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AGENTS IN INTELLIGENT TUTORING SYSTEMS: STATE OF THE ART

J. Grundspenkis, A. Anohina

Intelligent tutoring system, intelligent agent, animated pedagogical agent

1. Introduction

In this paper two research areas in the field of artificial intelligence – intelligent tutoring systems and intelligent agents – are considered. The main aim of intelligent tutoring systems is to provide sophisticated instruction on one-on-one basis adapting the learning process to the strengths, weaknesses and the level of knowledge and skills of each particular learner. Such systems have many tasks: the monitoring of actions of the learner in the learning environment and the appropriate responding to them, an assessment of learner's knowledge, choice and presentation of learning material, presentation of feedback and help, adaptation of teaching strategy, and so on. Moreover, system functioning conditions change with each action of the learner. Intelligent tutoring systems have been a focus of research since 1970, but their developments have received new breath with the appearance of the agent paradigm. The agent-based technology is concerned with the creation of entities, which have such properties as autonomy, reactivity, proactivity, capabilities of socialization and learning, reasoning, adaptability, mobility, and which are capable to act in complex dynamic environments, performing their tasks entrusted to them. As it is possible to see from the aforesaid, this technology is very suitable for the implementation of intelligent tutoring systems.

This paper surveys current state of research in the field of intelligent tutoring systems based on agent technology, trying to find answers to the following questions: what components of intelligent tutoring systems can be implemented as agents and what functions agents can perform in each component, as well as why agent technology is used for development of intelligent tutoring systems.

The paper is organized as follows. Section 2 briefly describes the main parts of architecture of an intelligent tutoring system. Section 3 discusses the agent concept and its characteristics such as autonomy, adaptability, mobility, transparency, ruggedness, reactivity, proactivity, capabilities of socialization and learning. Conclusions about usage of agents in each principle module of intelligent tutoring systems, as well as the brief description of the three-layer conceptual model of intelligent tutoring system that has been developed by one of the authors of this paper are presented in Section 4. Animated pedagogical agents, their roles, and some examples are described in Section 5. Section 6 summarizes the most important issues of the paper.

2. The concept of intelligent tutoring system

Research has been carried out in the domain of intelligent tutoring systems for over 30 years since the earliest SCHOLAR system [1] appeared. Some other significant systems such as WHY [2], SOPHIE [3], BUGGY [4], WEST [5], LISP Tutor [6], and GUIDON [7] should be

mentioned due to their role of establishing main principles of modern intelligent tutoring systems. During this time a variety of intelligent tutoring systems has been implemented for different areas. Although there are differences in the structure of these systems caused by peculiarities of certain area and technology used for the implementation of a system, they are united due to the fact that all these systems include knowledge about what and how to teach, and knowledge about learners. The aforementioned knowledge types determine three main parts of an intelligent tutoring system: the domain knowledge, the tutoring module, and the student diagnosis module.

The domain knowledge concerns objects and their relationships taught by the system. Sometimes the domain knowledge is presented as an expert module. This module most commonly is capable to solve problems in the domain and corresponds to the knowledge representation of the domain expert.

The tutoring module holds teaching strategies and instructions needed to implement the learning process. The primary tasks of this module are controlling of selection, sequencing and presentation of material that is most suitable to the needs of the learner, determining of the type and contents of feedback and help, and answering questions from the learner.

The student diagnosis module infers the student model that is formed for every learner. This model contains information about the current level of learner's knowledge, that is, what he/she has learned, what mistakes he/she had done, what misconceptions he/she has, etc. Additionally, this model can store information about learner's psychological features and his/her past experience. The student model allows tailoring of the learning process to the needs of a particular learner.

An intelligent tutoring system, as any other software intensively communicating with users, needs a part of architecture responsible for the interaction between the system and the learner. It is a communication model or interface and it controls screen layouts, interaction tools, and so on.

All mentioned components are only the basic components of intelligent tutoring systems. So, each particular system can have additional parts, which depend on features of the certain area and technology used for the implementation of the system.

3. Intelligent agents and their characteristics

A lot of intelligent agent definitions exists starting with very general ones, such as given in [8]: "an agent is anything that can be viewed as perceiving its environment through sensors and acting upon that environment through effectors", and ending with definitions that specify agents applied in narrowly focused areas.

In intelligent tutoring systems software agents are used. According to Michael Coen's definition given in [9]: "software agents are programs that engage in dialogs, and negotiate and coordinate transfer of information". Agents are fundamentally different from software packages because they must have special characteristics or attributes: adaptability, mobility, transparency and accountability, ruggedness, self-starter and user centered [9].

Adaptability means that agent must be able to solve problems by itself without input from the user as well as to work on multiple platforms, networks and operating systems. Mobility is considered as agent's ability to roam networks and the Internet according to decisions made internally about where to find information, and to interact with other agents in multiple networks and environments. An agent must be completely transparent to the user and must produce information on demand where it has been, what it has done, whom it did contact, and

when. If an agent is required to traverse network it must be rugged, that is, able to deal with errors, incomplete data, interpret different kinds of data, and so on. Moreover, it should be able to solve as many problems as it can without user intervention. An agent must be able to start and stop on the basis of its own criteria and to decide to gather information using the user's priorities. At last, but not least, the agent should act in the interests of its owner and the preferences that have been set for it.

