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Proceedings – Memoria

13th International Congress on Computer Science Research
7mo. Simposium Iberoamericano de Computación e Informática

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Esta obra incluye artículos tanto en español como inglés de los siguientes temas: Cómputo evolutivo, Inteligencia artificial, Ingeniería de software y Sistemas de cómputo distribuídos.

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Mensaje del Director del Inst. Tecnológico de Ciudad Madero

El Instituto Tecnológico de Cd. Madero (ITCM) y la Academia Nacional de Ciencias Computacionales (ANaCC) agradecemos y les brindamos una cordial felicitación a todos los participantes del 13avo. Congreso Internacional de Investigación en Ciencias Computacionales y al 7mo. Simposium de Computación e Informática.

Ésta es la decimotercera edición de este congreso que tuvo su origen en 1994 ante la preocupación de investigadores de la ANaCC y de aquellas otras instituciones con los que mantenemos relación académica en México y allende las fronteras por lograr una identificación y unir esfuerzos que generarán la sinergia necesaria, que hoy ha permitido y fomentado la obtención de logros significativos para crear nuevas y mejores tecnologías, que redundan en mayores y mejores oportunidades de desarrollo y beneficio de la educación, de la productividad y la de mejoras en la calidad de vida.

El grupo de investigadores del ITCM y la ANaCC, con su responsabilidad asumida, establecen como una de sus principales metas, la organización de este 13avo. congreso. Hoy se ve realizada esta meta, después de un año de trabajos encaminados al logro del éxito de este magno evento.

Los vertiginosos cambios que definen la evolución del descubrimiento y la generación tecnológica nos han permitido, lo que es una fortuna, participar y observar que aún la teoría de la futurología cambia por el propio cambio, y hoy nos encontramos en la era del conocimiento, que sólo con los adelantos y desarrollo de los sistemas informáticos y computacionales, así como de la Internet y las tecnologías de la información en general, ha sido posible.

Dos aspectos caracterizan este congreso, el primero es que se abren puertas a los investigadores y cuerpos académicos, ya que se busca lograr el acercamiento de las diferentes regiones tal como lo exige el desarrollo mundial actual. El segundo es el lograr que este congreso se constituya en un verdadero foro en el que los investigadores y académicos den a conocer los resultados de sus experiencias investigativo-académicas para compartirlas entre ellos, y así seguir enriqueciendo el desarrollo de las ciencias computacionales e informáticas.

Así para el ITCM, la organización de este evento representa una ocasión más para seguir fomentando y estableciendo los vínculos necesarios entre investigadores, académicos e instituciones, ser el marco propicio de un espacio de reflexión colectiva y de una convivencia en que convergen inteligencia, conocimiento, motivación y camaradería.

Es mi deseo firme que los trabajos realizados en este evento sean de gran provecho para mantener la relación entre instituciones y provocar logros que coadyuven a la integración de un nuevo paradigma científico-académico en beneficio de profesores, investigadores, estudiantes y sector productivo, con una sólida responsabilidad ética y un claro compromiso social. Todo ello con la idea de que el conocimiento es el único bien que más crece cuando más se comparte.

Ing. José Fausto León Jacobo
Director del I.T.C.M.

Mensaje del Comité Organizador

Las ciencias de la computación continúan siendo una de las disciplinas que más impacto tienen en todos los ámbitos de nuestra vida. El ejemplo más notable es que, en los últimos años, la computadora ha pasado de ser una herramienta de trabajo a un artículo del hogar. Indirectamente, la computación, combinada con otras disciplinas y tecnologías, se encuentra presente en ámbitos tan importantes como Internet, telefonía inalámbrica, equipos médicos, automóviles, cajeros automáticos, comercio electrónico, gestión de empresas, etc.

Desde su creación en 1992, la Academia Nacional de Ciencias Computacionales (ANaCC) se propuso contribuir a incrementar el nivel académico de profesores y estudiantes en el área de computación de las instituciones del Sistema Nacional de Educación Superior Tecnológica en particular y del País en general. Para tal efecto, **la ANaCC ha organizado anualmente durante 15 años de manera ininterrumpida, primero dos congresos de alcance nacional y después 13 congresos de alcance internacional**.

Este año la ANaCC celebra el 13vo. Congreso Internacional de Investigación en Ciencias Computacionales (CIICC'06) y el 7mo. Simposium Iberoamericano de Computación e Informática (SICI'06), con el propósito de proporcionar un foro para que investigadores y académicos intercambien sus más recientes resultados originales de investigación y aplicación de las ciencias computacionales.

En esta ocasión el CIICC'06-SICI'06 cuenta con la participación de más de 40 ponentes y conferencistas procedentes de 27 instituciones representando a 4 países. El programa del CIICC'06-SICI'06 incluye conferencias magistrales y ponencias científicas y técnicas.

Los temas a tratar incluyen, entre otros, temas de actualidad como computación evolutiva, multiagentes, Internet, computación inalámbrica y ubicua, inteligencia artificial e ingeniería de software, así como aplicaciones en ingeniería y administración.

