INTELLIGENT AGENT AND KNOWLEDGE MANAGEMENT PERSPECTIVES FOR THE DEVELOPMENT OF INTELLIGENT TUTORING SYSTEMS

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Abstract: The development of intelligent tutoring systems is discussed from intelligent agent and knowledge management perspectives. A conceptual model in which both perspectives are integrated is proposed. The model consists from system's layer based on agent paradigm and knowledge worker's layer responsible for personal knowledge management of knowledge worker (teacher and/or student). The implemented prototype of intelligent knowledge assessment system is described.

1 INTRODUCTION

Nowadays more and more modern organizations realize that knowledge is their most important asset. As a consequence a new type of intellectual work, usually called a knowledge work, emerges. It is obvious that teaching and learning also should be changed to provide an effective turning of information into knowledge. Concurrently one can observe a rapid penetration of computer and communication technologies into education that has changed the traditional forms of teaching and learning. Education from teacher-centered has become student-centered (Waterhouse, 2004). During last decades a lot of approaches, methods, systems and environments has been proposed and developed under the umbrella term of technology-based learning.

Although today's teaching and learning settings are quite distinct from those of recent past, and more distance education environments, e.g., eLearning, mLearning, hybrid learning, etc. are used, the experience shows that learning effectiveness is still behind the desired level. The main reason is that the intelligent support of teaching and learning processes demonstrated by these systems is far behind of that provided by the human teacher who is able to adapt to each learner individually, to give a flexible feedback (help, explanation, etc.) and to assess the learner's knowledge at all levels of the well-known Bloom's taxonomy (Bloom, 1956). All mentioned issues (but not only) still are the challenges for the developers of the intelligent tutoring systems.

The first intelligent tutoring system SCHOLAR (Carbonell, 1970) gave the origin to the successor systems of such kind (BUGGY (Brown and Burton, 1978), GUIDON (Clancey, 1979), LISP Tutor (Anderson and Reiser, 1985), ILIAD (Lincoln, 1991), ADIS (Warendorf and Tan, 1997), FLUTE (Devedzic, Debenham and Popovic, 2000), BUT (Butz, Hua and Maguire, 2004) are only some examples). Faster progress can be observed when Web-based intelligent tutoring systems become the mainstream area of the research and development (Yang, Kinshuk and Patel, 2002) and agent technologies started to appear for the quality improvement of Web-based education (Johnson, 2003).

The paper is organized as follows. In the second section characteristics of intelligent tutoring system (ITS) and its architecture are presented. The third section is focused on applications of intelligent agents in ITS. Knowledge management perspective in ITS is discussed in the fourth section. A conceptual model of ITS in which intelligent agent and knowledge management perspectives are integrated is proposed in the fifth section. The sixth section gives the outline of implemented intelligent knowledge assessment system which is part of ICT under the development at the moment. Conclusions

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summarize the proposed approach and outline some directions of future work.

2 CHARACTERISTICS AND ARCHITECTURE OF INTELLIGENT TUTORING SYSTEMS

Regardless of variety of already developed methods and systems the unambiguous definition of ITS is not available. One definition which is mainly focused on authoring systems is given in (Tennyson and Christensen, 1988): "Intelligent tutoring systems are inference-making systems that seek to continuously improve the learning of each learner by prescribing instruction that has a high probability of preventing learner error or misconception, and by continuously adapting this instruction according to moment-to-moment diagnosis." ITS's use knowledge about the domain, the student and about teaching strategies to support flexible individualized learning (Wenger, 1987; van Rosmalen and Boticario, 2005).

The main characteristics of ITS are the following:

- it is a computer based system,
- it uses methods of artificial intelligence such as natural language processing, knowledge representation, inference and machine learning (Brusilovsky and Peylo, 2003),
- it is an adaptive system (Benyon and Murray, 1993),
- it simulates human teacher (supervisor),
- it tries to provide advantages of face-to-face learning.

The ITS captures three types of knowledge:

- knowledge about "what to teach" (problem domain knowledge),
- knowledge about "how to teach" (pedagogical knowledge),
- knowledge about a learner (student).

Types of knowledge define an architecture of ITS which consists from the expert module, the pedagogical module, the student diagnosis module and the interface module. The architecture of ITS is shown in Figure 1.

It is worth to point out that the wide variety of terms are used as synonyms to denote the components of ITS. Examples are: expert module, expert model, or expert solver; student diagnosis module, student modeller, or user modeling component; pedagogical module, curriculum and instruction module, expert tutor, instruction model, pedagogical model, tutorial module, or tutoring component; interface, communication module, graphical user interface shell, or supervisor unit, and others.

