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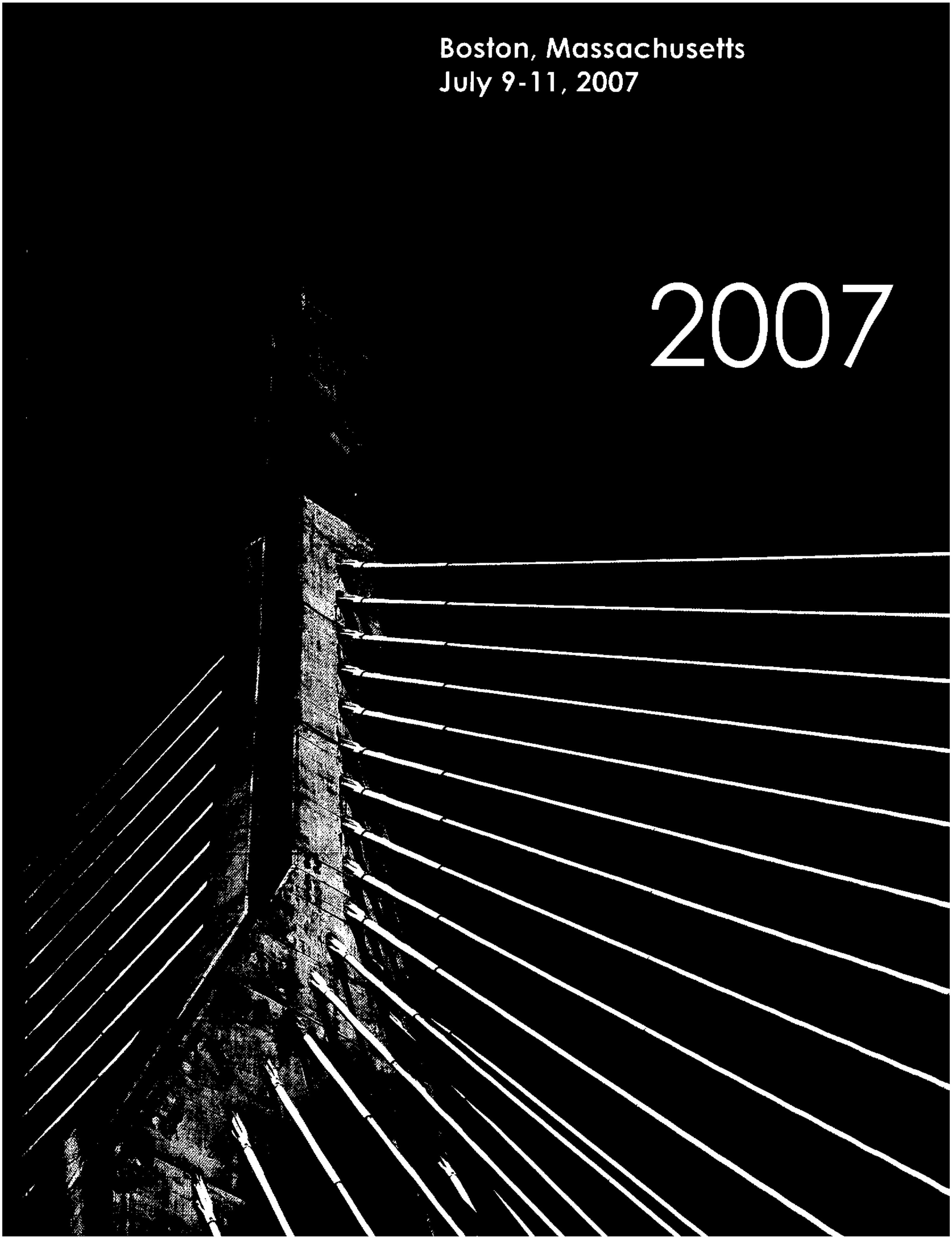
# 2007



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# The 19th International Conference on Software Engineering & Knowledge Engineering

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## Technical Program

**July 9-11, 2007**
**Hyatt Harborside Hotel, Boston, Massachusetts, USA**

## Organized by

Knowledge Systems Institute Graduate School

ISBN 1-891706-20-9 (paper)

Additional Copies can be ordered from:
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Proceedings preparation, editing and printing are sponsored by
Knowledge Systems Institute Graduate School

Printed by Knowledge Systems Institute Graduate School

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# Industrial Workshop

**Note: (S) means short paper.**

# A Three Level Multi-agent Architecture to Foster Knowledge Exchange

Juan Pablo Soto, Aurora Vizcaíno, Javier Portillo-Rodríguez, Mario Piattini
*Alarcos Research Group, Information Systems and Technologies Department, UCLM-Soluziona Research and Development Institute, University of Castilla – La Mancha*
*Ciudad Real, Spain*
*jpsoto@proyectos.inf-cr.uclm.es, {aurora.vizcaino, mario.piattini}@uclm.es, javier.portillo@alu.uclm.es*

## Abstract

*This paper proposes a multi-agent architecture based on the concepts of communities of practice and reputation to manage knowledge management systems. The main goal of this proposal is to emulate the behavior of communities of practice where people exchange information and in this way attempt to foster the reuse of information in organizations which use knowledge base or knowledge management systems.*

## 1. Introduction

The need to support knowledge processes in organizations has always existed. However, its importance has definitely increased in the last few years. Recently, the concept of knowledge management suggests a paradox since compared with traditional production factors knowledge is so complex, scattered and hidden that it is rather complicated to manage it.

