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# Marinas and other ports and facilities for the recreational craft sector: an ontology domain to support spatial planning.

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# MARINAS AND OTHER PORTS AND FACILITIES FOR THE RECREATIONAL CRAFT SECTOR: AN ONTOLOGY DOMAIN TO SUPPORT SPATIAL PLANNING.

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## ABSTRACT

Marinas and other ports and facilities for the recreational craft sector in Sardinia (Italy) can host more than 19,000 pleasure boats and yachts, according to a recent estimate (Osservatorio Nautico Nazionale, 2010); this capacity, at the national level, is second only to that of the Liguria region. However, Sardinian infrastructures and facilities are not part of a coherent network. Moreover, they are unevenly scattered along the coastline and are very diverse, in terms of type, dimension, and endowment of facilities for sailors.

A key issue to be taken into account in the early stages of the preparation of a plan for the pleasure craft sector, which might create the conditions for the setting up of a coherent network, is the lack of a proper, detailed knowledge of the system of Sardinian marinas and other facilities.

To this end, this paper begins with an analysis of current information (both spatial and non-spatial) and attempts to build a spatial database that integrates available data. The analysis identifies differences in structure and semantics, together with differences in purpose and date of production/update of the data, as the roots of inconsistencies among existing data produced by different sources. Such differences in structure and semantics risk, if not properly identified, considered and handled, to cause an incorrect integration of data.

Following the methodology provided by the guidelines produced by the Ordnance Survey with regards to domain ontologies, the construction of an ontology of the domain of infrastructure and facilities for the recreational craft sector is therefore proposed as a possible solution to the problem. By applying this methodology, a “knowledge glossary,” consisting of a shared vocabulary of core and secondary concepts and of relationships (some of which

spatial) among concepts is developed, leading to the construction of a conceptual model of the domain, later formalized by means of the software Protégé.

## SARDINIAN PORTS FOR PLEASURE BOATS: AN ANALYSIS OF AVAILABLE KNOWLEDGE AND EMERGING ISSUES OF DATA INTEGRATION

In order to describe Sardinian marinas and ports for the recreational craft sector, with regards to both their spatial distribution and characteristics, the following documents and data were analyzed:

1. Technical and economical feasibility study of Sardinian ports for the recreational craft sector (2004);
2. Feasibility study on the completion of Sardinian ports network for the recreational craft sector (2010);
3. Second report on the recreational craft sector – year 2010;
4. Spatial Database of the Sardinian Regional Landscape Plan;
5. Multi-resolution Spatial Database of the Autonomous Region of Sardinia;
6. [www.sardegnaturismo.it](http://www.sardegnaturismo.it), web portal of the Autonomous Region of Sardinia concerning the tourism sector;
7. websites specialized in providing sailors with services and information.

Such sources of information provide inconsistent pictures of the network of Sardinian ports for pleasure crafts.

The first source of information is a feasibility study commissioned by Department for Tourism, Handicraft and Commerce of the Regional Administration of Sardinia. Completed and adopted in 2004, this study lists a total of 56 ports for pleasure boats, approximately a half of which (29) publicly owned, and the remainder (27) privately owned. The study estimates in 13,140 the number of pleasure boats and yachts that could be moored in the ports. As far as the reliability of information is concerned, this document mostly relies on secondary data. The number of berths, for instance, was generally taken from a ministerial document, and it was corrected only in dubious cases, either by taking into account the size of the docks, of the quays and of the piers so as to obtain a rough estimate of the number of berths, or by means of on-site inspections to collect primary data.

The second source of information is a second feasibility study, commissioned in 2009 by the Department for Public Works of the Regional Administration of Sardinia. According to this feasibility study, Sardinia hosts a total of 79 harbours for recreational crafts; as far as their

classification is concerned, out of 79 above infrastructures 40 are classed as “marinas” (*porto turistico* in Italian), 11 as “landing places” (*approdo* in Italian), and 28 as “minor mooring facilities” (*punto d’ormeggio* in Italian), which include, for instance, jetties and docksing slips (Ambiente, Criteri e Prima, 2010, Part I, pp. 534-538). This classification draws upon Decree of the President of the Republic (DPR) of 2 December 1997 no. 509, “Regulations on the procedure for the granting of the assets of coastal areas that are state property for the construction of facilities dedicated to recreational boating”;<sup>1</sup> figures 1.a, 1.b and 1.c show some examples of structures belonging to the above three categories.

Such infrastructures are generally operated by private enterprises: according to the study, only 13 are operated by the public sector (which generally means by municipalities), 10 by public-private partnerships and the remainder 56 by private organizations. With regards to berths, the total supply is estimated to equal 18,458, out of which 14,375 are contained in marinas, 2,100 in landing places as previously defined and 2,073 in minor mooring facilities. On top of these, a further 1,828 boats can be moored by making use of mooring buoys (an example is shown in Figure 1.d), which make up for a significant percentage of the total number of available moorings because groups of mooring buoys are widespread in particularly sensitive areas of the island (for instance, within Marine Protected Areas, where the public bodies in charge of the MPAs usually operate the buoys) so as to prevent impacts on the Neptune grass and on the seabed. Characteristics of the ports (such as total number of berths, maximum length of boats that can be moored in a certain port, availability of services) appear to be based mostly on secondary data, and more specifically on data available on the Internet.