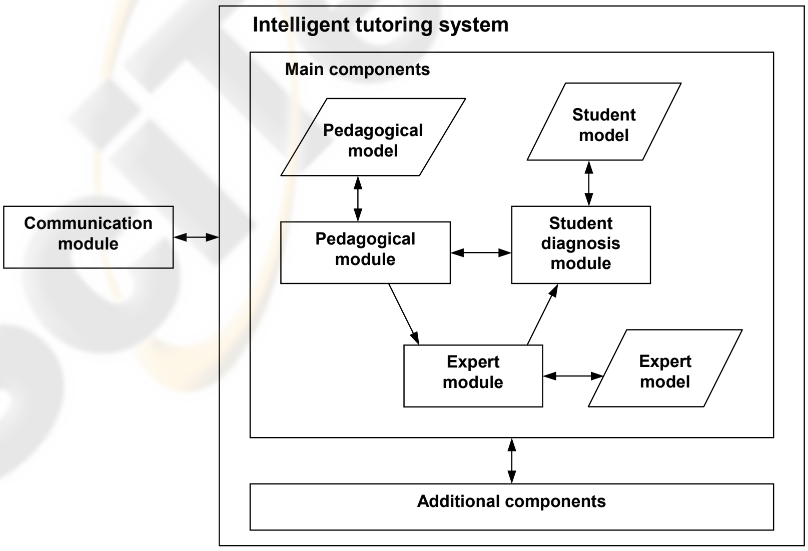

Figure 1: The architecture of intelligent tutoring system.

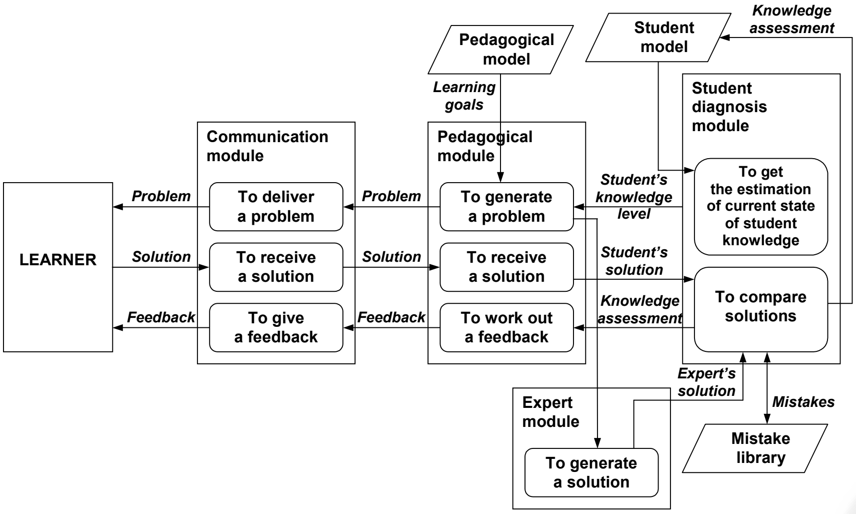

Figure 2: Operation schema of ITS.

To avoid misunderstanding in this paper the term "module" is used to denote the identified component of the system which have certain functionality while the term "model" is used in the traditional meaning, i.e., for simplified representation of an object. For instance, expert model represents expert's knowledge, and expert module includes algorithms for generation of problem solutions. Student model, in its turn, represents information about each particular student, and student diagnosis module processes this information.

ITS may have also additional components, for example, an explanation module to explain reasons of mistakes or a development module to make changes in the contents of the study course.

Communication module, i.e., an interface provides functionality that allows to work with ITS. The learner gets a problem from the pedagogical module, gives the solution and receives a feedback. Interactions between a learner and modules of ITS are shown in Figure 2.

A pedagogical module provides the knowledge infrastructure to adapt teaching and learning process to needs and characteristics of each particular learner. The main goal of this module is to decrease and even to eliminate gap between the expert's (teacher's) and the student's knowledge.

The role of a student diagnosis module is to compare problem solutions given by a student and an expert, to construct a student model and to use it for estimation of current state of student knowledge.

The expert module is responsible for generation of problem solutions which are passed to the student diagnosis module for comparison.