The most often mentioned properties by which agents are characterized are their autonomy, social ability, reactivity, proactivity, and learning capability. Agent is autonomous "to the extent that its behaviour is determined by its own experience" [8], in other words, agent is capable to operate without the intervention of other agents or human being based on its built-in knowledge and knowledge acquired during agent's performance. Learning provides the agent with an opportunity to improve its experience through the acquisition of new knowledge. Very often it is necessary for an agent to share the knowledge and to communicate with other agents inhabiting the same environment in order to achieve a common goal. The property of social ability helps it. The agent perceives its environment and is capable to respond immediately to changes within it without reasoning (reactivity), but also it is capable to show reactions which require planning, diagnosis, and prediction (proactivity).

One can conclude that agents have many useful features that are desirable for intelligent tutoring systems. It is the main reason why the usage of the intelligent agent paradigm has recently become so popular in the development of intelligent tutoring systems, especially stimulated by the fact that learning effectiveness of distance learning environments is behind the needed level.

Agent role in intelligent tutoring systems is at least twofold. First, a set of agents may constitute the architecture of the intelligent tutoring systems. Second, there are so called animated pedagogical agents that are developed as 2D or 3D animated characters. Both cases are described below.

4. Usage of agents in intelligent tutoring systems

Use of agents as autonomous entities is the most promising in areas where the problem can be divided into independent parts or can be considered from various perspectives. Each of the parts or perspectives can be implemented as the separate agent. In this sense intelligent tutoring systems provide many opportunities:

- The architecture of an intelligent tutoring system is composed of several modules and, therefore, each of them can be implemented in the form of the agent or a set of agents.
- The tutoring module can provide several tutoring strategies and each of them can be entrusted to the separate agent.
- The user interface, through which learner interacts with the system, includes various tools such as buttons, menus, input fields, panels, and others. For system reasoning process it is often very important what the learner has chosen or where he/she has clicked. Thus, it is possible to provide the separate agent for each tool of interest.
- The information stored in the student model can be categorized into several groups: information about learner's knowledge assessments, information of learner's psychological characteristics, causes of learner's mistakes and misconceptions, etc. Thus, it is possible to develop the agent that will be responsible for gathering and processing of the certain kind of information.

- The system can support various interaction devices (e.g. monitor + mouse + keyboard or head mounted display + motion tracking + data glove + voice recognition [10]) that allow the learner to communicate with the system. In this case it is possible to develop agents responsible for management of separate devices.
- The domain knowledge can be divided into educational units and each unit can be controlled by the separate agent.

Thus, all components of the architecture of an intelligent tutoring system mentioned in Section 3 can be implemented as agents. This statement is confirmed with intelligent tutoring systems implemented till now. We have studied the following systems during the analysis of the usage of agent paradigm in intelligent tutoring systems:

- Intelligent virtual environment for training [10]:
- Ines [11] – an intelligent tutoring system for the task of nurse training;
- ABITS [12] – a multi-agent intelligent tutoring system that extends a traditional course management system with a set of "intelligent" functions allowing student modeling and automatic curriculum generation;
- WADIES [13] – a Web- and agent-based adaptive learning environment for teaching compilers;
- A multi-agent architecture for distance education systems [14] composed of a management system and a multi-agent intelligent system;
- IVTE [15] – an intelligent virtual teaching environment which main purpose is to assist and to back up the ecological character of children from 8 to 10 years old, providing them an opportunity to keep contact with the kinds of garbage from daily life and to select them correctly when the child makes his/her way home after a day at school or in his/ her home.

The main tasks of agents comprising student diagnosis module typically are the evaluation and updating of information concerning a particular learner. This information is related to learner's cognitive states and psychological characteristics, mistakes and their causes, as well as to all other information that could be useful for adapting the learning process. The mentioned agents are implemented in ABITS [12] as evaluation agents and affective agents, in the multi-agent architecture for distance education systems [14] as evaluation agent, and in the intelligent virtual environment for training [10] as a set of student modeling agents. The possible set of agents in the student diagnosis module is shown in Figure 1.

Agents in the tutoring module can evaluate, update and generate curriculum as pedagogical agents in ABITS [12] or in the multi-agent architecture for distance education systems [14] do it. As it is specified in [16] "the use of multiple learning strategies calls on a multi-agent architecture", so this module can also contain some agents implementing different teaching strategies (e.g. one-on-one tutoring, learning with a co-learner, learning by teaching, learning by disturbing [16]) as it has been done in the intelligent virtual environment for training [10] or only one particular strategy can be delegated to an agent, for example, WADIES [13] system includes the self-assessment agent. Some agents can be responsible of generating and presenting the feedback, explanations and help as the feedback agent and the explanation agent in Ines [11]. Other agents depending on pedagogical specificity of the system also can be included in the system as agents monitoring the elapsed time during a task or the order of tasks in Ines [11]. The possible set of agents in the tutoring module is shown in Figure 2.

