MIPITS and IKAS – Two Steps towards Truly Intelligent Tutoring System Based on Integration of Knowledge Management and Multiagent Techniques

Janis Grundspenkis

Abstract: *During the last decades modern information and telecommunication technologies which enable student-centered and one-to-one learning are widely used. The concept of intelligent tutoring systems (ITS) emerged and many systems are developed to add adaptivity and intelligence to traditional distance learning systems. The common architecture of ITSs is overviewed. The conceptual framework based on integration of knowledge management and multiagent techniques for development of ITSs is proposed. The ITS named MIPITS which is based on the holonic multiagent architecture and its tutoring scenario is presented. The concept map based multiagent adaptive intelligent knowledge assessment system (IKAS) is described from its architecture's and functionality viewpoints.*

Key words: *Intelligent Tutoring System, Intelligent Knowledge Assessment System, Intelligent Agent, Multiagent System, Knowledge Management.*

INTRODUCTION

Nowadays advanced countries all over the world are moving towards the knowledge society. A new type of intellectual work, so called knowledge work, emerges. As a result, education process as a whole should be changed to provide an effective turning of information into knowledge. Actually education at all levels starting from kindergartens and ending with lifelong learning should be ambient. In this situation education process must be promoted by modern information and telecommunication technologies (ICTs) which enable student-centered and one-to-one learning in traditional as well as in computational environments [52].

During last decades a lot of approaches, methods, systems and environments have been proposed, developed and implemented under the umbrella term of technology-based learning [2]. Although today's teaching and learning settings significantly differ from those of recent past, and more and more distance education environments, e.g., e-Learning, m-Learning, Web-based learning, blended learning, etc. are used, the experience shows that the achieved learning effectiveness still is behind the desired level. Large number of students registered for the same study course, their different initial knowledge levels and learning styles are the main reasons for that. A human teacher must create all learning materials and tests which he/she is able to adapt (at least theoretically) to each individual learner and to give flexible feedback. Contrary, different e-learning systems and environments among which Blackboard (http://www.blackboard.com) and Moodle (http://moodle.org) are the most popular ones used for teaching large numbers of students in this way facilitating availability of education, offer the same learning materials and various tests for all learners. Thus, such kind of systems cannot adapt to specific characteristics and learning styles of individual learners. These systems usually cannot generate learning materials and/or tests using domain knowledge. Even more, with the dissemination of distance learning knowledge assessment of learners has become a constant concern, too [46]. A regular knowledge assessment in distance learning and very frequently also in traditional learning is based on various objective tests where students receive a set of questions such as multiple choice or multiple response questions, graphical hotspot questions, fill-in-blanks, text/numerical input questions or matching questions with already pre-defined answers [16]. Such tests can be used for initial, formative and summative assessment that is performed at the beginning of learning process, during instruction and at the end of learning, respectively. Subjective tests, which are much more time consuming, are based on essays and free text responses, but at the same time they also are not adaptive at all [39]. That is why computer-assisted adaptive testing in which students receive more difficult or easier test items depending on their previous answers appeared [45]. Thus, students' knowledge levels are more accurately estimated but even usage of adaptive testing does not support sufficiently wide and comprehensive knowledge assessment mainly because tests allow assessing of learner's knowledge only at the first four levels of the well-known Bloom's taxonomy [7] including three levels of lower order skills: knowledge, comprehension, and application, and analysis that along with synthesis and evaluation belongs to three higher order skills. Tests do not allow to assess learner's knowledge structure, i.e. how he/she understands relations between concepts and how new concepts are connected with previously mastered ones [26].

At least part of the abovementioned drawbacks are eliminated by intelligent tutoring systems (ITSs). ITSs are more adaptive because they simulate a teacher in realization of individualized tutoring using domain and pedagogical knowledge as well as knowledge about the learner. ITSs to the certain extent can adapt learning materials, generate tasks and problems from the domain knowledge, assess a learner's knowledge and provide informative feedback [11].

The purpose of this paper is to give an overview of ITSs, outline the conceptual framework of truly intelligent tutoring system based on integration of knowledge management and intelligent agent paradigms which is under the development at the Department of Systems Theory and Design of Riga Technical University, and describe already implemented an agent based intelligent tutoring system (MIPITS) and a concept map based intelligent knowledge assessment system (IKAS). The paper is organized as follows. Section 2 is devoted to the conventional architecture of ITS, its main characteristics and agent-based ITSs. In Section 3 the conceptual framework which has system's and multiagent layers and is based on integration of knowledge management and multiagent paradigm intended for truly intelligent tutoring system development is proposed. In Section 4 the architecture and tutoring scenario of the MIPITS is presented. Section 5 gives the architecture of the IKAS and shortly describes its operation scenario and the usage experience of it. Conclusions summarize the proposed approach and outline some directions of future work.

CORE ARCHITECTURE OF ITS AND AGENT-BASED ITS

The first ITS named SCHOLAR for teaching South America's geography [14] gave the origin to the successor systems. Such ITSs as BUGGY [9] and WEST [12] both for teaching mathematics, SOPHIE [10] for physics, LISP Tutor [1] for programming language LISP, GUIDON [15] for infectious disease diagnosis and therapy selection, WHY [50] for teaching causal knowledge and reasoning, FLUTE [18] for formal languages, and Slide Tutor [17] for visual classification problem solving in medicine, have established a common viewpoint that modern ITSs must include knowledge on what and how to teach, and knowledge on qualities of learners. The abovementioned examples establish a common functional modular architecture which nowadays has become the core of every ITS: the domain knowledge module, the tutoring module, and the student diagnosis module (Fig.1). The tutoring (pedagogical) module provides the knowledge infrastructure for adaptation of teaching and learning process to the needs and characteristics of each individual learner. It tailors appropriate learning activities such as problem generation, receiving of learner's solutions and working out a feedback (explanation and help). The domain knowledge (expert) module includes algorithms for generation of problem solutions. The student diagnosis module processes information about learners for estimation of their current state of knowledge, carries out knowledge assessment and constructs a student model. The communication module (interface) provides functionality that supports interaction between the ITS and its users. Each particular ITS may include also additional components, for example, explanation module for explanation of reasons of mistakes.

Operations of core modules are based on corresponding models. The pedagogical model holds teaching strategies and instructions needed to implement learning activities. The expert model represents objects and their relationships (expert's knowledge) to be learned. The student model contains information about each individual student: his/her personal data, achieved results, current knowledge level, etc. Operation schema of ITS is shown in Fig.2.