Los artículos incluídos en la memoria, fueron evaluados por dos revisores tomando en cuenta su originalidad, interés y presentación. El programa técnico ofrece a los participantes una magnífica oportunidad para incrementar sus conocimientos, conocer a nuevos colegas, e intercambiar ideas y experiencias.

En nombre del Comité Organizador del CIICC'06-SICI'06, les damos la más cordial bienvenida y los invitamos a realizar un fructífero intercambio de información técnica.

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Contenido – Contents

SESIÓN 1B: MULTIAGENTES E INTERNET
SESSION 1B: MULTI-AGENTS AND INTERNET

SESIÓN 1C.1: INGENIERÍA DE SOFTWARE Y ADMINISTRACIÓN I
SESSION 1C.1: SOFTWARE ENGINEERING AND MANAGEMENT I

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Design of a Multi-Agent Architecture to Manage Knowledge

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Abstract

Our aim in this paper is to demonstrate that the use of software agents can be very helpful during knowledge management process. Due to the importance that currently knowledge represents for the organizations we propose a generic multi-agent architecture (based on a knowledge cycle) to help developers to implement knowledge management systems. This architecture was developed by considering the main published knowledge process models and life cycles that related literature proposes. The architecture has different types of agents in charge of supporting the activities of acquisition, storage, use, application and evolution of knowledge, basic stages for a knowledge management process.

Key words: Multi-Agent Architecture, Knowledge Management.

1. Introduction

In recent years, knowledge has become a very important factor in organizations's competitive advantage. In fact, intellectual capital is one of the most important assets for many organizations [10]. Because of this, topics such as Knowledge Management (KM) are currently of special interest to organizations who are worried about their employees' learning and competitiveness. One way to assess an organization's performance is to determine how well it manages its critical knowledge.

KM can be defined as a discipline that enables an organization to take advantage of its intellectual capital in order to reuse it and learn from previous experience [25]. Skyrme [28] suggests that KM is the purposeful and systematic management of vital knowledge along with its associated processes of creating, gathering, organizing, diffusing, using, and exploiting that knowledge. KM provides methods and techniques that can help organizations to increment the collaboration of their members, for example, supporting the sharing of knowledge between them. Documented examples of benefits that can come from managing knowledge effectively include: reduced time-to-market; reduced development costs; innovative uses of existing products; revolutionary product ideas; and reduced employee turnover [22, 28].

On the other hand, Knowledge Management Systems (KMS) are tools whose main goal is to support knowledge creation [11]. To develop KMS is a difficult task since it is often necessary to know a priori what information will be requested, who will demand the information, who will supply the information, and when and how it will be used. Moreover, before developing this kind of systems it is advisable to study and understand how the transfer of knowledge is carried out among people in the real life and then to provide tools that foster that interchange of information. On the other hand, a lack of many traditional KMS is that they are mainly focused on the technology without taking into account the fundamental knowledge problems that KMS are likely to support [9].

Different techniques have been used to implement KMS. One of them, which is proving to be quite useful, is that of intelligent agents [29, 32]. Software agent technology can monitor and coordinate events or meetings and disseminate information [2]. Furthermore, agents are proactive; this means they act automatically when it is necessary. The autonomous behaviour of the agents is critical to the goal of this research; reducing the amount of work that employees have to perform when using a KM system. Another important issue is that agents can learn from their own experience. Consequently, agent systems are expected to become more efficient with time since the agents learn from their previous mistakes and successes [13].

Because of these advantages different agent-based architectures have been proposed to support activities related to KM [7]. Some architectures have even been designed to help in the development of KMS. However, most of them focus on a particular domain and can only be used under specific circumstances. What is more, they do not take into account the cycles of knowledge in order to use knowledge management in the system itself. For these reasons, in this paper we propose a generic design of a multi-agent architecture for managing knowledge as will be explained in the remainder of this paper. Therefore, in section 2 we summarize different knowledge models proposed in literature. Additionally, we propose our knowledge model. In section three, previous works based on multi-agent architectures are outlined. In Section four our architecture is described by explaining how each agent support the stages of the KM cycle. Finally, conclusions and future work are explained in section five.

2. Knowledge Models

In this section, we describe different proposals for knowledge life cycles. To foster the interchange of knowledge flow different techniques can be used and they may be supported by tools such as classic groupware tools. For instance, newsgroups, mailing lists, forums, bulletin boards, shared whiteboards, document sharing, chat, instant messaging, and or videoconferencing. Moreover, specific systems as KMS have been developed for this goal. However, as it was mentioned in the introduction many of these systems were developed from a technological point of view and less attention was paid to the fundamental knowledge problems. In order to avoid this problem, we have studied different knowledge models proposed in literature.

One of the most widely discussed approaches is the SECI process [19] where the interaction between tacit and explicit knowledge emerges as a spiral (knowledge spiral) that includes four layers of knowledge conversion:

- *Socialization*, when tacit knowledge is created from tacit knowledge. For instance, by communication between employees. One important point to note here is that an individual can acquire tacit knowledge without language. Apprentices work with their mentors and learn craftsmanship not through language but by observation, imitation and practice [18].