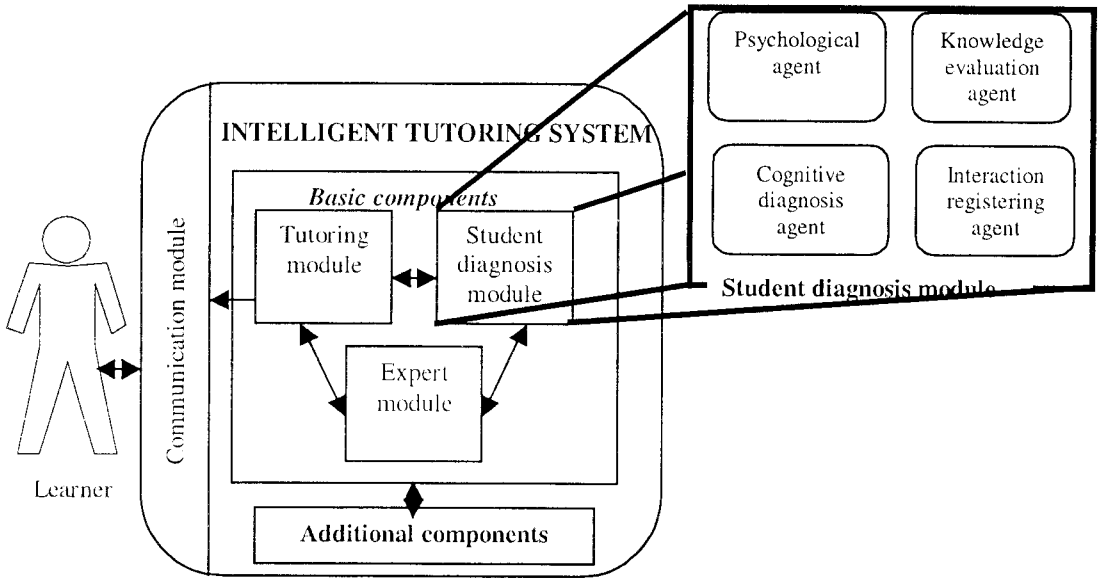

Figure 1. Agents comprising the student diagnosis module of intelligent tutoring system

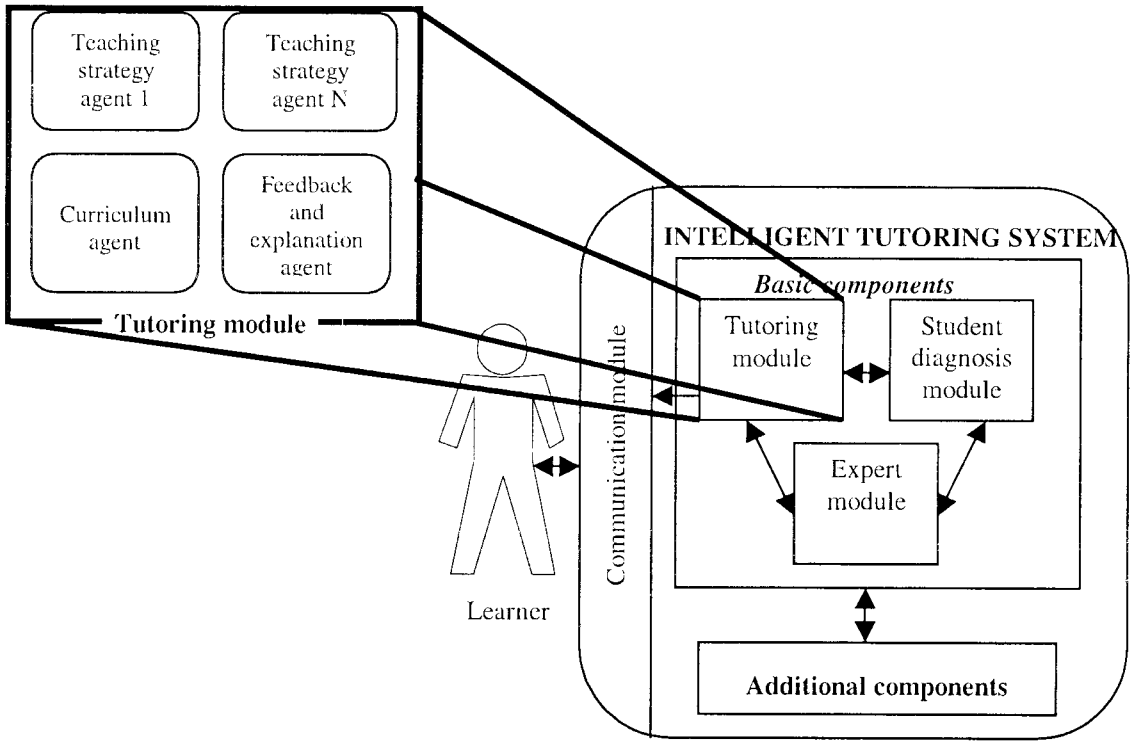

Figure 2. Agents comprising the tutoring module of intelligent tutoring system

The agents-experts solve problems and tasks related to the subject matter and examples of them are presented in the multi-agent architecture for distance education systems [14] and in the intelligent virtual environment for training [10]. It is straightforward that a set of these agents depends on the domain that is being taught to the learners. The possible agents in the expert module of intelligent tutoring system are shown in Figure 3.