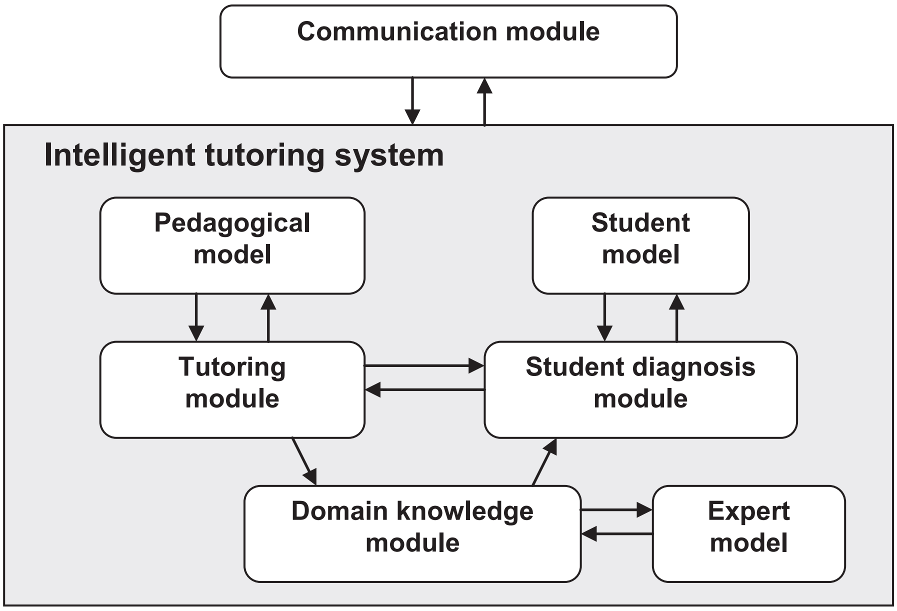

Fig.1. Core architecture of intelligent tutoring system

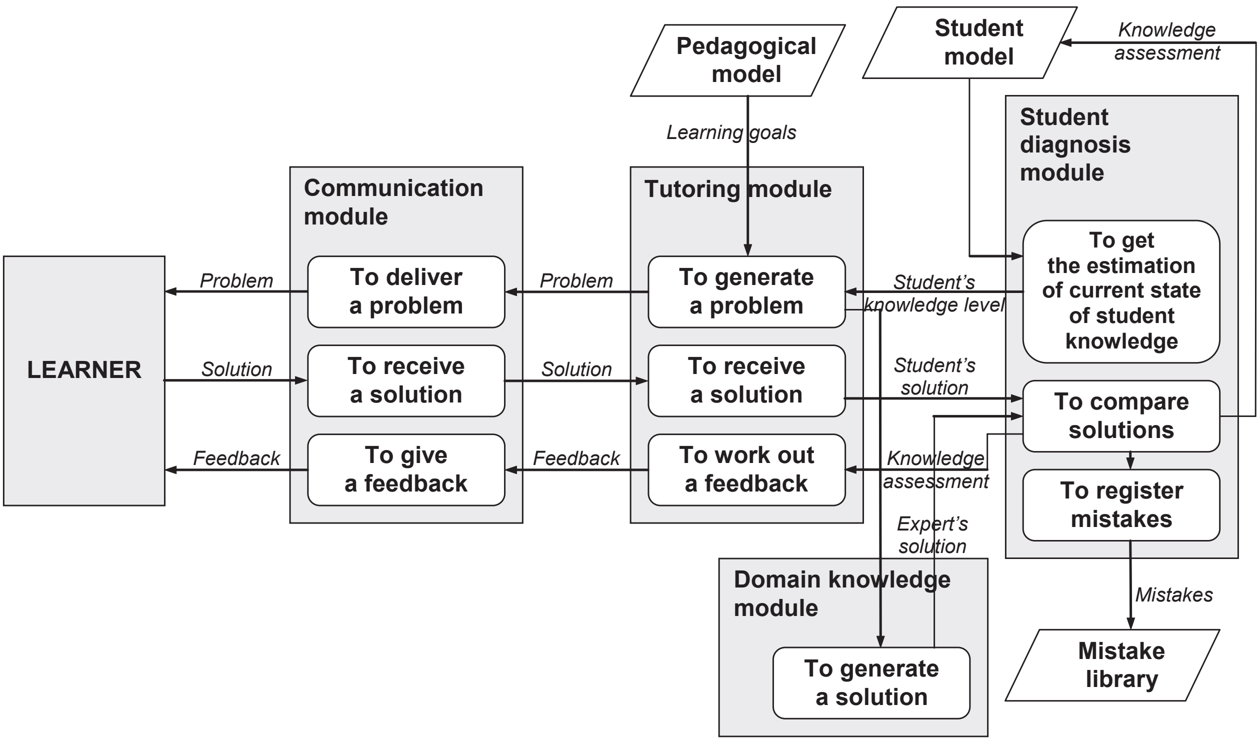

Fig.2. Operation schema of ITS

Thus, ITSs use knowledge about the domain, each individual learner and about teaching strategies to support flexible individualized learning [47, 54]. Typical ITS has the following characteristics:

- It is an adaptive computer-based system [6].
- It simulates (to a certain extent) a human teacher and tries to provide advantages of face-to-face learning.
- As a rule, it uses methods of artificial intelligence such as knowledge representation, inference, natural language processing and machine learning [11].

A modern approach to artificial intelligence based on agent paradigm [49] has influenced the development of ITSs, too. That is why recently rather many agent-based ITSs appeared. Analysis of already developed such systems, namely, ABITS [13]. IVTE [43], WADIES [20], Ines [31], an intelligent virtual training environment [4], and a multiagent architecture for distance education systems [19] allows to conclude that all core modules of ITSs may be implemented using agents [22].

