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A Comparison of Knowledge Management Approaches based on Multi Agent Systems

A. Ben Miled[1], D. Monticolo[1], V. Hilaire[1], and A.Koukam[1]

[1]University of Technology Belfort Montbéliard, 90000 Belfort France

***Abstract*—The economic challenge around the reduction and optimization of product development is important for industrial companies. The modern enterprise depends upon timely and effectively flows of knowledge through its organizations for success. The growing focus on knowledge management is leveraged by rapidly advancing information technology and, more importantly, driven by fundamental structural change and transformation towards information driven organizations. This paper presents an overview about different research works in knowledge management domain based on multi agent systems and their contributions under the angle of the knowledge life cycle process.**

***Index Terms*— Knowledge management, multi agent systems, knowledge capitalization, knowledge reuse.**

I. INTRODUCTION

The economic challenge around the reduction and optimization of product development is important for industrial companies. The modern enterprise depends upon timely and effective flows of knowledge through its organizations for success. The growing focus on knowledge management is leveraged by rapidly advancing information technology and, more importantly, driven by fundamental structural change and transformation towards information driven organizations [1].

The main goal of Knowledge Management (KM) is to provide relevant knowledge to assist users in executing knowledge intensive tasks. KM is about facilitating an environment where work critical information can be created, structured, shared, distributed and used. To be effective such environments must provide users with relevant knowledge, that is, knowledge that enables users to better perform their tasks, at the right time and in the right form [2]. Knowledge Management (KM) has been a predominant trend in business in the recent years. As it is often mentioned in the literature, knowledge tasks have a collaborative aspect, that is, an individual can best acquire and use knowledge by reusing information already collected and annotated by others or by making use of existing relations among people (communities) [3]. Furthermore, a KM system must be able to adapt to changes in the environment and to the different needs and preferences of users.

Intelligent agents are a paradigm for developing software applications and are currently the focus of intense interest on the part of many fields of computer science and artificial intelligence [4].

Multi agent systems (MAS) are used in knowledge management domain, for example, to assist users in their tasks or to capitalize knowledge and to propose it to the right person at the right time in the right form.

In this paper, we intend to present an overview of the different categories of research works in knowledge management domain based on MAS**.** In order to compare these approaches we propose the identification of their respective contributions to the phases of the knowledge life cycle. In addition to this first categorization we have considered the models underlying the different approaches, the type of knowledge that can be managed, the existence of techniques for knowledge evaluation and how the knowledge is stored.

The paper is organized as follows: Section 2 defines and introduces the main phases of the knowledge life cycle. Section 3 explains the basic concepts of Multi-Agent Systems and their use for knowledge management. Section 4 discusses some research works in knowledge management based upon MAS. Finally, section 5 presents our conclusions.

II. KNOWLEDGE LIFECYCLE

We consider knowledge as the interpretation of information by a human being, in a given context [5]. KM is a vast domain which can be considered in several ways. In this paper, we consider it under the angle of the knowledge life cycle to categorize the various contributions. The study of the main researches on the knowledge life cycle [6]-[7] advances four main phases: the generation, the storage, the distribution (transfer) and the application of the knowledge (reuse). These phases are presented in the following figure (figure 1).

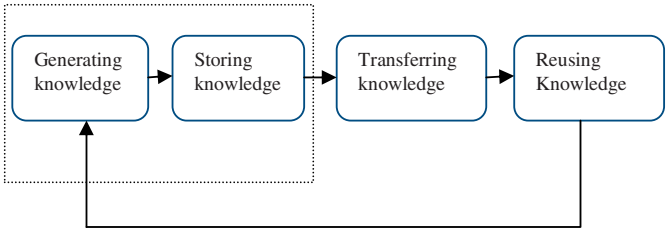

FIG 1. Knowledge life cycle

A. *Generating knowledge*

The knowledge generation phase corresponds to the development of new contents or to the replacement of existing contents. This phase is identified by various terms as: acquisition, search, generation, creation, capture or supply [8]. All these terms have a common objective the accumulation of knowledge.

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The model of creation of knowledge developed by [9] describes how knowledge conversion takes place through an iterative and spiral process of socialization, externalization, combination and internalization. This conversion is an effective means of making individuals' tacit knowledge available to the broader organization in order to create new knowledge and then apply this new knowledge within their business processes towards achieving the organization's vision, objectives and performance standards.

