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Dynamic Organization of Multi-Agent Systems

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ABSTRACT

Many models of organizations for multi-agent systems have been proposed so far. However the complexity implied by the design of social organizations in a given multi-agent system is often not mentioned. Too little has been said about rules that must be applied to build the architecture of acquaintances between agents. Moreover, tools for managing the dynamic evolution of organizations are seldom provided in current framework propositions.
In this paper we discuss self-adaptation of organizations in multi-agent systems according to the dynamic of interactions between agents. Starting from a default organization, the architecture of acquaintances evolves autonomously depending on messages flow in order to improve the global behaviour of the system. We propose three principles that can be applied to adapt the organization: "have a good address book", "share knowledge", "recruit new able collaborators".
These principles have been applied in our multi-agent platform called MAGIQUE.

full paper available at
http://www.lifl.fr/MAGIQUE/dynamicity

1. INTRODUCTION

Multi-agent systems can be seen as societies of interacting agents. This notion of interaction, which allows agent to find each other and then to exchange information, is a central point for the design of multi-agent applications. Some methodologies have been proposed, and they always identify the need that agents have to *get in touch* with other agents, but they seldom provide guidelines to design the acquaintances structure. The GAIA methodology, for instance, identify this stage as the *acquaintance model*, which is defined as follow : *"An agent acquaintance model is simply a graph, with nodes in the graph corresponding to agent types and arcs in the graph corresponding to communication pathways. Agent acquaintance models are directed graphs, and so an arc $a \rightarrow b$ messages to b, but not necessarily that b will send messages to a. An acquaintance model may be derived in a straightforward way from the roles, protocols, and agent models."*

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We see that this definition just defines what we could call the *natural* notion of acquaintance. The notion of organization is even not clearly identified. Other methodologies, often state the same kind of concepts but seldom identify that the acquaintance structure is a first-class citizen of MAS entities. Some works highlight the importance of the notion of organization in multi-agent systems. Unfortunately, these works seldom reify this notion. Building an organization to optimize agent interactions is not straightforward : how should we spread functionalities among agents, and how is it possible to reduce the cost of communication, and overall how can the system deals with agents that freely leave or join it? Lastly, how organizations can deal with the ever-changing flow of agents interactions? This paper postulates that this complexity should not be exclusively addressed by the multi-agent system designer. Organizations infrastructures should provide default behaviours to dynamically optimize communications flow, in order to lower the number of messages that are exchanged, or to improve the quality of service. Too few works have been done in this direction.

In the first section, we describe the needs to have an adaptive organization. We first present static organizations and their limitations, then we study how social organizations deal with those problems before we apply their solutions to multi-agent systems. The second section introduces the MAGIQUE multi-agent framework and uses it to illustrate dynamic organizations through some simple experiments described in section three.

2. ADAPTING THE ARCHITECTURE OF THE ORGANIZATION

Before we consider how to adapt the organization of a multi-agent system, some problems with predetermined static structures must be considered. We will then propose some general strategies to tackle these problems.

Some problems with static organizations. One of the first problem, and probably the basic one, is to determine how acquaintances are created? That is, how an agent can have information about the existence of another able agent. One solution of course, is that this can be predetermined and established by the multi-agent system designer, but this is not a satisfactory answer.
A second problem is more connected with the distribution of the skills over the agents and is related with performance issues similar to load balancing. How can the system be organized in such a way such that no agent becomes a critical overloaded resource? This implies that even if an organizational structure has been chosen, this is not enough. You need to choose how the skills are distributed among the agents.
Lastly, consider the situation where one agent may often have to use some given service for which he must make requests to an able agent. In this case, even if the service provider agent is not over-

burdened, the client agent will probably be penalized by too many requests, at least because of the communications. It would have been better, when designing the system, to qualify this agent with the service, or to allow the agent to dynamically acquire it.
Aware of these problems, a multi-agent system designer will take them into account and try to anticipate them in order to limit them. He could succeed in that, but what happens in the context of dynamic multi-agent systems, where agents can freely join or leave the system? This implies that some services will become available at some time and unavailable at other. Agents must adapt themselves to this dynamic environment. The designer cannot predetermine these situations. Therefore the only thing he can do is to prepare his agents in such a way that they can adapt autonomously to the changes that occur within their environment.

How do social organizations manage these problems ? In the three above described cases, the problem of cost or efficiency appears. In social organizations, there is a trend to aim at better efficiency. This trend can be natural – we all have tendency to apply the law of least effort –, or economical by trying to reduce cost – unless the intent is to increase profit? –. We have identified three principles that can be used to improve the global behaviour and that implies a dynamical organization of the social structure : firstly "*having a good address book*", secondly *sharing knowledge* (or selling it...), and thirdly *recruiting new able collaborators*. These principles deal with the three previously mentioned problems.