- *Externalization,* which requires the expression of tacit knowledge and its translation into comprehensible forms that can be understood by others, for instance, by formalising it in reports, documents, etc.
- *Combination*, when explicit knowledge creates more complex explicit knowledge by combining information that resides in formal sources like documents.
- *Internalisation*, when explicit knowledge generates tacit, for instance when a person consults formal sources like a book and increases his/her tacit knowledge. Frequently, enterprises lack of methods to foster this flow of knowledge and this fact leads to a repetition of mistakes and "reinvention of the wheel" [13].

In addition to SECI, different proposals about knowledge life cycles exist. There is no consensus in defining the stages that form a KM life cycle. While Davenport and Prusak [4] identify three tasks of knowledge management: (generation, codification/coordination and transfer). Wiig [35] observes five KM processes: (knowledge creation, knowledge storing, knowledge use, knowledge leverage, knowledge sharing).

Model	Stage1	Stage2	Stage3	Stage4	Stage5	Stage6
Nonaka and Takeuchi [19]	Socializa-tion	Externalization	Combina-tion	Internalization		
Wiig [35]	Creation	Storing/ gathering	Use	Leverage	Sharing	
Davenport and Prusak [4]	Generation	Codify/ Coordinate	Transfer			
Tiwana [31]	Acquire	Sharing	Use			
Rus and Lindvall [25]	Creation/ Acquisition	Organization/ Storage	Distribu-tion	Applica-tion		
Nissen [17]	Creation	Organization	Formalize	Distribute	Application	Evolve
Dickinson [5]	Identification	Acquisition	Develop-ment	Distribu-tion	Use	Preservation

Table 1. Knowledge Life Cycle Models

Table 1 describes different models found in literature where some authors consider in greater detail than others the distribution of the stages that compose the cycle. Some similarities found in the stages of the models of Table 1 helped us to define a process that is able to integrate the different proposals. For example, all the proposals consider stages to create, acquire, transfer, distribute, and disseminate knowledge. Another important aspect to take into account is that the capture or storing, and the access or retrieval of knowledge is also an important part of a KM life cycle model.

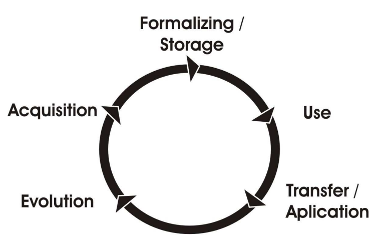

Figure 1. Knowledge Life Cycle Model Proposed

Taking the different stages that each model indicates into account, we have choosen those stages that we believe should be supported by our architecture to manage knowledge (see Figure

1) and that are critical for this kind of systems. They are acquisition, storage, use, application and evaluation.

3. Related Work

There exist a variety of KM frameworks, architectures, and approaches. Some of them helped us to consider what issues we had to take into account before developing our architecture.

Traditional KM systems have received certain criticism, as they are often implanted in companies overloading employees with extra work, since the employees have to introduce information into the KMS and worry about updating this information. One proposal to avoid this extra burden was to add software agents to perform this task in place of the employees. Later, intelligent agent technology was also applied to other different activities, bringing several benefits to the knowledge management process [14, 23, 24, 27, 29].

The benefits of applying agent technology to knowledge management include distributed system architecture, easy interaction, resource management, reactivity to changes, interoperation between heterogeneous systems, and intelligent decision making. The set of KM tasks or applications in which an agent can assist is virtually unlimited, for instance:

- CoMMA [7] project, (Corporate Memory Management through Agents), combines emergent technologies allowing users to exploit an organizational memory.
- In [14] a multi-agent system is proposed for knowledge sharing in a system designed to advise good programming practice.
- Wang et al. in [33] propose a multi-agent architecture to provide support to cooperative activities.

Besides these works we found others which focused on document classification [20, 36], mailing list management [16], or data mining [8].

These and other existing systems were often developed without considering how knowledge flows and what stages may foster these flows. Because of this, they often support only one knowledge task without taking into account that knowledge management implies giving support to different process and activities, for instance those which form the SECI model and that guarantee an increase of knowledge.

On the other hand, KM systems often focus on the technology without taking into account fundamental problems that this kind of systems is likely to support [9].

4. A Multi-Agent Architecture to Manage Knowledge

As our goals is to design a multi-agent framework centered on KM we will start this section by describing the knowledge model that our agents are based on and how they try to foster or support each process.

