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**Conference Paper**

## Ontology of multi-agents processes of spatial decision

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## ONTOLOGY OF MULTI-AGENTS PROCESSES OF SPATIAL DECISION

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### ABSTRACT

In the paper of Cavezzali, Girotti and Rabino presented at ERSA 2003 conference, features of multi-agent models and their potentiality for the study of territorial phenomena are discussed. Starting from this study, the present paper digs deeper mechanisms of multi-agent systems working, describing their ontology in a more complete and articulated way as possible, and investigating: the properties of the actors, the mechanisms of interaction among actors and between actors and environment. About the environment, particular attention has been paid to the consideration about the various modalities of treatment of territory (from pure physical support to active reactive/cognitive agent in relationship with the other agents). For these modalities, finally, two typical case-studies of multi-agent model are shown: simulation of pedestrian paths choice, the software “*Turisti*”, and a competitive dynamic of service centres location, “*Wilson*”.

## **1. Introduction**

In the study of natural and social phenomena you can easily observe which are defined as group behaviours: different elements that interact with each other till to create a single element. To describe these systems we consider them composed by elements, as agents, and environment, in which the agents live and move.

The agents are fundamental elements of the system, exactly named multi-agent systems, the agents act and interact (with each other and with the environment) and eventually can modify their behaviour on base of the learning level and the knowledge they are provided.

In the first part of our work we'll try to define the multi-agent systems ontology, in other words we'll get into the descriptive detail to analyse the agent properties, their interaction mechanisms both between agents and agents and environment.

Multi-agent systems imposed themselves thanks to versatility characteristics and support of numerous develop software that allowed the scientific community to run many experiments based on these models. Among these protocols we indicate Swarm, realised in the Santa Fe Institute; we realised our applications using this protocol.

Finally we present two software realised, named "*Turisti*" and "*Wilson*", by them we can show multi-agent systems potentiality and capability to get into the descriptive detail of apparently simple phenomena too, like, in our analysis, a tourist movement or a commercial centre evolution.

## **2. Ontology of multi-agent processes of spatial decision.**

The multi-agent systems allow to face the problem of group behaviour through the study of individual elements that made up the system, the agents, and the environment where they live and move: the agents act and interact (with each other and with the environment) and eventually modify their behaviour on base of the learning level and the knowledge they are provided.

The systems studied have the peculiarity to trascend from the ability of each individual that that is included in the system itself: in many cases behaviours reliable and effective are highlighted from simple interaction rules between system elements. For the description of these systems is required a punctual description of the world that we are analyzing, isn't possible to use descriptions like "black box" or to neglect the least detail of the reality, object of the study. The models are very versatly, they represent, for their characteristics, an answer to the requirements of flexibility, adaptability and computation possibilities.

When we require to a model to be versatly, we intend to demand, to the model realized with a computer, the possibility to do tests about hypothesis, to explore new theories and to build wider and more complex worlds compared with the initial ones, instead of reformulate the problem from the beginning.

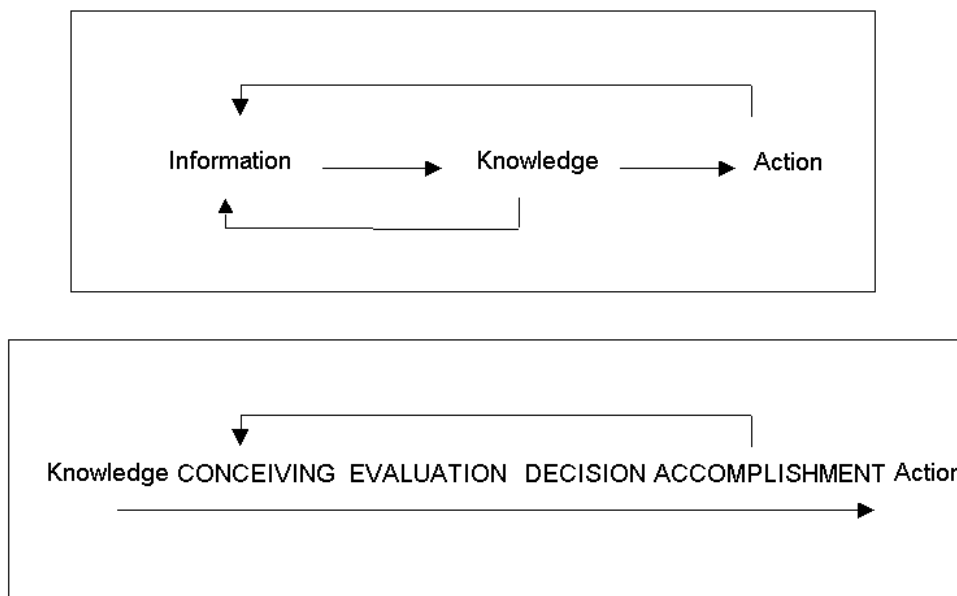
These models give the possibility to do complex mental experiments, but they allow also to face different aspects of the reality compexity.