The three principles applied to multi-agent systems These three principles can be applied to achieve a self organization of the social structure in multi-agent systems. By applying them, we want an evolution of the acquaintance structure and the distribution of skills in order to reduce, firstly, the number of messages exchanged in the system and, secondly, the time necessary for a service request to be treated.
According to these principles, we start from a predetermined organization, where the agents have default acquaintances and where skills (or services) are more or less arbitrarily distributed over the agents. The idea is to have an evolution of the structure of acquaintances where the natural links are favoured at the expense of predefined ones. Of course the major benefit is for the designer of the multi-agent system who can prepare his multi-agent system as it seems the most fitted and then rely on these principles to adapt the efficiency of his system.

3. EXPERIMENTS

To experiment these principles, we need a framework that provides code mobility in order to apply the dynamic acquisition of skills. Thus, we used our multi-agent framework called MAGIQUE[1]. We will briefly introduce this framework and then experiment dynamic organizations of multi-agent systems with it.

MAGIQUE proposes both an organizational model, based on a default hierarchical organization, and an agent model, which is based on an incremental building of agents[1]. The agent model could be summarized as: "*building agents by making them skilled*". It is based on an incremental building of agents from an elementary (or atomic) agent through dynamical skill acquisition. The organizational model in MAGIQUE, is based on a default acquaintance structure which is a hierarchy. It offers the opportunity to have a default automatic mechanism to find a skill provider. These models have been put into concrete form as a JAVA API, it is available at `http://www.lifl.fr/MAGIQUE`. Dynamicity is a keypoint in MAGIQUE and the three principles of self-organization we have presented above, need this dynamicity in order to be implemented.

We have made three terse experiments that put into concrete form the three described principles of dynamic organization. These experiments have been completed with MAGIQUE[2]. The first experiment is concerned with the first principle : create the acquaintances that follow the natural flow of messages in the multi-agent system (see Figure 1, we have no space here to present this in detail and even to show similar figures for experiment 2 and 3). In second, the distribution of skills in the system is dynamically changed by skill exchange between agents In the third experiment, an overloaded agent creates new collaborators in order to get rid of the need to treat too many requests for a given service and thus he can more easily satisfy other requests.

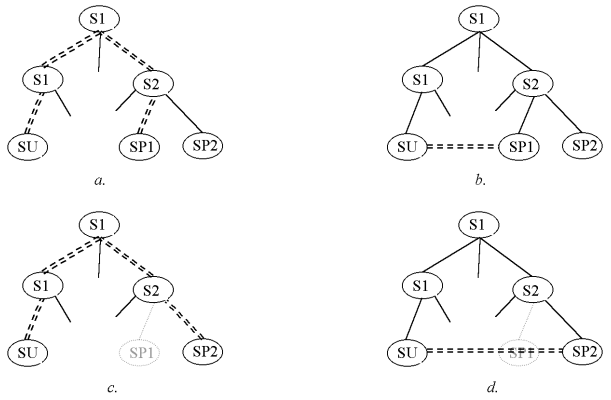

Figure 1: Dynamic organization of acquaintances in a multi-agent system. *a.* Beginning: multi-agent system is hierarchically organized, requests for σ sent by *SU* (see double dash lines) use the default hierarchical organization and *SP1* is reached. *b.* Self-organization: direct acquaintance link with *SP1* is created. *c.* *SP1* disappears: service requests use again the default organization and *SP2* is reached. *d.* Self-organization: direct acquaintance link with *SP2* is created.

4. CONCLUSION

Static organizations have defaults. In order to be efficient, there is a need to be reactive and to adapt the organization to the reality of agents exchanges. Our thesis in this paper is that the needs are the same for multi-agent systems. It is too difficult (and probably even impossible) for a multi-agent system designer to foresee the flow of messages within his system.
We have proposed some principles to adapt the organization in order to reduce the number of messages in the multi-agent system and to improve the delay before a request is satisfied: creation of new specific acquaintance relations to remove the go-between, exchange of skills between agents and creation of new agents to reduce overloading. Agents can apply these principles autonomously depending on some decision of their own.

5. REFERENCES

[1] JC. Routier, P. Mathieu, and Y. Secq. Dynamic skill learning: A support to agent evolution. In *Proceedings of the AISB'01 Symposium on Adaptive Agents and Multi-Agent Systems*, pages 25–32, 2001.

[1] Magique stands for the french "Multi-AGent hiérarchIQUE" which obviously means "hierarchical multi-agent".

[2] The sources of these experiments can be downloaded at `http://www.lifl.fr/MAGIQUE/dynamicity`.

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