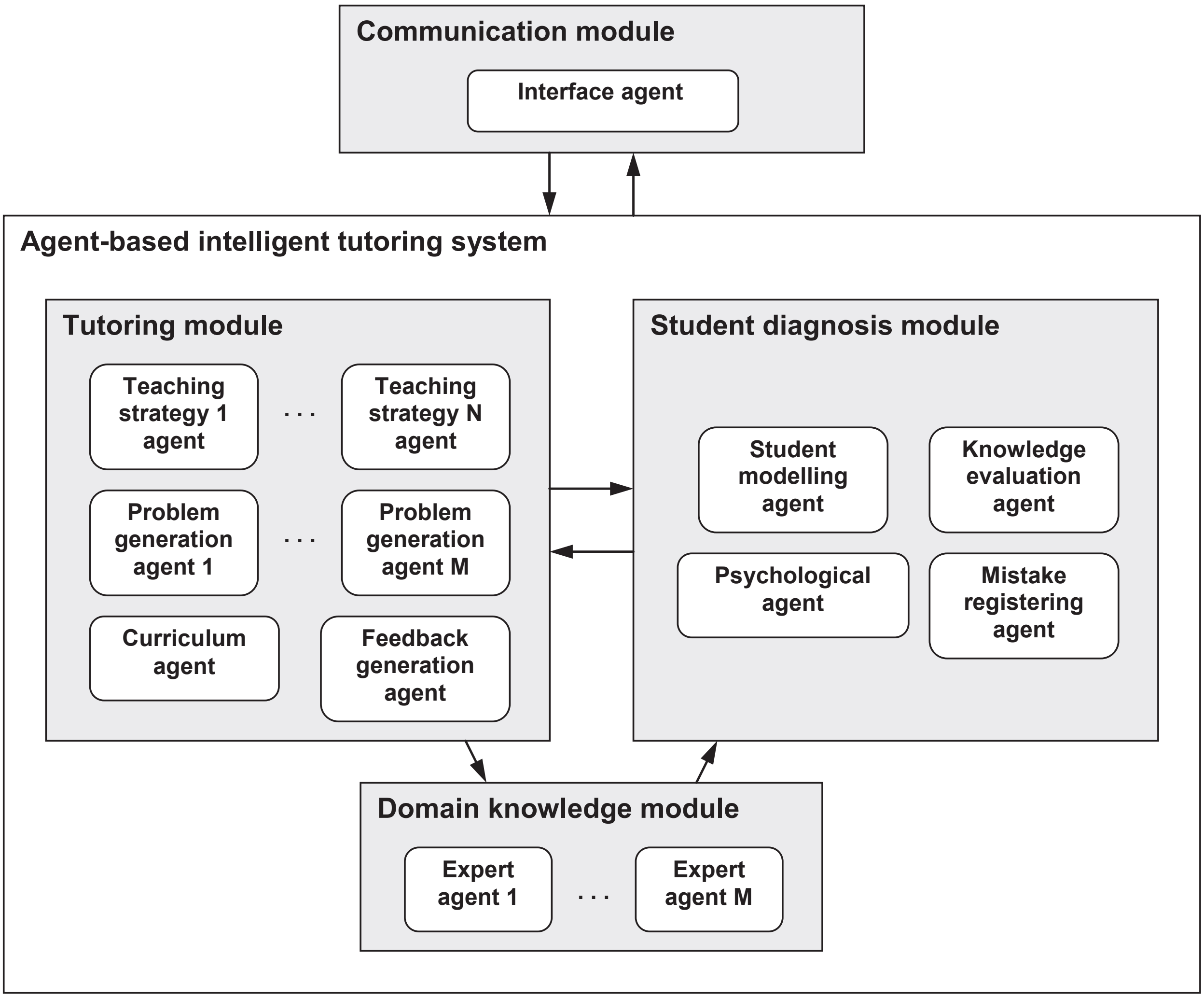

Fig.3. Architecture of agent-based ITS

A typical set of agents which may constitute the architecture of agent-based ITS is shown in Fig.3. The tutoring module consists of the teaching strategy agent, the curriculum agent, the problem generation agent and the feedback generation agent. Adaptivity is provided by including several teaching strategy agents for implementation of different teaching strategies, and several problem generation agents responsible for generation of specific problems. The domain knowledge module includes a set of expert agents. Each expert agent is responsible for a specific problem solving (the number of expert agents is the same as the number of problem generation agents). The student diagnosis module comprises the following agents: the student modelling agent, the knowledge evaluation agent, the psychological agent for building a profile of learner's psychological characteristics (learning style, preferences, attentiveness, etc.) and the mistake registering agent.

The functions of interface agent implemented in the communication module are management of different interaction tools and devices, monitoring interactions between learners and ITS, and registration of history of interactions of individual learners with the system for student model updating.

A specific ITS can contain also agents determined by specific features of the problem domain or peculiarity of ITS architecture and its implementation. For example, WADIES [20] has the authoring agent, ABITS [13] uses the spooler agent, but some ITSs include animated agents like widely known Steve and Adele [32].

THE CONCEPTUAL FRAMEWORK FOR INTEGRATION OF KNOWLEDGE MANAGEMENT AND INTELLIGENT TUTORING SYSTEMS

In educational settings both kinds of knowledge workers, namely, teachers and students (learners), are working with ICTs. A conceptual model describing how knowledge workers who are using an ICT may be embedded into a knowledge management system (KMS) was proposed in [23]. The KMS is an infrastructure of mutually integrated techniques and tools created for the support of networks of knowledge workers and knowledge management process: knowledge acquisition, storage, processing, distribution and application [40]. The KMS enables turning of information into action and connecting people to knowledge. Taking into account that the most relevant aspect of effective learning is the construction of knowledge at the individual level as well as in result of cooperation and teamwork, it is obvious that KMSs enable effective and active learning process [40]. Moreover, the KMS supports expansion of individual's personal knowledge to the knowledge of a group and an organization as a whole, i.e. a knowledge management environment contributes both personal and organizational knowledge. In this context emerges the concept of personal knowledge management (PKM) – a collection of processes that an individual carries out in order to gather, classify, store, search and retrieve knowledge in his/her activities [51]. The 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 he/she uses [5]. All abovementioned aspects are important in education and should be considered in the context of ICTs.

Looking a bit closer, one can find more reasons why knowledge management may play the important role in the ITS development. For competitiveness each educational organization continuously must enhance its knowledge assets or at least must keep them on the needed level. Unfortunately, education organizations may lose their knowledge assets rather easily when teachers leave them. KMSs to the certain extent may avoid loses by capturing, formalization and storage of knowledge in a way that allows it to be described, shared, distributed and leveraged to produce a higher valued asset. Nowadays it is not necessary to store all needed knowledge in human brains because technologies including those used in KMSs help to share and exchange it in a direct and effective way. In education frequently it is enough to know where to find necessary information and knowledge, and to access it quickly enough. This activity may be supported by the PKMS.