We define a "complex system" when the addiction of subject behaviour produces non-linear effects (or unforeseeable or unpredictable) compared to the single elements.

The complexity implies all those relations that are not evident nor expressible with physical or mathematical terms, that connects each other entities of a system and the same systems with other; maybe is right to think, like to assert Morin (Morin E. "La Méthode (1): La Nature de la Nature") that "whole is in the part that's in the whole", and we can suppose that put borders to the study imposes the introduction of many simplifications that send away from understanding of phenomena.

Complexity principle appears in the multi-agent systems and represents the overtaking of the paradigm of the simplification so far ruling in our culture.

Speaking about multi-agent systems ontology could appear in contradiction with the criticism to the reductionism introduced by the definition of complexity, but the real meaning is different: defining an ontology allows to give a logic to understand the meaning of this model, joining formal and substantial process of the model.



**Figure 1 - Ontology of perception-action process**

In the classical philosophy, the ontology is the science that studies an human being like that's, applied to the computer science discipline ontology allows to categorize different entities of the system. The explanation of the model ontology allows to investigate the complex relations between system properties (phenotype) and system structure (genotype): it assists the investigation of typical themes of the study of multi-agent systems. Besides a phenomena complexity

analysis, multi-agent systems look for connectionism and individual-organisation relation too.

In the systems studied, the absence of a rigid hierarchy among the system elements is pointed out, relations among individual agents are mainly functional, and produced by the necessity to complete a task, but subject to variations too that don't reflect typical hierarchic logic: this doesn't imply total absence of dependence relation among agents or groups of agents but only the absence of rigid task structure. This idea drives to connectionism concept, that signifies the presence, merely from a logical point of view, of a "network" structure where there isn't a centre a priori defined of system organization, centre that instead appears with system structure evolution.

The other important theme investigated by multi-agent systems is the relation between single individual and the organization. When we schedule an agent, this is considered an integral part of a system where there are other agents like it. Effect of many agents presence carries the organization definition as agents able to reach defined target (that many times can't reach themselves), but also as a result, often unpredictable, of agents coexistence in the system.

A multi-agent system consists of agent series (the active entities of the system), an artificial environment where agents live and many series roles, that control their activities.

The agent is the active and self-governing system entity and it has a particular behaviour and interaction rules. An agent is an element able to

- Act in an environment;
- Be in communication with other agents;
- Have the knowledge, even if it's limited, of the around environment;
- Become aware of other agents;
- Have own resources to catch target;
- Have ability available for other agents too;
- Follow interaction rules.

The description of these features allows to define the agent behavior: we will analyze this peculiarity studying the process able to catch information for the agent up to knowledge, till the real action. These passages, in sequential logic, have numerous feed-backs, sublevels that make the description more complex and not linear. In particular, when we speak of human behavior, we can't analyze these levels without think that the individual is able to develop these stages in more levels.

The agent is made of these parts, logically connected:

- The knowledge, that is the cleverness to understand the around environment;
- The resolution, that allows to put together the information and the own targets;
- The execution, that makes the action be true.

The surrounding environment is also an agent: the environment perception makes to act in consequence of the situation which is realized, in presence of numerous agents this situation becomes impossible to forecast and complex phenomena emerge, which the multi-agent systems would like to describe.

