INCA: AN INTELLIGENT COGNITIVE AGENT-BASED FRAMEWORK FOR ADAPTIVE AND INTERACTIVE LEARNING

Liana Razmerita, Thierry Nabeth, Albert Angehrn, Claudia Roda

albert.angehrn@insead.edu , *thierry.nabeth@insead.edu*
INSEAD - Centre for Advanced Learning Technologies
Bd. De Constance, F-77300 Fontainebleau France
http://www.insead.edu/calt/

liana.razmerita@inria.fr
INRIA, The National Institute for Research in Computer Science and Control
Project Acacia, 2004, route des Lucioles - B.P. 93 06902 Sophia Antipolis, Cedex

c.roda@ac.aup.fr
American University of Paris

ABSTRACT

This paper presents the design principles, development and implementation of an e-learning framework, called Intelligent Cognitive Agents (InCA). The InCA framework is an ontology driven system articulated according to three interrelated components: (1) a user ontology that covers various characteristics of the user and an inferred behavioral profile (2) a domain ontology, a set of interrelated concepts and learning objects, (3) different types of agents which access the user model and the knowledge elements in order to evaluate his/her level of adoption of knowledge sharing behaviors and to provide adapted interaction with the user. InCA is designed to support a user centered, interactive and collaborative model of learning. The InCA framework is exemplified in the Knowledge Intelligent Conversational Agents (KInCA) system: an e-learning platform to support the adoption of knowledge management practices with emphasis on knowledge sharing processes.

KEYWORDS

cognitive agent, learning system, user modeling, personalized interaction, user-centered design.

1. INTRODUCTION

There is both a need and a market for tools and techniques that improve public education, continuous learning and/or industrial training. Thus, in recent years there has been a focus on increasing the deployment and take-up of technology-enabled learning through multiple delivery channels (education and training, through internet and intranet).

On one hand the continuous development of new technologies (semantic web, grid computing, etc) has opened new perspectives for more advanced learning services. On the other hand new paradigms of learning need to be integrated in the design of these new learning services. A new vision of learning requires a fundamental shift from current content-oriented e-learning solutions towards a more user-centered, interactive and collaborative model of learning. The new paradigms of learning approach learning processes more then a simple absorption of knowledge and data. The learner in not anymore a simple passive recorder of data and information, he is stimulated to play an important role in constructing his knowledge; learning processes are taking place through complex interactions (e.g. learning by doing, educational games, simulation environments, problem based learning, learning by discussing, etc).

Moreover the development of advanced educational applications, such as Intelligent Tutoring Systems (ITS), Intelligent Learning Environments (ILE) and other AI-based software takes too long and costs too much because most of the systems are designed as custom software applications, meaning that most of these systems are built from scratch. For each system, researchers must design their own system architecture, develop knowledge representation and reasoning mechanisms, acquire and encode the relevant domain knowledge, decide on an instructional theory or pedagogical strategy and implement all required modules. All these require a lot of effort and costs.

Motivated by these concerns, we have designed and developed an open, modular, ontology-driven platform called InCA (Intelligent Cognitive Agents). InCA is designed to support a user centered, interactive and collaborative model of learning. The collaboration is often associated in this paper with a knowledge sharing process. The paper's objective is to present the design and implementation of this adaptive learning environment with emphasizes on the process of modeling the knowledge sharing behavior of the users. The use of the framework is illustrated with a concrete scenario within the Knowledge Intelligent Conversational Agent (KInCA) system. KInCA implements a story telling based learning strategy dedicated to support the adoption of knowledge management practices.

The paper is structured as follows: the second section presents the framework design principles. The third section describes the Inca's architecture and its basic modules. The fourth section describes the implementation of InCA and it gives a concrete example of conversational agents supporting learning processes. The fifth section comprises some conclusions and pinpoints future work and future research directions.

2. DESIGN PRINCIPLES OF INCA

2.1 Learning processes and user modeling in InCA

In our view learning is not only a process of acquiring new pieces of knowledge but it often involves a behavioral change for the user at the individual level. We approach learning from a change management perspective. From this perspective a system can also provide feedback and stimulus for behavioral change at the individual level. Through user modeling processes, the system tracks a series of "behavioral" characteristics of the user interaction with the system (such as level of activity, level of adoption of knowledge sharing, type of activity etc.). These elements make the user aware of his behavior in the system and are intended to motivate the user to be active in the system and to participate in knowledge sharing processes. Moreover, based on the identified stages of the users different type of agents intervene to stimulate and coach the user towards the adoption of a set of desired behaviors (e.g. adopters of knowledge sharing behavior) (Angehrn et al., 2001, Roda et al., 2002). More details on the user modeling processes will be provided in section 3.

