MULTI-AGENT PROPOSITIONS TO MANAGE ORGANIZATIONAL KNOWLEDGE
Position paper concerning a three-dimensional research project

Jorge Louçã, César Rosa, Francisco Guimarães, Valmir Meneses
ISCTE - DCTI, c.296, Av.das Forças Armadas, 1649-026 Lisboa, Portugal

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Abstract: This paper presents the work in progress in a three-dimensional project, including the theoretical foundations and main goals of the lines of research incorporating our project: user modeling in a distributed cooperative system, interactive cooperation in a multi-agent structure, and knowledge representation in a cognitive agent architecture. These lines of research are complementary and share a main goal, to make propositions regarding the use of multi-agent systems in organizations, namely in what concerns support to decision making processes and, in a general way, knowledge management within organizations.

1 INTRODUCTION

This paper presents the work in progress in a three-dimensional project, including the theoretical foundations and main goals of the lines of research incorporating our project: user modeling in a distributed cooperative system, interactive cooperation in a multi-agent structure, and knowledge representation in a cognitive agent architecture. These lines of research are complementary and share a main goal, to make propositions regarding the use of multi-agent systems in organizations, namely in what concerns support to decision making processes and, in a general way, knowledge management within organizations.

What makes knowledge management hard is the ill-structured and subjective nature of different types of knowledge present in the organization. Moreover, distinct organizational actors interact in ill-structured domains. Knowledge management should be distributed, as the organization is multi-dimensional, should characterize individuality of organizational actors, representing their beliefs and supporting their reasoning processes, should support interactions between organizational actors, as working processes are for the most part based on interactions, and finally should propose an adequate working environment, helping people in their tasks.

Aiming to support knowledge management processes with the characteristics above, we propose to found our research on *cognitive mapping*, allowing the simplification of complex ill-structured domains of knowledge, and on *multi-agent systems*, allowing to use artificial cognitive agents to characterize organizational actors and to represent agents interactions. This way, our project has an interdisciplinary nature, putting together domains like distributed artificial intelligence, user modeling, knowledge representation and reasoning techniques. We also take our inspiration from social science theories, mainly from psychology and sociology.

Previous work concerns the use of cognitive maps to represent artificial agents beliefs (Louçã,2003a), a distributed architecture to support organizational actors interactions (Louçã,2003b), and a conceptual framework to represent emergent social phenomena in organizations (Louçã,2003c).

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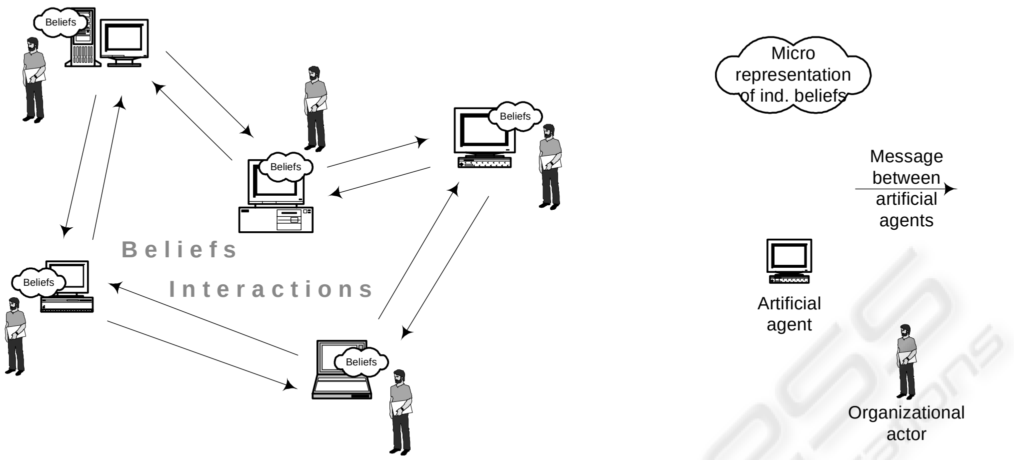

Figure 1: Generic architecture for agent supported interactions in an organization (Louçã,2003c)

This paper is organized as follows: section 2 describes the theoretical foundations and main goals of the research concerning user modeling in a distributed cooperative system; section 3 regards interaction in a multi-agent structure; section 4 is related to our propositions about knowledge representation in a cognitive agent architecture; finally section 5 presents a brief conclusion.