4.1 Knowledge Model

This model differentiates five KM processes (see Figure 1): Knowled acquisition, Knowledge formalizing/storage, Knowledge use, Knowledge transfer/application and Knowledge evolution:

- *Knowledge acquisition* is the stage responsible for making the organization knowledge visible. This stage considers the activities necessary to create organizational knowledge. Furthermore, the acquisition stage determines the organization skills for importing knowledge from external sources. The definition of the knowledge to be acquired can be assisted by classifying types of knowledge and knowledge sources [5]. To support this stage we propose to include in our architecture an agent called *Captor Agent*. The Captor Agent is responsible for collecting the information (data, models, experience, etc) from the different knowledge sources. It executes a proactive monitoring process to identify the information and experiences generated during the interaction between the user and groupware tools (email, consulted web pages, chats, etc.). In order to accomplish this, the Captor Agent uses a knowledge ontology which defines the knowledge to be taken into account in a domain. Another useful ontology is the source ontology which defines where each type of knowledge might be found (see Figure 2). Both of these are based on Rodriguez's ontologies for representing knowledge topics and knowledge sources [24].

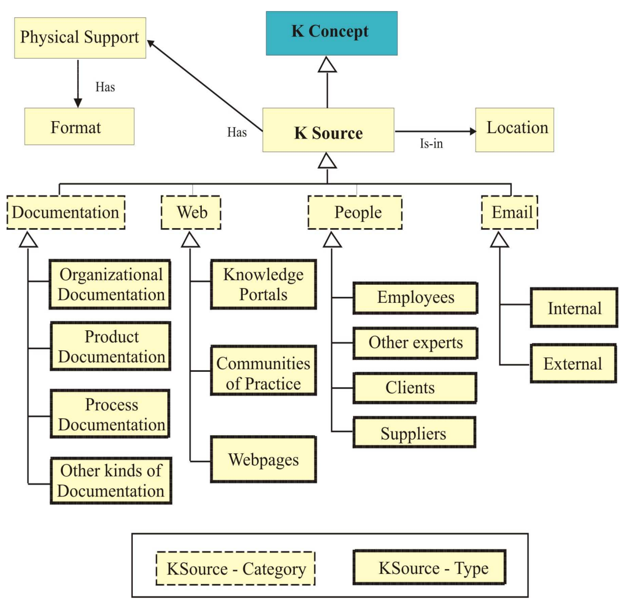

Figure 2. Knowledge Source Ontology

The ontology has four knowledge source categories. These are: Documentation, which can be subdivided into: documentation related to the organization's philosophy, documentation which describes the product/s which the company works with, documentation that describes the process that the company carries out. And other Types of documentation that an organization has but that cannot be classified into any of the previous subgroups. Another important source where the Captor finds information is the Web, which can also be divided into other subcategories such as Portals, Communities of practice, etc. The main knowledge source in a company is, without any doubt, people. Depending on the type of company, people may be classified as clients, employees, etc. The last knowledge source that the Captor Agent uses is email that can be classified as internal mail (mail sent between employees), and external mail (emails sent to other people outside the organization). The Captor Agent communicates with another agent (the *Constructor Agent*) which is in charge of creating knowledge. For example, when the Captor Agent acquires information that should be converted into knowledge sends this information to the Constructor Agent.

One advantage of this architecture is that the Captor agent can work in any domain since by changing these ontologies the Captor knows what key knowledge should be found and where it might be.

- *Knowledge formalizing/storing* is the stage that groups all the activities that focus on organizing, structuring, representing and codifying the knowledge with the purpose of facilitating its use [4]. To help carry out these tasks we propose a *Constructor Agent*. This agent is in charge of giving an appropriate electronic format to the experiences obtained so that they can be stored in a knowledgebase to aid retrieval. Storing knowledge helps to reduce dependency on key employees because at least some of their expert knowledge has been retained or made explicit. In addition, when knowledge is stored, it is made available to all employees, providing them with a reference to how processes must be performed, and how they have been performed in the past. Moreover, the Constructor Agent compares the new information with old knowledge that has been stored previously and decides whether to delete it and add new knowledge or to combine both of them. In this way, the combination process of the SECI model is carried out, producing new knowledge resulting in the merging explicit knowledge plus explicit knowledge.

- *Knowledge use* is one of the main stages, since knowledge is useful when it is used and/or reused. The main enemy of knowledge reuse is ignorance. Employers often complain because employees do not consult knowledge sources and do not take advantage of the knowledge capital that the company has. KM systems should offer the possibility of searching for information; they can even give recommendations or suggestions with the goal of helping users to perform their tasks by reusing lessons already learnt, as well as previous experiences. In our framework the agent in charge of this activity is the *Searcher Agent*, which searches in the knowledgebase for information that is needed. The result of the search will be sent to the *Interface Agent.* This will be explained in the next section. This agent could be implemented with different retrieval techniques. Since this architecture is proposed at a high level these aspects will not be dealt with in this paper. However, we would like to emphasize that the *Searcher Agent* fosters the internalization process of the SECI model, since the employees have the opportunity of acquiring new knowledge by using the information that this agent suggests.

