability of *individuals* to quickly disseminate and coordinate intentions has advanced rapidly as a result of the Internet, social networking services and the growing trend for data sharing between web services. It is this capability and the resulting phenomena that I have termed “Intention Broadcasting”.

Already services are starting to use aspects of intention broadcasting, however, there are no dedicated models that can be used to analyze the processes involved and the main aim of this paper is to start filling this void.

This paper is a summary of my master’s thesis<sup>1</sup>, which drew on research and work undertaken at Zipipop – a social media agency I co-founded in July 2007.

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<sup>1</sup> Richard von Kaufmann 2009, Intention Broadcasting – A model for computer-mediated intention sharing and coordinating, MA, University of Art and Design Helsinki (Media Lab).

## 2 Definition of the key terms in the context of this paper

### 2.1 Broadcasting

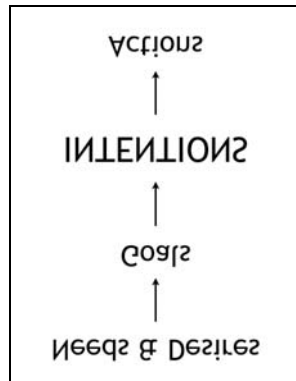
The term “broadcasting” is most commonly understood as the transmission of television or radio programmes to a wide audience. In relation to the concept of Intention Broadcasting, however, it is used metaphorically to create a simple, concrete and “sticky” conceptual model.

The concept of Intention Broadcasting is also a catchall term that includes other less well know forms of casting, for example, narrowcasting (for selected or specialist audiences) or multicasting (for distribution via networked connections).

What they all have in common is the ability to instantly disseminate information to many people.

### 2.2 Intentions

Since intentions come before actions, those wishing to better facilitate actions should pay attention to how people formulate and communicate their intentions.



*Figure 1: Everything starts from needs or desires that become goals. In order to achieve their goals people frame intentions that lead to actions.*

### 2.3 Computer-mediated

The use of the term ‘computer-mediate’ in my model title was inspired from ideas related to computer-mediated communication (CMC). CMC applies to any human communication achieved through, or with the help of, computer technology [Thurlow, 2004]. CMC also covers the social effects of networked, two-way communications and how this fundamentally differs from the previously highly governed models (e.g. radio broadcasting), which “were designed to send messages from a centre to a periphery” [Lister, 2003]. CMC allows for one-to-many, many-to-many, synchronous (live) or asynchronously (without time constraints) communications. It is this ability of individuals and organizations to easily “broadcast” their messages to specific or wide networks, and for their audiences to be able to respond just as easily, that has catalyzed and enabled the greatest change in the way we communicate since the

introduction of the Internet. With that in mind, I describe intention broadcasting as *computer-mediated* intention sharing and coordination; i.e. the sharing and coordination of intentions through, or with the help of, computer technology.

### 3 Intention Broadcasting

#### 3.1 Introduction

Intention Broadcasting (IB) is the process of computer-mediated intention sharing and coordination. An IB process can be observed in its simplest form when people use “status messaging” or “micro-blogging” services, such as Facebook and Twitter, to “broadcast” their intentions, e.g. “Anyone up for a drink after work?” or “Who wants to go for a picnic at the weekend?”. Friends can then respond through the commenting or reply features.

A fully functioning intention broadcasting system (IBS), however, should provide a feedback loop to allow participants to work together to convert intentions into fixed plans. For example, recipients of an invitation to an event should be able to easily and quickly indicate whether or not they intend to accept the invitation. The individual responses should then be collated and coordinated so that the inviter will know who and how many will attend the event.

#### 3.2 Existing Intention Broadcasting Services

IB-related services can utilize any method of one-to-many computer-mediated broadcasting strategies. In almost any situation in which you can define a clear intent/desire/need you can build an IB-related system. Aspects of intention broadcasting are already appearing on the web, as illustrated by the following examples:

- **Dopplr** (travel): Narrowcast your intention to travel to a particular city so that friends can “serendipitously” meet up with you. [[www.dopplr.com](http://www.dopplr.com)].
- **Kiva.org** (micro lending): An organization that connects private lenders to entrepreneurs in developing countries. The intending borrowers first post (broadcast) how much they need and what the loan would be for. [[www.kiva.org](http://www.kiva.org)]
- **Lending Club** (peer-to-peer banking): Peer-to-peer lending of consumer credit at much better rates than traditional banking. [[www.lendingclub.com](http://www.lendingclub.com)]
- **National Carshare** (car-pooling): Broadcast your wish (intention) to travel from A to B so that you attract others to share cars and travel expenses – and help save the planet. [[www.nationcarshare.co.uk](http://www.nationcarshare.co.uk)]
- **CouchSurfing** (hospitality exchange network): Enables members to broadcast their intention to travel and then receive offers to stay in the private accommodation of fellow members. [[www.couchsurfing.org](http://www.couchsurfing.org)]

These examples are based around sharing intentions with *people*, however, often intention broadcasting involves letting *systems* know your intentions; for example, the airline industry handles intentions well with many services such as eDreams



providing lists of possible alternative flight choices for the same routes across many different carriers. This has been made possible by decades of enforced standardization and highly specified ontologies.

It is interesting to note that in the mobile communications sector one of the few services to be maturing and generating significant revenues is turn-by-turn navigation. This service deals with clear intentions, i.e. intentions to get from A to B. Picking up on the broadcasted intentions enables the services to provide preference-based, contextually relevant advertising, i.e. where is the next most convenient petrol station. Could it be that such services, which can clearly identify their users' intentions, have a better chance of succeeding?

Many services are now starting to offer real-time searches that notify you via email or RSS when something of interest comes up; for example, the popular US listings service Craigslist has a real-time (or constant) search that will notify you if what you are looking for comes on the market. And it has become almost a standard for online real-estate services to provide the option to receive notifications when a potentially interesting property (based on your criteria: place, size, cost, etc) becomes available. Such services could be viewed as using real-time search criteria to input and transmit intention-related information that will facilitate future actions, such as making purchases.

### 3.3 Potential Intention Broadcasting Services

Intention broadcasting has many potential uses:

- **Social plans:** Broadcast your social intentions so that your friends will be aware and can join you.
- **Baby-sitting:** Broadcast your need for (intention for finding) a babysitter and use collaborative rating to evaluate trustworthiness.
- **Buying/Selling:** The customer broadcasts an intention to buy a product (either new or second-hand). Sellers see this intention and make direct offers. The customers benefit by being able to see and compare offers in one place and get more open independent expert advice. The sellers benefit from the direct contact to active customers and a better understanding of the customer needs. They also save money on inefficient, and often unwelcome, marketing intermediaries. Both benefit from the collaborative feedback censorship system that rates the reliability of buyers and sellers (as in eBay).
- **Freelance work:** To find skilled labour organizations often prefer to engage freelance workers. However, it is not always clear who to contact or what is a fair wage. To overcome this dilemma those who need work done could broadcast their needs and freelance workers could determine the offers that are best suited to them. A ratings system would help customers avoid unreliable workers.

## 4 Model Research

In the previous section I outlined a number of services that use some intention broadcasting concepts. From such examples it is possible to identify common

features that could be used to create a coherent model showing the components and dynamics that would exist in a generic Intention Broadcasting System (IBS).

After analyzing various “action” models and theories in the fields of interaction design (particularly D. Norman’s Seven Stages of Action model), situated cognition, and cognitive science (particularly the work of Michael Tomasello), I created the diagram below to help identify how an intention broadcasting system might change how agents/actors go about organizing social get-togethers.