2 USER MODELING IN A DISTRIBUTED COOPERATIVE SYSTEM

In a competitive context, where the environment continually changes, organizations are compelled to dynamically adapt themselves. Changes are political, demographical, legal, technological, concerning consumers and competition. Organizations tend to consider strategy a flexible and continuous process, facing dynamic environmental factors. Strategic processes should allow evaluation and control, proposing corrective measures as result of organizational learning.

Evaluation and control depend on continuously obtained metrics, supporting decision-making at each activity level and, by aggregation, at organizational level. That's why systems such as EIS – *Executive Information Systems* and DSS – *Distributed Support Systems* are important software tools to support decision-making processes. Their main feature is to facilitate communication and dialogue at all organizational levels. To do this, they should monitor different activities inside the organization, be used to communicate and compare data, and finally support discussion and negotiation around strategic issues.

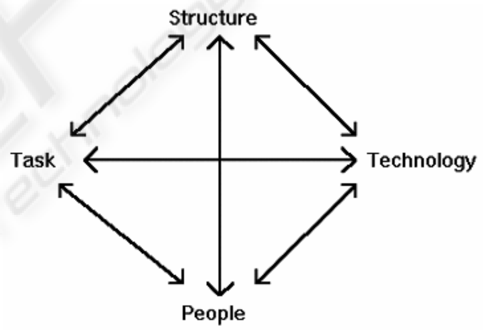

Figure 2: Leavitt diagram (Wilson,1995)

Organizational structure, working processes and interactions inside the organization should be tailored to EIS-DSS tools. The way technology is used and its connections to structure, tasks and people are essential, like suggested by the Leavitt diagram, expressing the cohesion between key concepts in an organization (Wilson,1995).

Let's consider an organization where cognitive agents support actors. Figure 2 depicts this general idea. Specific software tools and knowledge-based systems compose artificial agents. In this environment, interactions between actors can be made through artificial agents in a multiagent system. *Information systems* design is determinant to model such distributed systems, and has become more than a technique issue – in particular, the *user modeling* perspective is, in this context, a way of modeling IS according to the cognitive character of users, modeling their reciprocal interactions and with sub-systems in the organization. This *context-awareness* allows capturing, analyzing and manipulating user's contextual data.

Other research projects use the notion of user context to model an IS. (Bauer et al.,2000) observes user's activity and recognizes his goals, considering the context of the user, his behavior and educational level. (van Elst & Abecker,2002) describes a process-oriented knowledge management architecture, where users are coupled with roles in particular contexts, looking to support the integration of individuals in the organization. Generally, those propositions are based on the observation of users behavior, recognizing context and roles in workflow systems, supporting tasks and providing on-line help. Nevertheless, they don't address the fundamental issue of decision support based on a panel of ratios and data concerning strategic orientations. Also, they don't deal with user's collective goals neither with intuitive interfaces according to individual and/or collective goals.

This line of research has its theoretical foundations on *cognitive mapping*, *cognitive artificial agents*, and also on interaction models inspired on *user modeling*. Its goal is to bring together disparate notions such as *strategy*, *organizational processes*, *people* and *technologies*. To do this, the notion of *workflow* will be used, depicting departments, groups or individuals, implementing negotiation rules, emotional intelligence and processes orientation according to organizational strategic purposes. This way, each task will be embedded with some organization high-level goal, improving overall consistency of individuals, behaviors and roles.

An important issue about knowledge management software concerns the kind of relationships and communication protocols used by artificial agents to support organizational actors interactions.

