A Distributed Prototype Model to Manage Regional Competitiveness Simulation

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Abstract: We consider a multi-lateral, multi-scale perspective for building cooperative relationships that enhance competitiveness Regionally. Our modeling approach of this multidisciplinary domain is inspired with self-adaptive systems of systems. From this perspective the paper focus on the dynamics and highlights the prototype's architecture and implementation.

1 Introduction

The inland logistics is the most complex and the most important part of the whole supply chain. It is complex because supply chains develop in a moving of the spatial scales, in wanted services sophistication (just in time, requirements of distribution networks), in an unstable spatial competition (off shoring and back shoring of firms) and in more complex environmental requirements.

The aim of our work is not the analysis of the factors underlying differences in regional competitiveness. However we are more interested in the dynamic aspects. We need to understand why and how the complex networks notion of interaction is effective to elaborate models and simulations leading to an "intelligent" territory management. We will deal with a multidisciplinary approach specifically suited to the context of transport and logistics.

This paper will mainly focus on our modeling approach and prototyping. A short discussion will deal with decision-making. The approach concerns a System of Systems methodology whereby entity relationships are captured and defined along several dimensions involving multiple constituents and multiple domain concerns. A distributed business simulation game approach is used for prototyping the model.

In the following paragraphs, we recall the position of the problem as a system of systems. Then we propose its modeling through a serious game approach.

2 System engineering considerations

When thinking to all the stakeholders and the participants in the territory activities we can follow the approach given in [2] and look at the territory modeling such as an adaptive system.

The different stakeholders and participants exchange continuously information and goods can be seen such as an organization of autonomous proactive parties that have to take into account their environment and their tasks. They need to coordinate their activities and decisions and to act in real time. The challenge is to define a model as closed as possible to the reality and to simulate it.

We are interested in distributed systems that manage very large flux of information for the control of numerous large numbers of activities, assuring the coherence of each local activity with the global state of the system activities. We deal with self-adaptive systems where each local entity has autonomy in the way of strong coactivity with other entities to make the emergence of a coherent general state of the complete system [5]. This constraint of strong coherence between non-homogeneous entities leads to a fine control using the dynamic links between the actions of the local activities and the global situation, passing from actions of aggregation or recession of the local entities. The approach of adaptive systems appears to be consistent enough.

By the very nature of the industry, a multidisciplinary approach that also considers the economic and legal dimensions of this problem is appropriate and fundamental to understand the studied phenomenon. So certain study aspects require legal and economic reflections, and the integration of contributions from other disciplines (such as management, economy, tax system, competition, etc.) as well as understanding the legal requirements in transport, environment and customs, etc. Hence a multi-disciplinary approach will allow us to integrate several of these variable factors that impact the effective structure of such a complex system as presented in [1].

We can regard the core problem as the complex control of a complex system. The substratum (one region with a measure of autonomy, etc.) is a field where occurs an interconnected web of activities which gives rise to the production of multiple informative exchanges. It is also the place where diverse rules can be applied (economic, legal, etc.).

Diverse participants act within the framework of these rules but for their own needs and with rooms for manoeuvre. We are not studying this as a complex natural system, such as those governed by laws of the physics, and subjected to certain disturbances. In contrast, we consider a frame of reference where the entities have the freedom to act upon their own account and can be in outright conflict with other participants in the system (resources reason for example).

To simplify, it operates within this context of a living system that has to remain alive reaching a certain balance. The system is in continual evolution with respect to certain rules that are changeable and hence cannot be easily modelled by a classic model. By being alive, it reacts, readjusts and modifies its hypotheses through auto-adaptation.

3 Dynamic model of social organizations

To draw a model of social organizations (Friedberg 1993, Sibertin-Blanc 2010), we need to define a meta-model view as an abstraction expressing all the concepts and all the properties of the social organizations studied. We have to consider that some elements of the social organization are functional, strictly controlled, and that some other elements are rather autonomous with unpredictable behaviour, like human decisions. We have to consider that many components of the social organization are composed of elements and that composition is not totally stable but can evolve in some precise or imprecise cases.

The components of the model of this organization will express the actions, the movements, the decisions, the variations, and not only the fixed elements of the real.

That model takes into account the following elements:

- Basic elements
- Structures of basic elements
- Relations between basic elements and structures
- Human decisions of action
- Plans of actions and sub-plans
- Composed plans of action and interactions
- Relations between plans of action and decisions
- States of the situation

- Point of view and modifications of the decisions
- Evolution of the structures and organizations
- Stables states and bifurcations
- Etc.

One these elements, we need to have the following properties:

- Any element can be associated with another to define a new component having new properties.
- Any element can be expressed as an organization of more simple elements.

These algebraic properties must lead to the definition of a very particular model, where the abstract elements have strongly these properties of aggregation, union and decomposition.