The communication model based on agent technology is implemented in the intelligent virtual environment for training [10] as the communication agents or in IVTE [15] as elements of IVTE scenery/environment. Such agents are responsible for monitoring the interaction between the learner and the system and they perceive learner's activities in the learning environment.

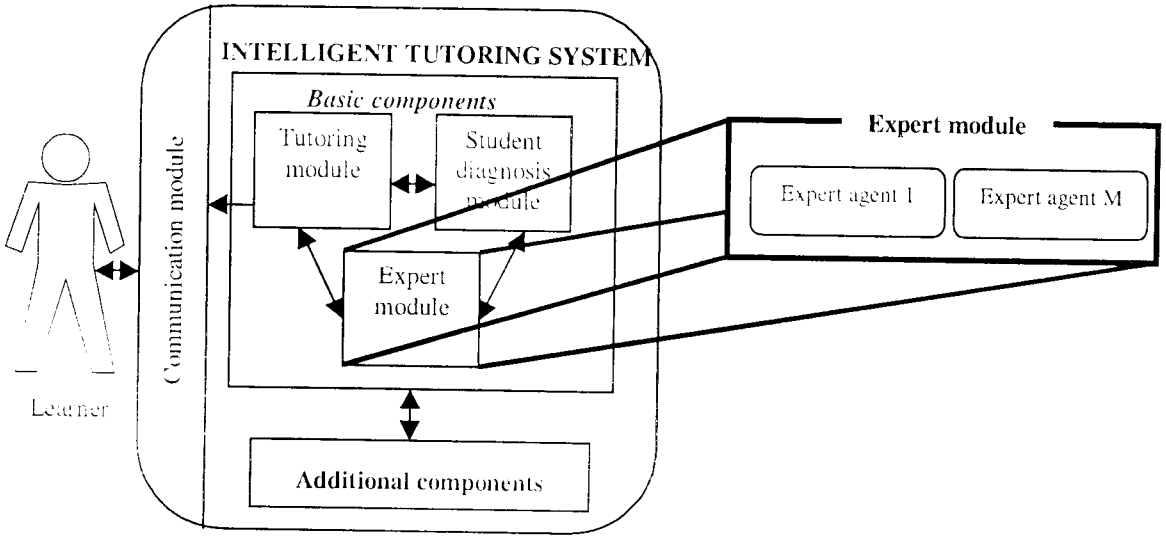

Figure 3. Agents comprising the expert module of intelligent tutoring system

Summary about functions of agents in the main components of an intelligent tutoring system is given in Table 1.

Table 1. Agent functions in the main components of an intelligent tutoring system

The component of an intelligent tutoring system	Agent functions
The student diagnosis module	• building a model of learner's current level of knowledge and skills based on assessments • building a profile of learner's psychological characteristics (learning preferences, learning style, attentiveness, personality traits etc.) • registering history of the learner's interactions with the system • determining and registering learner's mistakes and their causes
The tutoring module	• evaluation, updating and generation of the curriculum • implementation of different teaching strategies • generation and presentation of feedback, explanations and help
The communication module	• monitoring the interaction between the learner and the system • management of various interaction devices
The expert module	• solving problems and tasks related to the subject matter

An intelligent tutoring system can also contain some specific agents that aren't related to the typical architecture of such systems. Kinds of these agents are determined by domain or peculiarity of system's architecture and technology used for its implementation. For example,

specific agents are implemented in the intelligent virtual environment for training [10] as a set of the world agents and in WADIES [13] as the authoring agent.

The studied systems allow to conclude that the multi-agent architecture is typically used for the implementation of the system and rarely the system contains only one or two agents. In multi-agent intelligent tutoring systems at least one agent is a managing agent that controls and coordinates actions of other agents, for instance, the spooler agent in ABITS [12] or the examination agent in Ines [11]. The interaction between agents is modeled using some kind of the agent communication language.

Thus, both the intelligent tutoring system in general and its components in particular can be implemented in the form of multi-agent architecture. If a separate component is based on multi-agent paradigm, it is often necessary to have the agent who will manage other agents in a given component. This agent "may relate to, communicate with and delegate some tasks to other subordinate agents, giving rise to multi-level agent architecture" [10].

The possible set of agents, which may constitute the architecture of an intelligent tutoring system, is displayed in Figure 4.

