A MULTI AGENT SYSTEM MODEL TO EVALUATE THE DYNAMICS OF A COLLABORATIVE NETWORK

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Abstract: The paper provides a model based on the Multi Agent System (MAS) paradigm able to give a methodological base to evaluate the dynamics in a collaborative environment. The model dynamics is strictly driven by the competence concept. In the provided MAS the agents represent the actors operating on a given area. In particular, it is supposed the agents being composed by two distinct typologies: (i) the territorial agent, and (ii) the enterprise agent. Each agent has its local information and goals, and interacts with the others by using an interaction protocol. The decision-making processes and the competences characterize in a specific way each one of the different agent typologies working on the system.

1 INTRODUCTION

The rapid evolution in customer requirements is forcing major changes in the overall industrial system. One possible strategy for facing these changes is based on the adoption of collaborative way of working where different abilities and competences are brought together with the goal of exploiting benefits and sharing the risks.

This paper aims at providing a model for understanding the dynamics of a network composed of heterogeneous actors, and suggests a competence-based collaborative way of working, where the competence is defined as the ability to perform activities by using a combination of knowledge, skill and attitude. As Camarinha-Matos and Afsarmanesh (2006) argue in their work, the definition of a model certainly represents one of the main topics concerning the collaborative network organization research field.

The model well represents actors working on a given geographical area, where the area boundaries are both physical, and due to the existence of consolidated business connections among the actors. In particular, the model represents a breakthrough with respect to the work by Confessore, Liotta, and Rismondo (2006), where the authors exploited the concepts of "competence measure" and "competence map" to solve the problem of assigning to collaborative enterprises the activities required for carrying out an emerging business process. They provided a Multi Agent System -MAS- (see Jennings and Wooldridge, 1995), in which the actors share information about their degree of competence in doing the activities without reveal private data. In fact, the competence there represent an aggregate data based on a local evaluation, and all the actors measure themselves with respect to the same set of competences given by the competence map (see also Hammami, Burlat, and Champagne, 2003). On the basis of the previous MAS, the new model considers new agent typologies and new features for the decision-making processes in order to allow the evaluation of the impact of new configurations of the network with respect to key performance indicators. The new configurations of the network are generated whenever emerging business processes and possible public funding (e.g., as calls for National and European research project) arise, and it is required to define the roles and responsibilities through the actors.

2 THE SCENARIO

The paper provides a model for the understanding of the dynamics of a collaborative network. The network is represented by a coordinator, and private actors. The coordinator makes decisions for increasing the territorial attractive capacity respect

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to new investments and new projects. Its main tasks are:

1. The monitoring of new business opportunities by doing intensive market analysis. The output are: the proposal of activities to the agents in order to meet the business opportunities; the identification of new possible attractive industrial sectors that could be exploited with the actual territorial resources;
2. The monitoring of call for National and International research projects. The output is to suggest possible combinations of actors in order to create the suitable composition of partners meeting the call requirements;
3. Providing to the actors the competence map in order to meet both the business and funding opportunities while using a competence-based criterion as a way for comparing the actors' capability.

Due to the competence-based criterion, each private actor has the main goal of increasing its competences. Indeed, this condition allows it to obtain an increasing number of activities of an emerging business process or it allows becoming an eligible actor for a research project as a partner. A greater number of activities and of research project participations, generate greater revenue for the private actor that could be invested again for increasing the competences by generating a positive feedback. Summarizing, the competence-based criterion driving both the business process activities assignment, and the public funding exploitation, generates a process of continuous development of the territorial competences, stimulating the collaboration between private actors. Moreover, the investments growth pulls new research projects and business processes by attracting also new enterprises actors that are motivated to join the collaboration or to work in the profitable territory.

For measuring the benefits given by the competence-based collaborative network, the following Social Wellness indicators are suggested:

- Number of new research projects/business processes approved and finished. These indicators represent a measure of the territory attraction with respect to research project and business processes, respectively.
- Number of new competences characterizing the territory. The set of competences is not static since new competences can be required, and others can be not more useful to realize a research project or a business process. This indicator is useful for understanding how the competences of the network evolve.
- Number of actors operating on the territory. It indicates the development of the collaborative network with respect to the actors' composition.