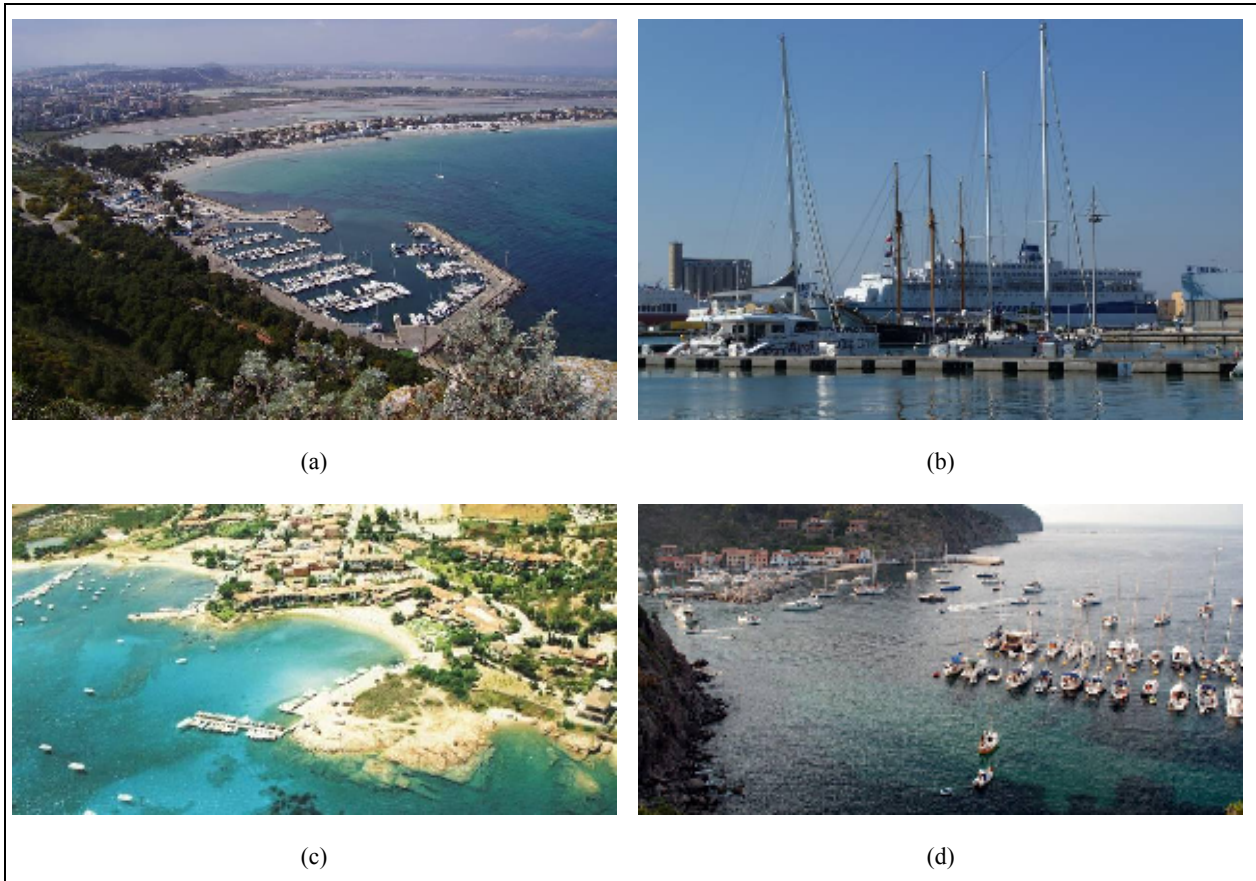
Information on whether the structures are managed by the public or by the private sector are provided only by the above two documents, which is not surprising, given their aims. The 2004 feasibility study aims at estimating the resources that would be necessary to complete, improve or re-organize existing structures for pleasure boats and at providing the regional

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<sup>1</sup> Article 2 of the Ministerial Decree no. 509 of 1997 defines and classifies structures for pleasure boats as follows:

- a) “marina” (*«porto turistico»*): an infrastructure consisting of both permanent and temporary structures put in place both on the water and on the seashore, and completely or mainly dedicated to pleasure boats, which can host a range of facilities and services for sailors and yachtsmen;
- b) “landing place” (*«approdo»*): a portion of a multi-functional port (*i.e.* one that could host two or more of the following: a passenger port, a commercial port, an industrial port, a fishing port, an area reserved for yachts and smaller pleasure boats) dedicated to yachts and pleasure boats only, which can host a range of facilities and services for sailors and yachtsmen;
- c) “minor mooring facilities” (*«punti d’ormeggio»*): public areas, both on the shoreline and on the sea, that host temporary and removable structures for the mooring, the launch, the hauling and storage of small pleasure boats.

administration with recommendations on priority investments. Similarly, the 2010 feasibility study identifies those structures that need enlarging, and puts forward a proposal for four new marinas building upon a multidisciplinary study of the whole regional coastal area and upon an estimate of demand and offer of berths in the island.



*Figure 1. (a) A marina (“Marina Piccola,” Cagliari, picture by the author); (b) a landing place (“Porto Vecchio,” portion dedicated to pleasure boats within the multi-purpose port of Cagliari, which serves also as a commercial port and as a passenger port, picture by the author); (c) a minor mooring facility (“Porto San Paolo,” from <http://www.sakanatravel.com>); (d) an organized and managed system of mooring buoys (from: <http://www.nauticaforum.it>)*

The third document, that is the 2010 national report on boating (Osservatorio Nautico Nazionale, 2010, pp. 31-35), despite being coeval with the above mentioned 2010 feasibility study, provides a different picture of the regional system of structures for the recreational craft sector, especially with regard to their classification. According to the report, Sardinia hosts a total of 78 structures for pleasure boats; out of these 78, 11 are classed as “marinas,” 41 as “portions of multi-purpose harbours,” and 26 as “minor mooring facilities.” The total number of available berths, according to the report, equals 19,415, out of which 5,049 in marinas, 9,720 in portions of multi-purpose harbours and 3,184 in minor mooring facilities.