3 AGENTS IN INTELLIGENT TUTORING SYSTEM

A modern approach to artificial intelligence is connected with the development and applications of intelligent agents "that are anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors" (Russell and Norvig, 2003). An ITS can be considered as a system of human agents (supervisors and students) and/or software agents. Software agents are programs that engage in dialogs, and negotiate and coordinate transfer of information (Murch and Johnson, 1999). Software agents fundamentally differ from software packages because they are user centered, autonomous, have such attributes as adaptability, mobility, transparency and accountability, ruggedness, self-starter, social ability, reactivity, proactivity, and learning capability (Grundspenkis and Anohina, 2004).

It is obvious that agents have many useful features that are desirable for ITS. Agent perspective provides several opportunities since the architecture of ITS consists from several modules. So, each of them can be implemented as an agent or a multiagent system (Russell and Norvig, 2003). The domain knowledge (study course content) may be divided into knowledge units each of which can be controlled by a separate agent. A pedagogical module can provide different tutoring strategies and each of them can be entrusted to the separate agent. Information stored in a student model can be categorized into several classes: learning styles, psychological characteristics, causes of mistakes and misconceptions, etc. It is possible to develop an agent that will be responsible for gathering and processing the certain type of information. ITS can support various interaction devices that allow the learner to communicate with the system. In this case it is possible to develop agents responsible for management of different devices, such as, for instance, monitor + mouse + keyboard or data glove + motion tracking + voice recognition. The same approach can be applied for user interface which includes various tools, e.g. buttons, menus, input fields, panels, and so on.

In fact, all components of ITS described in the previous section can be implemented as agents. Analysis of already developed ITS, namely, Ines (Hospers, et.al., 2003), ABITS (Capuano, et.al., 2000), WADIES (Georgouli, Paraskakis and Guerreiro, 2003), IVTE (Nunes, et.al., 2002), a multi-agent architecture for distance education systems (Dorea, Lopes and Fernandes, 2003) and intelligent virtual environment for training (De Antonio, et.al., 2003), allows to outline the possible agent-based solutions for all ITS modules (Grundspenkis and Anohina, 2004).

Agents in the pedagogical module can evaluate, update and generate curriculum, implement different teaching strategies (a case when a multiagent architecture is required), and generate a feedback (explain and to provide help). So, the typical set of agents in a pedagogical module is a curriculum agent, a feedback and explanation agent, and teaching strategy agents (one for each available teaching strategy). The main task of agents that comprise a student diagnosis module is the evaluation and updating of information about a particular learner. In this case agent functions are building a profile of learner's psychological characteristics (learning preferences, learning style, attentiveness, etc.), building a model of learner's current state of knowledge and skills, registering learner's mistakes and his/her history of interactions with the system.

The set of typical student modelling agents of student diagnosis module includes cognitive diagnosis agent, psychological agent, knowledge evaluation agent, interaction registering agent, and mistake registering agent. The set of agents in an expert module strongly depends on the problem domain and, as a rule, multiagent architecture is used in this module. The number of agents used depends on the number of knowledge units in which a study course content is decomposed. If a communication module is based on agent technologies, agent functions are management of different interaction tools and devices, and monitoring the interaction between the learner and the system.

A typical set of agents which may constitute the architecture of ITS is shown in Figure 3.

Of course, ITS can contain also specific agents, that aren't included in typical sets of agents, and are determined by specific features of the problem domain or peculiarity of ITS architecture and technologies used for its implementation. Several examples of specific agents may be found, for instance, the authoring agent in WADIES, or the spooler agent in multiagent architecture of ABITS. It is worth to point out that in several ITS animated pedagogical agents are used. Such agent emulates aspects of dialogue between a human teacher and a learner.

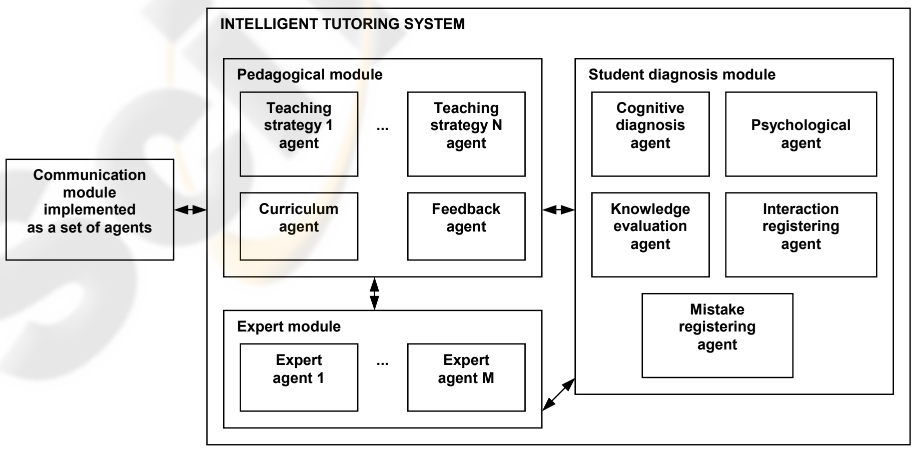

Figure 3: A typical set of agents included in ITS.