3 INTERACTION IN A MULTI-AGENT STRUCTURE

This line of research concerns interactions between artificial agents to support communication inside the organization. The main proposition is to adopt a *Web Service* (or *Service-Oriented Architecture*)-like architecture for agents to communicate (W3C,2003). The advantage of a *Service-Oriented Architecture* is that web services provide standard means of interacting between different software applications, allowing agents to communicate between themselves as well as to interact with the external environment. This way, same communication protocols could be used both between agents and between agents and external entities, improving flexibility and autonomy.

Service-oriented-like architectures are characterized by communication between agents (senders and receivers) and by the definition of services as "sets of functionalities" provided by agents. *Provider entities* are persons, departments or organizations proposing services through their artificial agents. On another hand, *requester entities* are persons, departments or organizations wishing to make use of those services. According with this basic architecture, *requester agents* will exchange messages with *provider agents*, in order to *requester entities* attain *services* proposed by *provider entities* (W3C,2003).

A goal of this line of research is to define WSD – *Web Services Descriptions*, that is, message formats, datatypes, protocols and transport serialization formats to be used by agents. Another point is to define the location at which a *provider agent* can be invoked, and where it may provide some information about a given service.

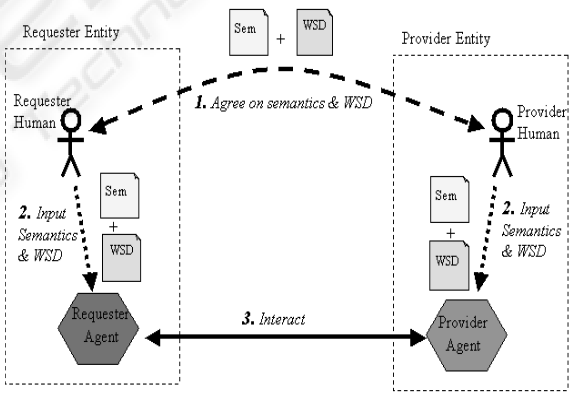

Figure 3: Basic architectural roles in service-oriented-like architectures [W3C,2003]

Message semantics (service description) represent a kind of "contract" between requester and provider concerning a given service, on how and why agents will interact, regarding also the meaning and purpose of interactions (W3C,2003).

Web Services and Service-Oriented Architectures have been recently presented as the subject of several research projects (Arabnia & Mun,2002).

Specifically, our goal is to propose a multi-agent architecture where cooperative agents announce their services to the multi-agent community. Agents will also announce the availability of services to the exterior, through Internet. This would be useful in e-commerce environments, where organizations provide web based on-line services.

According to several litterature sources (Robins et al.,,2003) (Li et al.,2003) (Luck et al.,2003), the advantages of SOA architectures are the implementation of open, generic and modular architectures with loosely coupled infrastructure, reduced costs and simpler agent integration in the multi-agent system, interoperability between Web services, scalability, extensibility and manageability of Web services, integration with the World Wide Web, all resulting on competitive advantage and organizational innovation.

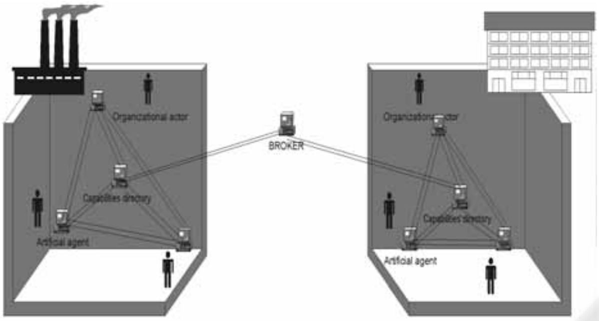

Figure 3: SOA-based Open Cube Architecture

Thes SOA architecture we propose can be used to allow interactions between multi-agent systems. According to Figure 4, the open cube is used to symbolize a department or company site. Each actor (person) interacts with the system through an artificial agent. Within these MAS, a capabilities directory is maintained. Such directory registers its entries in a UDDI compatible format as described in (Sycara et al, 2002). Each agent publishes its beliefs and capabilities in this directory upon entrance in the MAS. When needed, an agent can query the directory for desired capabilities and receives a list of agents that fulfill the query. It is then free to interact with the agents without further query to the directory. Such directory service is provided only inside the company site boundaries. This service also provides the Broker address in case an agent needs to interact with other MAS outside its own domain.