The fourth source of data is the Regional Landscape Plan (RLP) of the Autonomous Region of Sardinia, approved in 2006, which grounds its indicative and prescriptive contents on a spatial analysis based on the layers of a Geographical Information System (GIS). Ports, together with airports and railway stations, are included by article 102 of the Planning Implementation Code (PIC) in the so-called “transport nodes,” for which articles 103 and 104 of the PIC detail indications and prescriptions, respectively. Transport nodes are geographically defined and represented by means of a point feature class<sup>2</sup> in which the type of node (be it a port, an airport or a railway station) can be identified by means of a field in the attribute table. If we take into account exclusively the ports, and narrow down the analysis to the two categories (that is, marinas and ports for passenger ships and pleasure boats) that can host recreational boats, a total of 46 structures can be identified. As previously said, these are represented within the GIS by means of points, which means that no information on the size of the structure can be inferred, and no additional information (apart from the type of transport node), such as the number of berths or the classification of the structure, is provided in the attribute table. According to Madau e Contini (2009), who claim that the structures for pleasure boats as identified by the RLP can host 14,479 berths,<sup>3</sup> the RLP takes account of permanent and larger infrastructures only, voluntarily neglecting those smaller structures that can be easily removed (such as jetties and piers) because, in the opinion of the authors, with reference to ports for pleasure boats the RLP can only suggest strategies on regeneration and renewal of existing structures, while more in-depth analyses would be out of its scope.

The fifth source of data, geographical as in the previous case, is the Multi-Resolution Spatial Database (MRSD) of the Autonomous Region of Sardinia,<sup>4</sup> a spatial data set that covers the whole island. Data in the MRSD are organised according to a hierarchical three-tier structure (layer, theme, class). Of interest for the representation of the system of ports for the recreational craft sector are two classes. The first class, named “Area for port facilities and services” (code: ST10TE01CL03) consists of polygons; its definition in the technical specifications is as follows: “the land area needed for storage, embarkation or disembarkation, management of port operations, [that] does not incorporate the portion of water area necessary

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<sup>2</sup> The shapefile “NodiTrasporti” can be downloaded at <http://webgis.regione.sardegna.it/scaricocartografia/CDPPR/AssettoInsediativo.zip> [last accessed: May 31, 2011].

<sup>3</sup> This information, however, refers to 56 structures, while a thorough analysis of the feature class “NodiTrasporti.shp” reveals that 46 points only can host pleasure boats according to the RLP.

<sup>4</sup> Technical specifications, metadata and the whole set of feature classes can be downloaded at <http://www.sardegneoportale.it/index.php?xsl=1598&s=140641&v=2&c=8831&t=> [last accessed: May 31, 2011].

for port operations,” and which therefore includes those areas that belong to ports and are used both for the exchange of goods and for passengers’ transits (Autonomous Region of Sardinia, 2009, p. 92). The second class, called “Port buildings” (code: ST02TE02CL09) contains “buildings pertaining to the inner area of a port” (Autonomous Region of Sardinia, 2009, p. 40), and it contains, in two separate feature classes, both polygons and points. In the attribute table, the field “01” (corresponding to “type”) gives information on the type of building.



*Figure 2. Multi-Resolution Spatial Database: Two examples of spatial data non-compliant with the ST02TE02CL09 and ST10TE01CL03 class definitions provided in the technical specifications.*

Given the definitions of the classes provided in the technical specifications, all the items belonging to the second class (that is, port buildings) should be contained within entities (polygons) belonging to the second class (that is, areas for port facilities and services); the

latter, according to the same definitions, should not have any water area. Failure to comply with both conditions (as shown in Figure 2) does not allow for the immediate re-use of data contained in MRSD, which describe the island's system of ports only in a partial way and not without contradictions.

The sixth source of data is the thematic website of the Sardinia Region dedicated to the tourism sector, which contains a section devoted to marinas.<sup>5</sup> The site, which aims at providing sailors and yachtsmen with information, summarizes in 58 web pages data concerning as many structures for pleasure boats; some of them are geographically referenced and superimposed on satellite imagery by means the geo-visualizer "*Sardegna 3D*."<sup>6</sup> By analyzing data contained in the above mentioned web pages, it is possible to quantify the total regional supply of berths in the 58 facilities listed in 14,795. Finally, a number of websites specialised in providing sailors with information (for instance on the number of berths and on available services) were also analyzed.

## ONTOLOGICALLY APPROACHING DATA INTEGRATION

The attempt to build a complete picture of the current system of marinas and other structures for pleasure boats by collecting and integrating data and information from different sources shows that a number of inconsistencies occur, and this happens because of various reasons, the most important of which are as follows:

- mismatch caused by differences in date of production and updating of information: as far as infrastructures are concerned, given the absence of closure down of any Sardinian ports, the most recent sources of information should list a number of port facilities not smaller than that of older sources, but this is not always true;
- different aims of documents and sources investigated: some (*e.g.* 2004 feasibility study) aim to provide information to public decision-makers to support them in programming financial investments and choosing which projects are to be funded, and are therefore strongly oriented towards infrastructures, especially to publicly owned infrastructures; others (*e.g.* geographic databases of the RLP and MRSD) are designed to store, analyze and retrieve data related to physical geographical objects and characteristics of places and to support the making of urban and regional plans; others (*e.g.* Internet web sites) address

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<sup>5</sup> "*Sardegna Turismo*" <http://www.sardegnaturismo.it/offerta/mare/porti.html> [last accessed: May 31, 2011].