Learning, no matter whether individual or collective, is not possible without memory where data, information and/or knowledge is stored [40]. From the knowledge management viewpoint corporate memory may be interpreted as a possible mode in which collection and retrieval of knowledge is performed [8]. Passive collection and passive distribution of knowledge characterizes the simplest form of corporate memory management, so called knowledge attic. Often it is the most feasible in practice because it is not intrusive and emphasizes the bottom-up nature of learning. At the same time it requires high discipline and motivation of the knowledge worker but rather frequently it is not the case even for university students. Active collection and passive distribution (knowledge sponge corporate memory) of knowledge, in fact, is implemented in distance learning environments where teachers' prepared materials are offered to students who are free to use or not to use them. Ultimate goal of any academic organization should be the corporate memory which is characterized by active collection and active distribution of knowledge (knowledge pump corporate memory). For implementation and applicability of mentioned type of corporate memory intelligent agent perspective looks quite promising because intelligent agents can work tirelessly without emotions all 24 hours long.

Moreover, agents are fundamentally different from software packages because they have such characteristics as autonomy, adaptability, mobility, social ability, reactivity, proactivity and learning capability [49]. Agent is autonomous because it is able to operate without the intervention of other agents or human beings. Agent is adaptive because it can solve problems without input from the user and work on multiple platforms, networks, operating systems and environments. Agents may be mobile, i.e. they are able to roam networks and the Internet according to decisions made internally about where to find information. The characteristic of social ability helps to share knowledge and to communicate with other agents. Learning provides an agent with possibility to improve its experience through acquisition of new knowledge. An agent perceives its environment and is capable to respond immediately to changes without reasoning (reactivity) or to show reactions that require planning, diagnosis, and prediction (proactivity). So agents have useful characteristics that are needed for the development of systems that are included in the proposed conceptual framework and carry out active and intelligent interaction with their environment. As a consequence, agents are highly perspective for reaching the formulated goal – the development of truly intelligent tutoring system.

The conceptual framework supporting this type of corporate memory is based on integration of knowledge management and multiagent techniques in an intelligent tutoring system [23, 25]. The framework, which initial version up to now is essentially modified, is displayed in Fig.4. At the systems level it is shown that the traditional tutoring system is expanded and it interacts with an organization's (university) KMS and PKMS of knowledge workers. Due to historic reason described in Section 5 the intelligent knowledge assessment system is considered as a separate system that is not included in the intelligent tutoring system.

Development of the proposed conceptual framework is pushed forward by strong belief that its implementation as a multiagent system [55] which operates in technologically advanced environment finally will lead to the truly intelligent tutoring system. At the moment only two components shown in Fig.4 have been implemented – the intelligent tutoring system MIPITS and the intelligent knowledge assessment system IKAS which are briefly described in Section 4 and 5, respectively. Research on PKMS of knowledge worker has been carried out and a prototype of such system based on mobile devices is implemented now [44].

Due to the scope of this paper let only shortly describe conception of agent based PKMS of knowledge worker (for details see [24, 25]). The internal circle of agents consists of such personal agents as search, assistant, filtering and workflow agents. Internal communication agents such as messaging, team, collaborative and cooperative agents provide communications between individuals. Agents for communication with external systems are network agents, database agents, connection and access agents and Intelligent Web agents. The latter may play the most important role in the PKMS because nowadays the Web is the richest source of data, information and knowledge that is useful for learning and is accessible for any user. Unfortunately, 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 because knowledge is encoded using various languages and practically unconnected ontologies. Efforts to solve this problem resulted in appearance of the so called Web Intelligence [53] which is challenging and promising research field for ITS developers. Theoretical aspects of elements of KMS of the Department of Systems Theory and Design are started to describe but this investigation is not completed yet. Some directions concerning the environment are also explored, for example, Web Intelligence, Semantic Web and ontologies, agent based Web services, and semantic search of learning objects.