B. Storing Knowledge

The storage consists of identifying, collecting and making exploitable, whatever is the context, the knowledge acquired or created by an organization and his members [10]. So, the organization must be capable of organizing, integrating, associating, structuring, coordinating and of distributing this knowledge [11].

Stein [12] describes this process of storage of the knowledge in two phases: 1) a first phase of acquisition and preservation and; (2) a phase of search and restoration of the knowledge. The first phase is interested in the representation of the knowledge in a way that it can be besides reused by various organizational members. The second phase consists of search and restoration. It is strictly connected to the first phase as what concerns the codification of the knowledge.

C. Transferring Knowledge

Knowledge transfer irrigates the organization with knowledge and allocates new knowledge [13]. Knowledge must be actively distributed to those who can make use of it. The transfer speed of knowledge is increasingly crucial for the competitiveness of companies. Pieces of knowledge are transferred from where they were created, captured or stored to where they may be useful [14]. It is called "activation of the memory" to avoid oblivion knowledge buried and dormant in a long forgotten report [11].

Most of the literature relative to the knowledge transfer in organizations is established in the field of the strategic management. It is mainly about the sharing of knowledge or more exactly about sharing the best practices with another organization or between various departments of the same company.

D. Reusing Knowledge

The process of knowledge management is going to take all its sense when knowledge is reused in the organization; it is the process of application of the knowledge [15].

The transfer of the knowledge constitutes the first stage of knowledge application. The re-use implies at the same time the reminder of the information which was stored, in such place, under such index or plan of classification, and the identification which means that knowledge is reused by the right users at the right time, so that users really apply the knowledge [16].

III. Agents And Their Interests For KM

A. Intelligent software agents

The key issue in software agents is **autonomy**, which refers to the principle that agents can operate on their own, without the need for human guidance. An autonomous agent has the control over its own actions and internal state. That is, an agent can decide whether to perform a requested action. Furthermore, agents are problem-solving entities, with well-defined boundaries and interfaces, designed to fulfill a specific purpose and exhibit flexible and pro-active behavior. Autonomous agents have the possibility to interact with other agents using a specific communication language, thus creating a sort of social ability that allows them to perceive their environment, respond to its changes or achieve goals by simply adapting and reacting to other players. A Multi-Agent System (MAS) can therefore be defined as: "a collection of possibly heterogeneous, computational entities, having their own problem solving capabilities and which are able to interact among them in order to reach an overall goal" [17].

Agents usually operate in a dynamic, non-deterministic complex environment, in which a single input action can often produce unexpected results. MAS environments assume no global control, data decentralization and asynchronous computation.

Furthermore, agents in a MAS are assumed to operate with incomplete information or capabilities for solving the problem. Communication is thus the key for agents to share the information they collect, to co-ordinate their actions and to increase interoperation.

B. Motivations for using MAS for KM

In heterogeneous systems, knowledge sharing is hampered by the lack of common ontologies. Therefore, adequate support for ontology matching and meaning negotiation is of great importance to MAS.

KM environments can be described as distributed system where different actors, acting autonomously on behalf of a user, and each pursuing its own goals, need to interact in order to achieve their goals. In such environments, the ability to communicate and negotiate is paramount. Furthermore, the number and behavior of participants cannot be fixed a priori and the system can be expected to expand and change during operation, both in number of participants as in amount and kind of knowledge shared. The choice for multi-agent systems for KM is motivated by the following observations:

- KM domains involve an inherent distribution of data, problem solving capabilities and responsibilities (conforms to the ideas of autonomy and social ability of agents).
- The integrity of the existing organizational structure and the autonomy of its subparts need to be maintained (uses autonomous nature of the agents).
- Interactions in KM environments are fairly sophisticated, including negotiation, information sharing, and coordination (requires complex social skills with which agents are endowed).
- KM domains call for a functional separation between knowledge use and knowledge sources as a way to

incorporate dynamic behavior into information systems design (agents can act as mediators between source and application of knowledge).

- The solution for KM problems cannot be entirely prescribed from start to finish and therefore it is required that problem solvers can respond to changes in the environment, to react to the unpredictability of business process and to proactively take opportunities when they arise (requires the reactive and proactive abilities of agents).

In order to cope with the inherent complexity of a more comprehensive solution, the concept of Agent-mediated Knowledge Management (AMKM) proposes agent based approaches to deal with collective aspects of the domain in an attempt to cope with the conflict between desired order and actual behavior in dynamic environments.