<sup>6</sup> "*Sardegna 3D*" <http://www.sardegna3d.it/navigatori/sardegna3d.html> [last accessed: May 31, 2011].



the boaters and focus on services available in port areas. As a result, not only do the sources describe facilities for recreational boating in relation to different aspects, but also some sources neglect to analyze those ports or facilities not deemed of interest;

- semantic ambiguity, a characteristic of natural language that can be observed in the different classifications of the elements of marinas, in which the same term can be used to refer to two different things (polysemy) or, conversely, two different terms can be used to the same object (synonyms). The polysemous word *approdo*, for instance, is polysemic in this context. Article 2 of the DPR no 509 of 1997 classifies the structures dedicated to pleasure boats in three categories (see note 1), out of which *approdo* is the second, defined as a portion of port facilities dedicated to recreational boating, which may or may not also provide services to yachtsmen. The second national report on recreational boating, while maintaining the three conceptual categories of the decree, uses a different terminology in order to be able to integrate the criteria of the DPR with the information from “*Pagine Azzurre*,” the most prominent Italian producer of nautical maps; the three categories thus become respectively “marina,” “multi-purpose ports” (further classed into three groups) and “minor mooring facilities” (further divided into three groups, the first of which is named *approdo*). Therefore, while *approdo* in the definition of the DPR is a portion of a multi-purpose port reserved for recreational boating, in the national report is a type of minor mooring facility consisting of “temporary structures, often not protected from weather conditions and mainly used to get off the boat and for short-term parking needs.”

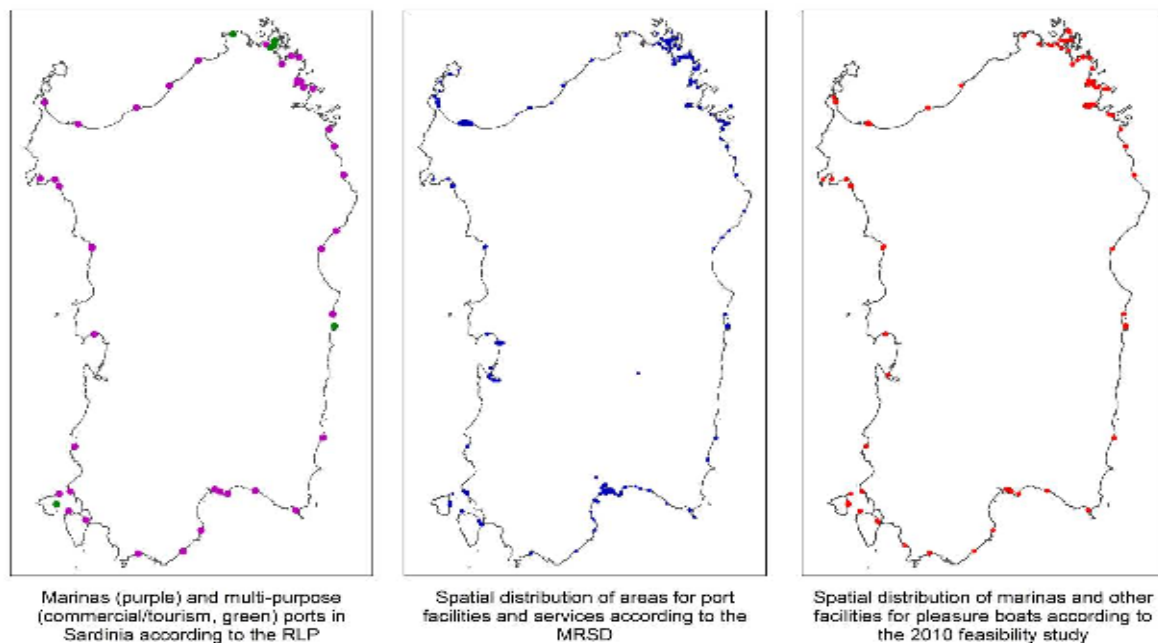
The attempt to depict the geographical structure of the system of Sardinian marinas by reusing existing information cannot, therefore, be successful by simply integrating available data and information, since they differ with regards to both structure<sup>7</sup> and semantics. As an example, Figure 3 shows three different pictures of the spatial distribution of the island’s port system that can be obtained from three of the sources here investigated.

Several authors (for instance, Murgante, 2011) have emphasized that while until not long ago the main problem in knowledge building was the lack of adequate information, today there are plenty of available data, both spatial and non-spatial, so much so that the proliferation of data sets built in the absence of common standards has become an issue when it comes to

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<sup>7</sup> For instance, some pieces of information are available as digital data, while some are not. Among digital data, some are geographically referenced; geographically referenced data can differ with regards to the essence of the object being represented: for instance, the RPL’s data set contains *ports*, while the MRSD contains *areas for port facilities and services* and *port buildings*, not “*ports*” per se, which leads to different conceptualizations of the objects, with reference to both geometries and descriptive attributes.

sharing and re-using existent information. Homogenization of data and resolution of semantic conflicts are, therefore, crucial to ensuring that data from different sources be properly integrated (Mizen *et al.*, 2005). This integration is generally referred to as “interoperability.” According to Noy and McGuinness (2001), one of the most important reasons that spurred research on ontologies was the need to reuse existing knowledge. Ontologies, in the context of artificial intelligence, do not deal with “the specification of what exists and what does not exist, but rather with the creation of a data set that contains concepts related to the domain under inquiry” (Las Casas and Scardaccione, 2008); in other words, they tackle the problem of describing a given domain of interest by identifying key concepts that define the domain, relations that connect the concepts, and existing constraints, thus making possible both formalization and knowledge sharing within the given domain. For this very reason, the ontological approach is now also used to support the modelling of spatial databases (Schuurman, 2006).