We express the model of social organization as composed of elements having always a kind of autonomy: elements that are not reduced to fixed objects with reactive behaviour. In this way we use the proactivity fundamental concept because it allows unifying the abstract domain of social organizations.

Thanks to this approach, we can analyze the mass of information exchanges and transform these into knowledge. By highlighting the cognitive elements at diverse scales, we think we can give a representation of the state of the substratum with intervention onto the controllable elements.

In our approach, a self-adaptive system is a system composed of two different but strongly linked layers [6]. Figure 1 shows the two layers linked to the real world. The semantics and the knowledge of information entering into the system are expressed and evaluated for its tendencies. The description of these layers is:

- Operational layer is to interpret and manage inputs and the reactive effects as well as for logical and rational automatic actions.
- Distributed control layer is to represent the current action of the system in its environment, and also to control the operational layer according to a set of predefined general characteristics.

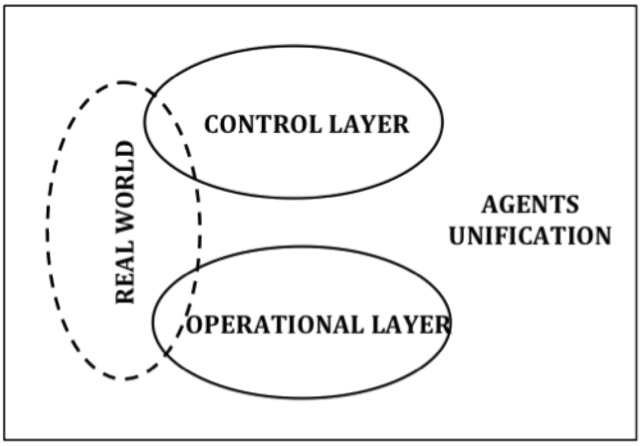

Figure 1. The two interactive layers

The system is active with predefined general goals and tendencies with the means of its structure. The control layer represents a precise description of the current situation generated from the flux of information. The information is analyzed by the elements of the operational layer with the objective to react under its good tendencies. This control layer is constituted of many entities in permanent action of reorganization, adapting it internally to make the emergence of the pertinent local actions to make on the environment, in the light of a coherent global action.

Such a system must continuously construct representations of the whole events of the environment according to reasons that will be of its own, according to its specific situation of action into this environment. The notion of representation, the internal distributed objects continuously constructed, that represents a general plan of action is declined into many sub-plans. It is fundamental. The notion of adaptivity is therefore considered in the strong way. In the system specification, the determinants of this representation allowing reaction into an adaptive way are defined first, according to the capacity of action of the system and to its general tendencies. They give precision to the very general goals of the system, its fundamental characters of regulation, choice or survival. The system has to solve many sub-problems under the focus of a general goal specified by the current representation of the situation. Then, the system conceives a representation of the real situation from the operational layer under some fundamental tendencies, it elaborates some local plans, generates a global and an unified plan of action using synthesis and emergence, and acts on-line, continuously analyzing the effects of these actions. The entire system interacting with the real world is shown in figure 2. It shows the link between the real world and the user. We use different organizations of agents to allow an on-line interpretation of the situation. The agents are obtained thanks to the agentification process. The interpretation is made thanks to morphological agents, another organization of agents [3].

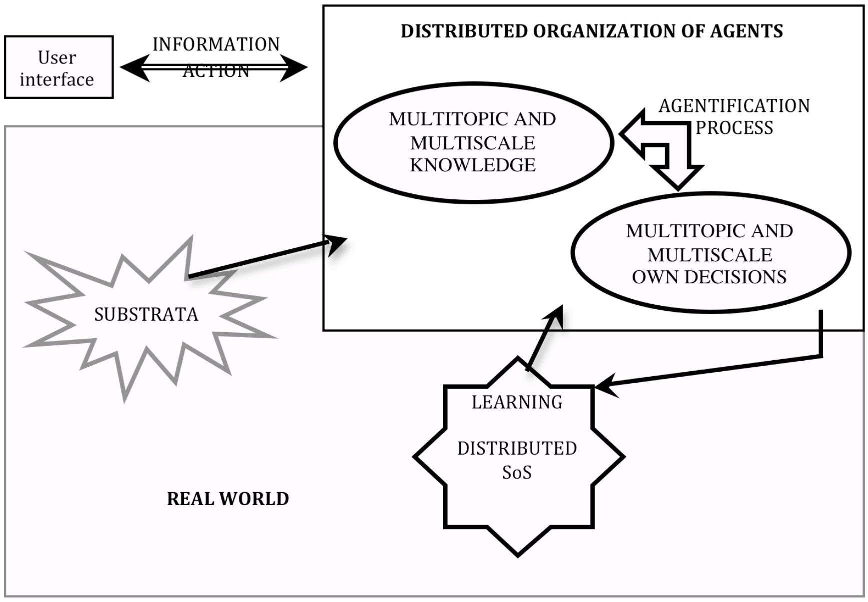

Figure 2. General architecture of the adaptive system

To construct such system, we need the decomposition into precise functional parts applying optimization functions. The reason is because the active parts have roles that evolve during the plans generation and the global situation has no stable state. The fundamental property of such system is the continuous re-organization of its operational layer that allows generation of on-line plans according to the general representation. For these reasons, the multi-agent paradigm is used at all specification levels of the system's architecture.

