A CONCEPTION OF AGENTS-BASED USER MODELLING SHELL FOR INTELLIGENT KNOWLEDGE ASSESSMENT SYSTEM

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ABSTRACT

The paper presents a conception of the AGENT-UM user modeling shell for students modeling purposes which will be integrated with the concept map based intelligent knowledge assessment system. The latter already has been developed and tested in several study courses at Riga Technical University. The AGENT-UM shell is an agents-based system, i.e. a multiagent system. It incorporates several useful features – open and editable user model, agent-based architecture, learning capabilities – that extend the functionality of existing user modelling shells. Key principles and requirements for the development of any modern user modelling shell are defined and explained. Software agents that will be used in the implementation of the AGENT-UM shell are described in details.

KEYWORDS

User modeling, user model, user modeling shell, stereotyping, software agents, intelligent knowledge assessment system

1. INTRODUCTION

Nowadays it has already become a fact that e-systems which incorporate adaptation to a user are more efficient and useful in comparison with systems which have no adaptation features. E-system's good adaptation promotes user and machine user friendly interaction thus significantly increasing the efficiency of e-system's services.

One of the techniques used for adaptation purposes is user modelling. User modelling is a process of inferring new assumptions about user's knowledge, beliefs, goals and preferences based on observed information about a user from the application system. The result of user modelling is a user model that reflects specific characteristics of the user. A user model is used as a main source of the adaptive behavior of interactive software systems (Gouli et al. 2004, Wen et al. 2008).

User modelling components in e-systems often are time-consuming and expensive to develop. In fact, system developers each time had to start from scratch (Heckmann 2005, Kobsa 2001). Therefore, research projects on so called reusable user modelling shells and servers have started (Heckmann 2005, Kay et al. 2002, Kobsa and Pohl 1995, Kobsa 2001, Kyriacou 2007, Orwant 1995, Paiva and Self 1994). These research projects are aimed at the development of integrated representation, reasoning and revision tools that form an „empty" user modelling mechanism. External user modelling mechanisms are just plugged into the application system thus supplying it with ready to use user modelling functionality and assisting the application system significantly in adapting to users.

This paper presents a conception of AGENT-UM (AGENT-based User Modelling) shell which is based on software agents. After implementation the shell will be integrated with already developed and tested intelligent knowledge assessment system (Anohina and Grundspenkis 2007, Grundspenkis 2008). The shell is being developed taking into account future trends in the development of e-learning applications (Kobsa

2001). Therefore, the shell incorporates some useful features which are expected to extend the generic functionality of a typical user modelling shell.

The paper is organized as follows. Section 2 gives a brief overview of existing user modelling shells and servers. In Section 3 architecture and functionality of the concept map based intelligent knowledge assessment system is described. In Section 4 requirements for the shell and architecture of the AGENT-UM shell are presented. At the end of the paper conclusions are given and future work is discussed.

2. OVERVIEW OF USER MODELLING SYSTEMS

The purpose of user modelling systems is to separate user modelling functionality from user-adaptive application systems through provision of a number of user modelling services for a target application system. Application of user modelling systems from one hand decrease time and efforts needed to incorporate user modelling functionality into a target e-system and from other hand increase adaptation abilities of a target e-system to end user (Heckmann 2005, Kobsa 2001).

How does a typical user modelling system work? At runtime when the user interacts with the application, user modelling system accepts information from the application concerning observed beliefs, goals and actions of the user. It can also directly obtain information from the user via a questionnaire. Information about the beliefs and goals of the current user that are communicated to user modelling system are represented in the user's individual model. Additional assumptions are acquired by various kinds of inferences that are based on the current entries in the user model, the user's answers in the questionnaire, observed user actions as communicated by the application system, and stereotypical knowledge about user subgroups. In general, functionality provided by any user modelling system to the user-adaptive application system is as follows (Kobsa and Pohl 1995):

- infer assumptions about the user based on his interaction with the application system,
- represent and store these assumptions,
- infer additional assumptions based on initial assumptions,
- take appropriate actions when inconsistencies between assumptions are detected,
- supply the application with current assumptions about the user.