On the other hand, traditional Knowledge Management Systems (KMS) have received certain criticism as they are often implanted in companies overloading employees with extra work; for instance, employees have to introduce information into the KMS and worry about updating this information. As a result of this, these systems are sometimes not greatly used by the employees since the knowledge that these systems have is often not valuable or on other occasions the knowledge sources do not provide the confidence necessary for employees to reuse the information. For this purpose, companies create both social and technical networks in order to stimulate knowledge exchange. An essential ingredient of knowledge sharing information in organizations is that of "community of practice", by which we mean groups of people with a common interest where each member contributes knowledge about a common domain [12]. The ability of a community of practice to create a friendly environment for individuals with similar interests and problems in which they can discuss a common subject matter encourages the transfer and creation of new knowledge. Many companies report that such communities help reduce problems caused by lack of communication, and save time by "working smarter"[13]. For these reasons, we consider the modelling of communities of practice into KMS as an adequate method by which to provide these systems with a certain degree of control to measure the confidence and quality of information provided by each member of the community.

In order to carry this out, we have designed a multi-agent architecture in which agents try to emulate human behaviour in communities of practice with the goal of fostering the use and exchange of information where intelligent agents suggest "trustworthy knowledge" to the employees and foster the knowledge flow between them.

The remainder of this work is organized as follows. The next section presents two important concepts that exist in the development of our work (agents and trust). In Section Three the multi-agent architecture proposed to manage trustworthy KMS is presented..In Section Four a prototype developed to evaluate our architecture is explained in order to illustrate how it could be used. Finally, conclusions are presented in Section Five.

## 2. Agents and trust

Because of the importance of knowledge management, tools to support some of the tasks related to knowledge management have been developed. Different techniques are used to implement these tools. One of them, which is proving to be quite useful, is that of intelligent agents [10]. Software agent technology can monitor and coordinate events, meetings and disseminate information [1]. Furthermore, agents are proactive; this means they act automatically when it is necessary. The autonomous behavior of the agents is critical to the goal of this research since agents help to reduce the amount of work that employees have to perform. On the other hand one of the main advantages of the agent paradigm is that it constitutes a natural metaphor for systems with purposeful interacting agents, and this abstraction is close to the human way of thinking about their own activities [14]. This foundation has led to an increasing interest in social aspects such as motivation, leadership, culture or trust [3]. Our research is related to this last concept of "trust" since artificial agents can be made more robust, resilient and effective by providing them with trust reasoning capabilities.

For agents to function effectively in a community, they must ensure that their interactions with the other agents are trustworthy. For this reason it is important that each agent is able to identify trustworthy partners with which they should interact and untrustworthy correspondents with which they should avoid interaction. The stability of a community depends on the right balance of trust and distrust.

## 3. Our proposal

The goal of this work is to provide a reputation model for communities of practice using a multi-agent architecture that:

- Assists employees in identifying trustworthy entities.
- Gives artificial agents the ability to reason about the trustworthiness of other agents or of a knowledge source.
- Encourages knowledge exchange between the community members.
- Provides the confidence necessary to foster the usage of information and knowledge of the KMS.

To do this, we first need to define a conceptual model for the agent that permits it to obtain the level of confidence of an information source or of a provider of knowledge.

The conceptual model of the agent is based on two related concepts: trust and reputation. The former can be defined as confidence in the ability and intention of an information source to deliver correct information [2] and the latter as the amount of trust an agent has in an information source, created through interactions with information sources. There are other definitions for these concepts [4, 6]. However, we have presented the most appropriate for our research since the level of confidence in a source is based on, in our case, previous experience of this.

The reputation of an information source not only serves as a means of belief revision in a situation of uncertainty, but also serves as a social law that obliges us to remain trustworthy to other people. Therefore, people, in real life in general and in companies in particular, prefer to exchange knowledge with "trustworthy people" by which we mean people they trust. People with a consistently low reputation will eventually be isolated from the community since others will rarely accept their justifications or arguments and will limit their interaction with them. It is for this reason that the remainder of this paper deals mainly with reputation.