4 System of systems adaptive approach

We consider an adaptive system of systems and the problem of multi-scale control. The problem is to realize a real-time control according to global but multi-scale objectives of groups of heterogeneous local reactive systems varying in their behaviors, having possibility of exchange information about theirs states and behaviors to put them in a virtual self-adaptive network managing with coherence their behaviors (Keating and al. 2009).

Within the hierarchy of systems of systems we will focus on an open network of proactive systems: a new model with virtualization of the systems mapping the real reactive systems, with on-line control of the behaviors, links, aggregations of activities of groups of systems, management of the emergence of coalitions of actions for the global on-line pseudo-optimization of the activity of the set of proactive systems.

The basis for the construction of such a system is the agentification of the knowledge and the global goals and tendencies that allow the activity of the system in its dynamic environment. An introduction to this approach can be read in (Wooldridge and Jennings 1995). We construct an interpretation layer ie the agentification of both knowledge and functionalities. We determine that we know about the problems the sets of functional components have to solve. We also determine what we know about the interaction between the components at all the levels. We must use ontology for the extraction of this knowledge about states, facts and functionalities, as in classical Knowledge Based Problems: see Lena and Guha (1990). For that, we can use the statistical analysis about the situations we have to express in the specific domain of application of the system. Then we obtain several hierarchies of knowledge and meta-knowledge with their relations.

From this first structured knowledge, we use an agentification methodology for the transformation of the structural knowledge into a dynamic one using specific aspectual agents17. In fact, we extract from knowledge all the pertinent characters of the states and relations between the system's states, and we called them semantic traits. At each semantic trait, we associate several aspectual agents expressing dynamically the pertinence of this semantic trait into the contexts of activity. We thus obtained a massive multi-agent organization of aspectual agents.

More precisely, any information in the functional system has the form of some symbolic data. We first apply a categorization about this information with transformation of information into knowledge as, for example, with the images and statistics we can use. The transformation of the basic information and physical elements behaviors into agents is not a simple one-to-one application, but an interpretation transposing symbolic structures into dynamic structures. For each information the object system manipulates, we obtain some semantic traits expressing the characters of the knowledge this information can express in the possible contexts. So, each semantic trait is expressed with several aspectual agents. We can notice that any semantic trait has many aspectual agents matching it: the well-corresponding aspectual agents, the converse agents, the proxy agents and so on, expressing the semantic trait with a cloud made of a dynamic group of aspectual agents around the reified semantic trait.

This aspectual organization will wrap all the basic information of the object layer in order to extract its current characters. By their actions and proactivities, the active aspectual agents will generate the emergence of pertinent groups of semantic traits relative to the current behavior and actions, taking into account the characters of their contextual relations. Each agent expresses characteristics and partial signification about the situated information contained in the active information, and the meaning of all the current information is expressed with the formation and transformation of groups of coactive aspectual agents. For the generation of this emergent agent's representation we shall use a specific kind of agents' organization management that will be a unified multi-scale control. This is a highlight of how the building work of modeling the Region activities such as an adaptive system of systems begins. The whole building of this system can be read in [4].

5 The prototype's schema

The studied region is approached as an eco-system where different entities evolve making their own business and assuring the coherence of the whole. In our approach we suppose the eco-system closed, that is to say there is no need to look outside its frontiers for any transaction. A network allows the entities communication to come or leave the system and to exchange information and goods. A special entity, the network-monitor acting as a specific virtual network, evolves in the same environment. The different entities report their external trade actions to the network-monitor (see figure 3). Thanks to those reports, the network-monitor can follow the eco-system dynamics.

The network-monitor has two main roles:

- As a stock exchange it shows the different demands and offers of goods available in the eco-system for trade. Such information comes from the entities at anytime and is immediately taken into account for publication.
- As a regulator it supervises the different activities. This means it can intervene in the exchanges to stimulate the entities actions or discourage them from an action. For example, one network-monitor's tool can be a general VAT or any specific tax for transactions, goods transportation, etc. Heuristics can be developed for supervision.

