

Social Knowledge in Multi-Agent Systems

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INTRODUCTION

The development in the recent decade has proven that the multi-agent paradigm represents a challenging framework for solving very complex tasks of cooperation in virtual organizations. Each partner/unit engaged in a virtual organization can be considered as an autonomous unit with its own resources, knowledge and goals and represented by a corresponding software module—a software agent.

A multi-agent system (MAS) usually consists of a set of autonomous units capable of:

- Independent operations aimed at meeting their *local goals*, and
- Cooperative actions contributing jointly to the *global goal* shared across the community.

There are various types of agent-oriented applications. Throughout this contribution we will refer to a specific category of multi-agent systems that are designed and developed in order to allow intelligent, flexible and robust integration of already existing software/IT components for the needs of virtual organization cooperation and management. We are addressing namely the key aspects of such a category of multi-agent systems which are important for the tasks connected with virtual organization, namely with the agent's social reasoning, agent's integration in the community, responsibility delegation, task decomposition, and organization of negotiations. The agents' abilities to communicate, mutually coordinate their actions, cooperate and share the global goals determine the level of their integration-oriented behavior. These abilities depend mainly on the extent and quality of knowledge available to the agents. In this contribution, we do have in mind just the *knowledge-centered aspects* of functional integration in the heterogeneous communities of agents representing virtual organizations.

Let us present how agents can acquire, administer, maintain, exploit and “own” the knowledge. Knowledge—a true piece of evidence in which the agent believes—can either:

- Guide agent's autonomous local decision making processes (aimed, e.g., at providing an expertise or search in the agent's database)—this is what we call agent's *problem solving knowledge*, or
- Express the other agent's behavioral patterns, their capabilities, load, experiences, commitments, knowledge describing conversations or negotiation scenarios—which we will refer to as *social knowledge*¹ (Marik, Pechoucek, & Stepankova, 2001) later.

Hereafter, when referring to knowledge we primarily mean the agent's social knowledge.

BACKGROUND

Undoubtedly, the multi-agent systems should be equipped with a vast portion of knowledge to perform highly efficient cooperative behavior and to achieve global solutions. Such knowledge can be—in the extreme cases—stored either *centrally*, in a fully informed central unit, or *locally* owned by each of the agents. The latter case fits better the general visions how the multi-agents systems should be organized and implemented.

The main questions connected with the “local ownership” of the global knowledge are:

- What should be the reasonable extent of global knowledge administered locally, by individual agents?
- How much the agents should know about the global rules and knowledge ontologies?

- How much do they need to know about the particular cooperating “colleagues”?
- How to structure the locally stored knowledge to enable its efficient up-date and maintenance leading to reduction of the communication load in the multi-agent community?

Classical knowledge-centered architecture of an agent separates its functional *body* containing the agent’s individual problem solving knowledge from its *wrapper* that accounts for the inter-agent communication and contains mainly the social knowledge. The body is assumed to have no awareness of the multi-agent community. The *wrapper* will contain knowledge structures and reasoning mechanisms required for communication, coordination, cooperation, and integration with the rest of the community.

SOCIAL KNOWLEDGE AND ITS MAINTENANCE

Let’s discuss a more detailed definition of the social knowledge.

Social knowledge (SK) represents necessary and optional information which an agent needs for its efficient operation in the multi-agent community. The social knowledge is mainly used for reduction of com-

munication, acceleration of agents’ internal reasoning processes, but also provides self-interested agents with a competitive advantage and allows agents to reason about the others in environments with partial communication accessibility. Processing social knowledge replaces voluminous communication among many agents.

We can categorize the agent’s social knowledge as shown in Table 1.

The simplest possible, while inevitable instances of social knowledge are pieces of information that facilitate agents’ interaction—knowledge of symbolic name, physical address, the appropriate instance of the agent communication language (ACL). More sophisticated social knowledge is of the yellow-page (YP) list type that collects the services the particular agent provides the community with. Second order social knowledge provides the agents with the information about other agents nonpermanent properties, for example, computational load, trust, and relations with other members of the multi-agent community. The higher order types of social knowledge, the more sophisticated models of agents behavior that are used for modeling agents intent, predicting future course of behavior can be represented.

From the point of the knowledge maintenance perspective, we distinguish among the following levels of sophistication/complexity of the knowledge maintenance algorithms:

Table 1. Order of social knowledge: Examples

sk	Social knowledge	Example
0	minimal social knowledge	IP address, port, ACL
1	YP social knowledge	capabilities, services
2	agent-properties	load, trust, relations
3	models of behavior	intents, preference

Table 2. Social knowledge maintenance: Examples

km	mechanism	Example
1	centralized	facilitators, platforms, components
2	special agents	brokers, matchmakers
3	individual	periodical revisions, subscriptions
4	meta-reasoning	monitoring, reflection

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