- *Knowledge transfer/application* is the stage in charge of transfering tacit and explicit knowledge. Tacit knowledge can be transfered if it has been previously stored in shared means, for example: repositories, organizational memories, databases, etc. The transfer stage can be carried out by using mechanisms to inform people about the new knowledge that has been added. For this stage we propose a *Disseminator Agent*, which must detect the group of people, or communities who generate and use similar information: for example, in the software domain, the people who maintain the same product or those who use the same programming language. Therefore, this agent fosters the idea of a community of practice in which each person shares knowledge and learns thanks to the knowledge of the other community members [34]. An appropriate knowledge management linked to communities of practice helps to improve the organization's performance [12]. Disseminated information may be of different types; it may be information linked to the company's philosophy or specific information about a determined process. Finally, the Disseminator agent needs to know exactly what kind of work each member of the organization is in charge of and the knowledge flows linked to their jobs. In order to do this, the Disseminator Agent contacts with a new type of agent called the *Personal Agent* which gives him information about the profiles of the user. Comparing this stage with the SECI model we can say the *Disseminator Agent* fosters the socialization process since it puts people who demand similar knowledge in touch and once in contact they can share their experience, thus increasing their tacit knowledge.

- *Knowledge Evolution*. This stage is responsible for monitoring the knowledge that evolves daily. To carry out this activity we propose a *Maintenance Agent*. The main purpose of this agent is to keep the knowledge stored in the knowledgebase updated. Therefore, information that is not often used is considered by the Maintenance Agent as information to be possibly eliminated.

4.2 Multi-Agent Architecture

Once the knowledge model which the architecture is based on and the agents which support the different stages are defined we can then describe how the agents are organized into different agencies. Figure 3 shows that the architecture is formed of two agencies made up of several agents.

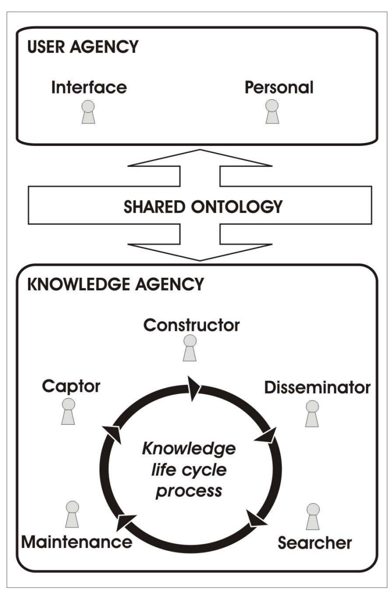

Figure 3. Multi-Agent Architecture for KM Systems.

The *Knowledge Agency* consists of the Constructor Agent, the Captor Agent, the Searcher Agent, the Disseminator Agent and the Maintenance Agent, previously described. Therefore, the agency is in charge of giving support to the KM process.

The *User Agency* consists of the *Interface Agent* and the *Personal Agent*. The *Interface Agent* acts as an effective bridge between user and the rest of the agents. Thus, if any agent wants to give a message to the user the agent needs to send it to the Interface agent which is the only one allowed to "talk" to the user. The Interface Agent also communicates with the *Personal Agent* which obtains user profiles and information that is relevant to users' knowledge and which helps to determine the expertise level and knowledge that each person has or that a person may need.

Another component used in this architecture is the *Shared Ontology*, this ontology is shared by all agents and provides a conceptualization of the knowledge domain. The Shared Ontology is used for consistent communication of the agencies.

4.3 Agents Collaboration and Some Implementation Aspects

As it was mentioned before, the agents must collaborate with other agents. In order to show how they collaborate we are going to describe a possible scenario that can take place in an organization.

Scenario

Let us imagine that a person is writing a mail and the agents start to work in order to check whether the mail contains information that should be stored in the knowledgebase (we suppose that the employees know that the mail are reviewed and they agree with this).

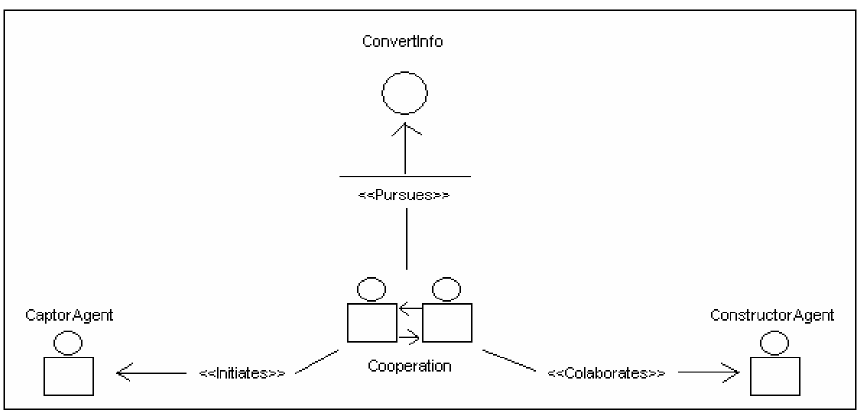

Figure 4. Cooperation between Captor and Constructor Agent.