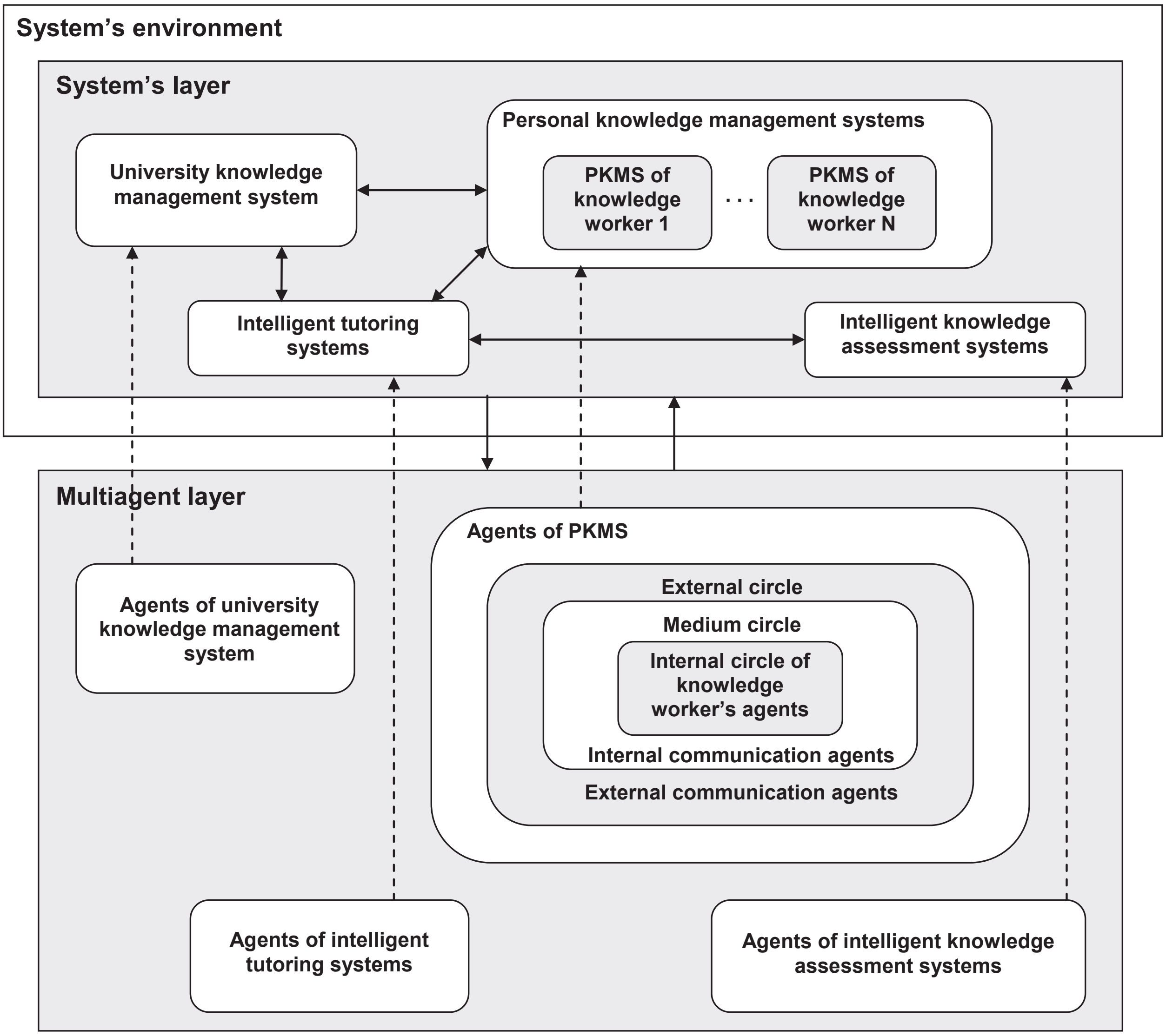

Fig.4. Two layers of conceptual framework

INTELLIGENT TUTORING SYSTEM MIPITS

Analysis of agent based ITSs [4, 13, 19, 20, 31, 43] shows that, as a rule, such systems are developed for specific study courses. The MIPITS system is developed for the study course "Fundamentals of Artificial Intelligence" taught at the bachelor level for third year students of Faculty of Computer Science and Information Technology. The MIPITS offers learning materials and problems to learners, evaluates their knowledge in each topic and provides feedback. The system adapts problems to the current knowledge level of each learner taking into account his/her preferences [36]. The development of MIPITS is supported by the multiagent system based ITS development methodology MASITS [35] and the corresponding tool [34]. According to the MASITS methodology the MIPITS is implemented in the JADE platform (http://jade.tilab.com). The MIPITS has an open holonic multiagent architecture [33] which is shown in Fig.5.

The communication module is implemented as an interface agent that is responsible for all interactions with learners. Its tasks are the following: collection and registration of learner's information and his/her preferences, carrying out a registration and login processes, perception of learner's requests and their forwarding to appropriate agents, giving learning materials, all types of problems (tasks) and feedback. The interface agent consists of the head of a holon and three body agents for visualization of tests, search problems and two person game problems.

The tutoring module includes teaching strategy, curriculum and feedback generation agents and the problem generation holon. The teaching strategy agent provides learning materials of each topic. The curriculum agent creates the curriculum during registration of learner. The problem generation agent is responsible for generation of all types of problems and their adaptation to the current knowledge level and preferences of each learner.

The domain knowledge module is represented by the expert agent which is implemented as a holon consisting of the head and three body agents responsible for problem solving of all types of problems.

The student diagnosis module consists of the student modelling agent and the knowledge evaluation holon which, in its turn, includes the head of the holon and three body agents for evaluation of learners' solutions of tests, search and two person game problems as well as for finding learners' mistakes. The student modelling agent is responsible for creating, updating and providing the student model if the request for any other agent is received. The initial student model is created during registration process and is modified in result of reactions on different actions reported by other agents. Student models contain personal data of learners, their preferences collected during registration process (preferred difficulty level, practicality and size of problem), the curriculum with status of each topic (initial, started, finished theoretical part, finished), all problems given to each learner and evaluation results [36].

So, there are four open holons which make the MIPITS very flexible because it is easy to add or delete any topic and to add or delete in four open holons corresponding agents responsible for test and problem generation, their solutions and evaluation, respectively. Heads of open holons only find the appropriate body agents and forward results received from them.

The MIPITS realizes the following tutoring scenario. A learner fills a form containing his/her personal data and preferences which are needed for problem adaptation. A learner submits a registration form and the interface agent checks data, inserts into the database and sends to the student modelling agent. The latter creates the initial student model based on his/her preferences and asks the curriculum agent to create the individual curriculum which is added to the initial student model by the student modelling agent and sent to the interface agent that opens the main window with the curriculum and information about the first module. Agents interact using simple messages which content is expressed by predicates from the domain ontology [36].