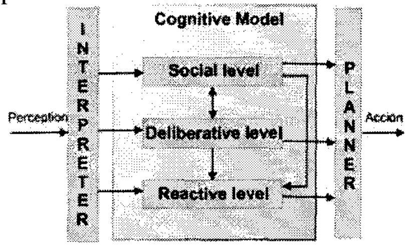

Figure 1. General architecture

Taking the concepts reputation and communities of practice into account we designed a multi-agent architecture which is composed of three levels (see Figure 1): reactive, deliberative and social. The reactive and deliberative levels are considered by other authors as typical levels that a multi-agent system must have [9]. On the other hand, the social level is not frequently considered in an explicit way, despite the fact that these systems (multi-agent systems) are composed of several individuals, interactions between them and plans constructed by them. The social level is only considered in those systems that try to simulate social behaviour or those that represent a more generic architecture prepared to represent this or other behaviour. Since we wish to emulate human feelings such as trust, reputation and even intuition we have added a social level that considers the social aspects of a community which takes into account the opinions and behaviour of each of the members of the community. Other previous works have also added a social level, for instance in [5] the author tries to emulate human emotions such as fear, thirst, bravery and also uses an architecture of three levels: reactive, deliberative and social.

In the following paragraphs we will explain each of these levels in detail.

***Reactive level:*** This is the agent's capacity to perceive changes in its environment and to respond to these changes at the precise moment at which they happen. It is in this level when an agent will execute the request of another agent without any type of reasoning. That is to say, the agent must act quickly in the face of critical situations.

***Deliberative level:*** The agent may also have a behaviour which is oriented towards objectives, that is, it takes the initiative in order to plan its performance with the purpose of attaining its goals. In this level the agent would use the information that it receives from the environment, and from its beliefs and intuitions, to decide which is the best plan of action to follow in order to fulfill its objectives.

***Social level:*** This level is very important as our agents are within communities and they exchange information with other agents. Thanks to this level they can cooperate with other agents by using an expressive language. This language analyzes the present situation, considering the goals and interests of the agent and structure solutions in the form of plans.

Two further important components of our architecture are the *Interpreter* and the *Planner*. The former is used to perceive the changes that take place. The planner indicates how the actions should be executed.

In this paper only the deliberative architecture is described due to space restrictions.

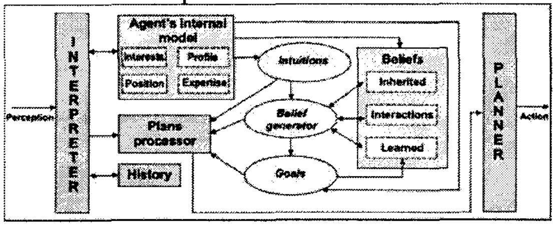

Figure 2. Deliberative architecture.

The components of the Deliberative Architecture are (see Figure 2);

***Agent's internal model***: As an agent represents a person in a community this model stores the user's features. Therefore, this module stores the following parts:

- The *interests*. This part is included in the internal model in order to make the process of distributing knowledge as fast as possible. That is, the agents are able to exchange knowledge automatically, checking whether their stored knowledge matches with the interests of other agents. This behaviour fosters knowledge sharing and reduces the amount of work employees have to do because they receive knowledge without making searches.
- *Expertise*. This term can be briefly defined as the skill or knowledge of a person who knows a great deal about a specific thing. This is an important factor since people often trust in experts more than in novice employees.
- *Position*. Employees often consider information that comes from a boss as being more reliable than that which comes from another employee in the same (or a lower) position as him/her [11]. In an enterprise this position can be established in different ways, for instance by using an organizational diagram or classifying the employees according to the knowledge that a person has.

Such different positions inevitably influence the way in which knowledge is acquired, diffused and eventually transformed in the local area. Because of this these factor will be calculated in our research by taking into account a weight that can strengthen this factor to a greater or to a lesser degree.

***History***: This component stores the interactions of the agents with the environment.

***Belief generation***: This component is one of the most important of the cognitive model because it is in charge of creating and storing the agent's knowledge. Moreover, it defines the agent's beliefs.

***Beliefs***: The beliefs module is composed of the inherited beliefs of the organization, lessons learned, and agents' interactions. Inherited beliefs are the organization's beliefs that the agent receives. For instance: an organizational diagram of the enterprise, the expertise of each employee, the philosophy of the company or community. Lessons learned are the lessons that the agent obtains while it interacts with the environment This interaction can be used to establish parameters in order to know what the agent can trust (agents or knowledge sources).

***Intuitions***: The intuitions are beliefs that have not been verified but which it thinks may be true. According to [7] intuition has not yet been modelled by agent systems. In this work we have tried to adapt this concept by comparing the agents' profiles to obtain an initial value of intuition that can be used to form a belief about an agent.