Interface Agent captures each event that is trigged by the Employee. In this case the employee sends an email. Then, the Interface Agent advices the Captor Agent that an even has been triggered. Afterwards, the Captor Agent determines the type of groupware tool used (email) to identify and obtain information topics about related task. In order to obtain information from the mail, a new agent can be added to the system (it would not form part of our architecture) but would be an agent that has been already developed to assist in this task. There exist several

agents implemented to deal with email [13]. Most of the current implementations are text classifiers [26, 30] or keyword extractors [15]. The Captor Agent would study whether the information sent by the "email agent" should be transformed into knowledge. Finally, the Constructor Agent receives the information which is structured in form of, for instance, cases for its later storage. Figure 4 shows an interaction model diagram between the Captor and the Constructor Agent.
Methodology

This architecture has being designed by using INGENIAS [21] which provides meta-models to define MAS, and support tools to generate them. Using meta-models facilitates enormously the development of the system since they are oriented to visual representations of concrete aspects of the system.

Following, we are going to use the agent meta-model diagrams to describe the roles and tasks of each agent proposed in our architecture.

Agent roles

Roles represent the position of an agent in a society and the responsibilities and activities assigned to this position and expected by other to be fulfilled [6].

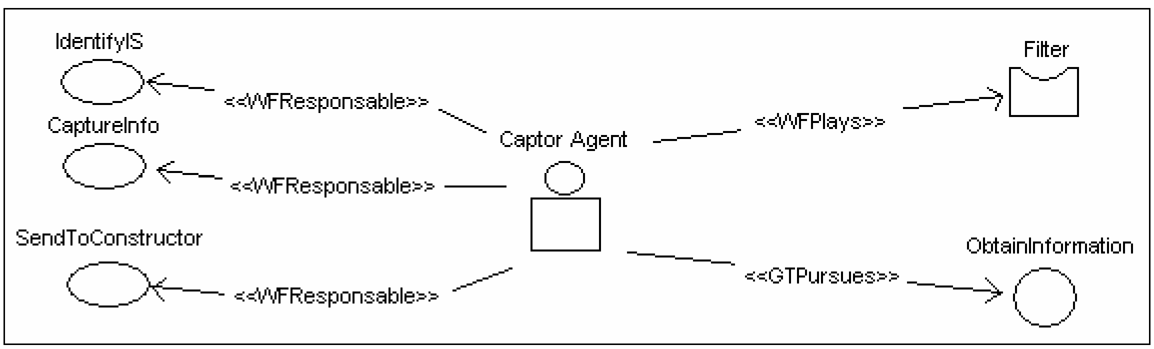

Figure 5. Captor Agent diagram

Figure 5 shows the goal, roles and tasks performed by the Captor Agent. The goal of this agent is to obtain information that should be stored. Its roles are "filter" since it must decide what information should be transformed into knowledge; the purpose being to use it in future projects. In the following lines, we describe each one of the task carried out by this agent.

- *CaptureInfo*: The agent must capture information.
- *IdentifyIS*: This task consists of identifing available information sources in the system.
- *SendToConstructor*: Once the suitability of storing the information has been analyzed, the Captor sends it to the Constructor Agent.

Figure 6 shows the role and tasks performed by the Constructor Agent whose roles are: sculptor and treasurer since it is in charge of giving an appropriate electronic format to the information (sculptor) and of storing it in the knowledgebase (treasurer).

The tasks developed by Constructor Agent are:

- *CompareInfo*: The agent is in charge of comparing the new information with the previously stored knowledge.
- *CombineInfo*: The agent is also in charge of combining the new information with the previously stored knowledge. In this way, the combination process of the SECI model is carried out, producing new knowledge resulting in the merging explicit knowledge plus explicit knowledge.
- *ClassifyInformation*: Another task is to classify the information received by the Captor Agent (for instance: models, structures, files, diagrams, etc.).
- *SendToDisseminator*: This is a critical task which consists of sending knowledge to the Disseminator Agent.
- *SaveKnowledge*: One of the most important tasks is to store the new knowledge into the knowledgebase.