*Figure 3. A comparison between the spatial representation of marinas and other ports for pleasure boating according to the RLP (left), areas for port facilities and services as depicted by the MRSD (centre), and facilities for recreational boats according to the 2010 feasibility study (right).*

Many are, in the field of artificial intelligence, the definitions of the word “ontology” proposed in the literature (Winter, 2001). As Cagliioni and Rabino (2006) observe, there is no single definition, and conceptual definitions “that regard ontology as a reference system for knowledge” coexist with “others, more operational, which lay the grounds for their actual

construction, development and use.” One of the most used and most cited definitions is that of Gruber (1993), for whom an ontology is an “explicit specification of a conceptualization”: this conceptualization, or in other words the construction of an abstract and simplified conceptual model of a given object, or phenomenon, or process represented by the ontology is explicit because each concept, relationship and constraint is explicitly defined. The subsequent definition by Studer *et al.* (1998) (“formal, explicit specification of a shared conceptualization”), enriches Gruber’s one with two additional requirements: first, an ontology should be formal, that is machine-readable; in addition, the conceptual model of the object being represented needs to be agreed by a group of individuals (Agarwal, 2005), and therefore consensus of members of a given community is necessary (Murgante and Laurini, 2008).

#### AN ONTOLOGICAL REPRESENTATION OF THE SARDINIAN NETWORK OF PORTS FOR PLEASURE BOATS

For the construction of an ontology of the domain of infrastructures and facilities for the recreational craft sector guidelines and methodological documents produced by the Ordnance Survey (Kovacs *et al.*, 2006, Hart and Goodwin, 2007, Hart *et al.*, 2007) have proven to be very helpful. According to these guidelines and documents, the process must begin with the identification of the purpose of ontology (*i.e.*, the specification of needs and requirements for the development of the ontology, by asking the question “what is this ontology going to be used the for”?) and the definition of its scope, that is a decision on what is going to be included in the ontology and what needs to be left out. An ontology domain, in fact, must not be comprehensive, meaning that it should not include all those entities that somehow relate to the domain; on the contrary, it should include only those concepts, relationships, constraints that are relevant, the only ones that are deemed necessary to meet the goals set at the beginning. With reference to the first point (*i.e.* the purpose), the ontology here proposed aims to develop a conceptualization of the network of marinas in Sardinia that can be used for the modelling and representation of spatial information domain and that can support planning processes. As far as the second point (*i.e.* the scope) is concerned, the domain is here restricted to those elements of the port system that can be put on a map. Moreover, being a domain ontology, the one here proposed must allow for the modelling of concepts and relationships in an abstract way, so as to guarantee that the ontology is reusable within the domain. This is precisely a key aspect that distinguishes domain ontologies from other types

of formal ontologies with a lower level of abstraction, developed to define specific processes and activities (such as, for example, task ontologies, or application ontologies), and therefore not easily reusable. Once defined aims and scope of the ontology in this way, the next step is the preparation of a glossary, in which key concepts (defined in the above cited documents as “*core concepts*”) are listed and defined in Italian, by using natural language, and are separated from the so-called “*secondary concepts*,” which are those concepts that, although necessary for the description of the key concepts, are not strictly part of the domain because of the way the scope has been defined. In this phase, relationships between concepts are identified and defined, again in Italian, by using the natural language only. Core and secondary concepts were defined on a documentary basis, by analyzing relevant national legislation on the subject (such as State Law no. 84 of January 28, 1994 titled “Reorganization of port legislation,” or the aforementioned DPR no. 509 of 1997), technical documents (such as the “Technical recommendations for the design of marinas,” produced by the Italian Section of the Word Association for Waterborne Transport Infrastructure, PIANC-AIPCN), and Italian dictionaries.

With regard to relations, a second glossary was compiled; in addition to the traditional taxonomic (“*is a*”) and mereological (“*is part of a*”) relationships, this glossary lists also a series of spatial relations chosen among those contained in some ontologies already developed by the Ordnance Survey.<sup>8</sup> The process led to the creation of two tables, one containing concepts (an excerpt is shown in Table 1) and one containing relations (an excerpt is shown in Table 2); for each element, in these tables its definition in natural language is given together with the source of the definition and in some cases of a list of synonyms (the latter for concepts only). The use of such sources ensures that definitions here introduced are shared among domain experts.

Despite being an explicit and shared specification of the entities that constitute the abstract and simplified domain model here developed, the glossary does not constitute a formal specification yet. For this reason, further steps are needed to turn the ontology (which, at this stage, is still a conceptual one) into a formal, machine-readable ontology.

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<sup>8</sup> These ontologies are available at <http://www.ordnancesurvey.co.uk/oswebsite/ontology> [last accessed: May 31, 2011]. In particular, relations contained in the module “Spatial Relations” and in the domain ontology “Building and Places” were used.

For computational aspects the software program Protégé was used; the software allows for the introduction of concepts in a hierarchical structure, divided into classes and subclasses on the basis of the taxonomic relationship “*is a*.”