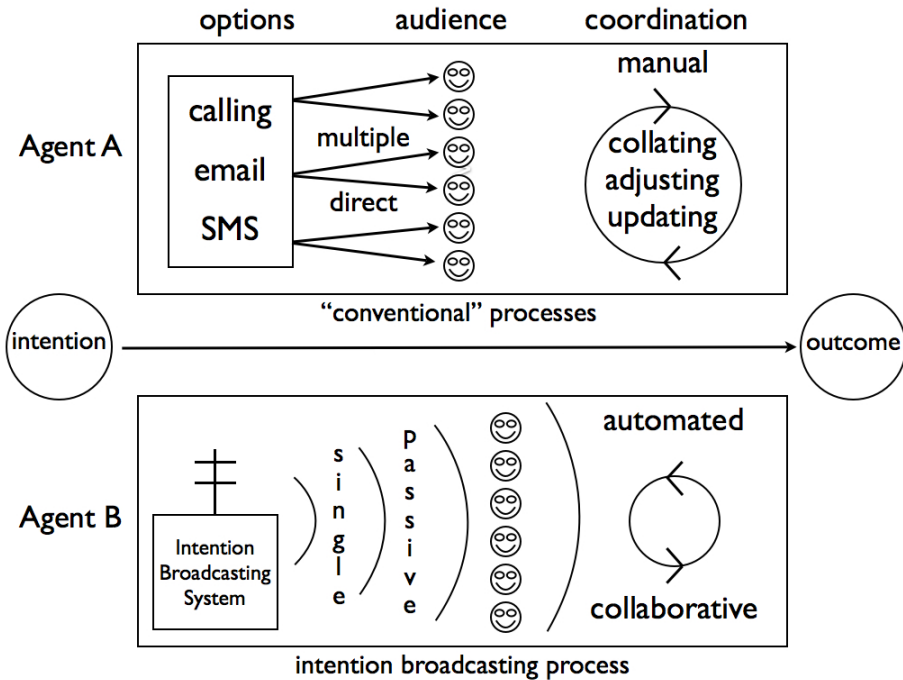


Figure 2: A process comparison between organizing a get-together via “conventional” methods and an intention broadcasting approach.

- **Agent A** chooses a combination of “conventional” options (calling, SMS, and emailing) to let the audience (friends) know that he is planning (intends) to have a party. These methods can be time-consuming since the replies have to be manually collated, adjustments made, and updates sent multiple times.
- **Agent B** opts to use an intention broadcasting system. Agent B “broadcasts” her intention to her friends. The intention is picked up passively through the system or directly via notifications sent out via email, SMS, social networking services, etc. The system would then automatically collate the responses and instantly update participants as the planning process proceeds.

A well-designed IB-system should be able to “funnel” the participants in a smooth collaborative process towards the desired goal and the coordination phase should be as automated as possible.

## 5 An Intention Broadcasting Model

In the process of seeking out and identifying the common IB process stages, the “broadcasting” metaphor was naturally extended with the added advantage of making it more memorable.

I propose that the key components of a model for an intention broadcasting system should be:

- **Goal:** the agent has a need or desire for a particular outcome.
- **Options:** the agent has various options based on the combined knowledge, skills and the perceivable affordances in their environment.
- **Intention:** the agent selects an intention aimed at achieving the outcome.
- **Broadcast:** the agent broadcasts their intention to a defined target audience (broad or narrow) via computer-mediated networks, e.g. email, social networks, etc.
- **Tuning:** the targeted audience is “tuned in” to receive relevant intentions using any method or technology that can help filter the intentions: groups, real-time searches, etc.
- **Rating:** if necessary a collaborative rating system can be used to help protect both the broadcaster and audience from malevolent intentions or unreliable respondents, e.g. a bad plumber or a dangerous driver.
- **Coordination:** systems for enabling the parties to overcome contextual problems though interaction and collaboration.
- **Outcome:** Outcome achieved.

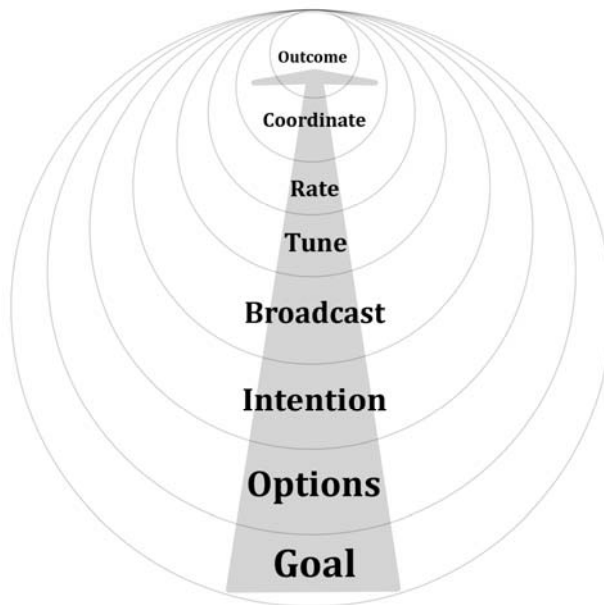


Figure 3: *A model for computer-mediated intention sharing and coordination.*

## 6 Intentions and the Pragmatic Web

In order to complete collaborative tasks we first have to share our goals and then coordinate them [Tomasello 2005]. This can be on a person-to-person or person-to-machine (system) basis. Such knowledge of intentions is often helpful in resolving many problems such as the need to get to a certain place in a city. By framing destination as intention, and by taking account of context (e.g. current location), a system could guide the traveller across a public transportation network in real-time.