The analysis of the process perception-action is developed through 5 steps:

- The specific nature of the process phase;
- The realization mode (the rational aspects);
- The neuro-psychological aspects (memory, emotions);
- The intentionality of the action (relationship among purposes);
- The interaction among information, knowledge and action.

The agent can have several types of knowledge, it can have a conscious or unconscious knowledge, or it can completely ignore the situation; moreover it can be conscious of the own knowledge or be informed by default.

The interactions between the agents are of different types, and they depend mainly on their objectives and on the tools they need. When two agents have conflictual objectives, for example obtaining an agent target limits the satisfaction of other agents, their relationship is of pure antagonism; to the other side the

relations can be of cooperation, if the presence of other agents helps the target reaching, or of indifference, when other elements are not able to modifying the situation.

The interaction between the agents can be intentional, when the agents know that the cooperation could help them, or only deducible a posteriori from the user, through the number of interactions or communications made by the agents.

The communication can be sender-receiver, point-to-point, addressed only to one agent, if the receiver is known; instead it is broadcasting, if the receiver isn't known and the message is sent to all agents: therefore they will be the receiver able to recognize it and to act consequently. The communication is intentional, if it's a decision taken from the agent, or accidental, when it's made without wishes.

The communication happens through a media and, like in reality, the nature of media with which it is communicated is important: in the multi-agent systems the message can endure an attenuation (linear or quadratic) based on the distance, for this the agent has to find out the ideal position for being able to communicate and to receive information.

Finally, we can't forget to describe the system organizational structure that manifest itself in a real structure of the system; the typical structures are hierarchical and equal: first one is characterized from a flow of top-down orders, while in the second one all the agents participate in the equal way to the decisions.

The building of the multi-agent models is supported by object-based programming protocols and by reference outlines that clear the role of the agents, of the environment, of the interaction rules, and of the modalities of their modification.

The analysis of the relations of the agents with the available resources and the environment, permitted us not to consider the environment as a simple support grid to the agents anymore, but as a true agent. The consideration of the territory in this way, therefore, allowed us to describe much better the relations between the elements and the territory. Inside of the urban and regional planning, we are concentrated especially on the spatial simulation field; we have realized two



simulations, with the scope to show the abilities of an multi-agent system: “*Turisti*” and “*Wilson*”. These two models enclose different characteristics that permit to differentiate between them: “*Turisti*” shows delocalised agents, which interact with an virtual environment (representation of a real one), “*Wilson*” shows, instead, localized agents which change their characteristics in the time, with the system.

### **3. Turisti**

The “*Turisti*” software simulates the behaviour of tourists visiting a city, of which they don’t know the map a priori. This is the main characteristic of the model: the tourist-agent creates a geographic mental map by himself, while it crosses the places, which are initially unknown.

The movement considers the short information about the territory possessed by tourist: without knowing where his destination will be, it is not possible to formulate an algorithm of minimal distance. The scope of the simulation is to go over the gravitational concept and the limits of the estimation of the distances, and obtaining a qualitative analysis of the agent behaviour.

The model is composed of:

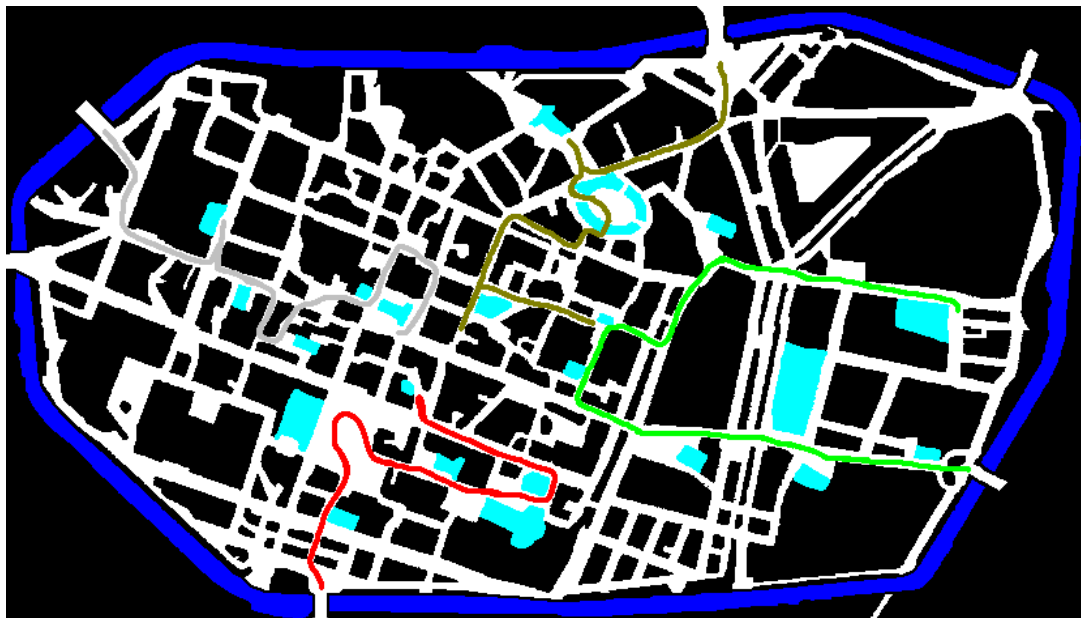
- An agent series, the tourists;
- a virtual environment, representation of a real one;
- behavioural rules;
- instruments of the system observation.