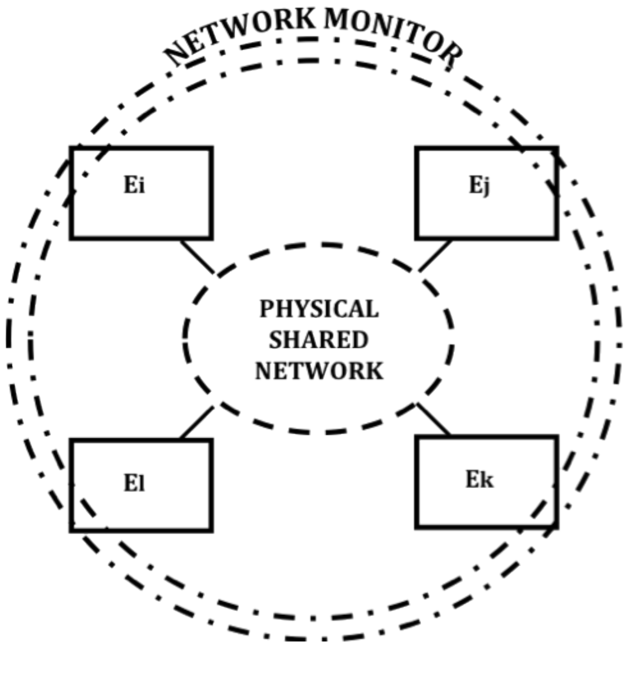

Figure 3. The prototype's schema as a serious game

Each Ek is a proactive entity that represents one company or institution. Such entity is involved in the environment for its own interest but with respect to the eco-system's rules (legal aspects, for example: to accept the tax Policy). Each entity contacts directly or indirectly the network-monitor to report its needs and/or offers of goods. This is its main way to trade. We already noticed the present « internal » preference for goods exchanges. An entity that cannot prosper in this environment is condemned to death. New entities can be introduced once they are in the network and after their declaration to the network-monitor.

The whole system can be seen as a distributed serious game. The players join the network with a business objective that suits the eco-system to be studied. The network-monitor's objective is to adjust the activity towards a long period of prosperity for the community. Each entity follows its own strategy defined by the attached player. The network-monitor's strategy can be based on global economy indicators with the objective of maintaining dynamically some eco-equilibrium of the whole system as long as possible.

Discussion: Such current prototype does not suit exactly the model expressed in precedent paragraphs. It needs another "entity" on top of the whole. Its role is to follow all the actions at all the levels towards a representation (structure and organization) of the system's state [7] and then acts on the present prototype with respect to its intentions. These are works in progress and should give an evaluation way of the present network monitor actions and the meta system's actions.

6 Distributed architecture of the prototype

The building of a first prototype is based on the following principles:

- To use existing simulation environments when necessary.
- To develop on each environment an example (SME, transport company, etc.) with many stakeholders.
- Each environment should run on one PC.
- To use a real network supporting the simulation environments and other software in their communication needs.
- Each scenario entity has to exchange information with others through the shared network and the intentional network.

Of course, thanks to the virtualization techniques one can run the whole system in a single machine. Thanks to simulation environments with blocks we can build different examples dealing with logistics, transportation, commerce, etc. called companies. To live, those companies need to exchange with others (information, goods…) and must respect some rules. Companies can grow or decline depending on their activities, management, etc. The companies are expressed as autonomous proactive systems.

From the practice side, in a first step we need a group of potential players or group of players. One of them will ply the role of network-monitor and the others will represent different stakeholders. Each stakeholder works on specific software that simulates its activities. Different PCs run those different simulation examples. Interested persons use tablets to communicate with the examples on the PCs: each tablet is linked to one example.

On each tablet the user can follow some indicators and can act on the example by giving "orders". The network-monitor is communicating on the global system. It is in charge of those global rules to respect (such as tax). Playing with those rules can modify the state of the eco-system. One objective of the players is to maintain or improve the activity of the global system that means to respect some global indicators without loss of balance.

In order to manage the links between the physical and virtual networks as well as the different peers we use a zero-configuration networking. To create and manage the peers of the system we need to use a distributed platform. In our first experiment we used JXTA for reasons of team experience. But we felt let down by the stop of the maintenance work on this platform. Then we want towards a new experiments at a lower level thanks to Avahi, a free zeroconf implementation. Our present main development goal is to create a concord into a group of peers in order to distribute a computation in an automated and mostly abstract fashion.

7 Conclusion

We showed our plan to represent the interconnected management and decision entities of a Region and gave a frame to the competitiveness notion where decisions are made from upper and lower levels continuously to maintain the levels of coherence. The sustainable aspect will be viewed as a control problem on multi scale fields and knowledge. We highlighted the model and the current work in progress dealing with the prototyping on top of an underdevelopment distributed platform.

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