Original italian	Concept		Definition (natural language) <sup>9</sup>	Source
		Tentative translation in English		
<i>Approdo turistico</i>		Landing place	A portion of a multi-purpose port dedicated to recreational boating, which may or may not also provide services to yachtsmen and host Ancillary activities.	DPR no. 509 of 1997
<i>Area a servizio portuale</i>		Area for port services and facilities	Land area needed for storage, embarkation or disembarkation, management of port operations, that does not incorporate the portion of water area necessary for port operation. It includes those areas that belong to ports and are used both for the exchange of goods and for passengers' transits.	Technical specifications of the MRSD
<i>Banchina</i>		Quay	Structure of a port that serves, together with piers and pontoons, to let passengers on or off a boat or to moor the boat. A quay defines the inner border of a port basin.	Technical recommendations for the designing of ports for pleasure boats
<i>Pontile</i>		Pier	Structure of a port that can be fixed or floating and that serves, together with quays, to let passengers on or off a boat or to moor the boat.	Technical recommendations for the designing of ports for pleasure boats
<i>Porto commerciale</i>		Commercial port	Port for the movement of freights and passengers.	IL Grande Italiano di Aldo Gabrielli
<i>Porto di categoria I</i>		1 <sup>st</sup> Category port	Port for national security and military defence.	State Law no. 84 of 1994
<i>Porto di categoria II, classe I</i>		2 <sup>nd</sup> Category, 1 <sup>st</sup> class port	Port that is relevant at the international level.	State Law no. 84 of 1994
<i>Porto di categoria II, classe II</i>		2 <sup>nd</sup> Category, 2 <sup>nd</sup> class port	Port that is economically relevant at the national level.	State Law no. 84 of 1994
<i>Porto di categoria II, classe III</i>		2 <sup>nd</sup> Category, 3 <sup>rd</sup> class port	Port that is economically relevant at the regional or trans-regional level.	State Law no. 84 of 1994
<i>Posto barca</i>		Berth	Part of a port's water basin, adjacent to a quay, a pier or a pontoon, where boats are moored.	Technical recommendations for the designing of ports for pleasure boats

Table 1. Table of the concepts: an excerpt.

To say that an element belongs to a subclass of a given class is tantamount to say that the given element belongs to the class and therefore inherits its properties. In this way, key concepts identified in the previous phase were first organized in taxonomic order according to the classes and subclasses, and for each class and subclass the corresponding definitions (taken from the glossary) were added. For example, the class “Physical elements” includes

<sup>9</sup> Since the definition is translated from Italian sources into English, some semantic imprecisions in English are inevitable. As we understand, the meanings of some English terms (for instance quay, pier, wharf) overlap in some aspects, while the original Italian are unambiguous. For this reason, the ontology here proposed is language-dependent and would not work in English.

subclasses such as “Area for services and facilities,” “Docks,” “Berth,” “Pier,” “Breakwater.” For each of these subclasses, whose definition and source of information contained in the glossary were introduced in Protégé by means of appropriate forms, the relation “is a” holds true. This means that the statement “the docks is a physical element of a port” holds true in the domain here investigated and represented. Similarly, for each of the other classes the corresponding subclasses have been identified.

Once the taxonomic structure of classes and subclasses (whose number of tiers varies depending on the class) was built within the software, a number of slots were defined and created for each class and subclass. Slots can be used to characterize the elements of a class by means of attributes of various types (*e.g.* textual, numerical, enumerated), or they can be used to describe the relationships between instances, defined as the entities belonging to a class or subclass that constitute the basis of the hierarchy.

Relation	Definition of the relation in natural language	Notes
Is a	A an instance of B.	
Is part of	A is a part of B.	“Is part of” is inverse of “Has part”
Has part	A has B as part.	“Has part” is inverse of “Is part of”
Contains	A completely contains B (where A is a human created legal entity or similar such as a county).	“Contains” is inverse of “Contained by”
Contained by	A is completely within B (where B is a human created legal entity or similar such as a county).	“Contained by” is inverse of “Contains”
Does not overlap	A and B do not share any physical portion.	Symmetric relation
Is adjacent to	A is positioned such that it physically touches B.	Symmetric relation

*Table 2. Table of the relations: an excerpt (largely based on relations belonging to ontologies developed by the Ordnance Survey and available at <http://www.ordnancesurvey.co.uk/oswebsite/ontology>).*

For instance, the class “Port” was given eight slots whose labels are as follows “Port name,” “Port category,” “Port city,” “Management,” “Operator,” “Available berths,” “Has use,” and “Contains.” “Port name,” “Operator,” and “Available berths” are alphanumeric descriptive attributes; the first and the third are mandatory and have single cardinality, while the second is optional, since to correctly identify the operator is not always possible, and has multiple cardinality because a marina can be operated by more than one operator. “Management” is also a descriptive attribute, but its type is enumerated (that is, it can take only one of the default values, in this case “Public management,” “Private management,” or “Public-private management”).

“Port city” is a mandatory descriptive attribute whose type is enumerated, too, but, unlike the previous one, it has multiple cardinality, as it can take one or more default values (because a port can belong to more than one municipality, although this happens only in a very few cases), and allowed values are only those in a list that contains the names of Sardinian coastal municipalities. The remaining slots, that is “Port category,” “Has use,” and “Contain,” explicitly formalize spatial relations between entities belonging to the class “Porto” and classes “Category,” “Usage,” and “Physical elements” respectively.

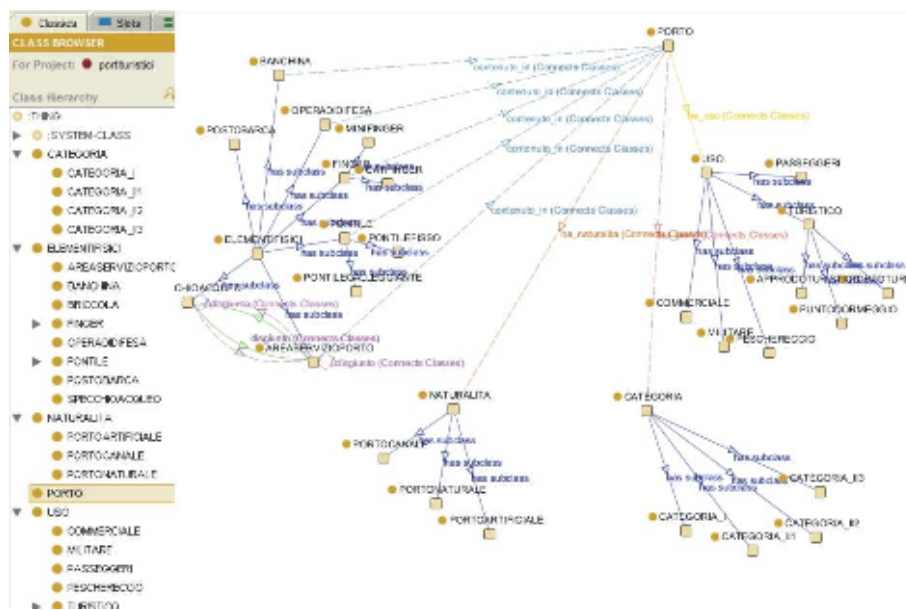


Figure 4. Classes and subclasses of the domain in Protégé (original, in Italian).