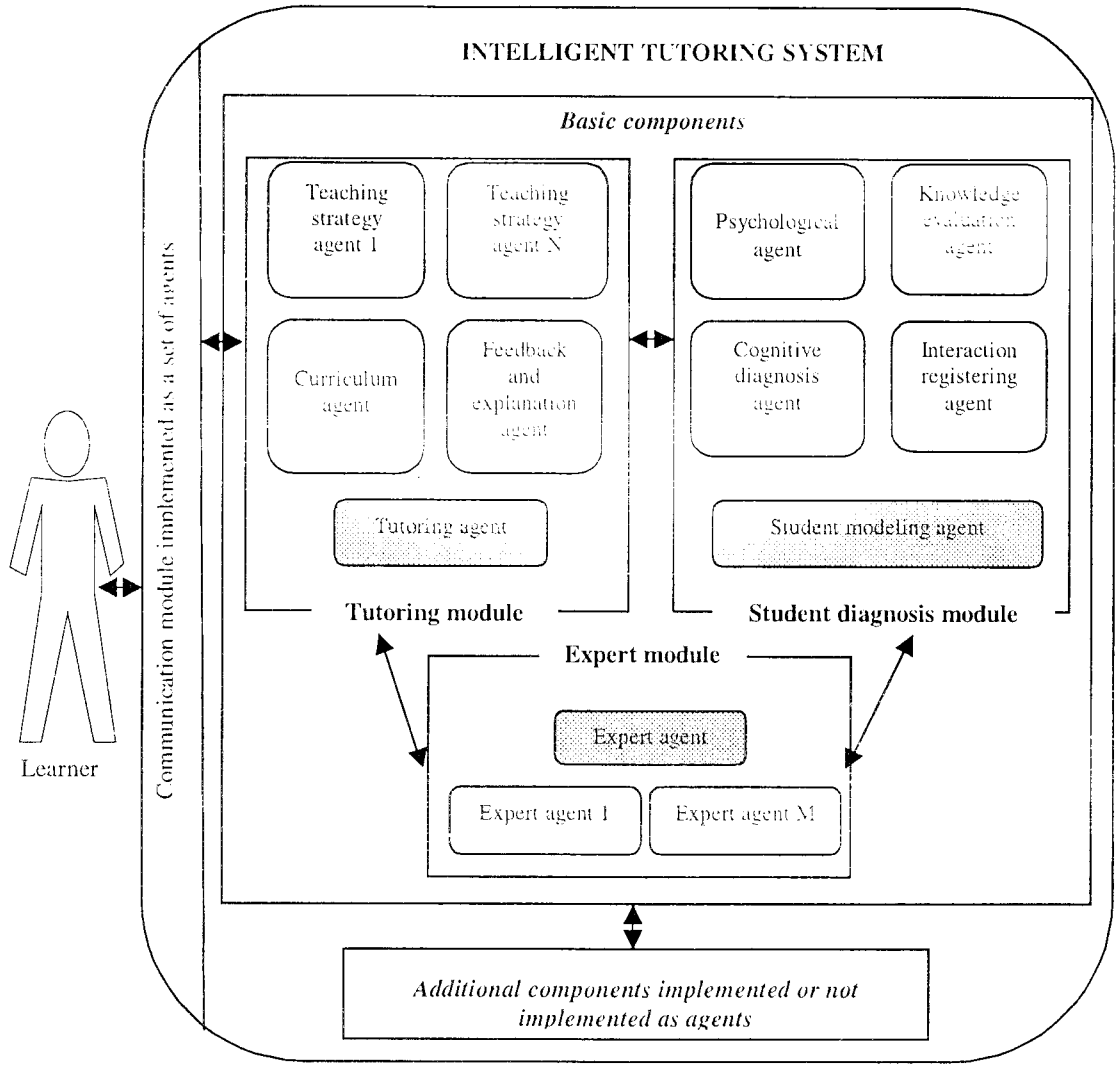

Figure 4. A set of agents comprising the architecture of an intelligent tutoring system (grey boxes are managing agent in a given component)

A novel conceptual model of intelligent tutoring system that has three layers: system's layer, multi-agent layer and knowledge worker's layer has been proposed in [17]. At the system's layer the conceptual model is similar with the architecture shown in Figure 4, and includes the student model, the expert model, the tutoring module, the domain knowledge base, and the interface. These components correspond to the learning agent architecture [8]. The domain knowledge base corresponds to the agent's built-in knowledge base. The interface plays the role of an agent's sensors and effectors system. The tutoring module corresponds to the problem generator. It includes the planning agent that provides an appropriate learning plan and the search agent to choose the best plan.

At the multi-agent layer there is a set of agents that simulates a group of students and the teacher. So, a multi-agent system simulates the teaching and learning process as a cooperative work and communication of agents [18].

At the knowledge worker's layer students and teacher are supported by a plethora of intelligent agents. An agent-based environment of the knowledge worker includes personal agents (search, filtering, assistant and work-flow agents), communication agents (messaging, cooperative, communication facilitation, collaborative and team agents), and agents for communication with external systems (connection and access, database, network and intelligent Web agents).

The conceptual model is under the development at the present moment. A lot of work must be done to implement this model in full scale. We hope that the implementation of the conceptual model in the intelligent tutoring system will promote more intelligent support of teaching and learning process.

The use of agent paradigm facilitates implementation and support of an intelligent tutoring system. The architecture of the system passes from monolithic, where all components are closely interconnected with each other, to modular architecture, where components can be added, removed or replaced without consequences for the system in general. Thus, agents promote system expandability, maintainability and reuse.

5. Animated pedagogical agents

All previously described agents weren't directly visible to the learner as they were implemented inside a certain system and didn't have visual appearance. However, agents can be developed as 2D or 3D animated characters, which actively use face and body language, gestures, and even voice. Such agents are called animated pedagogical agents. They are put into some environment with the purpose to make the learning process more interesting, funny, similar to entertainment, and, therefore, to increase the learner's attention to learning and, as a consequence, to increase learning effectiveness.