3 MULTI AGENT SYSTEM

The MAS is composed of classes of interacting agents each one having its local information and goals. In this setting, the decision-making processes and the competences characterize in a specific way each one of the different agents working in the system. In particular, it is supposed the agents being represented by two distinct typologies: (*i*) the Territorial Agent (TA), and (*ii*) the Enterprise Agent (EA). TA represents the coordinator, while each EA (e.g., representing a private company) interacts with the other agents in order to pursue its goals. The following notations are used through the paper:

- Let $E = \{e_1, e_2, \ldots, e_z\}$ be the set of z EAs.
- Let $A = \{a_1, a_2, \ldots, a_k\}$ be the set of k activities in which a business process or a research project can be decomposed.
- Let $C = \{c_1, c_2, \ldots, c_w\}$ be the competence map, that is a set of w competences identified in a certain time on the territory and globally accepted by all the agents.

Next, the decisional processes are explained.

3.1 Territorial Agent

According to the described scenario, TA acts as a coordinator and it solve the decisional problem called Assignment Problem (AP): given a set of enterprise and a set of activity we want to assign each activity to exactly one of the EA at minimum total cost. By solving the AP, TA obtains the efficient allocation of the activities of a business process to the EAs. The parameters ω_{ij} represents the capability of $e_j \in E$ with respect to the execution of the activity $a_i \in A$. These values are provided by each EA and are computed as described in the next Section 3.2. Given the binary decision variable x_{ij} equal to 1 if the activity a_i is assigned to the enterprise agent e_j, and 0 otherwise, it is possible formulizing the AP as following:

$$\begin{aligned} \text{Min } & z = \textstyle\sum_{i\in A}\sum_{j\in E} \omega_{ij}\, x_{ij} \\ \text{s.t } & \textstyle\sum_{j\in M\cap E} x_{ij} = 1 \quad \text{for all } a_i \in A \end{aligned} \tag{1}$$

3.2 Enterprise Agent

Each EA has to: (*i*) be able to define its degree of competence respect to the competences required by the activities of a business process; (*ii*) solve the decisional problem of choosing which typology of investment select in order to increase its competence, that can be referable to a special case of the Capital Budgeting Problem (Tobin, 1999); (*iii*) decide if a coordinator proposal can be profitable or not. Each EA has to evaluate its degree of competence with respect to each activity, thus it has to define the value ω_{ij}. This value can be computed as described in Confessore, Liotta, Rismondo (2006) by modelling the subsets of competences required by an activity and declared by an actor as vectors. The value of ω_{ij} is obtained by computing the Euclidean distance between the given vectors. Then the model formulized in (1) aims at assigning each activity to exactly one enterprise while minimising the distance among vectors that is obtaining the solution maximising the competence value.

3.2.1 Capital Budgeting Problem

The problem is to select the investments maximizing the total return in term of competence while respecting the budget constraints. The best solution is the one producing the maximum competence increment. The following parameters are introduced:

- Let L be the set of possible investments.
- Let $Q(e_j)_{[h,i]}$ be a matrix of parameters where the generic element $q_{hi}(e_j)$ represents the return of competence $c_h \in C$ for $e_j \in E$, respect to the investment $i \in L$.
- Let ε_{jh} be a positive value in [0, 1] representing the degree of competence of the enterprise e_j respect to a specific $c_h \in C$.
- A budget $B(e_j)$ representing a monetary value, for all $e_j \in E$.
- A cost of investment $b_i(e_j)$, for all $i \in L$, and $e_j \in E$.

Given the binary decision variable x_i equal to1 if the investment i is selected, and 0 otherwise, it is possible formulizing the problem above mentioned as following:

$$\begin{aligned} \text{Max} \quad & t = \textstyle\sum_{h\in C}\sum_{i\in L} q_{hi}\, x_i \\ \text{s.t} \quad & \textstyle\sum_{i\in L} b_i x_i \le B(e_j) \qquad \text{for all } e_j \in E \\ & \textstyle\sum_{i\in L} (\varepsilon_{jh} + q_{hi}(e_j)) \le 1 \quad \text{for all } e_j \in E \text{ and } c_h \in C \end{aligned} \tag{2}$$

The second constraints model the idea that for each competence exists a threshold value equal to 1. This value was introduced in Confessore, Liotta, Rismondo (2006) as the maximum value for doing as best one activity given the common scale of benchmark values.

Once the decisional problem is solved, the EAs update their competences, that is $\varepsilon_{jh}' = \varepsilon_{jh} + q_{hi}(e_j)$ if x_i equal to1 thus the investment $i \in L$ is selected, for all $e_j \in E$ and $c_h \in C$. Noteworthy, the system dynamics is based on the hypothesis that if the actors do not invest in a competence for long time, the value ε_{jh} decreases.

3.2.2 Project Participation Evaluation

Each EA decides to participate to a business process or to a research project based on the following data:

- Capacity availability.
- Profitability with respect to the increment of the degree of competences.
- Profitability with respect to the collaboration. For instance the collaboration with other actors could remain also when the project ends.
- Project relevance at scientific and research levels.