Inherent to AMKM is a social layer, which structures the society of agents by defining specific roles and possible interactions between them. Van Elst and Abecker [18] argued that "the basic features of agents (social ability, autonomy, re- and pro-activeness) can alleviate several of the drawbacks of the centralized technological approaches for KM".

In KM environments, agents can check the dynamic conditions of the environment, reason to interpret those perceptions, solve problems, draw inferences and determine actions, and finally, act accordingly. The use of agents in KM can be seen in two perspectives [19]-[2]. On the one hand, agents can be used to model the organizational environment where the KM system will operate and, on the other hand, software agents can be used to implement the functionality of KM systems. Most existing KM projects involving agent technology concentrate on using agents as implementation tool modeling primitives. Agents are used there to support and extend the activity of (human) users. However, more and more researchers' works are showing the advantages of agent-based modeling of KM environments.

IV. Different Research works

In this section, we try to make an overview about knowledge management domain based on multi agent systems by studying different research works which tackle this research area. In the first subsection we establish some criteria in order to categorize the different approaches. The three last subsections present different families of approaches. The first uses MAS as implementation technique for KM. The second considers MAS as a modeling technique fitted for KM and the third proposes methodologies based upon MAS for KM.

A. Criteria

In Table 1, we try to compare between some research works listed in the previous section based on their contributions to support knowledge management.

To compare the different knowledge management research works we have chosen some criteria. These criteria are: their contributions relatively to the knowledge life cycle, the underlying model used, the existence of techniques for knowledge storing and evaluation and the knowledge type(s) considered.

As we have explained knowledge life cycle in Section 2, we define the other criteria in the next paragraph.

- Underlying model: in order to manage knowledge a model of the concerned real domain is necessary. This model enables the understanding and provides means for the analysis of the concerned domain. This domain can be represented by a model constructed with a modelling formalism [20]. It is used to model pertinent aspects of the domain depending on the specific goals of the Knowledge Management System.
- Knowledge type: in our study we consider explicit knowledge types that have been or can be articulated, codified, and stored in certain form like documents, links, multimedia etc. It can be readily transmitted to others [9].
- Knowledge evaluation: it assesses the availability and needs of knowledge [21]. However it also aims at evaluating the solution chosen for the memory and its adequacy, comparing the results to the requirements, the functionalities to the specifications etc.
- Means to store knowledge: knowledge should be identified, collected and so stored to be exploitable. They are many means to store knowledge like project memories, knowledge base, RDF Resources etc.

B. Agents as implementation technique

Knowledge Management Environments can be implemented as communities of different types of agents that collaborate to provide the required support to users on their knowledge intensive tasks. In agent-based implementations of knowledge management systems, software agents are employed as tools to manage loosely coupled information sources, to provide unifying presentation of distributed heterogeneous components and to personalize knowledge presentation and navigation. Possible agent-based services in a KM system are [22]:

- Search for, acquire, analyze, integrate and archive information from multiple heterogeneous sources,
- Inform us (or our colleagues) when new information of special interest becomes available,
- Negotiate for, purchase and receive information,
- Explain the relevance, quality and reliability of that information,
- Learn, adapt and evolve to changing conditions.

These services are often specified in terms of the following types of agents [21]-[23]:

- **Personal Assistants** represent the interests of a user and provide the interface between users and the system. They are concerned with user preferences and needs, and will present information in the preferred format, at the right time. A proactive personal assistant agents will not only perform the tasks given to it by a user, but will also suggest knowledge sources or other resources that are not explicitly requested if they match the user's interests.
- **Cooperative Information Agents** (CIAs) focus on accessing multiple, distributed and heterogeneous information sources. A CIA needs to maintain actively its information by communicating with others and reasoning about its own information.

- **Task analysts** are agents that monitor a certain task in the business process, determine the knowledge needs of the task, and gather that knowledge by communicating with other agents. The agent can also monitor the execution of a task and evaluate the applicability of the knowledge provided. The lessons learned here are used to update its internal state and optimize the task knowledge.
- **Source keepers** are agents dedicated to maintaining knowledge sources and are responsible for describing the knowledge contained in the source and extract relevant information for a given request.
- **Mediators** are agents that can provide a number of intermediate information services to other agents. They may suggest collaboration between users with common interests, or provide information about the available tools.