Figure 1 demonstrates the overall architecture and working principle of a typical user modelling system (UMS). Worth to point that the most common attribute shared by every UMS is the ability to classify users in groups (stereotypes) and infer assumptions about their characteristics based on the stereotypes they belonged. A stereotype represents a collection of attributes that is inherent in a group of people. Using stereotyped user models enables the systems to make justified inferences about users' attributes based on various small samples of information (Kay 2000).

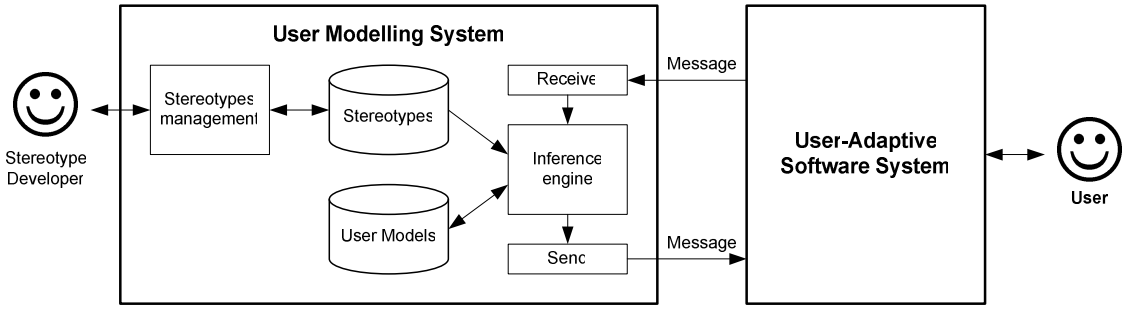

Figure 1. The overall architecture of a user modelling system

Communication between the UMS and the application system is based on messaging. For example, the application can inform the UMS about observed user's actions, beliefs, goals, or the application can ask the UMS for its current assumptions about the user, and the UMS can answer such questions of the application. The greatest advantage of using the UMS is that the application system need not have any knowledge about the internal structure of the UMS, except that it must be able to send appropriate messages to the UMS as well as interpret the messages that come from UMS.

Nowadays a number of user modelling systems are already developed and successfully applied in practice (Heckmann 2005, Kay et al. 2002, Kobsa and Pohl 1995, Kobsa 2001, Kyriacou 2007, Orwant 1995, Paiva and Self 1994). All existing systems can be divided into two groups – user modelling shells and user modelling servers. A user modelling shell, when filled with application-dependent user modelling knowledge, becomes a part of the application and receives information about the user only from this application, and supplies only this application with assumptions about the user. Examples of user modelling shells are GUMS, UMT, Um, TAGUS (Kobsa and Pohl 1995, Kobsa 2001, Kyriacou 2007, Paiva and Self 1994). In contrast, a user modelling server is not a part of any application system, but rather independent from it – a user modelling server is a centralized user modelling system for more than one application on a network. Examples of user modelling shells are DOPPELGANGER, Personis, Deep Map User Modeling System (Heckmann 2005, Kay et al. 2002, Kobsa and Pohl 1995, Kobsa 2001, Kyriacou 2007, Orwant 1995).

Despite of variety of user modelling systems the aim of all these systems stays the same – provision of a number of services for representation of knowledge about the user, reasoning and inferring new assumption about the user thus assisting interactive software systems in adapting to users.

3. ARCHITECTURE AND FUNCTIONALITY OF THE CONCEPT MAP BASED INTELLIGENT KNOWLEDGE ASSESSMENT SYSTEM

The system, for which purposes a new user modeling shell is intended to be developed, is the concept map based intelligent knowledge assessment system (IKAS). This system has been developed by the researchers from the Department of Systems Theory and Design of the Faculty of Computer Science and Information Technology of Riga Technical University. The system allows the teacher to assess student's knowledge regularly, that is, at each stage of the study course, and to use assessment results for the analysis and the improvement of learning content and teaching methods. At the same time the student can use the system for knowledge self-assessment in order to control and to keep track of his/her own learning progress.

The developed IKAS consists of three modules as it is shown in Figure 2. The administrator's module allows to manage data about users (learners and teachers) and study courses providing functions of data input, editing, and deleting. The teacher's module supports teachers in construction of concept maps. The main functions of this module are the following: editing and deleting of concept maps, evaluation of learners' completed concept maps and assigning the scores which characterize the level of correctness of learners' concept maps. The learner's module includes tools for completion of concept maps given by a teacher and for viewing feedback after the solution is submitted.