The simulation has been executed on the city of Lucca, a city estimated as ideal for our simulation because of the great aptitude to attract tourist and characterized by:

- historical center encircled by walls with 6 doors of access
- historical center closed for the automobile traffic;
- presence of 4 tourist ways;

- 22 points of attraction chosen between the numerous ones, offered by the city;
- 1 constant visual point of reference.

We have thought to choose like generic attractor, for the tourist without a map, a point that can be easily seen: the area between the two towers has been chosen as reference, because of the morphology of the city, it represents a constant reference.

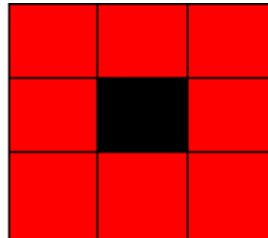


**Figure 2- The city of Lucca map, with the tourist attractors and ways.**

The tourist-agent arrives in the city center through the access doors and it is on a map in which the parts that can be walked on, the civil buildings and all the attractors are evidenced. During the temporal step of every simulation, agent moves to one cell, estimating the movement in a short range, the successive square on the grid: not knowing the map, the tourist cannot estimate the medium or long range.

The agent knows his own position constantly and it interrogates the physical map for having the characteristics of the surrounding territory; it values its

surroundings, corresponding to that defined in Moore theory, that's all the eight cells surrounding the agent.

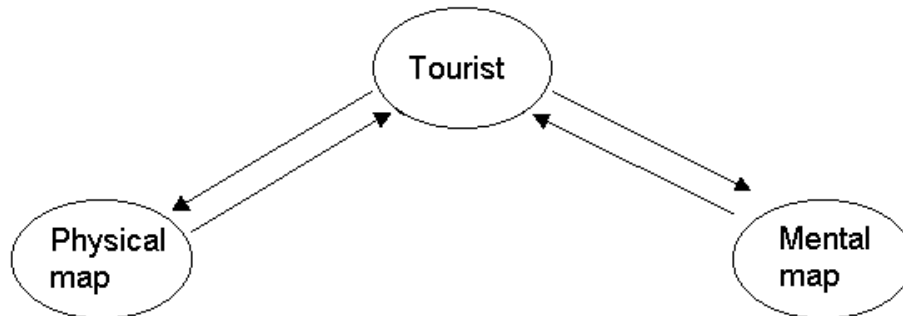


**Figure 3 - The surround analyzed by the agent in every step.**

In the surroundings analyzed, the tourist evaluates the cells which it can walk on, through the behavioral rules. When created it's characterized by:

- a value of visual amplitude, it evaluates if moving more times in the same direction it will meet obstacles;
- an objective to catch up that can be generic, for example if it wants to make a random visit of the city, or to see a precise list of places;
- preferential directions of movement depending on the visual reference;
- desire of giving continuity to the his movement.

These characteristics allow the agent to characterize the more suitable position for the next step, without excluding any point surrounding the tourist. Beyond to the reactive part of the agent behavior, there is a cognitive part that describes what the tourist knows about the territory: this one is characterized from the interrogation of the mental map, where the movement of the agent and its last behavior is recorded. The mental map is a second level map, not physical, that it serves to the tourist in order to "remember" its behavior.

