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An agent-based system to build project memories during engineering projects

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ABSTRACT

Engineering projects are organizations where several actors with different professional fields and know-how work together to carry out the same aim: to develop a new product. Inside these organizations, heterogeneous and distributed information has to be managed in order to create project memories that will be useful in future projects. In this paper we describe a Multi-Agent System (MAS), which is based on the social and cooperative approach to support the knowledge management process all along mechanical design projects. Indeed, this multi-agent system, called KATRAS, aims to capitalize and reuse knowledge according to the roles involved in the design projects. We will present in this paper how the agents capitalize six different types of knowledge (professional vocabulary, process, expertise, project evolution, and return of experience) and how they help the professional actors to reuse knowledge.

1. Introduction

Current competitiveness has led companies to fast product renewal coupled with lower costs. Today, manufacturers are creating more and more efficient products while meeting shorter deadlines in order to satisfy the customer's needs and target sales.

These companies have to break into new markets by showing how creative they are in order to grow more profitable. Such creativity requires an optimized organizational mastery, a control of the industrial process and the development of a 'learning company' in which getting the innovation knowledge represents an asset for the ongoing projects. Learning within the company has now become the best way to be competitive. The 'learning culture' implies that every co-worker, every team and even the whole company will be able to optimize their capacities by continuously sharing their knowledge and their know-how and to learn about the best actions and the failures encountered in the past.

In this article we present a knowledge management approach based on a multi-agent system, which captures knowledge according to the roles of the professional actors. We will focus on the various roles played by the actors and their cooperation. Our approach will dwell on the study and the modeling of different design activities from an organizational point of view.

Organizations can be defined as a set of connected entities run by social interactions between independent actors in order to achieve a common goal [14,9]. Every actor is autonomous thanks to his/her knowledge and know-how, but also every co-worker communicates with every other so that their common activities will be performed successfully. Due to the sustained interactions between actors, knowledge is shared and experiences are created inside the organization. These organizations need to be modeled in order to create a system that is able to capitalize knowledge and build up project memories including experience reuse. The system will also enable the reuse of knowledge every time the actors involved in the project demand it.

In the first part of this paper, we will introduce a description of the various project memory types. Section 2 presents an analysis of knowledge engineering research using the agent paradigm. This paper will lead us to a thorough analysis of the proposed multi-agent system regarding knowledge management. Finally, some knowledge management packages, especially the experience reuse module, will be presented.

2. Heterogeneous and distributed project memories

Knowledge is an organization's most powerful resource used to improve profitability and maintain competitiveness, an aspect which determines the knowledge management to become critical for organizational success [34]. The need to store knowledge inside the companies has led to the creation of organizational memories, often called project memories [48].

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A project memory can be defined as an explicit and continuous representation of knowledge, data or data source within an organization [27,45]. Moreover Abecker et al. [2] adds the fact that the project memories also contain the context in which the knowledge has been created, as it allows the annotation of the information and facilitates the reuse of information.

Therefore, the stake of the project memory management is to allow professional actors to reuse and share knowledge, which has been capitalized from previous projects in order to carry out a new one [5]. Our design project analysis in different companies led us to the conclusion that:

- A project memory is by nature a source of heterogeneous and distributed information coming from software programs, technical documentation or staff meeting reports [32].
- The project memory users are heterogeneous and distributed. They have specific qualities and play different roles all throughout projects, such as design engineers, mechanical engineers, automatic engineers, and assembly technicians. These professional actors have to collaborate during the project and are in different geographic locations.

In order to do this, the creation of a project memory, by taking into consideration these heterogeneous and distributed information sources, is based on different stages, as expressed by [18]: the needs, the detection, the construction and structuring, the diffusion and the contents, the exploitation of the contents, the evaluation of the objectives, the maintenance and the evolution of the contents.