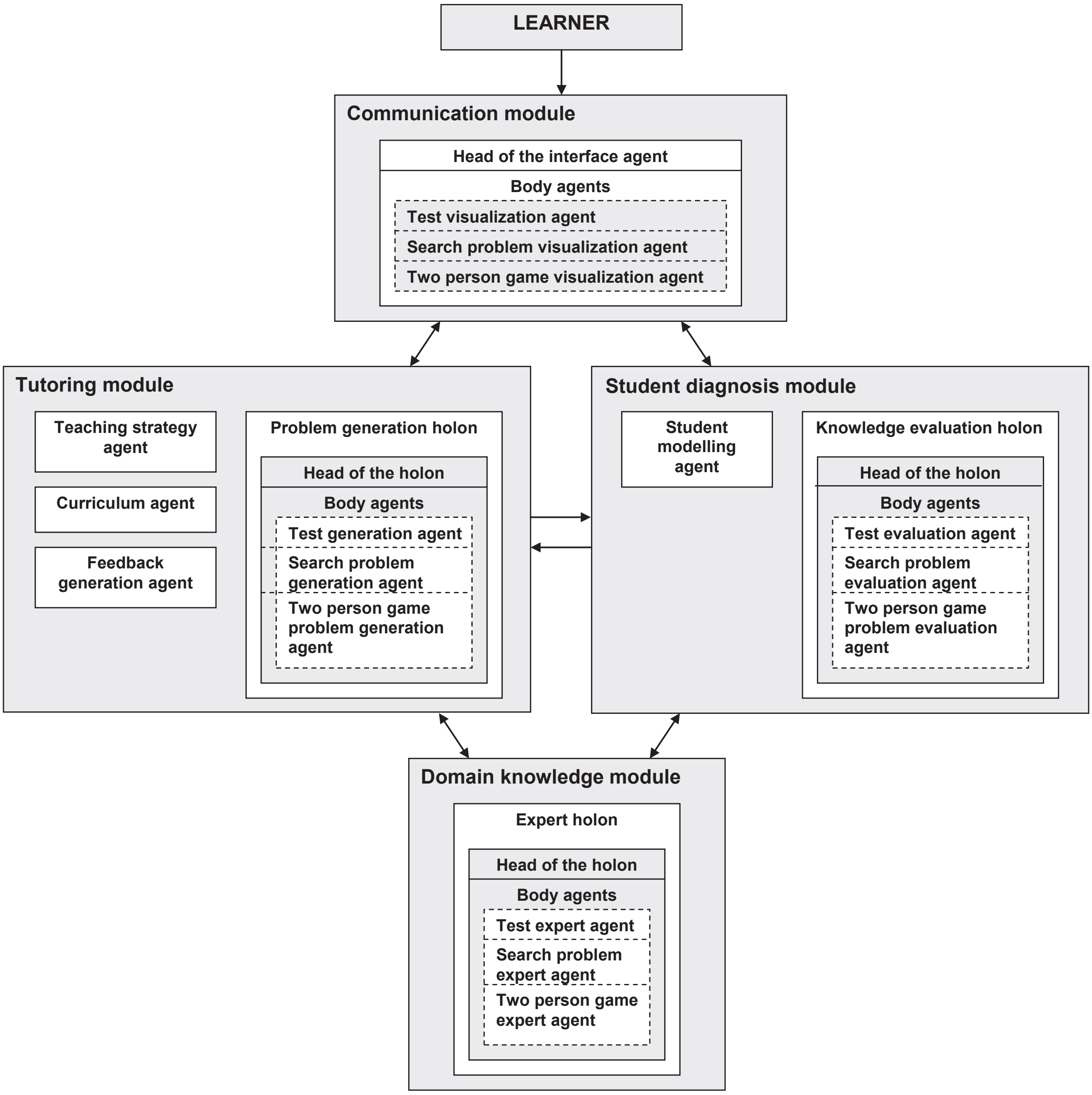

Fig.5. Architecture of MIPITS

Each time when a registered learner logs in the learning process is restarted at the topic that was open when a learner quit the system last time. Three consequent steps are fulfilled. First, the interface agent validates a learner's data and sends them to the student modelling agent. Second, the latter gets the student model from the database and sends it to the interface agent. Third, the interface agent requests the teaching strategy agent to provide the material of the current topic and opens the main window with the curriculum and the learning material of the topic.

The curriculum of the study course consists of modules that, in their turn, consist of topics. When a learner has chosen a learning topic, the MIPITS starts the theoretical step. A learner learns a theoretical material which is generated by the teaching strategy agent and shown by the interface agent. The teaching strategy agent notifies the student modelling agent that a learner has started to learn the current topic. The student modelling agent changes the status of the topic in the student model from "initial" to "started". After finishing a theoretical material a learner asks for a test and the system switches to the problem solving step.

During this step the MIPITS gives a learner a chance to practice in different types of problems. The interface agent asks the head of the problem generation agent to generate a problem of the current topic. The head gets a student model and the directory facilitator finds the body agents for generation of appropriate problems taking into account learner's characteristics or sends message of failure. The head chooses the most appropriate problem taking into account the difficulty level, the size, the practicality of the problem and the frequency of the problem type (values of these criteria are calculated using corresponding formulas given in [36]). The problem with the highest appropriateness is sent to the interface agent that gives it to a learner, to the expert agent that is responsible for the correct solution and to the student modelling agent that changes the status of the topic to "finished theoretical part" in the student model. Heads of the interface holon and the expert holon using the directory facilitator find the appropriate body agents of their holons. These agents pass the problem to a learner and solve it, respectively.

After a learner submits his/her solution the system switches to the knowledge evaluation step. During this step a learner's solution is evaluated and he/she receives a feedback. The interface agent sends the submitted solution to the knowledge evaluation holon. The head of the holon finds the needed body agent that compares expert's and learner's solutions, finds mistakes and evaluates the learner's solution. The head also forwards the evaluation to the student modelling agent and the feedback agent. The student modelling agent records knowledge evaluation result in the student model and changes the status of topic to "finished". The feedback generation agent creates the textual feedback about the result and the learner's mistakes. The feedback is sent to the interface agent that gives it to the learner.

The MIPITS adapts problems to learners' current knowledge levels and preferences by minimizing the difference between the preferred and real values of problem difficulty level, practicality and size. Experiments with the MIPITS showed that learners received problems that matched their preferences considerably closer in comparison with situation where the same problem was given to all learners.

INTELLIGENT KNOWLEDGE ASSESSMENT SYSTEM IKAS

The design of the intelligent knowledge assessment system (IKAS) started in 2005 with the goal of supporting student-centered systematic knowledge assessment which is based on concept maps (CM) [28, 30]. CMs as a pedagogical tool have been developed by Novak and Govin [41, 42]. A CM represents a part of a learner's cognitive structure, revealing his/her particular understanding of a specific knowledge area. The representation of knowledge structure is the topmost quality of CMs which substantiates their usage as alternative knowledge assessment tool concurrently with different tests, essays and free text responses. CMs are semi-formal knowledge representation tools visualized as graphs [30]. Natural language is used to define concepts and/or relationships between concept pairs. In general terms, CMs represent semantic knowledge and its conceptual organization (structure). Mathematically, a CM is a graph consisting of a finite, non-empty set of nodes representing concepts and a finite, non-empty set of arcs representing relationships among concepts. Graphs may be undirected or directed, homogeneous or heterogeneous, and may be represented as attribute graphs (arcs have linking phrases specifying the kind of relationship between a concept pair).

There is a wide variety of CM tasks which made CM based knowledge assessment adaptable to learners' knowledge levels and preferences. Tasks vary with regard to task demands, task constraints and the content structure of tasks [48]. Task demands are related to demands made on students in generating their CMs and determine two commonly used classes of tasks: fill-in-the-map tasks and construct-the-map tasks. Task constraints refer to the restrictiveness of the task which, in its turn, depends on constraints that are defined for the concept set and the linking phrase set [30]. The content structure of tasks refers to the intersection of the task demands and constraints with the structure of the subject domain to be mapped [48].

Under the IKAS framework the teacher divides the study course into several stages and learners must acquire certain concepts at each stage. The teacher must include concepts and relationships learned at the first stage in the first CM which is used for knowledge assessment. At the second stage, new concepts and relationships are introduced, and the teacher must add them to the first CM. So each new CM is an extension of the CM of the previous stage, and the final CM includes all concepts and relationships of the course [3].

The IKAS has two classes of users – teachers and learners who are supported by corresponding modules. The teacher's module ensures the construction of CMs. The learner's module includes tools supporting solution of CM tasks and viewing feedback after a solution is submitted and evaluated. The administrator's module manages data about users and study courses providing function of data input, editing and deleting. The IKAS core is the intelligent knowledge assessment agent which is implemented as a multiagent system that consists of four software agents: the communication agent, the interaction registering agent, the agent-expert and the knowledge evaluation agent as it is displayed in Fig.6.