In accordance with (Baylor and Kim, 2003) animated pedagogical agents can play three roles: agent as an expert, agent as a motivator and agent as a mentor. Some details about animated pedagogical agents (including widely known Steve and Adele) also called guidebots can be found in (Johnson, 2003).

4 KNOWLEDGE MANAGEMENT PERSPECTIVE IN INTELLIGENT TUTORING SYSTEM

In all education systems regardless of their kind (face-to-face, distance, mobile, hybrid, etc.) there are two groups of actors, namely, supervisors (teachers) and students (learners) who are working with knowledge. In (Grundspenkis, 2005) a conceptual model is proposed in which actors of the intelligent tutoring system are considered to be the knowledge workers embedded into a knowledge management system (KMS) as it is shown in Figure 4.

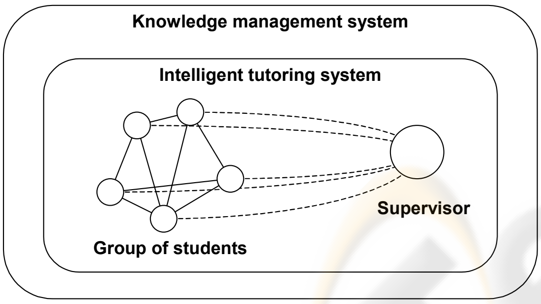

Figure 4: Intelligent tutoring system embedded in its environment.

A KMS is an infrastructure of mutually integrated techniques and tools created for such knowledge management process support as knowledge acquisition, processing, distribution and usage, as well as for generation of new knowledge. Following (Thierauf, 1999) the main KMS functions are:

- detection of information and/or knowledge,
- storage of information and/or knowledge,
- inference of conclusions,
- retrieval and visualization of knowledge,
- decision making.

The KMS enables to turn information into action and to connect people to knowledge, i.e., enables an effective and active learning process. The most important aspects of effective learning process are construction of knowledge, co-operation and teamwork, and learning through problem solving. In other words, the KMS supports expansion of individual's personal knowledge to the knowledge of a group as a whole. It means that knowledge management environment must contribute both personal knowledge and organizational knowledge as well. In this context a concept of personal knowledge management (PKM) emerges. PKM is a collection of processes that an individual needs to carry out in order to gather, classify, store, search and retrieve knowledge in his/her activities (Tsui, 2002). PKM is an integrative discipline that integrates many aspects and many perspectives from different fields. A PKM system (PKMS) is a complex system that includes psychological, social and technological aspects: individual's emotional intelligence, his/her understanding and aims, environment and society where he/she lives in and acts, as well as technologies (Apshvalka and Grundspenkis, 2005). It is quite obvious that practically all mentioned aspects are important in teaching and learning process.

Let have a closer look on why knowledge management may play an important role in ITS development. First, each educational organization must enhance its knowledge assets or at least must keep them on the needed level. Unfortunately, education organizations very easily may lose their knowledge assets when teachers are leaving. To avoid loses (at least to the certain extent) educational organization must extend its intellectual capital. According to (Stewart, 1994) an intellectual capital is an intellectual material that has been formalized in some useful order, captured in a way that allows it to be described, shared, distributed, and leveraged to produce a higher valued asset. So, it may be effectively supported by the KMS.

Different types of knowledge that education organization possesses and various knowledge possessors in it is the second factor why knowledge management may play an important role in the context of ITS. The widely known classification of knowledge into two classes, namely, tacit knowledge and explicit knowledge is proposed in (Nonaka and Takeuchi, 1995). Tacit knowledge is personal knowledge embedded in individual experience. Most commonly it is shared and exchanged through direct, face-to-face contact and can be communicated in a direct and effective way. Nowadays technologies help and it is not necessary to store all needed knowledge in human brains. In many cases including education it is enough to know where to find necessary information and knowledge and to be able to get it quickly enough. This is where PKMS should help.