A Broker service (Sycara et al, 2000) is used to allow interoperability between remote MAS. The Broker encapsulates the translation and formatting of the message interchanged through the MAS.

This distributed cooperative architecture will allow interactions between artificial cognitive agents. The next line of research explores conceptual tools to represent organizational actors knowledge and reasoning procedures in cognitive agents.

4 KNOWLEDGE REPRESENTATION IN A COGNITIVE ARTIFICIAL AGENT ARCHITECTURE

Multiagent systems are completely distributed – the reasoning process goes on internally to each artificial agent. This feature allows the representation of heterogeneous agents, using complementary technologies and representing different cognitive models. The knowledge representation and reasoning technologies that have been used to this purpose are chosen according to their specific features, each attending to some things and ignoring others (Luck et al.,2003). When choosing a given technology, we are in fact selecting a point of view about knowledge representation and reasoning. Each technology is an approach to the task of determining how well it approximates to the reality we mean to represent (Sowa, 2001). For instance, logic concerns a point of view of individual entities and relations between them, rule-based systems consider rules of inference, frames represent prototypical objects and semantic nets are graphical representations of different kinds of entities through a network topology. Each of these approaches has both benefits and drawbacks. In fact, the choice of a given technology is motivated by the characteristics of a given domain, as well as by some insight indicating how people reason intelligently. On another hand, formal technologies are problematic in practice. Recent research in multiagent systems has searched for new technologies. These should be simple and operational enough to be used in organizations, and quite powerful and adapted to hill-structured domains. According to this idea, cognitive maps have been proposed to model beliefs of cognitive agents in a multiagent environment, as reported by (Chaib-draa,2002) and (Louçã, 2003a).

A cognitive map is a graphical representation of the behavior of an individual or a group of individuals, concerning a particular domain. Cognitive maps can be employed at a micro level, to represent individual cognitive models, and at an institutional level through the use of collective cognitive maps. Psychologists mainly use cognitive maps as data structures to represent knowledge. Generally, this kind of cognitive model facilitates communication inside a group, supporting discussion and negotiation between the elements having different points of view. This way, cognitive maps can be used to detect conflicts. Several software systems are proposed to represent organizational discourse into cognitive maps, describing mental models in artificial agents (Chaib-draa,2002) (Louçã, 2002a and b).

A cognitive map is composed by *concepts* (representing things, attitudes, actions or ideas) and *links* between concepts. Those links can represent different kinds of connections between concepts, such as causality or influence links. Figure 4 exemplifies a cognitive map, where links can represent very positive influence (++), positive influence (+), negative influence (-), and very negative influence (--). This particular type of cognitive map is used to represent strategic thought in organizations, as reported by (Louçã, 200a).

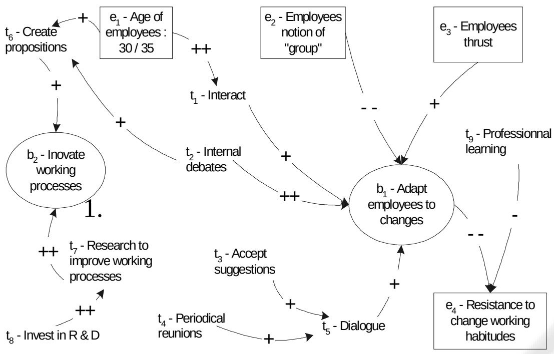

Figure 4: Example of a cognitive map (Louçã, 2003a).