The IKAS supports the following scenario. Using the graphical user interface, the teacher prepares a CM for each stage (the system supports teacher's actions for drawing CMs on the working surface). In order to make this work easier, already developed ontologies corresponding to study course domains may be transformed into CMs [21]. Learners get a CM task that corresponds to the current stage of learning and the preferred degree of task difficulty. After completing the task, the learner confirms his/her solution, the communication agent sends it to the knowledge evaluation agent that compares the teacher's and the learner's CMs on the basis of graph patterns (subgraphs constituted from paths and/or cycles of limited length [28, 29]. For each graph pattern the knowledge evaluation agent assigns a score characterizing the level of its correctness. This agent also calculates the final score reflecting the correctness of learner's CM as a whole and sends this score to the interaction registering agent, and as part of feedback containing information about the correctness of the solution to the communication agent. Comparison and evaluation of CMs is performed by developed comparison algorithms which complexity has increased concurrently with the number of recognizable graph patterns [30].

Other operations of the IKAS are as follows. The agent-expert forms a CM of a current stage using a teacher's CM and a learner's CM of the previous stage, and passes it to the communication agent for visualization. The agent-expert also sends a teacher's CM and a corresponding ontology to the knowledge evaluation agent for comparison which is needed for finding synonyms of concepts if learners have used them. The communication agent perceives learner's actions and is responsible for changes of the degree of task difficulty which depends from task demands and task constraints. This

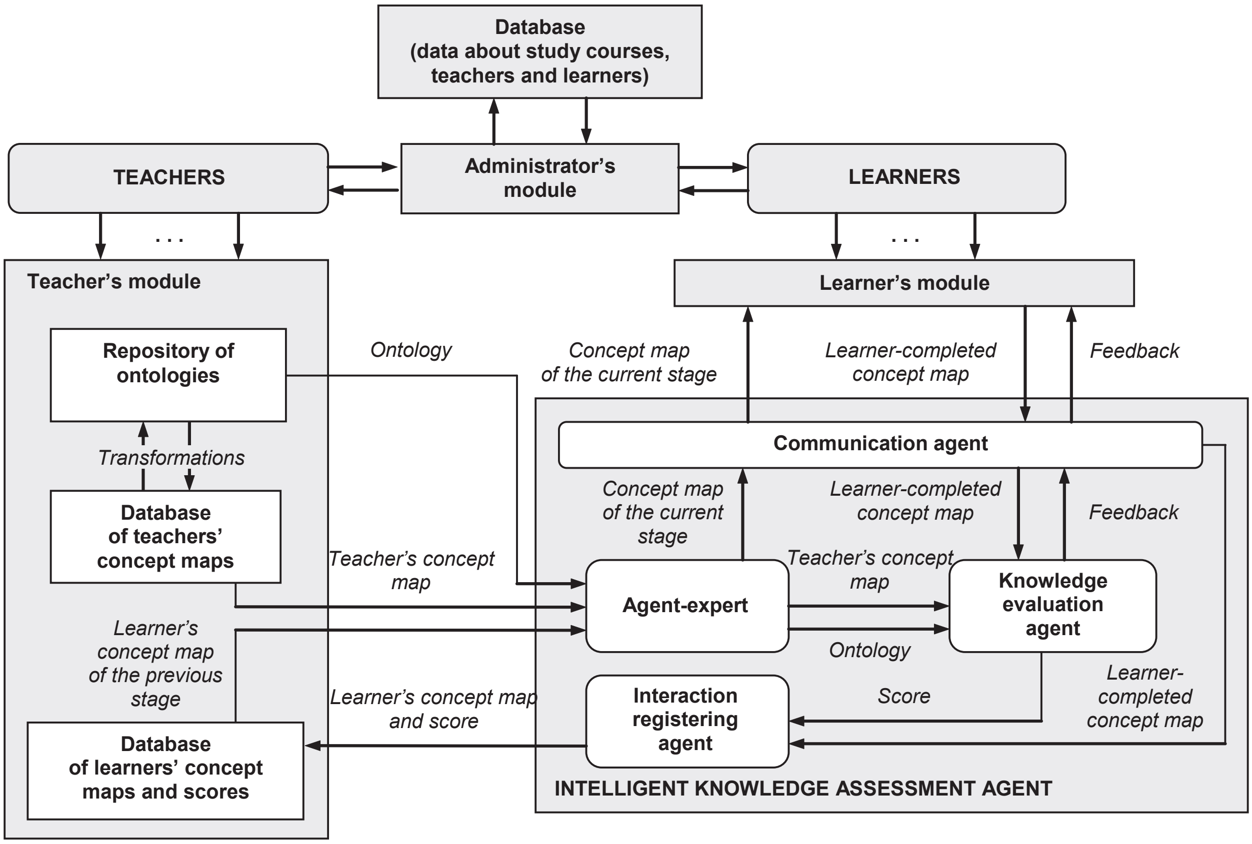

Fig.6. The IKAS and its environment

agent is responsible also for the form of feedback that contains information (definition, short description or example of concept) explaining those concepts which cause difficulties for a learner [30]. The communication agent also visualizes the CM received from the agent-expert and is responsible for the output of feedback received from the knowledge evaluation agent. The interaction registering agent after receiving a learner's solution and its assessment stores them into the database.

The IKAS has a capacity for adaptation to each learner's current knowledge level. Adaptation may be realized in two ways shortly described below (details are given in [28]) and refers to computer generated response format. First, change of the degree of task difficulty may be initialized by the IKAS that makes the decision based on a learner's previous task solving results. A learner also can initialize this change, for example, during the fill-in-the-map task solving a learner can ask the system to insert the chosen number of concepts in correct places in this way reducing the degree of task difficulty. Second, a learner can choose the initial form of feedback and change it during solution of CM task. The IKAS keeping track of learner's actions determines which form of feedback is of greatest value for a particular learner is his/her efforts to create a correct graph pattern.

At the beginning the IKAS was developed more as a self-assessment system but its evolution in fact resulted into an intelligent tutoring system which provides adaptive feedback and help for each individual learner if he/she has difficulties solving CM tasks. For this reason the intelligent knowledge assessment system in the proposed conceptual framework described in Section 3 is considered as separate system (not included in the ITS).