In the literature, different works propose new methods and models for data acquisition and construction of project memories. For example, Ribière et al. [50] proposes a project memory based on conceptual graphs for knowledge representation, Matta et al. [42] develops a project memory by capitalizing the trace of old projects, while others focus on the design of novel methods for tracking the design rationale: QOC [52], DRCS [38] or on the evolution of decisions during a project, like DyPKM [6]. Recent studies have been building project memories by exploiting the connection between knowledge sharing and employee service performance [40], or by creating a transactive memory system [36].

The main objective of a project memory is to help the involved actors to accomplish their activities or to solve new problems. To achieve these activities, the actors need to use a common terminology, especially when they are geographically distant; this explains why organizational memories are often based on ontologies, an aspect which will be discussed in the following section.

Thus we propose to design a knowledge-based system that enables to manage heterogeneous and distributed information and to take into account the social and collaborative aspects concerning professional actors. The distributed artificial intelligence domain, and more particularly the Multi-Agent Systems (MAS) facilitate the modeling of increasingly sophisticated systems. Studies have shown that the agent paradigm has turned out to be well adapted to the software structure design that ensures heterogeneous and distributed information management.

Indeed, a MAS can provide a flexible organizational memory, i.e. to adapt the structure of the memory according to the role of the actors and the knowledge they can create, share or use.

The next section will present the benefits of using software agents in the knowledge management domain.

3. The agent paradigm in knowledge engineering

Knowledge engineering is meant to gather, study, organize and represent knowledge. Multi-agent systems seem to be able to perform such a task. Klusch made a list of the services that a multi-agent system can offer in a knowledge management approach [39]:

- Knowledge search, acquisition, analysis and classification from various data sources.
- Information given to human and computing networks once usable knowledge is ready to be consulted.
- Negotiation on knowledge integration or exclusion into the system.
- Explanation of the quality and reliability which are related to the system integrated knowledge.
- Learning progressively all along the knowledge management process.

Such services are mostly implemented to create two MAS categories devoted to knowledge management. The first MAS type is based upon an agent cooperation to solve complicated problems related to the knowledge types. The second MAS category gathers management assistant agents depending on the actors' needs. We describe these categories in the following subsections.

3.1. MAS used in knowledge engineering

In this range, agents are expected to be flexible, proactive and reactive regarding user requirements [56,14]. In other cases, this feature is completed with the agent's ability to run distributed data and solve difficulties such as knowledge distribution cooperation in a community of practice [32].

Some of these MAS were created as complementary tools in information management (workflows, ontologies, information research systems, and so on) to design platforms such as FRODO [1], CoMMA [24], Edamok [8] and KRAFT [46]. All these works have pointed to the 'Multi-Agent Information System' or MAIS. A MAIS is a multi-agent system whose functions manage and use distributed information [15,16,24]. Moreover, access authorization, data upgrading and compiling heterogeneous information are some of the MAIS capacities.

In addition, Van Elts in [58] suggests to take into account the collaborative dimension of a domain along with the actors' needs and goals in the same domain. This approach is known as 'Agent Mediated Knowledge Management' or AMKM. AMKM agents are defined in *agent organizations* with a specific description of their roles and configurations that enable interactions. These organizations make knowledge management easier in dynamic environments. It is therefore the first contribution towards the importance of collaborative and social aspects in a domain for MAS specification dedicated to knowledge management.

Thanks to this, the system is able to calculate how much knowledge to capitalize, and to anticipate the actors' needs when they carry out their professional activities. Agent organization modeling is one approach to the MAS specifications. We propose to use this approach in order to define our knowledge-based system.

However, even if agent organizations make it possible to take into account the social and collaborative aspects of the project teams, we have to provide these agents with the capability to handle knowledge. This functionality can be performed if the MAS uses a ontologie to understand the knowledge world. In the next section we will present some research works using the ontologies for knowledge exploitation.

3.2. Ontologies used in MAS to handle knowledge

3.2.1. Ontologies to help knowledge modeling

Knowledge created and used in engineering projects comes from the interpretation of the professional actors having a collection of technical data in a given activity [59].

Ontology is an object of Artificial Intelligence that recently came to maturity, and a powerful conceptual tool of Knowledge Modelling [7,25]. It provides a coherent base to build on, and a