Animated pedagogical agents can be very simple two-dimensional characters in the cartoon style using primitive animation and the dialogue boxes presenting feedback and hints on the basis of the text. They can be more complex three-dimensional characters using a wide range of gestures, voices and not only providing feedback and hints, but also answering questions, demonstrating the execution of a task and pointing out the important objects in the environment.

Typically animated pedagogical agents emulate the aspects of dialogue between a human teacher and a learner. Such agents can play different roles within an intelligent tutoring system. The following three roles are described in [19]:

- Agent as an expert. It is similar to the human expert that exhibits mastery or extensive knowledge and performs better than the average within a domain. Such agent has limited gestures and limited intonations, and mainly provides information.
- Agent as a motivator. It suggests his own ideas and encourages the learner to sustain the tasks. It is highly expressive and speaks enthusiastically and rapidly.
- Agent as a mentor. It incorporates characteristics of both the expert and the motivator. It is also highly expressive, but speaks calmly and engaging.

Classical examples of pedagogical agents described in the literature are Adele [20] and Steve [21], but they are not unique. SQL-Tutor [22] is a computer based teaching system that has been developed to help the learners in learning structured query language. This system has an animated pedagogical agent called Smart-egg. It is 2D cartoon character, which is able to perform a number of gestures. The main role of the agent is to present feedback messages to the learners in the exciting and enjoyable way to increase their motivation and, as a consequence, to increase the learning effectiveness.

Cognitive agents are presented by a tutor called Gilly in the IVTE system [23]. It observes a learner's performance in the environment and sends feedback messages. These messages include face and body language, clues about garbage, alert message, questions, etc. Messages are chosen based on student model and teaching strategies.

Some more examples of animated pedagogical agents are described in [22], while the generic advanced distance education architecture for Web-based instruction is presented in [24].

6. Conclusions

In spite of the fact that research in the field of intelligent tutoring systems is carried out during several decades with the emergence of a paradigm of agents the development of intelligent tutoring systems reaches the new phase. Application of agent-based technology to the implementation of intelligent tutoring systems allows to pass from the monolithic structure of such systems to the structure of relatively independent components. The general architecture of such systems offers many opportunities of their division into various subparts or perspectives. The modular architecture noticeably improves an opportunity to expand and reuse these systems, facilitates their maintainability. This paper is based on examples of the already implemented intelligent tutoring systems, describes a possible set of agents within the framework of the general architecture of intelligent tutoring systems, and considers their functions. One can conclude that not only the intelligent tutoring system but also its components can be implemented in the form of multi-agent architecture and, moreover, in the form of multilayer multi-agent architecture.

Future work is connected with the implementation of the conceptual model of three layered intelligent tutoring system proposed for the first time in [17]. Concurrently with implementation of the narrowly focused first version of intelligent tutoring system (aimed for teaching and learning of MIN-MAX algorithm for two person games in the course of "Foundations of Artificial Intelligence"), first search agents for knowledge worker's layer has been developed. If tests of these agents will be successful, the next step will be the development and implementation of other agents (filtering, assistant and work-flow agents) and their integration to get an agent supported knowledge worker's environment. Reaching this stage, the prototype of multiagent system will be developed that will allow to model agent cooperative work in teaching and learning process. After that the development and

implementation of communication agents is foreseen. The final goal is the development of all needed agents and their integration into an intelligent tutoring system that will be based on the proposed three layered conceptual model. This system would be used as a test bed for evaluation of effectiveness of teaching and learning process supported by the intelligent tutoring system. Several other goals are put forward for the already ongoing and planned research activities. The distribution of functions between human teachers and intelligent software agents is one of the hot topics, in particular, in so called hybrid educational systems which include face-to-face and distance education modes. Investigations on the role of ontologies in management of process oriented education and development of student models are planned, too.