C. MAS as modeling technique

Dignum [2] proposed a framework for agent societies called OperA. OperA uses the agent paradigm to analyze and *model organizations* and their knowledge needs, and to provide a reusable architecture to build KM systems and which contributes essentially to knowledge transfer process. Authors adopted the organizational model and used links and multimedia as type of knowledge.
Different knowledge intensive tasks need knowledge from different sources and in different presentation formats. Therefore, the framework distinguishes between application, description and representation of knowledge and provides a common, uniform description of knowledge items (both sources and needs). A community of collaborative agents is responsible for the matching of knowledge supply and demand taking in account the user needs and preferences and the knowledge needs of a task. By collaborating with each other and with users, agents will learn and dynamically extend this framework by checking the current conditions of the environment. Agents will collaborate to interpret those perceptions, solve problems, draw inferences and determine actions, and finally, act accordingly. Information agents specialized in the different types of sources can provide this description.
Lieberman [24] has developed Letizia, a user interface agent that assists a user browsing the World Wide Web which contributes to knowledge capitalization and reuse.
He adopted a user's preference model as underlying model and used documents as knowledge type. Letizia's role during user interaction is merely to observe and make inferences from observation of the user's actions that will be relevant to future requests by learning *user's preferences*. In parallel with the user's browsing, Letizia conducts a resource-limited search to anticipate the possible future *needs of the user*. Letizia adopts a strategy that is midway between the conventional perspectives of *information retrieval* and *information filtering* [25]. Letizia can interleave both retrieval and filtering behavior initiated either by the user or by the agent but it doesn't make an evaluation to the knowledge proposed to the user.
Soto *and al* [26] proposes a generic model for developing KMS which aims to capitalize and reuse knowledge. The architecture has two Agent Agencies. The first one is the User Agency that includes the Interface and the Personal Agent. The Interface Agent works like a bridge between agents and users showing the information to the users. The Personal Agent is in charge of obtaining the user's profile in order to know the user's preferences with the goal of adapting the representation of the knowledge to each user's preference.
On the other hand, there is a Knowledge Agency to support the activities described in each stage of the knowledge model. Therefore, they have defined a Captor Agent that must extract information from different knowledge sources previously defined in ontology. Authors use a Maintenance Agent which evaluates which knowledge is most frequently used and which should be deleted because it has become obsolete or is inconsistent with the new knowledge.
Renata and al [19] focused on *organizational reengineering* to favor KM. He adopted an organizational model and used links and multimedia as type of knowledge. He proposed an approach named ARKnowD to support the analysis and design of KM solutions in organizational settings. ARKnowD is intrinsically agent-oriented, recognizing the suitability of agents to be used as analysis abstractions, representing humans, organizations and systems involved in the organizational setting which facilitates the knowledge transfer.
Tacla's research [29] focuses on how he intends to automatically capture the operations performed on a desktop computer by using personal assistant agents, and how he intends to organize them as Lesson Learned. He adopted Petri Nets to model his approach and used documents as type of knowledge. He was also interested in how agents help users with the sharing of the acquired Lesson Learned. The proposed system provides a path for the re-use of the knowledge by explaining how to capitalise upon it, but it did not tackle the automatic assistance of users to help them by reusing knowledge.
Van Elst *and al* [30] have proposed the Mymory workbench approach. Mymory is based on a semantic wiki system and supports manual as well as automated annotations of wiki documents. It consists of three main elements which are realized on top of a light-weight service framework: i) *Document Work Services* support core activities like document production (writing, annotating, *etc.*) and document consumption (reading). ii) *Context Services* realize the acquisition of user context and attention information. iii) *Information Services* comprise tools which aim at supporting a user's current task with relevant information (*e. g.*, search) and which contributes to knowledge reuse process. The vocabulary which is used by these services is provided by ontologies (modeling context and annotation types) and a Personal Information Model (PIMO) which represents the mental concepts used by the knowledge worker to get his work done. PIMO provides a vocabulary for describing information elements on an individual desktop (for example persons, projects, and locations). It comprises relatively informal tag or topic map-like elements as well as more formal aspects with the expressivity of RDF/S.