***Goals***: The goals are formed by the objectives of the agent. For instance, one of the goals of each member of a community of practice is knowledge exchange. The goals are defined in accordance with the community or group in which the agent interacts

## 4. Prototype

In order to test our architecture we have developed a prototype system into which people can introduce documents and where these documents can also be consulted by other people. The goal of this prototype is to allow software agents to help employees to discover the information that may be useful to them thus decreasing the overload of information that employees often have and strengthening the use of knowledge bases in enterprises. In addition, we try to avoid the situation of employees storing valueless information in the knowledge base.

The main feature of this system is that when a person searches for knowledge in a community, and after having used the knowledge obtained, that person then has to evaluate the knowledge in order to indicate whether:

- The knowledge was useful.
- How it was related to the topic of the search (for instance a lot, not too much, not at all).

To design this prototype we have designed a *User Agent* and a *Manager Agent*. The former is used to represent each person that may consult or introduce knowledge in a knowledge base. Therefore, the *User Agent* can assume three types of behavior or roles similar to the tasks that a person may carry out in a knowledge base. The User Agent plays one role or another depending upon whether the person that it represents carries out one of the following actions:

- The person contributes new knowledge to the communities in which s/he is registered. In this case the User Agent plays the role of **Provider**.
- The person uses knowledge previously stored in the community. Then, the User Agent will be considered as a **Customer**.
- The person helps other users to achieve their goals, for instance by giving an evaluation of certain knowledge. In this case the role is of a **Partner**. So, Figure 3 shows that in community 1 there are two User Agents playing the role of Partner, one User Agent playing the role of Consumer and another being a Provider.

The second type of agent within a community is called the *Manager Agent* (represented in black in Figure 3) which must manage and control its community.

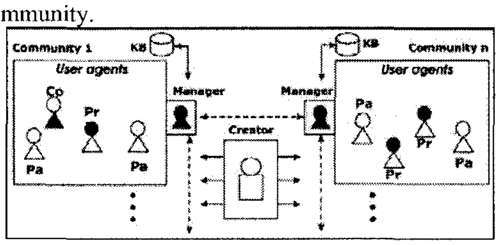

Figure 3. Communities of agents

The prototype provides the options of using community documents and updating reputation values, proposing new topics in the community, etc. Due to space limitations, we shall now describe only the following situation:

*Using community documents and updating reputation values*. People can search for documents in every community in which they are registered. When a person searches for a document relating to a topic his/her User Agent consults the Manager Agent about which documents are related to their search. Then, the Manager Agent answers with a list of documents. The User Agent sorts this list according to the reputation value of the authors, which is to say that the contributions with the best reputations for this Agent are listed first. On the other hand, when the user does not know the contributor then the User Agent consults the Manager Agent about which members of the community know the contributors. Thus, the User Agent can consult the opinions that other agents have about these contributors, taking advantage of other agents' experience. To do this the Manager consults its interaction table and responds with a list of the members who know the User Agent. Then, this User Agent contacts each of them. If nobody knows the contributors then the information is listed, taking their authors' expertise and positions into account. In this way the User Agent can detect how worthy a document is, thus saving employees' time, since they do not need to review all the documents related to a topic but only those considered most relevant by the members of the community or by him/herself according to previous experience with the document or its authors.

Once the person has chosen a document, his/her User Agent adds this document to its own document list (list of consulted documents), and if the author of the document is not known by the person because it is the first time that s/he has worked with him/her, then the Community Manager adds this relation to the interaction table. This step is very important since when the person evaluates the document consulted, his/her User Agent will be able to assign a trustworthy value to that document. The formulas used to approach this have been explained in [8] (they have been omitted due to space constrains).

## 5. Conclusions

Communities of practice have the potential to improve organizational performance and facilitate community work. Because of this we consider it important to model people's behavior within communities with the purpose of imitating the exchange of information in companies that are produced in those communities. Therefore, we are attempting to encourage the sharing of information in organizations by using knowledge bases. To do this we have designed a multi-agent three-layer architecture where the artificial agents use similar parameters to those of humans in order to evaluate knowledge and knowledge sources. These factors are: reputation, expertise, position, previous experience and even intuitions.

This approach implies several advantages for organizations as it permits them to identify the expertise of their employees and to measure the quality of their contributions. Therefore, it is expected that a greater flow of communication will exist between them which will consequently produce an increase in their knowledge.

## 6. Acknowledgement

This work is partially supported by the ENIGMAS (PIB-05-058), and MECENAS (PBI06-0024) project, Junta de Comunidades de Castilla-La Mancha, Consejería de Educación y Ciencia, both in Spain. It is also supported by the ESFINGE project (TIN2006-15175-C05-05) Ministerio de Educación y Ciencia (Dirección General de Investigación)/ Fondos Europeos de Desarrollo Regional (FEDER) in Spain.

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