The modules interact sharing a common database where data about teachers and their courses, learners, teacher created and learners' completed concept maps, as well as learners' final scores are stored.

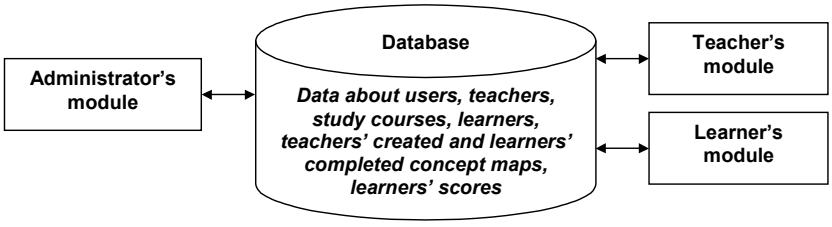

Figure 2. The systems architecture in terms of modules (Grundspenkis 2008)

For each stage the developed system supports the following scenario. A teacher divides a study course into N stages and defines all concepts and relationships between them. Using the system's graphical user interface, a teacher prepares concept maps for each stage. The system supports teacher actions for drawing concept maps on the working surface. During knowledge assessment or self-assessment students get a task (a concept map) that corresponds to the current stage of learning process. After finishing the task, a student confirms his/her solution and the system compares concept maps of the student and the teacher. The final score and the student's concept map are stored into the database, and a student receives feedback about correctness of his/her solution.

The system is a multiagent system which is shown in Figure 3. The agent-expert forms a concept map of a current stage using a teacher's map and a learner's map of previous stage, and passes it to the communication agent for visualization. The agent-expert also delivers a teacher's concept map to the knowledge evaluation agent for comparison. The communication agent perceives the learner's actions and is responsible for visualization of concept maps received from the agent-expert, and for the output of feedback received from the knowledge evaluation agent. The latter compares a learner's concept map with a teacher's map and recognizes patterns (correct or incorrect) of learner's solution. The interaction registering agent, after receiving a learner's solution and its assessment, stores them in a database.

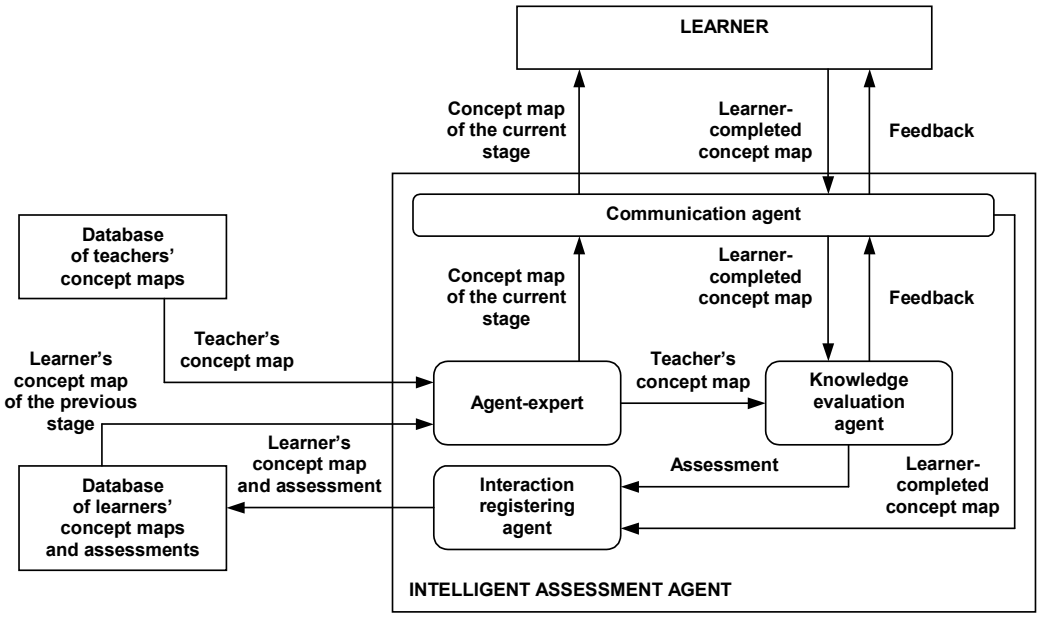

Figure 3. The architecture of the intelligent knowledge assessment system (Grundspenkis 2008)

More detailed description of the IKAS could be found in (Anohina and Grundspenkis 2007, Grundspenkis 2008, Lukasenko et al. 2008, Vilkelis et al. 2008).