The main interest of cognitive maps is their reflexive character, allowing people to became conscious of implicit knowledge, through the visualization of direct and indirect links between concepts. We each construct our private *versions of reality* and deal only with those constructions, which may or may not correspond to some real world (Louçã, 2003a).

Cognitive mapping can be compared with other knowledge representation technologies used in artificial intelligence, such as *conceptual graphs* (Sowa,2001). *Conceptual graphs* propose a symbolic representation, where the meaning of a concept is drawn from its position in the concepts hierarchy. Concepts semantic can be understood through the nature of links with other concepts. This way, a concept can have different meanings, depending on the specific context where it's used. Knowledge representation is done through a direct graph composed by nodes and arcs. Nodes represent physical or abstract objects, with properties and values. Arcs are links between nodes, meaning particular types of relationships between two given nodes (Sowa,2002). We think that cognitive mapping concerns a less constraint knowledge representation technique – in cognitive maps, concepts are not integrated in some particular hierarchy, allowing a non-restrictive representation of ill-structured domains.

Starting from the work already discussed in several conferences (Louçã,2003 a, b and c), this line of research will propose a methodology of reasoning based on an agent cognitive model. This methodology will use cognitive maps as instruments to represent and operate complex cognitive structures known as *schemes* and *schemas*. *Schemes* and *schemas* are basically composed by concepts. Agent's reasoning composes *schemes*, used to transmit complex ideas and plans in multi-agent communication.

From the cognitive mapping point of view, a *scheme* can be considered an ensemble of related concepts, used in a particular context to represent a complex thought or to solve a given problem. The notion of *scheme* has been deeply discussed in several scientific domains. The origin of the argumentation that has been used can be found in Descartes and Berkeley, with the notion of *mental image*, but it was since the writings of the philosopher Kant (18th Century), where he refers "innate structures which organize our world", that *schemes* became an important subject of research in cognitive science (Estivals,2002). In the beginning of last century, the psychologist Bartlett studied human memory and introduced the notion of *schema*. To Bartlett a *schema* is an organized structure of experience, containing general abstract concepts of individual experiences (Estivals,2002). Therefore, the notion of *schema* concerns a structure – a *schema* is a data structure containing generic concepts in memory. The notions of *schema* and *scheme* are frequently coupled in cognitive sciences, such as to Piaget, who used *schemes* to explain the evolution of knowledge throughout stages of development in young child (Piaget,1967). On another hand, psychological theories concerning deductive reasoning are based on the idea that contents and context are essential to reasoning, that deduction is supported by the mechanisms of mental representation, and by proceedings concerning those representations (Quelhas,2000). We stand that an operational representation of *schemes* and *schemas* can be useful to study human deductive reasoning - this is the main reason why we will put together the notions of *scheme*, *schema* and *cognitive mapping* in a *multi-agent environment*.

This line of research identifies several complementary goals:

- to adapt cognitive mapping to represent agent's beliefs;
- to recognize complex cognitive structures in agent's cognitive maps, such as *schemes* and *schemas*;

- to represent the context of a given concept through the notion of *scheme*;
- to conceive a reasoning methodology based on *schemes*;
- to use *schemes* to communicate between agents.

5 CONCLUSION

This paper has presented the work in progress in a three-dimensional project, including three complementary lines of research incorporating our project: user modeling in a distributed cooperative system, interactive cooperation in a multi-agent structure, and knowledge representation in cognitive agent architecture. These lines of research have diversified theoretical foundations: *cognitive mapping*; *multi-agent interaction*; *cognitive agents*; *knowledge representation*; *interaction protocols in open systems, such as service-oriented architectures*; *cognitive science foundations and contemporary psychological theorists*. We intend to make propositions regarding the use of multi-agent systems in organizations, namely in what concerns support to decision making processes and, in a general way, knowledge management within organizations. Finally, the result of our project will be provided to the research community, throughout a software library allowing the implementation of these ideas in organizations.

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