As an example, the slot “contains” has an inverse slot, “Contained by,” which accounts for the relation defined in Table 2; it is assigned to the class “Physical,” and it is inherited by almost all its subclasses (apart from the subclasses “Berth” and “Docks”). This means that, if the relation “Contains” between an instance of the class “Port” and an instance of the subclass “Pier” holds true, then the relation “Contained by” between the given instance of the subclass “Pier” and the given instance of the class “Port” holds true, as well. As a further example, the relation “Does not overlap” makes explicit the relation between entities belonging to “Area for services and facilities” and “Berth,” both subclasses of the class “Physical elements” since the first, according to the definition given in the glossary, comprises land area only, while the second is a portion of the port’s water basin enclosed within the breakwaters: this means that entities belonging to the two subclasses may not have any areas of overlap.

The construction of the ontology continues with the creation of instances and the filling of the values of the slots, and it is done by entering these values in appropriate forms that prevent

users from including values that are inconsistent with the ontological hierarchy previously defined. Once created the instances, the ontology is fully defined, and it can continuously be updated; the ontology can also be represented graphically as a graph tree (Figure 4) in which classes, subclasses and instances are represented as nodes, and relations by arcs. The graphs are customizable, meaning that the user can choose whether to display all of the ontology or just a part of it, by selecting the nodes or filtering the relationships that the user wants to be displayed; this feature can be very useful to explore extremely complex ontologies.

The formalization of the ontological domain allows to achieve several objectives related to the issue of spatially representing the regional system of marinas and other facilities for recreational boating.

First, it allows for a better understanding of the domain of interest (Uschold and Gruninger, 1996), thanks to the setting up of an iterative and continually adjustable learning process, which could include collaboration and participation of experts in the domain field, rather than relying on documentary sources only. Such a collective conceptualization of the domain would also greatly improve the chances of sharing and reusing the ontology in the domain field.

Second, since the ontology here proposed is a domain ontology, which seeks to represent and communicate knowledge on a certain area of interest regardless of potential applications, it is reusable, it can be updated and refined within the given domain (Agarwal, 2005), and it can lay the bases for the development of task-dependent or application-oriented ontologies in the same domain.

Third, the construction of a vocabulary that explicitly and unambiguously defines entities of the domain and the relationships between them helps reduce semantic conflicts (Las Casas and Scardaccione, 2008), and therefore makes it possible to address those problems of semantic heterogeneity that have been highlighted in the analysis of available data pertaining to marinas and facilities for pleasure boats in Sardinia.

Finally, the ontological representation of the domain on the one hand facilitates the modelling of the geographic database, since classes, subclasses and their descriptive attributes are defined within the ontology, and on the other hand makes easier to control spatial constraints, since these are defined within the formal ontology as slots that explicit spatial relations between classes.

As an example of the latter point, let us consider the classes “Area for services and facilities,” “Docks,” “Breakwater” and “Pier,” all of which subclasses of the “Physical elements” class. The relationships between these subclasses, introduced in Protégé at the slot level and already

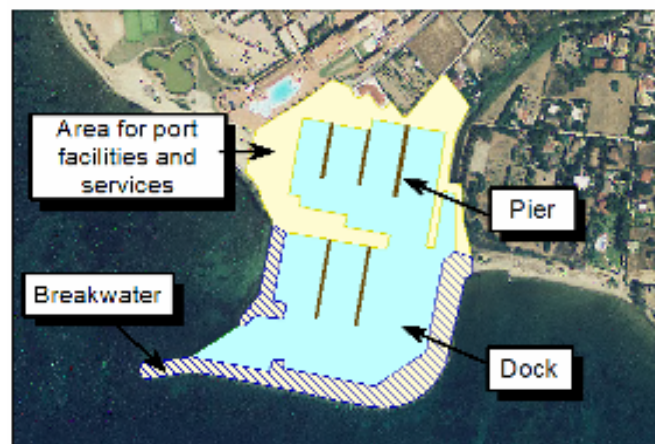


defined in the glossary (Table 2), are listed in Table 3. The fulfilment of these spatial constraints can be verified by means of spatial queries performed on the database that contains such elements organized in feature classes that follow the rules identified as relations within the ontology domain.

Class "A"	Relation	Class "B"
Pier	Contained in	Area for services and facilities
Breakwater	Contained in	Area for services and facilities
Docks	Does not overlap	Area for services and facilities
Pier	Does not overlap	Breakwater

*Table 3. Relations among some subclasses belonging to the domain.*

Figure 5 shows, superimposed on an orthoimage, entities belonging to the four above mentioned subclasses and pertaining to an instance of the class "Port" named "Marina di Capitana."