The system has already reached the certain level of maturity and has been used successfully in practice. Nevertheless future enhancement of the system should be done in order to make the system even more useful. For example, despite of existence of a learner's module (Figure 2) and a communication agent (Figure 3) the system has minimal functionality in modelling a user and adapting to a user at present. Therefore, use of services of a user modelling shell could help significantly in getting more complete user models that will be applied by the system afterwards to adapt to characteristics and needs of a particular learner. Adaptation on the basis of complete user model in the IKAS will refer to the adaptive presentation of assessment content and means the ability of the system to present individual concept maps for each student. In addition, complete user model could be used to provide intelligent problem solving support for the student. Taking into account characteristics of the learner stored in his/her model the system could trigger the help which is best suitable for each individual learner (Vilkelis et al. 2008).

4. CONCEPTION OF THE NEW USER MODELLING SHELL

Inspired with potentials of independent user modelling systems the authors of this paper have made a decision to develop the new user modelling shell which is intended to be integrated with the IKAS. The new user modelling shell from one hand would incorporate the best practices from existing shells and from other hand would include some useful features which extend the generic functionality of a user modelling shell.

Probably the existing shells could be used with the IKAS to model learners. Though the new user modelling system is required to incorporate such features as (see Chapter 4.2) – agents-based architecture, learning capabilities – which are currently not implemented in any existing user modelling shell. In addition, the IKAS is an agents-based system and it would be preferable if a user modelling shell is agents-based too. That motivates to develop the so called AGENT-UM shell.

4.1 Key principles of AGENT-UM

Before defining the requirements, key principles on which the new shell will be based should be mentioned. Alfred Kobsa, who was first to introduce the concept User Modelling System, defined the following principles of any user modelling shell system (Kobsa 2001):

- Generality, including domain independence
  Shell systems are required to be usable in as many applications and content domains as possible, and within these domains for as many user modelling tasks as possible.
- Expressiveness
  Shell systems are expected to be able to express as many types of assumptions about the user as possible at the same time.
- Strong inferential capabilities
  Shell systems are expected to perform different kind of reasoning such as reasoning supported by first-order predicate logic, reasoning with uncertainty and conflict resolution when contradiction is detected.

Taking into account future trends in the development of e-learning applications (Kobsa 2001) as well as available feedbacks of such systems we extended the abovementioned list of key principles as follows:

- Open and editable user model
  User modelling shells should give the possibility for the end user to view and edit his/her user model. This functionality could be implemented in two ways: 1) a user modelling shell provides graphical user interface (GUI) for a user to view and edit his/her model (in this case a user works directly with the UMS); 2) a user views and edits his/her model in the application system (in this case the UMS only sends and receives models from the application system).
- Learning capabilities
  User modelling shells are expected to be able to learn thus becoming more and more efficient and useful. Learning could be achieved through feedbacks supplied by users when they edit their models. Analyzing corrections made manually in a user model, a user modelling shell can reason what assumptions inferred by a shell about a user are wrong. Moreover, a user modelling shell can modify the inference procedure (or input data) accordingly to avoid making wrong assumptions in future. One area where learning could be successfully applied is stereotypes management. Stereotypes management is a set of operations performed manually by a system administrator or by a system itself in order to create, modify or delete stereotypes. Situations for stereotypes management may occur when initially defined stereotypes turn out to be wrong or out of date after time. This causes inference of wrong assumptions about a user. Therefore, a user modelling shell should be able to make necessary corrections into stereotypes on the basis of observed behaviour of users and collected feedback from users.
- Agent-based architecture
  Architecture of a user modelling shell is expected to be agent oriented. Each user must have his/her personal agent in a user modelling shell. This agent would maintain a user model and perform tasks related with perception of information about a user from the application system, reasoning on assumptions about a user and acting via supply of the application system with assumptions about a user. In addition, a personal agent of a user could: 1) communicate with other personal agents thus increasing potentials of inferring new assumption about a user; 2) learn from user observed behaviour and given feedbacks thereby adjust the work of a user modelling shell itself to a user.