References

1. Carbonell, J.R. *"AI in CAI: An Artificial Intelligence Approach to Computer-Assisted Instruction"*// IEEE Transactions on Man-Machine Systems, 11 (4), 1970, pp. 190-202.
2. Stevens A., Collins A. *"The Goal Structure of a Socratic Tutor"*// In: Proceedings of the National ACM Conference, 1977, pp. 256–263.
3. Brown J.S., Burton R.R., de Kleer J. *"Pedagogical, natural language, and knowledge engineering techniques in SOPHIE I, II and III"*// In D.H. Sleeman and J.S. Brown (eds.), Intelligent Tutoring Systems, London: Academic Press, 1982.
4. Brown J. S., Burton R. R. *"A paradigmatic example of an artificially intelligent instructional system"*// International Journal of Man-Machine Studies, vol. 10, 1978, pp. 323-339.
5. Burton R. R., Brown J. S. *"An investigation computer coaching for informal learning activities"*// In: D.H. Sleeman and J.S. Brown (eds.), Intelligent Tutoring Systems, London: Academic Press, 1982.
6. Anderson J. R., Reiser B. J. *"The Lisp Tutor"*// Byte, vol.10, 1985, pp.159-175.
7. Clancey W.J. *"Tutoring Rules for Guiding a Case Methods Dialogue"*// In: D.H. Sleeman and J.S. Brown (eds.), Intelligent Tutoring Systems, London: Academic Press, 1982.
8. Russell S. J., Norvig P. *"Artificial Intelligence: A Modern Approach"*// Upper Saddle River, N.J: Prentice Hall, 2003.
9. Murch R., Johnson T. *"Intelligent software agents"*// Upper Saddle River, N.J: Prentice Hall, 1999.
10. De Antonio A., Imbert R., Ramirez J., Mendez G. *"An agent-based architecture for the development of intelligent virtual training environments"*// In: Proceedings of the Second International Conference on Multimedia and Information & Communication Technologies in Education (m-ICTE 2003), Badajoz, España, 3-6 de Diciembre, 2003, pp.1944-1949. - bermudas.ls.fi.upm.es/~gonzalo/docs/publicaciones/micte03.pdf (last visited 13.08.2004)
11. Hospers M., Kroezen L., Nijholt A., Akker R., Heylen D. *"Developing a Generic Agent-based Intelligent Tutoring System and Applying it to Nurse Education"*, 2003. - http://wwwhome.cs.utwente.nl/~heylen/Publicaties/ines-2003.pdf (last visited 13.08.2004)
12. Capuano N., De Santo M., Marsella M., Molinara M., Salerno S. *"A Multi-Agent Architecture for Intelligent Tutoring"*// In: Proceedings of the International Conference on Advances in Infrastructure for Electronic Business, Science, and Education on the Internet, SSGRR 2000, L'Aquila, 2000. - http://www.capuano.biz/Papers/SSGRR_2000_P1.pdf (last visited 02.10.2004)
13. Georgouli K., Paraskakis I., Guerreiro P. *"A Web Based Tutoring System for Compilers"*// In: Proceedings of the 14th EAEEIE Annual Conference on Innovation in Education for Electrical and Information Engineering (EIE), Gdansk, Poland, 16th - 18th June, 2003. - http://www-ctp.di.fct.unl.pt/~pg/docs/Gdansk_2003_2.pdf (last visited 02.10.2004)

14. Dorēa F.A., Lopes C.R., Fernandes M.A. *"A Multiagent Architecture for Distance Education Systems"*// In: Proceedings of the the 3rd IEEE International Conference on Advanced Learning Technologies (ICALT'03), July 2003, pp.368-369. - http://csdl.computer.org/comp/proceedings/icalt/2003/1967/00/19670368.pdf (last visited 06.10.2004)
15. Nunes M.A.S., Dihl L.L, Fraga L., Woszezenki C.R. etc. *"Multi-agent Systems applied to Intelligent Tutoring Systems"*// International Conference on Artificial Intelligence, Las Vegas, Nevada, USA, 2002, pp. 361-366. - http://www.inf.ufsc.br/~lisi/Lasvegas.pdf (visited 06.10.2003)
16. Frasson, C., Mengelle, T., Aïmeur, E., Gouardères, G. *"An Actor-based Architecture for Intelligent Tutoring Systems"*// In: C. Frasson, G. Gauthier and G. A. Lesgold (eds), Intelligent Tutoring Systems, Third International Conference, ITS'96, Lecture Notes in Computer Science No. 1086, Springer-Verlag, Montréal, June 1996, pp. 57-65.
17. Grundspenkis J. *"Conceptual Framework for Integration of Multiagent and Knowledge Management Techniques in Intelligent Tutoring Systems"*// In: O. Vasilecas et. al. (eds), Information Systems Development. Advances in Theory, Practice and Education. Springer, Berlin, 2005 (to appear).
18. Wooldridge M.J. *"An introduction to multiagent systems"*// Chichester : Wiley, 2002
19. Baylor A.L., Kim Y. *"Validating Pedagogical Agent Roles: Expert, Motivator, and Mentor"*// Proceedings of EDMedia, 15th Annual Conference on Educational Multimedia, Hypermedia and Telecommunications, Honolulu, Hawaii, June, 2003.
20. Johnson W. L., Shaw E., Ganeshan R. *"Pedagogical Agents on the Web"*// Workshop on WWW-based Tutoring, ITS'98, San Antonio, Texas, 1998.
21. Rickel J., Johnson W. L. *"STEVE: A Pedagogical Agent for Virtual Reality"*// In: Proceedings of the Second International Conference on Autonomous Agents, Minneapolis/St. Paul, ACM Press, May 1998.
22. Suraweera P. *"An animated pedagogical agent for SQL- Tutor"*. - http://www.cosc.canterbury.ac.nz/research/reports/HonsReps/1999/hons_9908.pdf (last visited 01.09.2004)
23. Nunes M.A.S.N., Fraga L., Dihl L.L., Oliveira L., Woszezenki C.R., Francisco D.J., Machado G.J.C., Nogueira C.R.D., Notargiacomo M.G. *"Animated Pedagogical Agent in a Learning Environment"*// In: Proceedings of the international conference on "Social, ethical and cognitive issues of informatics and ICT (information and communication technology) - SECIII", Dortmund, July 22-26, 2002. - http://www.die.informatik.uni-siegen.de/dortmund2002/web/web/nunes.pdf (last visited 06.10.2004).
24. Johnson W.L. *"Using Agent Technology to Improve the Quality of Web-Based Education"*// In: N. Zhong, J. Liu, Y. Yao (eds), Web Intelligence, Springer-Verlag, Berlin, 2003, pp. 77-101.