2.2 InCA as a multi-agent system

Multi-agent systems are ideally suited to representing problems that have multiple problem solving methods, multiple perspectives and/or multiple problem solving entities. Such systems have the traditional advantages of distributed and concurrent problem solving and have the additional advantage of sophisticated patterns of interactions. The flexibility and high-level nature of these interactions distinguishes multi-agent systems from other forms of software and which provides the underlying power of the paradigm (Jennings and Wooldridge, 2002).

In our approach, based on the user's characteristics, different types of agents, with different goals and instructional strategies, are acquainted to involve the learner in interactive learning processes and to revise their interventions according to the user's behavior in the learning environment. The design of the InCA system respects the two design principles emphasized by Malone et al (1996), namely the principle of semiformal system and the principle of radical tailorability. The principle of semiformal system states: "don't build computational agents that try to solve complex problems all by themselves. Instead build systems where the boundary between what the agents do and what the humans do is a flexible one".

In the design of InCA we argue for computational agents that gradually support more and more the knowledge and processing based on an increasing "knowledge" about the user and learning processes. The second principle, the principle of radical tailorability recommends: "Don't build agents that try to figure out for themselves things that humans could easily tell them. Instead try to build systems that make it as easy as possible for humans to see and modify the same information and reasoning processes their agents are using."
In this framework, the user is able to access and control his/her user model and the learning associated processes and; in particular the user is able to access and modify the curriculum sequencing (Stern and Woolf, 1998) and the agent's interventions.

3. THE GENERAL ARCHITECTURE OF INCA

The framework is articulated according to three interrelated components: (1) a set of structured knowledge elements (a domain ontology containing learning objects, principle knowledge and how-to knowledge) to be delivered to the user accessible by the agents, (2) a user model (a user ontology that covers elements such as level of knowledge sharing, learning goals, domains of interests, etc.), (3) different types of agents coordinated by a pedagogical agent which accesses the user model in order to provide the appropriate instructional strategy, an adaptive curriculum sequencing to the user's level of expertise, to the user user's goal, etc.

3.1 Expert Agents and their coordination in InCA

Several agents implemented as components, with a stronger or weaker notion of agency (Wooldrige and Jennings, 1995) in a multi-agent system are interacting with each other and are intervening in the different phases of learning with different intervention strategies.
InCA relies on an architecture in which, on the server side, a pedagogical agent communicates with the user model in order to coordinate the different types of expert agents and to provide adaptive curriculum generation. The pedagogical agent delivers learning objects and coordinates the activity of the different agents based on the user characteristics and a curriculum generation agenda, which fit the different learning objectives and user preferences. The personal Pedagogical Agent (PA) is responsible for curriculum sequencing/generation, based on the characteristics of the user (user preferences and/or identified level of knowledge sharing). Based on the user's characteristics, the pedagogical agent decides which learning objects are more suited to a given situation and/or acquaint an adequate expert agent. Each expert agent can access different types of learning objects. Expert agents can be: story-teller, tutor, diagnose agents, etc. Each agent refers to certain ontology information maintained on the server side. Different types of expert agents can be defined and integrated gradually into the system. The curriculum sequencing is generated by a three-step procedure:

Loop {
  Step 1: Diagnose agent diagnoses the user and updates the user model;
  Step 2: Pedagogical agent identifies the learning strategy, selects the expert agent (storyteller, help, tutor, …) and updates the user model
  Step 3: Expert agent activates the learning objects to be presented to the user.
}