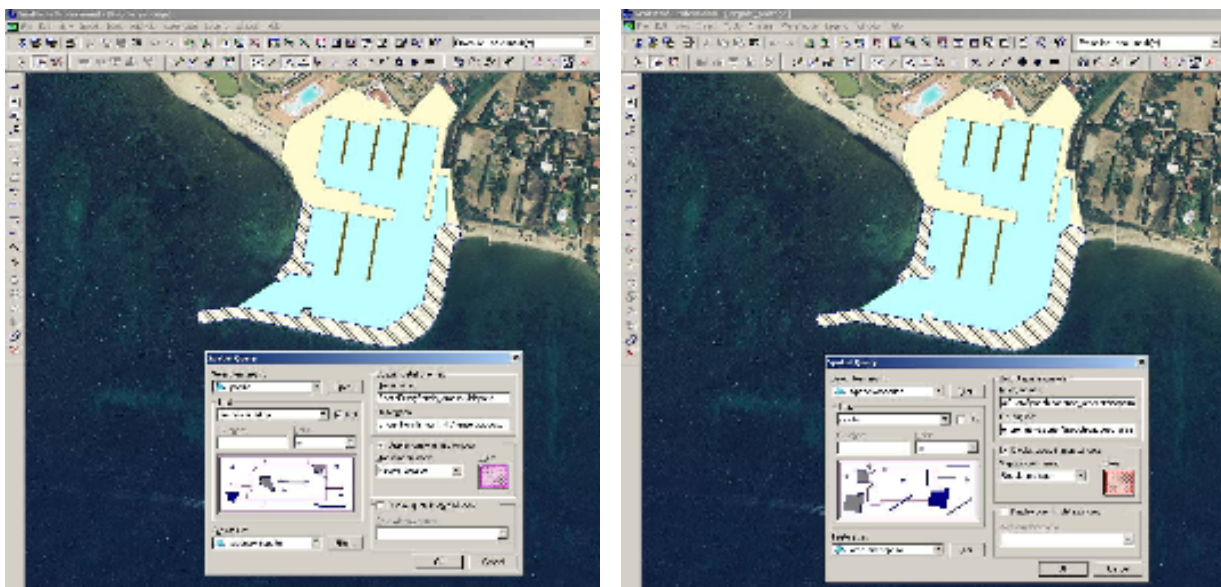


*Figure 5. "Marina di Capitana" (a marina on the south part of Sardinia): spatial representation of physical entities belonging to the following subclasses: "Area for port facilities and services," "Pier," "Breakwater," "Docks."*

Figure 6 presents two screenshots of the GIS software used to build the spatial data set containing elements of Sardinian marinas and other facilities for yachts and recreational boats. These two pictures show how it is possible to check that entities comply with spatial constraints corresponding to the relations defined within the ontology; the GIS software here used makes it possible to build dynamic queries, that is, queries whose result is not a static feature class, but an on-the-fly representation of entities that meet the conditions set by a query; this way, the result of the query is automatically updated whenever a change in the

feature classes (for instance, the creation or deletion or geometrical modification of an entity) being queried is made.

In the first picture (Figure 6, left) the relationship under scrutiny is that defined between entities belonging to the subclasses “Pier” and “Area for services and facilities”: the software is able to look for and display in real time (both in the view window and in the table window) all the objects belonging to the feature class “Pier” that are not contained within an object belonging to the feature class “Area for services and facilities” and are therefore not compliant with the spatial constraint imposed, or, in other words, for which the relation defined in the glossary and introduced in Protégé as a slot does not hold true.



*Figure 6. Form that allows to check that entities are compliant with the relation “Is contained by” (left) and “Does not overlap” (right).*

In the second picture (Figure 6, right) the relationship under scrutiny is that defined between entities belonging to the subclasses “Docks” and “Area for services and facilities”: again, the software is able to look for and display in real time (both in the view window, and in the table window) all the objects belonging to the feature class “Docks” that overlap at least an object belonging to the feature class “Area for services and facilities” and are therefore not compliant with the spatial constraint imposed.

## CONCLUSIONS

The European Parliament, with its resolution on a European ports policy,<sup>10</sup> has stated that “marinas are not only a showcase for their hinterland, and a powerful tool for promoting the exploitation of the port and its environs, but also an essential supply service for local businesses” (paragraph 46); their harmonious development and mutual cooperation therefore benefit the development of a region provided that some requirements elsewhere cited by the resolution are met, first and foremost the interconnection among ports and their connection to land and air transportation networks. In Sardinia, a fundamental element of this connection and interconnection, that is a plan for the regional network of marinas and other facilities for boating, is still missing. Since such a plan must start from a study of the current situation, the collection and reorganization of existing information and data is a key point. This paper has therefore attempted to outline a possible answer to the issue of re-organising available information as a prerequisite for a correct spatial representation of the network by putting forward a methodological proposal for the proper integration of data, be they spatial or not.

Still valid are some provocative questions posed by Winter (2001) who, commenting on the growing utilization of the term “ontology” in Geographical Information Science, wonders whether the word “ontology” is a buzzword, a different and perhaps more appealing way of presenting familiar concepts and practices, or whether we are in front of a real paradigm shift, a powerful tool that could actually help solve the problems of interpretation and interoperability of spatial data.

In this paper, an attempt has been made to show how the use of ontologies can contribute towards the achievement of two goals. On the one hand, this ontology helps deepen and better organize existent knowledge concerning a given domain (in this case, that of Sardinian marinas and pleasure boats) by formalizing the conceptualization of the domain through the construction of a glossary that makes use of a shared language. On the other hand, by making the spatial relationships between defined classes and subclasses explicit, it helps ensuring that spatial entities are compliant with tests designed on the basis of the relationships themselves.

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<sup>10</sup> “European Parliament resolution of 4 September 2008 on a European ports policy” (2008/2007(INI)), published on the Official Journal of the European Union C295E:74-79 of December 4, 2009, available at: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:C:2009:295E:0074:0079:EN:PDF> [last accessed: May 31, 2011].

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