The IKAS has three-tier architecture shown in Fig.7. There are three conceptual elements: the database server, the client application and the application server. Such architecture increases response speed and ensures security of the system because the database server is open for connections only from one computer – the application server Apache Tomcat. The IKAS is implemented using the following technologies: Eclipse 3.2, Apache Tomcat 6.0, PostgreSQL DBMS 8.1.3, JDBC drivers, Hibernate, VLDocking, JGoodies and JGraph [37].

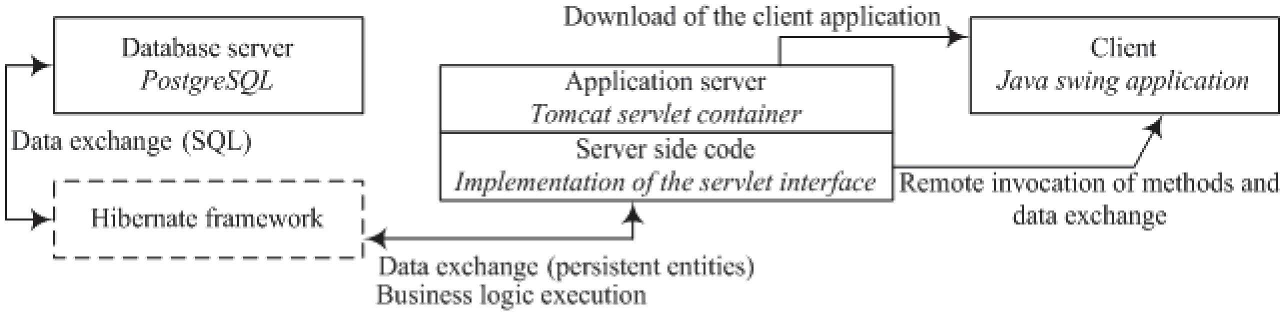

Fig.7. Three-tier architecture of the IKAS

During the last five years the IKAS was approbated in 14 different computer science and 2 pedagogical courses in Riga Technical University and Vidzeme University College. In total 264 students were involved and 237 questionnaires were received for collecting students' opinion about CMs as knowledge assessment tools and the IKAS itself. The questionnaire contains four groups of questions: the first group is focused on CMs as learning and knowledge assessment tools; the second group referred to the quality of interface and functionality of the IKAS; the third group was aimed at obtaining student opinion about the usefulness of reduction of the degree of task difficulty; the fourth group was centered on the quality of the received feedback and help. The encouraging factor for further modification of the IKAS and extension of its functionality was that overwhelming majority of students expressed positive attitude towards the usage of CMs (75% on average liked to use CMs as knowledge assessment tools, 46.8% on average wanted to use CMs in other courses, 41% on average answered that probably they will want to use CMs in future, 52.4% on average affirmed that CM tasks promoted better understanding of the study material, and 43% on average answered that better understanding was promoted partly).

Practical use and testing of the IKAS allowed to formulate two main lessons learnt. First, it shows the extreme importance of student model for achieving high degree of adaptability to different knowledge levels, preferences and learning styles of learners both in ITSs and intelligent knowledge assessment systems. That is why the conception of agent based student modelling shell AGENT-UM is proposed [38] for construction of complete student model. Second, the used scoring system which at the moment is rather immature should be considerably improved for the purpose to develop such scoring system by which learners' CMs can be evaluated accurately and consistently. That will open new possibilities to use CMs as knowledge assessment tools not only for "pass/fail" assessment or for intermediate assessment but also for final assessment (examination).

More information about analysis of questionnaires and decisions for extension of functionalities of the IKAS are given in [27, 28, 30].

CONCLUSIONS

In this paper needs for changes in a whole education process in connection with emergence of new type of intellectual work, so called knowledge work, are considered. Modern education should be promoted by ICTs which enable student-centered and one-to-one learning in traditional as well as in computational environments. Today, when more and more distance education environments are used, the achieved learning effectiveness still is behind the desired level. The main reasons are large number of students registered for the same study course, their different initial knowledge levels and learning styles that do not allow to implement individualized ICT based systems. At least partly this drawback may be eliminated by usage of intelligent tutoring systems, in particular, those ITSs which are based on intelligent agent paradigm.

The purpose of this paper is to outline the way how the truly intelligent tutoring system should be developed. The conceptual framework based on integration of knowledge management and intelligent agent techniques is described. The framework is intended for promotion of active collection and active distribution of knowledge which is one form of corporate memory management used in knowledge management domain. The system's layer of the framework includes interoperating organization's KMS, PKMSs, ITSs and intelligent knowledge assessment systems. The multiagent layer has sets of agents needed for implementation of abovementioned systems. Usage of intelligent software agents can provide active work with knowledge and knowledge acquisition from the environment. It is considered as prerequisite for truly intelligent tutoring systems.

Two steps towards such system have already completed, The agent-based ITS named MIPITS is already implemented using an open holonic architecture. The MIPITS offers learning materials, provides practical problems (tasks) and gives feedback to the learner about his/her solution evaluating his/her knowledge in the study course "Fundamentals of Artificial Intelligence". The concept map based intelligent knowledge assessment system named IKAS also has been developed and implemented. The IKAS is a multiagent system that can adapt to learners current knowledge level and preferences by changing the degree of task difficulty and providing different forms of feedback.

In the foreseeable future work is directed towards further extension and integration of both systems. In the MIPITS more problems will be added and CMs will be used for knowledge assessment. Other types of openness, for example, development of different types of learning materials (objects) is practically finished at the moment and will cause implementation of new open holons in the MIPITS in future. For IKAS new CM comparison algorithm based on a large set of graph patterns is under the development. The student modelling shell AGENT-UM and the algorithm for transforming study course ontology into CMs will be integrated with the IKAS. The development of PKMS based on mobile devices also will be finished in near future. Future research is focused on several directions. One is the development of scoring system which can evaluate students' CMs accurately and consistently taking into account such factors as the number of changes of the degree of task difficulty initiated by the learner of by the system, the number of student requests for checking the correctness of propositions (concept-relationship-concept triples), the number of requests for help, etc. Other directions are usage of agent based Web services, investigation of application of Web Intelligence for ITSs and semantic search of learning objects.

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ABOUT THE AUTHOR

Prof. Janis Grundspenkis, Dr.habil.sc.ing., Department of Systems Theory and Design, Riga Technical University, Phone: +371 67089581, E-mail: janis.grundspenkis@cs.rtu.lv