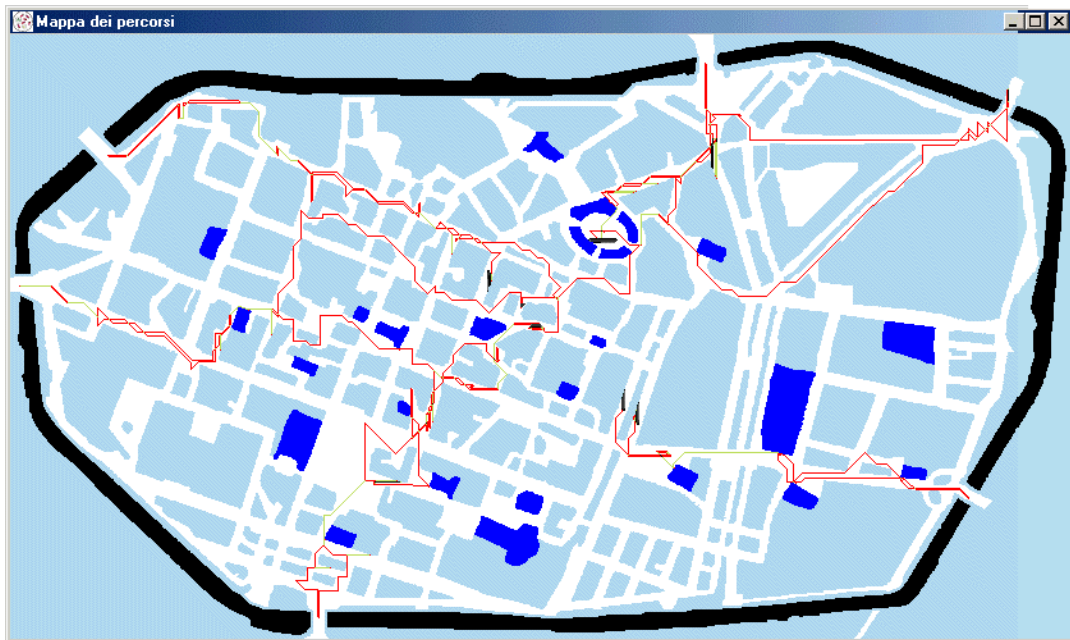


**Figure 4 - Interaction between agents and maps.**

The tourist perceives the presence and the characteristics of the surrounding agents, and if it has a common objective, it can adopt a imitative behavior.

The combination of these parameters allowed us to simulate the behavior of several tourist types:

- tourist completely “random”: it wants to visit the city but it doesn’t have any idea about how moving itself;
- Tourist with “generic” objective: it doesn’t have any specific objective, it has the barycentre of the two towers as visual reference, and it is attracted by what it meets;
- Tourist with route: when it finds a tourist route, it follows it and visits the places indicated;
- Tourist with a scope: it has as target to visit one or more places, but, without a map, it doesn’t know exactly where they are.
- Tourist with imitative behavior: it can have the characteristics of the agents analyzed before, but it’s inclined to follow the route more crowded by other agents, who can better guide it in the visit.



**Figure 5 - Tourists who move in the city of Lucca.**

#### **4. Wilson**

The “*Wilson*” model simulates the interaction between services supplier centres and users: their relationships meet demand and offer laws. Services supplier are centres that try to satisfy users requirements, changing their size in accordance with same users.

The territory is separated in homogeneous portions, where are both services and population, and we did experiments related to the Province of Milan.

The model consists of:

- A territory where the agents act;
- A big number of agents;
- Behavioural rules;
- Tools for system control.