4 THE MAS DYNAMIC

This Section summarizes the main features of the interaction protocol exploited by the agents, then defining the dynamics of the MAS. It is supposed that the agents react in response to two possible events, that is an emerging business or a funding opportunity arise. The result of each decisional problem contributes to the definition of a new system configuration.

4.1 Business Process

Whenever a business opportunity occurs, two levels of interaction between the agents can be defined.

First level: The information flow is from TA to the EAs and vice versa.

Information Domain: TA manages a list of codified competences (i.e. the competence map, globally accepted by the agents), a list of agents operating in the system. TA decomposes the business process in a set of activities, and defines the subset of competences required for each activity.

Goal: TA has to allocate each activities of the business process according to competence-based criterion, thus maximizing the total degree of competences for realizing the project.

Communication Protocol: TA communicates to the EAs the set of activities and the related set of competences required for doing them. Each EA then communicates to TA an aggregate data describing its level of competences.

Second level: It corresponds to the EAs actions in response to the business opportunities. Since at the first level TA decides by using the competence-based criterion, each EA has to improve its degree on competence by selecting possible investment.

Information Domain: Each EA knows the competence map.

Goal: Each EA solves the problem of selecting from a set of profitable investment the sub-set of them maximizing the return of competence while satisfying its budget.

Communication Protocol: Each EA communicates its availability in executing the activities, or its degree of competences in order to stimulate new collaborations

4.2 Funding Opportunities

Also in this scenario, whenever a funding opportunity occurs, two levels of interaction between the agents can be defined. In this paper, the funding opportunities arise when the TA observes a call for research project.

First level: The information flow is from TA to the EAs. It is important to notice that for the EAs the participation to a research project can be view as an alternative profitable investment.

Information Domain: TA manages a list of codified competences, a list of agents acting on the system. Furthermore, TA knows the competences that best suite a call for project, and codifies the composition of agent typologies that have the greater probability of obtaining the financial fund approval.

Goal: TA has to decide the best composition of agents.

Communication Protocol: TA contacts the agents for proposing the project participation.

Second level: it corresponds to the EA and PA actions in response to the funding opportunities.

Information Domain: each agent knows its degree of competences.

Goal: EAs aim at carrying out the activities of the research project by collaborating.

Communication Protocol: The EAs response to the TA request by communicating their availability to execute the project activities. If they decide to participate then communicate to TA their competences. The probability of obtaining the public funding will be a function of the agents' composition and on the total degree of competences. The agents collaborate during the project duration and they have a return of competences due to the research project collaboration.

5 CONCLUSIONS

The paper analyses a competence-based collaborative network, identifying roles, decision making processes and the interaction protocol between the actors. The model is based on the Multi Agent System paradigm and it is driven by the competence concept. Even if the model does not capture all the aspects of the collaboration, it represents a further step toward the representation of the collaborative networks, and the understanding of what and how a network of actors has benefits from the collaboration. Actually, both the dynamics and the decisional problems are faced by the implementation of ad hoc algorithms. In the future, the plan is to add new features to the MAS in order to suggest the model as a valid way for studying the complex connections between collaborative actors, and then to exploit it in a real case-study as preliminary done in Baffo et al. (2006).

REFERENCES

Baffo I, Dedonno L, Confessore G, Rismondo S., 2006, *Descrizione ex-post di una rete relazionale territoriale e realizzazione di uno strumento per la simulazione dinamica ex-ante*, in Proceedings of the XXVII Italian Conference of Regional Science - Impresa, Mercato, Lealtà Territoriale.

Camarinha-Matos, L. M., Afsarmanesh, H., 2006, in IFIP International Federation for Information Processing, Volume 224, *Nerwork-Centric Collaboration and Supporting Frameworks*, eds. Camarinha-Matos, L., Afsarmanesh, H., Ollus, M., (Boston: Springer), 2006, pp. 3-14.

Confessore G, Liotta G, Rismondo S., 2006, in IFIP International Federation for Information Processing, Volume 224, *Nerwork-Centric Collaboration and Supporting Frameworks*, eds. Camarinha-Matos, L., Afsarmanesh, H., Ollus, M., (Boston: Springer), pp. 121-128.

Hammami, A., P. Burlat, and J.P. Champagne. 2003, *Evaluating orders allocation within networks of firms*. In International Journal of Production Economics; 86 : 233-249.

Jennings N.R., and M.Wooldridge, 1995, *Applying agent technology*, Applied Artificial Intelligence; 9: 357-369.

Tobin, R.L., 1999, *A fast interactive solution method for large capital expenditure selection problems*. European Journal of Operational Research 116, 1–15.