The third aspect showing the potential role of knowledge management in ITS development is the mode in which collection and retrieval of knowledge is performed. Details of this aspect which is closely connected with notion of corporate memory are beyond the scope of this paper and can be found in (van Heijst, van der Spek and Kruizinga, 1998).

5 CONCEPTUAL MODEL OF INTELLIGENT TUTORING SYSTEM

Both discussed perspectives, that is, agent and knowledge management perspectives are integrated in a conceptual model of ITS. The ITS itself is under the development. The conceptual model has two layers – system's layer and knowledge worker's layer. Functioning of both layers is supported by sets of agents. At the system's layer all components of ITS shown in Figure 1 are included. The knowledge worker's layer supports students and supervisors involved in the teaching and learning process. Students and supervisors are knowledge workers, i.e., human agents which are working with knowledge. To make their work effective the PKMS is used which is based on a set of agents operating at the working place of each knowledge worker. Agents are located in three circles (Grundspenkis and Kirikova, 2005) as it is shown in Figure 5.

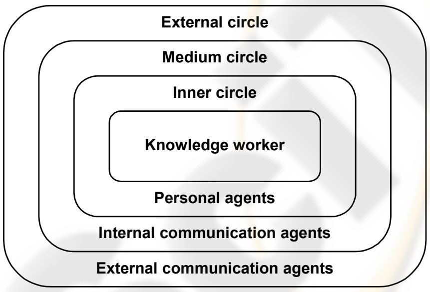

Figure 5: Agents of the knowledge worker.

Personal agents are search, assistant, filtering and workflow agents (Knapik and Johnson, 1998). Search agents are used to search titles of documents or directories on the Web. Filtering agents may monitor the data stream searching the text for knowledge and phrases as well as the list of synonyms, and try to forward only the useful information. Assistant agents usually are designed to wait for events such as E-mail messages to occur and then to sort them by sender, subject, time, priority, etc. Workflow agents are useful for task coordination and meeting scheduling. Smart agents (Case, et.al., 2001) may appear in near future that will be able to acquire, store, generate and distribute knowledge.

Internal communication agents provide communications between individuals. This set of agents includes messaging, team, collaborative and cooperative agents. Messaging agents can connect students within a group and with the supervisor no matter where they are and what communication medium is used. Team agents facilitate communication in the group of students, while cooperative and collaborative agents are able to cooperate and to collaborate with filtering agents in the internal circle.

Agents for communication with external systems are, for instance, network agents, database agents, connection and access agents, and intelligent Web agents. It is obvious that from the knowledge management perspective of ITS the most important role may play intelligent Web agents because nowadays the Web is the richest source of data, information and knowledge that is useful for learning and is accessible for any user. At the same time currently the Web contains a lot of data, structured data (structured documents, online databases), simple metadata but very little knowledge, i.e., very few formal knowledge representations (Web intelligence, 2003). The reason is that the knowledge is encoded using various languages and practically unconnected ontologies. As a consequence, each knowledge source requires the development of special wrapper for its knowledge to be interpreted and hence retrieved, combined and used. Efforts to solve this problem resulted in the appearance of a new paradigm, so called Web intelligence (Web intelligence, 2003) which is challenging and promising research field for ITS developers.

6 IMPLEMENTATION OF INTELLIGENT KNOWLEDGE ASSESSMENT SYSTEM

At the present moment part of the system's layer of conceptual model already has been developed, implemented and tested. Due to the scope of this paper in this section only the outline of the developed prototype is given details of which may be found in (Anohina and Grundspenkis, 2006).

In process oriented learning a teacher divides a study course into several stages. At the end of each stage the teacher gives assessment of learner's knowledge level. Assessment is based on the notion of concept maps. Concept maps are a special kind of mental model and a method for representation and measuring of individual's knowledge (Croasdell, Freeman and Urbaczewski, 2003). Concept maps are represented by graphs. Nodes represent concepts and arcs represent relationships between concepts.

The system's architecture includes modules of administrator, teacher and learner. The modules interact using a common database. The administrator maintains the system and manages data about individual learners, groups of learners, as well as teachers and the courses. The teacher's module supports the development of concept maps and examination of learner-completed concept maps. The learner's module includes tools for completion of concept maps and viewing the feedback after the evaluation of the correctness of learner's concept maps.

The core of the developed system is the intelligent assessment agent which is shown in Figure 6.