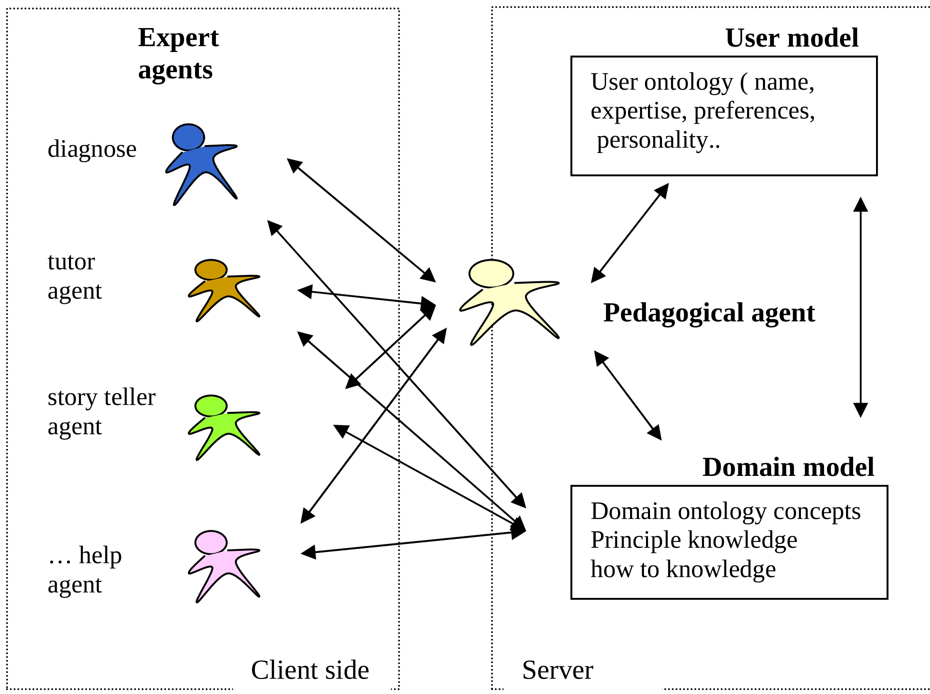

Figure 1: InCA Architecture

3.2 InCA's Domain Model

One of the main goals of the learning process is to understand and to acquire a body of knowledge for a given domain. Educational researchers agree on the fact that providing domain knowledge for learning environments is difficult and time consuming (Scholer et al., 2000). Often the domain model can be structured as a taxonomy of concepts, with attributes and relations connecting them with other concepts, which naturally leads to the idea of using ontologies to represent this knowledge. Mizoguchi (1998) argues that "making systems intelligent requires a declarative representation of what they know. Conceptualization should be explicit to make authoring systems literate and intelligent, standardization or shared vocabulary will facilitate the reusability components and enable sharable specification of them and theory-awareness makes authoring systems knowledgeable."

InCA structures the domain knowledge around: concepts, relationships between concepts and includes answers to basic questions like: What is it? Why and for whom is it relevant? How to practice it? Who can provide further information on it? These knowledge units are displayed by the system but are also accessible by the different agents represented in Figure 2.

The InCA framework is design to allow the management of the different knowledge domains and to integrate different types of "learning objects": hypertext, images, videos, "stories", "role-playing games" etc.

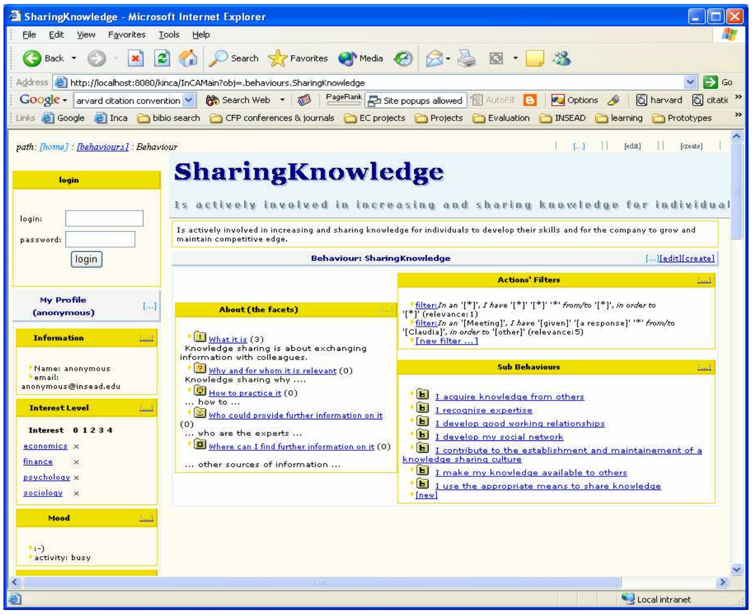

Figure 2 InCA's domain knowledge

3.3 User modeling and behavioral modeling process in Inca

One of the main objectives related to user modeling processes in InCA was to model the knowledge sharing behavior of the users. Through the knowledge sharing behavior we are trying to capture the level of adoption of knowledge sharing practices. We consider organizational and behavioral change management to be a critical success factor in the implementation of knowledge management strategies. "We describe users as undergoing a change process that brings them from their old practices to the conscious adoption of knowledge management practices (e.g. transition from low or non-existing levels of knowledge sharing practices to the widespread adoption of best behaviors in knowledge sharing)." (Roda et al., 2002)

We define a change process as a sequence of change operations upon user states, leading the acquisition of the desired behaviors. Using Near's (1993) terminology and mapping it into Rogers' theory (see Angehrn and Nabeth 1997; Manzoni and Angehrn 1998) the following user states related to the level of adoption of knowledge sharing behaviours can be identified: unaware, aware, interested, trial and adopter. These user states are represented in Figure 3 A model of the change process. The numbers indicate the mapping to Rogers' model.