Context is a fundamental part in the linguistic study of pragmatics and it is correspondingly important in pragmatic web developments. It is crucial in all areas of the pragmatic web from the creation of community-based ontologies to facilitating everyday activities. I propose that intentions and context could be used to describe the pragmatic web in the following way: “The coordinating of meaning, context and intention to facilitate communication and cooperation in achieving desired outcomes.”

## 7 Conclusions

There are many needs, desires, and problems that could potentially be addressed by framing them in relation to intentions. Many aspects of intention broadcasting are presently being developed but there is no coherent approach; however, applying the model proposed in this paper would make it easier to identify and improve future IB-related systems. Having said that, it is important to stress that no IB-related system needs to use all the components of this model.

A true IB type service is one where nothing can start until there has been an initial sharing of intentions, such as peer-to-peer banking, car-pooling or more specific services such as CouchSurfing or Dopplr. However, extending the use of IB beyond that could have a huge affect on many areas of web activity.

An important example of the use of IB is in farming out (“crowdsourcing”) the work of searching for things through the web by matching needs with solutions in a much more efficient manner; for example, finding a plumber or a second-hand tricycle.

I have demonstrated, through the analysis of existing services, that giving due attention to intentions can help find solutions to both business and everyday needs and desires. However, the concept of Intention Broadcasting is still in its infancy and more research is needed to fully assess its implications and potential. At Zipipop we developed our own service for sharing near-future social intentions (e.g. the wish to go for a drink, see a film, have a picnic, etc), but we failed to take into account that the current processes of organizing *small* social events, although inefficient, provide important means of reinforcing social connections, i.e. by calling my friends to invite them for a drink I also have the excuse to catch up with their lives. So although calling around might be time-consuming the effort is not a waste of time – since, even if friends can't join in, other social needs have been catered for in the process.

At the end of the day, the aim is to improve people's lives and, if services pay closer attention to recognizing and defining people's intentions, they will be forewarned and better able to anticipate needs and desires, resulting in more efficient and more personal services.

## 8 Future Work

My basic concept of Intention Broadcasting (IB) has already started to gain momentum on the web. It remains to be seen, however, if my model for computer-mediated intention sharing and coordination will be as widely accepted.

One of the biggest problems with intentions, particularly from a service point of view, is that they are hard to automate. A way forward could be found in analyzing patterns and data to anticipate people's intentions. For example, if you would like to meet some friends for a drink on a Friday night, a service could recommend a selection of bars that you and your friends often frequent. However, this would require users to actively log the locations they visit – as in the Brightkite service – or for the development of more sophisticated location tracking services with the capability of automatically identifying specific venues. Dopplr (see section 3.2) recently introduced their Social Atlas service, which enables frequent travellers to geographically tag venues (restaurants, hotels, etc.) as places they recommend.

Other aspects of intentions that will be hard to cater for are those important but low-level intentions that we carry around with us hoping to fulfil serendipitously without having to resort to specific plans. For example, if I bump into  $x$  I will ask them about  $y$ ; if I go past  $z$  I will do  $a$ . Very advanced systems would be required to handle such low-level intentions but they could be developed. For example, I am constantly intending to get a haircut and always leaving it to the last minute. A potential solution to this could be to let a system know how often I like to have haircuts and then it could cross-reference my own and my hairdresser's calendars to recommend a convenient booking time. For this type of service we will need the Semantic Web and intelligent agents to do the coordinating and it would be interesting to explore the potential of adding intent as a relationship component within semantic ontologies. Then systems could be taught to recognize and process intentions wherever they prove to be useful.

I predict that as information becomes ever more abundant and demands on our attention more acute there will be a growing demand for filtering services. And, like a good butler, services that learn our preferences, habits, quirks and intentions, will be better able to filter out the noise and provide evermore personal, contextually relevant information – for which we will be extremely grateful. In the meantime I will continue to analyze the processes of how people interact with IB-based systems and explore their current and potential sociological effects.

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