The communication agent perceives the learner's actions, i.e. concepts inserting into and removing from the structure of a concept map. It is also responsible for visualization of a structure of a concept map received from the agent-expert, and for the output of feedback received from the knowledge evaluation agent. After the learner has confirmed his/her solution, the communication agent delivers the learner-completed concept map to the knowledge evaluation agent which compares the concept maps of the learner and the teacher and recognizes five patterns of learner's solution (correct and incorrect ones).

The interaction registering agent receives the learner-completed concept map from the communication agent and results of its comparison from the knowledge evaluation agent, and stores them in a database. The agent-expert forms a structure of a concept map of the current stage on the basis of the teacher-created concept map and the learner's concept map of previous stage. The formed structure is passed to the communication agent for its visualization. The agent-expert also delivers a teacher-created concept map to the knowledge evaluation agent for comparison. The prototype has been developed using the following tools: Borland JBuilder 9.0, JGraph, PostgreSQL DBMS 8.0.3 and JDBC drivers for PostgreSQL.

The operation of the developed system has been tested in four study courses (two engineering courses "Systems Theory Methods" and "Fundamentals of SQL", and two courses of social sciences). Seventy four students have been involved in testing, 57% of them found that completing of concept maps was difficult for them, and 33% found it easy.

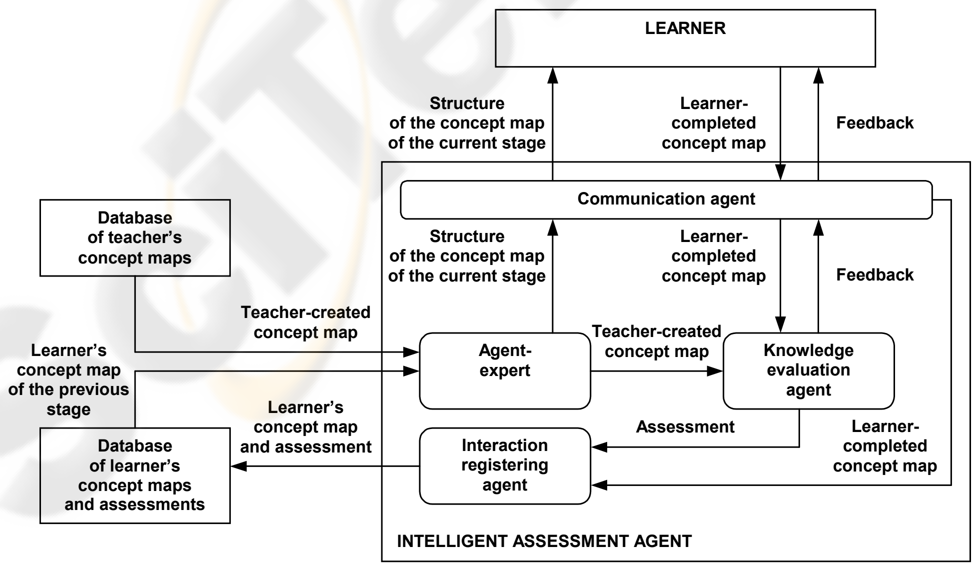

Figure 6: The architecture of the intelligent assessment agent.

More than a half (62%) answered that work with the developed system helped them to understand course contents better.

7 CONCLUSIONS

In this paper a system approach is used to integrate intelligent agent and knowledge management perspectives for the development of intelligent tutoring systems. The tutoring system is based on the intelligent agent paradigm and is embedded in the knowledge management system which plays the role of its environment. A synergy effect is expected from such kind of integration especially in hybrid course development where a part of contents is taught in the traditional face-to-face manner, and another part using distance learning facilities.

The implementation of the proposed conceptual model of intelligent tutoring system which consists from system's layer and knowledge worker's layer is already started. The prototype of the intelligent knowledge assessment system based on concept maps has been developed and tested. The prototype modules partly cover modules of traditional architecture of intelligent tutoring systems: implemented communication agent is one of needed agents of communication module; agent-expert realizes an expert module; knowledge assessment agent and interaction registering agent are part of student diagnosis module.

Despite that fact that a lot of work is needed to implement the proposed conceptual model as a whole, the developed prototype has a good potential for further evolution and research. One of planned directions of future work is to use ontologies for more flexible knowledge assessment taking into account semantics of links. To achieve this goal it is needed to develop algorithms and tools for concept map generation from course ontology, and algorithms for concept map evaluation. It is also necessary to improve feedback given to the teacher and to the learner. For the later the system should generate recommendations related to the learning material that the learner should revise to fill gaps in his/her knowledge.

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