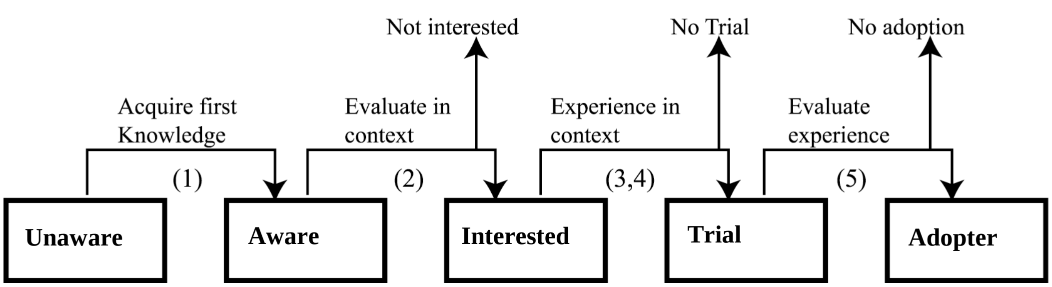

Figure 3 A model of the change process.

The classification of the users based on the level of knowledge sharing has been described and implemented using the principles of a fuzzy classifier system. (Razmerita, 2003a) The classification process takes into account the level of activity and the type of activity, characteristics of the users inferred based on the interaction of the user with a Knowledge Management System. Based on the type of activity the users are classified into: readers, writers, lurkers. Based on the level of activity the users are classified as: very active, active, visitor, inactive. The associated user modeling framework and user modeling mechanisms are described in Razmerita et al. (2003, b).

4. IMPLEMENTATION AND A CONCRETE USE CASE OF INCA

In this section we discuss a concrete example of the use of InCA in the context of an interactive learning system for knowledge management called KInCA, Knowledge Intelligent Conversational Agents. As described in section 2.1, the learning, in KInCA, is conceived as a change process and adapted to the context of organizational learning. The agents in KInCA are designed to support knowledge management behaviors and in particular the knowledge sharing behaviors. These behaviors are stored in the domain ontology as described in section 3.2.

In the last few years synthetic characters designed as embodied conversational agents have started to be applied in educational environments (Barker and Pilkington, 2001; Cassel, 2000, Tarau and Figa, 2004).Conversational agents aim at providing personalized guidance through the whole adoption process: from the introduction of the behaviors to the user (explaining what the desired behaviors are and why they should be adopted) to their practice within the community.

Nishida (2000) defines a story as a collection of associative representations relevant to a specific subject in a workspace. Story telling has recently emerged as a practical, efficient technique for knowledge disclosure and communication in Knowledge Management. Snowden [1999] affirms the role of story telling for Knowledge Management. “Managed and purposeful story telling provides a powerful mechanism for the disclosure of intellectual or knowledge assets in companies, it can also provides a non-intrusive, organic means of producing sustainable cultural change; conveying brands and values; transferring complex tacit knowledge.”

Figure 4: Story telling agents in KInCA

In InCA, story teller agents address to the novices in the domain of knowledge sharing, namely unaware users, who get some basic ideas about the importance of sharing knowledge through entertaining conversation which takes place between two synthetic characters. The different InCAs are able to engage themselves in a multimodal dialogue, using speech, tonality, gesture, and gaze in order to emulate a human face-to-face communication act in order to convey knowledge sharing practices as presented in figure 4.

InCA has been developed in Java, using servlet technology, integrating Ms-agent technology for the for story telling animated characters. For representing the knowledge we use a declarative formalism based on XML. A straightforward approach was adopted; this approach consisted in the definition of an object structure for story representation that can be serialized using introspection when needed into an XML representation. This XML representation is also used to generate structured and dynamic html pages (based on CSS) that the Microsoft Agent character technology is able to read, via a set of Javascripts.

The first tentative of using Semantic Web technology based on RDF for ontology representation, using KAON, appeared to be relatively heavy and difficult to use. We envisage reengineering InCA using Semantic Web technology when the ontology languages (and in particular OWL) will be more mature.