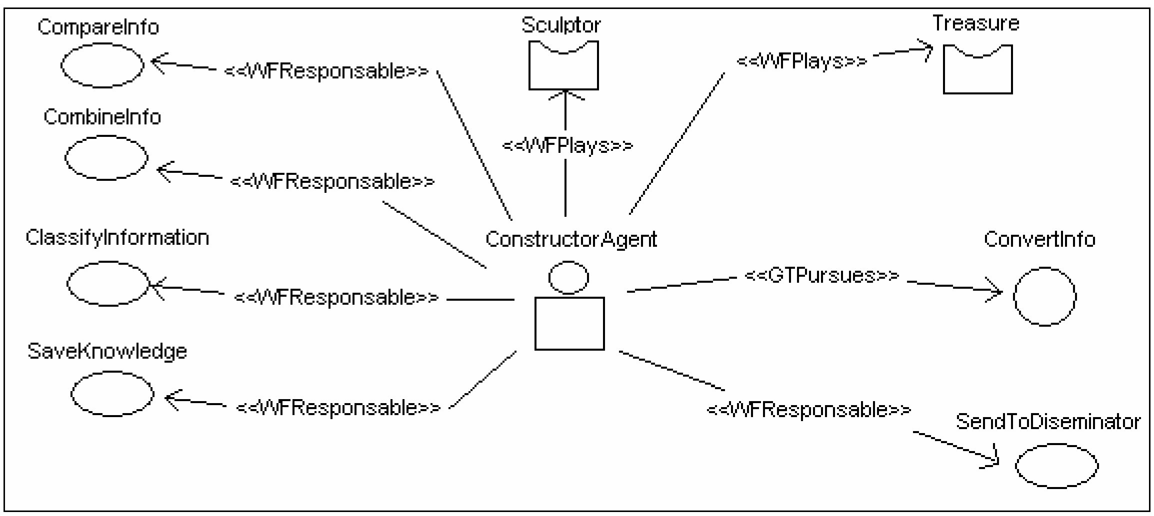

Figure 6. Constructor Agent Disgram

In this paper, only the Captor and Constructor Agent diagram are shown due to space constraints.

4.4 Implementation aspects

The platform that we are using to develop the architecture is JADE since it is FIPA compliant and it is currently one of the most widely used. Moreover, JADE has been successfully used in the development of other systems in the domain of knowledge management [1, 3, 6].

5. Conclusions and Future Work

The main contribution of this paper is the design of a multi-agent architecture that have the goal of creating, maintaining, sharing and distributing knowledge among the employees in an easy and efficient way. Another feature of this architecture is that it is based on a KM model to ensure that the multi-agent architecture supports the main processes that should be promoted by a

KM system. Moreover, the multi-agent architecture provides agents that foster the process of the SECI model with the goal of guaranteeing a continuous flow of knowledge.

Furthermore, it has been designed according to the INGENIAS methodology whose meta-models help future developers to understand how the different agents work.

As future work we are planning to document the architecture with a wide and detailed description of the possible techniques that could be used to implement each type of agent according to the main need that organizations usually demand. On the other hand, we are also studying JADEx in order to see how easy it would be to migrate to this new platform.

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References

[1] A. Abecker, A. Bernardi and L. van Elst, "Agent Technology for Distributed Organizational Memories: The Frodo Project", in *Proc. of 5th International Conference on Enterprise Information Systems (ICEIS'03)*, vol. 2, pp. 3-10, 2003.

[2] S. Balasubramanian, R. Brennan and D. Norrie, "An Architecture for Metamorphic Control of Holonic Manufacturing Systems", *Computers in Industry*, vol. 46, pp. 13-31, 2001.

[3] F. Bergenti, A. Poggi and G. Rimassa, "Agent Architectures and Interaction Protocols for Corporate Memory Management Systems", in *Proc. of the 14th International Conference on Artificial Intelligence*. *Workshop on Knowledge Management and Organizational Memories*, pp. 39-47, 2000.

[4] T.H. Davenport and L. Prusak, "Working Knowledge: How Organizations Manage What They Know", *Project Management Institute*. Harvard Business School Press, Boston, Massachusetts , 1997.

[5] Enhancing Knowledge Management in Enterprises (ENKE), IST Project, IST-2000-29482, http://www.ist-enke.com.

[6] F. Gandon, "A Multi-Agent Architecture for Distributed Corporate Memories. AT2AI-3", *Third International Symposium From Agent Theory to Agent Implementation in European Meeting on Cybernetics and Systems Research*, pp. 623-628, 2002.

[7] F. Gandon, "Multi-Agent System to Support Exploiting an XML-based Corporate Memory", in *Proc. PAKM*, pp. 10.1-10.12, Basel, Switzerland, 2000.

[8] C. Giannella, R. Bhargava and H. Kargupta, "Multi-agent Systems and Distributed Data Mining", *Cooperative Information Agents VIII: 8th International Workshop (CIA '04)*, LNCS 3191, Springer-Verlag, Erfurt, Germany, pp. 1-15, 2004

[9] J. Hahn and M. Subramani, "A Framework of Knowledge Management Systems: Issues and Challenges for Theory and Practice", *21st International Conference in Information Systems* (ICIS'00), Brisbane, pp. 302-312, 2000.

[10] M. Huysman and D. Wit, "Knowledge Sharing in Practice", Kluwert Academic Publishers, ISBN: 1402005849, Dordrecht, 2000.

[11] M.E. Jennex, "The Issue of System Use in Knowledge Management Systems", in *Proc. of the 38th Hawaii International Conference on Systems Sciences* (HICSS'05), IEEE Press, Hawaii, USA, pp. 253-c, 2005.

[12] E. Lesser, and J. Storck, "Communities of Practice and Organizational Performance", *IBM Systems Journal*, vol. 40, pp.831-841, Germany, 2001.

[13] P. Maes, "Agents that Reduce Work and Information Overload", *Communications of the ACM*, vol. 37, pp. 31-40, 1994.