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Grundspeņķis J., Anohina A. Aģenti intelektuālās mācību sistēmas: stāvoklis problēmsfērā
Aģentu tehnoloģijas strauja attīstība pēdējo desmit gadu laikā ir skārusi citu mākslīgā intelekta pētījumu sfēru – intelektuālas mācību sistēmas. Intelektuālu mācību sistēmu arhitektūra nodrošina daudzas iespējas aģentu pielietojumam šāda tipa sistēmu izveidei, un rezultātā uz doto brīdi ir izstrādātas daudzveidīgas uz aģentiem balstītas intelektuālas mācību sistēmas dažādām sfērām.

Šī raksta nolūks ir dot pārskatu par aģentu tehnoloģijas izmantošanu intelektuālu mācību sistēmu izstrādei. Pēc dažu jēdzienu, kas ir saistīti ar intelektuālu mācību sistēmu arhitektūru (studenta diagnosticēšanas modulis, pedagoģiskais modulis, problēmsfēras zināšanas, un komunikāciju modulis) ieviešanas, aģenta jēdziens un tā raksturojumi, tādi kā, autonomija, adaptācijas spēja, mobilitāte, caurspīdīgums, izturība, reaktivitāte, proaktivitāte un citi, tiek apspriesti. Tālāk tiek doti secinājumi par šādiem jautājumiem: kādas intelektuālu mācību sistēmas komponentes var tikt realizētas kā aģenti, un kādas funkcijas aģenti var izpildīt katrā komponentē, kā arī kāpēc aģentu tehnoloģija tiek izmantota intelektuālu mācību sistēmu izstrādei. Papildus intelektuālu mācību sistēmu konceptuālais modelis, ko ir piedāvājis viens no raksta autoriem, kas sastāv no trim slāņiem – sistēmas slāņa, daudzaģentu slāņa un zināšanu darbinieka slāņa – tiek aprakstīts vispārīgos vilcienos. Dotā raksta beigu daļā tiek apskatīti animētie pedagoģiskie aģenti, kas parādās intelektuālās mācību sistēmās kā divdimensiju vai trīsdimensiju personāži.

Grundspenkis J., Anohina A. Agents in intelligent tutoring systems: state of the art
Rapid development of agent technology during the last decade has affected the other area of artificial intelligence – intelligent tutoring systems. The architecture of intelligent tutoring systems provides many opportunities of agent application for the creation of such systems and, as a consequence, at present a variety of agent-based intelligent tutoring systems has been implemented for different areas.

The aim of this paper is to give an overview about usage of the agent technology in the development of intelligent tutoring systems. After introducing of some concepts concerning the architecture of intelligent tutoring system (the student diagnosis module, the tutoring module, the domain knowledge, and the communication model) the agent concept and its characteristics such as autonomy, adaptability, mobility, transparency, ruggedness, reactivity, proactivity, and others are discussed. After that conclusions about following issues are given: what components of intelligent tutoring systems can be implemented as agents and what functions agents can perform in each component, as well as why agent technology is used for development of intelligent tutoring systems. In addition, the conceptual model of intelligent tutoring system, proposed by one of the authors of this paper, that consists of three layers – system's layer, multi-agent layer and knowledge worker's layer – is outlined. At the end of the paper so called animated pedagogical agents that are used in intelligent tutoring systems as two-dimensional or three-dimensional animated characters are considered.

Грундспенкис Я., Анохина А. Агенты в интеллектуальных системах обучения: положение в проблемной области
Стремительное развитие технологии агентов в течении последнего десятилетия затронуло другую область исследований в искусственном интеллекте – интеллектуальные системы обучения. Архитектура интеллектуальных систем обучения предоставляет много возможностей для применения агентов для создания таких систем и поэтому на данный момент разработано множество интеллектуальных обучающих систем основанных на агентах.

Цель данной статьи состоит в том, чтобы дать краткий обзор использования технологии агентов в создании интеллектуальных систем обучения. После преоставления некоторых понятий относительно архитектуры интеллектуальной системы обучения (модуль диагностирования студента, педагогический модуль, знания проблемной области, и модель коммуникации) обсуждаются понятие агента и его характеристики, такие как автономия, адаптируемость, мобильность, прозрачность, прочность, реактивность, проактивность, и другие. После этого даются заключения по следующим вопросам: какие компоненты интеллектуальных систем обучения могут быть осуществлены как агенты и какие функции агенты могут выполнять в каждом компоненте, а также почему технология агентов используется для реализации интеллектуальных систем обучения. Дополнительно новая концептуальная модель интеллектуальной системы обучения, впервые предложенная одним из авторов данной статьи, и состоящая из трех слоев – системного слоя, слоя множества агентов и слоя работника со знаниями – описана в общих чертах. В заключительной части статьи рассматриваются так называемые анимированные педагогические агенты, которые появляются в интеллектуальных системах обучения в виде двухмерных или трёхмерных персонажей.