D. MAS as methodology for KM

Markus [27] has introduced an agent-oriented modeling approach for analyzing knowledge transfer effectiveness *in the light of stakeholders' goals* and has used different type of knowledge (documents, links etc). He has developed the Knowledge Transfer Agent KTA modeling method which has

the following contributions: First and foremost, it contributes to analyzing effectiveness of knowledge transfer instruments in the light of (potentially conflicting) stakeholders' goals. By introducing different levels of detail, the KTA modeling method aims to satisfy the need for different levels of analysis allowing both quick, high-level analysis and also more thorough, in-depth investigations of knowledge transfer instruments. It allows analyzing *how* knowledge transfer instruments work and achieve their goals, and *why* they can succeed or fail but doesn't contribute to knowledge reuse.

Monticolo *and al* [28] has proposed an *organizational approach* which aims to analyze and model the professional process used by project team in order to identify emanating Knowledge. He developed an organizational model (Called RIOCK) and used different types of knowledge. In collaboration with project teams, he has defined the types of knowledge to capitalize and which represent the structure of our project memory. Then he has explained and described each concept and relation of the project memory to build the associated ontology (Called OntoDesign). To manage project memory, he has developed agents to constitute a multi-agent system (MAS) i.e. a loosely coupled network of agents that work together as a society. He has defined several types of agent to support each part of the knowledge management process in order to assist engineers to exploit Knowledge all along projects. *Knowledge is evaluated* by different professional actors before its capitalization. Monticolo doesn't treat deeply knowledge transfer and reuse.

Gandon [21] has developed a multi-agents system for the management of a corporate semantic web based on an ontology. He adopted a user's preference model and used different types of knowledge. Three aspects were essentially developed in this work:

- the design of a multi-agents architecture supporting the organisational top-down approach followed to identify the societies, the roles and the interactions of agents;
- the construction of the ontology O'CoMMA and the structuring of a corporate memory exploiting semantic Web technologies;
- the design and implementation of the sub-societies of agents dedicated to the management of the annotations and the ontology and of the protocols underlying these groups of agents, in particular techniques for distributing annotations and queries between the agents.

In Gandon's researches work, knowledge is *evaluated by experts*. He gave some examples to transfer and reuse knowledge but he didn't treat them profoundly.

Other research works focus on knowledge evolution [11]. It is close to creation phase since it will deal with additions to the current memory. More generally it is the process of updating changing knowledge and removing obsolete knowledge; it is where the learning spiral takes place to enrich/update existing knowledge (improve it, augment it, precise it, re-evaluate it etc.).

In the following Table (Table 1) we present researchers' work listed above and their contributions following the criteria. If a criterion is treated by the author, we mark (+) else we mark (-). We also point out the underlying model used by authors and knowledge type(s) for each research work.

Author / criteria	Dignum	Lieberman	Soto	Markus	Monticolo	Gandon	Tacla	Renata	Van Elst
Generating knowledge	-	+	+	-	+	+	+	-	+
Storing knowledge	-	+	+	-	+	+	+	-	+
Transferring knowledge	+	-	-	+	-	-	+	+	-
Reusing knowledge	-	+	+	-	-	-	-	-	+
Underlying model	Organizational model	user's preference model	user's preference model	Goal oriented model	Organizational model	user's preference model	Petri nets	Organizational model	Personal Information model
Knowledge type	Links, multimedia	documents	documents	Different types of knowledge	Different types of knowledge,	Different types of knowledge	documents	Links, multimedia	documents
Knowledge evaluation	-	-	+	+	+	+	-	-	-
Means to store knowledge	-	Knowledge base	Knowledge base	-	Project memory	Project memory	Knowledge base	-	RDF resources

Table 1. Comparison between different research works

This table makes an overview of different research works in knowledge management domain based on multi agent systems. It shows their contribution to each criterion listed

above.

II. Conclusion

Current developments in KM indicate a need for systems that are reactive and proactive in relation to the needs and expectations of its users. In this paper, we have discussed the interest of multi agent system in the knowledge management process. We discussed also different research works which contributes to this domain using MAS. In such environments, the flow of knowledge within an organization (or organizations) must take in account not only the knowledge needs of business processes, but also the personal preferences and level of expertise of individual users. Knowledge management systems should support all phases of knowledge life cycle and also take into considerations knowledge evolution and evaluation. Different research works studied in this paper contribute to knowledge management through the contribution to the knowledge life cycle process and to other criteria like knowledge evaluation. We tried to make an overview which help researchers to make their own contributions.

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