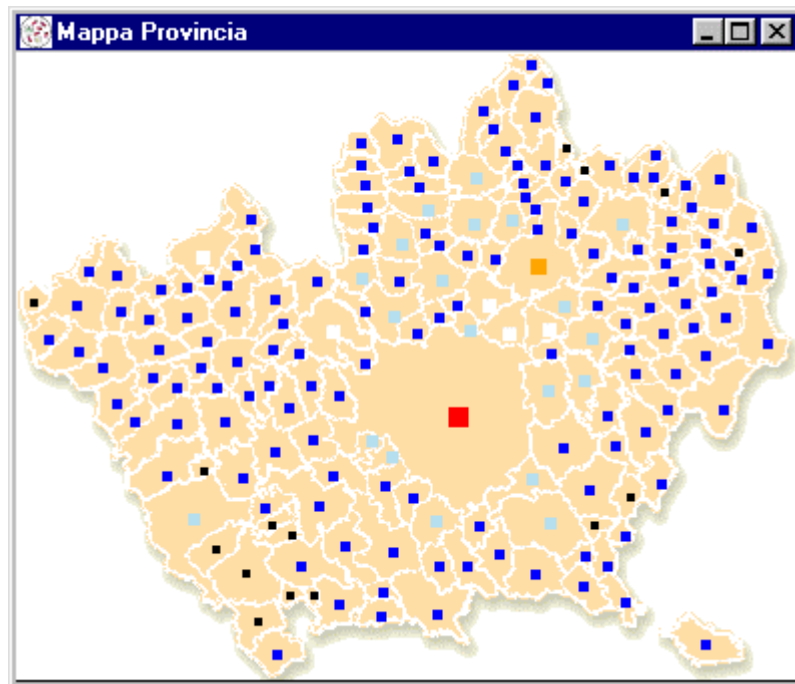


Figure 6 – Initial situation of the Province of Milan simulation

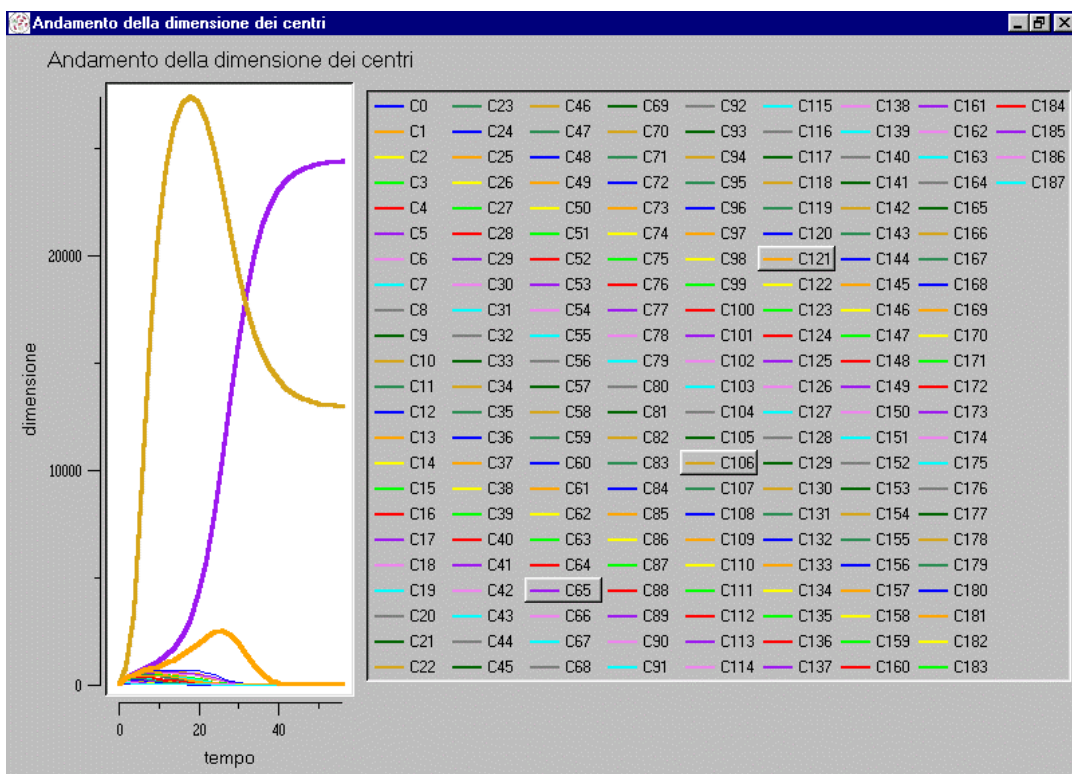


Figure 7 – Supplier centre size analysis

The main typologies of agents are:

- Services supplier centers, characterized by quantity of services provided in this area;
- Users, that are living in towns of the Province of Milan;

The interaction model among agents implemented was Harris and Wilson one (1978), in this model the centre distance is defined through a distance matrix in terms of time to go from a centre to another one.