5. CONCLUSIONS AND FUTURE WORK

In this paper we described InCA, a modular agent-based architecture framework, which integrates a set of interactive features allowing personalized and adaptive curriculum generation.
The framework is an open and modular framework which enables an incremental development and integration of different emerging technologies (semantic web technology, different types of expert agents, different types of learning objects, user modeling techniques which enable adaptive learning processes). The InCA framework was exemplified within a story telling scenario.

A number of useful extensions of InCA system have been identified and some work has already been initiated. A first direction consists in the use of better story representation mechanisms (via a story telling markup language). The definition of a story telling markup language would enable to represent non-linear stories, and more sophisticated interactions with the user. In a longer term, this story telling representation could benefit of the advances in ontology languages, facilitating the exchange of stories between various systems and story telling agents.

A second direction of extension for InCA is towards better support for collaborative learning. For this purpose, an instant messaging client based on the streaming XML protocols has now been incorporated into the system. This instant messaging system is intended to support real time collaboration and knowledge sharing processes between the users and the real time intervention of various personal agents.

Finally, another research direction is related to the design of new cognitive interfaces capable of focusing the users' attention and consequently deciding how to guide the user's attention. To gain, shift and maintain the attention of the users represent some challenging objectives for a next generation of advanced cognitive interfaces.

ACKNOWLEDGEMENT

This research was partially supported by Xerox funding.

REFERENCES

Angehrn, A., Nabeth, T., Razmerita, L., Roda, C., (2001), "K-InCA: Using Artificial Agents for Helping People to Learn New Behaviours", *Proc. IEEE International Conference on Advanced Learning Technologies* (ICALT 2001), August 2001, Madison USA,

Barker, T., Pilkington, R., M., (2001), Simulated Affectations of an Animated Pedagogical Agent, AISB01: Symposium on emotion, cognition and affective computing, University of York, U.K

Brusilovsky, P. (1999). In C. Rollinger and C. Peylo (eds.), Special Issue on Intelligent Systems and Teleteaching, *Künstliche Intelligenz*, 4, 19-25.

Cassell, J., Sulivan, J., Prevost, S., Churchil, E., (eds.). *Embodied Conversational Agents*. The MIT Press, 2000.

KAON Karlsruhe Ontology Infrastructure (KAON) http://kaon.semanticweb.org/

Jennings, N., and Wooldridge, M., (2002) "Agent-Oriented Software Engineering" in *Handbook of Agent Technology* (ed. J. Bradshaw) AAAI/MIT Press 2002.

Malone, T., W., Lai, K.,Y., and Grant. K., R., Agents for information sharing and coordination: A history and some reflections. In J. M. Bradshaw (Ed.) *Software Agents*, Cambridge, MA: AAAI/MIT Press, 1997

Mizoguchi, R. (1998), "Using Ontological Engineering to Overcome Common AI-ED Problems", http://www.ei.sanken.osaka-u.ac.jp/pub/miz/JAied.pdf

Nishida, T. (2000), *Dynamic Knowledge Interaction*, CRC Press 2000

Razmerita, L (2003a), "User Model and User Modeling in Knowledge Management Systems: An Ontology-based Approach", PhD thesis, University Paul Sabatier, Toulouse.

Razmerita, L., Angehrn A. & Maedche, A., (2003b). *Ontology-based user modeling for Knowledge Management Systems*, in Proceedings of "UM2003 User Modeling: Proceedings of the Ninth International Conference", Pittsburgh, USA, Springer Verlag, pp.213-217.

Roda, C., Angehrn, A., Nabeth, T., Razmerita, L., (2002), "Using conversational agents to support the adoption of knowledge sharing practices", *Interacting with Computers, special issue on Intelligence & Interaction in Community-based Systems*.

Snowden, D., Story telling: an old skill in a new context-speaker notes, Workshop on story telling, IKMS 1999

Scholer, A., Rickel, J., Angros, R. & Johnson, L., (2000) Learning domain knowledge for teaching procedural tasks, In *AAAI-2000 Fall symposium on Learning How to Do Things*, 2000

Stern, M. and Woolf, B. (1998), Curriculum Sequencing in a Web-Based Tutor, in the *Proceedings of Intelligent Tutoring Systems ITS'98*, Springer Verlag, p. 584-593, 1998.

Tarau, P. and Figa, E. (2004). Knowledge-Based Conversational Agents and Virtual Storytelling. In Proceedings 2004 ACM Symposium on Applied Computing, Vol. 1, p. 39-44. The Association of Computing Machinery, New York, NY. ACM ISBN: 1-58113-812-1

Wooldrige, M., Jennings, N. (1995), Intelligent Agents: Theory and Practice, *Knowledge Engineering Review*, Volume 10 No 2, June 1995.