[14] S. Mercer and S. Greenwood, "A Multi-Agent Architecture for Knowledge Sharing", in *Proc. of the Sixteenth European Meeting on Cybernetics and Systems Research*, Viena, 2001.

[15] K. Mock, "An Experimental Framework for Email Categorization and Management", in *Proc. of the 24th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval*, ACM Press, USA, pp. 392-393, 2001.

[16] E. Moreale and S. Watt, "An Agent-Based Approach to Mailing List Knowledge Management", in *Proc. of the Agent-Mediated Knowledge Management* (AMKM'03), LNAI 2926, pp.118-129, 2003.

[17] M.E. Nissen, "An Extended Model of Knowledge-Flow Dynamics", *Communications of the Association for Information Systems*, vol. 8, pp. 251-266, 2002.

[18] I. Nonaka and N. Konno, "The Concept of Ba: Building a Foundation for Knowledge Creation", *California Management Review*, vol. 40, no. 3, pp. 40-54, 1998.

[19] I. Nonaka and H. Takeuchi, "The Knowledge Creation Company: How Japanese Companies Create the Dynamics of Innovation", *Oxford University Press*, 1995.

[20] J. Novak, M. Wurst, M. Fleischmann and W. Strauss, "Discovering, Visualizing and Sharing Knowledge through Personalized Learning Knowledge Maps", in *Proc. of the Agents-Mediated Knowledge Management* (AMKM'03), LNCS 2926, Stanford CA, USA, pp. 213-228, 2003.

[21] J. Pavón, and J. Gómez-Sanz, "Agent Oriented Software Engineering with INGENIAS". *Multi-Agent Systems and Applications III, 3rd International Central and Eastern European Conference on Multi-Agent Systems* (CEEMAS 2003). LNCS 2691, Springer Verlag, pp. 394-403, 2003.

[22] B. Quinn, P. Anderson and S. Finkelstein, "Managing Profesional Intellect: Making the Most of the Best", *Harvard Business Review on Knowledge Management*, pp. 181-205, 1996.

[23] D.W. Rasmus, "Mind Tools: Connecting to Groupware", *PC AI*, September/October, pp. 32-36, 1996.

[24] O.M. Rodríguez, A. Martinez-García, A. Vizcaíno, J. Favela, M. Piattini, "Identifying Knowledge Flows in Communities of Practice", *Encyclopedia of Communities of Practice in Information and Knowledge Management*. IDEA Group, pp. 210-217, 2005.

[25] I. Rus, and M. Lindvall, "Knowledge Management in Software Engineering", *IEEE Software*, vol. 19, pp. 26-38, 2002.

[26] R.B. Segal and J.O. Kephart, "MailCat: An Intelligent Assistant for Organizing E-Mail", in *Proc. of the 3rd International Conference on Autonomous Agents*, Seatle, WA, USA, pp. 276-282, 1999.

[27] B.G. Silverman, N. Bedewi and A. Morales, "Intelligent Agents in Software Reuse Repositories", in *CIKM Workshop on Intelligent Information Agents*, Baltimore, USA, 1995.

[28] D. Skyrme, "Knowledge Management: Making Sense of an Oxymoron", *Management Insight*, vol. 22, 2003.

[29] C. Tacla and J-P. Barthes, "A Multi-Agent Architecture for Knowledge Management System", in *Second IEEE International Symposium on Advanced Distributed Computing Systems* (ISADS'02), 2002.

[30] J. Takkinen and N. Shahmehri, "CAFE: A Conceptual Model for Managing Information in Electronic Mail", in *Proc. of the 31st Annual Hawaii International Conference on System Sciences* (HICSS'98), IEEE Computer Society, Kona, Hawaii, vol. 5, pp. 44, 1998.

[31] A. Tiwana, "The Knowledge Management Toolkit: Practical Techniques for Building Knowledge Management Systems", *Prentice-Hall*, USA, 2000.

[32] L. van Elst, V. Dignum and A. Abecker, "Agent-Mediated Knowledge Management", in *International Symposium AMKM* '03, Springer-Verlag, Stanford, CA, USA, pp. 1-30, 2003.

[33] A. Wang, C. Reidar and L. Chunnian, "A Multi-Agent Architecture for Cooperative Software Engineering", in *Proc. of the Eleventh International Conference on Software Engineering and Knowledge Engineering* (SEKE'99), Germany, pp. 162-169, 1999.

[34] E. Wenger, "Communities of Practice: Learning Meaning, and Identity", *Cambridge University Press*, Cambridge U.K., 1998.

[35] K.M. Wiig, "Knowledge Management: Where did it come from and where will it go?", *Expert Systems with Applications*, vol. 13, pp. 1-14, 1997.

[36] J. Yang, P. Pai, V. Honovar and L. Miller, "Mobile Intelligent Agents for Document Classification and Retrieval: A Machine Learning Approach", in *Proc. of the Fourteenth European Meeting on Cybernetics and Systems Research* (EMCSR'98), Vienna, Austria, pp. 707-712, 1998.