Users can choose, step by step, according to their preferences and to services agglomeration, where approach to buy. The centre distance is a deterrent for his reaching while the growing size is a characteristic of attraction.

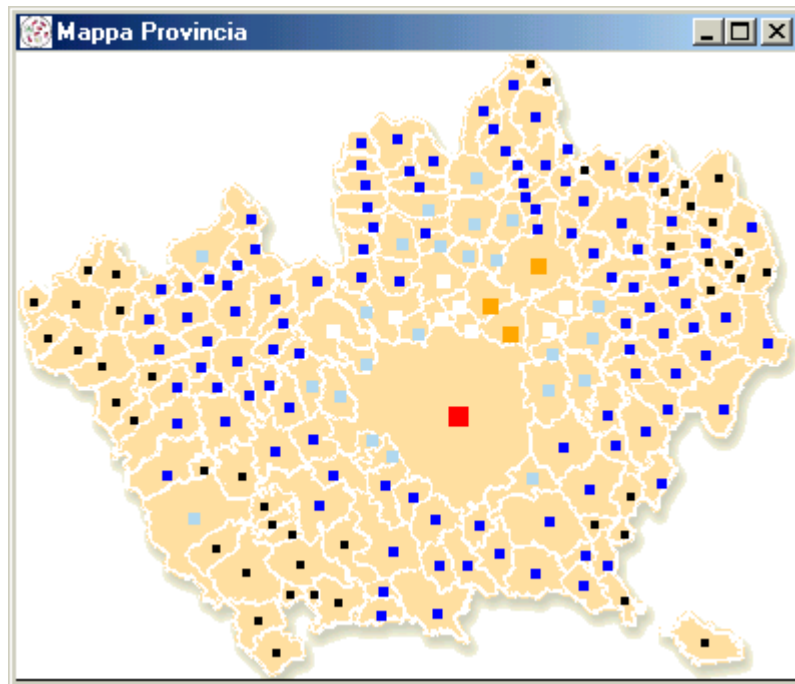
Services supplier centres react to users choices deciding, step by step, to grow up or reduce the size of activity in their area. The centres have a complete information of the system state, they know population and the matrix of travel costs: by this information, they can evaluate their size for the next time step. Agents characteristics make them like “reactive” agents: they value their situation and act accordingly.

The experiments ran can verify some existing theories about geographical organization of the retail trade in the Province of Milan territory. The Province is characterized by the central role of the capital, Milan, with a big number of inhabitants, the services users, and a lot of individuals, the services supplier.

With the parameters supplied centres, in particular the weight given to the centre size and to the distribution of run time, we can be able to:

- Reconstruct the current trend of trade structure map;
- Reconstruct the territorial reorganisation surrounding Milan;
- Observe the appearance of new polarities putting beside historical ones in the Province (Legnano, Abbiategrasso and Monza).

System evolution highlights results comparable with the results analysed in Lombardo and Rabino’s article (1989), with agents getting demand and offer equilibrium in a quasi-exponential path, and others following a humped path.



**Figure 8 - Example of system evolution**

## **5. Conclusion**

Capture the reality to create an active model means to propose, to oneself and to the others, a starting point of priceless value and rigour; to obtain this, it's necessary a lot of concreteness in the reality representation, avoiding excesses and stylized behaviours.

The definition of multi-agent system ontology, applied to our models allows us to get into analysed system descriptive detail. The creation of models “*Turisti*” and “*Wilson*” helps us to improve system descriptive ability, separating global characteristics from those of single agents that are described. Finally the models taught us to discover also the complexity that can be hidden under actions defined as simple by superficial observation.



The results obtained encourage the application of multi-agent systems to social, geographical, territorial and environmental models; to be able to analyse the territory like an active agent in a space and not only like a place where the agents interact, this is the real new deal to reach.

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