4.2 Requirements for the shell

General requirements which the AGENT-UM shell should satisfy are given below. We have defined these requirements based on the analysis of needs for user modelling functionality for the IKAS.

Current functional requirements defined for the AGENT-UM shell are as follows:

- The user modelling shell should incorporate appropriate functionality and GUI for a shell administrator to create, modify, activate and deactivate available stereotypes and tests.
  Rationale: stereotypes and different questionnaires are the main sources based on which assumptions about a user are inferred.
- The user modelling shell should have a set of interfaces for bidirectional communication with the IKAS. Exchange of data/ information between the user modelling shell and the IKAS should be based on messaging services.
  Rationale: communication possibilities with external systems are mandatory for successful application of a user modelling shell. If there is no communication with other systems then no user modelling could be performed.
- The user modelling shell should incorporate an inference mechanism which infers new assumptions about a user. Inference of new assumptions should be based on stereotyping.
  Rationale: inference ability is a core function of any user modelling shell. There is no sense in applying the user modelling shell if there are no inference abilities.
- The user modelling shell should have a set of interfaces to receive data from biofeedback sensors and send commands to effectors. The user modelling shell should monitor via biofeedback sensors user's temporary state (emotional and physiological state) and, if necessary, increase user's motivation via effectors. The user modelling shell should incorporate a mechanism for mapping information from biofeedback sensors to commands for effectors.
  Rationale: user's temporary state significantly impacts the efficiency of application of interactive software system. For example, a student whose current motivation is not high enough would probably demonstrate worse results in an e-learning system. Therefore, not motivated user should be either motivated or he/she should be advised not to use e-system right now.
- The user modelling shell should incorporate appropriate functionality and GUI for a user to view, fill and edit his/her user model. A user should be able to take tests from available repository of tests (for example, psychological tests) in order to fill his/her model with qualitative and quantitative data. In addition, functionality of importing/exporting user models should be available to a user, too.
  Rationale: this requirement accumulates the idea of the first extended key principle which states that a user model should be open and editable by the user. Thus, a user modelling shell becomes fully independent system which can be used to create and modify user models by users themselves.

These requirements are the basis for the definition of architecture of the AGENT-UM shell.

4.3 Architecture of the shell

Architecture of the AGENT-UM shell at the component level is shown in Figure 4. This is a high level architecture which will be elaborated in future work.

In general, architecture of the AGENT-UM shell (Figure 4) is similar to architecture of a typical user modelling shell (Figure 1). Nevertheless, the AGENT-UM shell incorporates some features, which make it slightly different from other user modelling shells. Firstly, the AGENT-UM shell uses questionnaires and tests in order to get additional information about a user. Need to mention, that only few known UMS also use questionnaires to get extra information about a user. Secondly, the AGENT-UM shell can be used directly by two types of users – an administrator and a student. An administrator can manage stereotypes and tests; in turn, a student can take tests and manage his/her user model. Thirdly, the AGENT-UM shell uses biofeedback sensors to monitor user's emotional and physiological state and uses effectors accordingly to motivate a student when necessary.

The research on application of biofeedback sensors and effectors in interactive learning environments has recently been completed at our university (Rikure and Novicky 2008). The results of experiments, in which 19 students were involved, show that the students motivated by the system via effectors in general demonstrate better results in comparison with students who were not motivated by the system. Therefore, we

believe that application of biofeedback sensors and effectors can add significant value to the AGENT-UM shell making the shell more useful and efficient for user modelling purposes. Currently all necessary biofeedback sensors and effectors as well as algorithms for mapping sensorial data to commands for effectors are at our disposal. The list of available sensors to monitor user's emotional and physiological state includes: pulse sensor, blood pressure sensor, galvanic skin response sensor, thoracic and abdominal respiration sensors, physical activity sensors, web-camera and microphone. The list of available effectors to motivate a user includes: electric vibrator, speakers or headphones, flavouring, electric massage effectors and luminous sources emitting different colours.

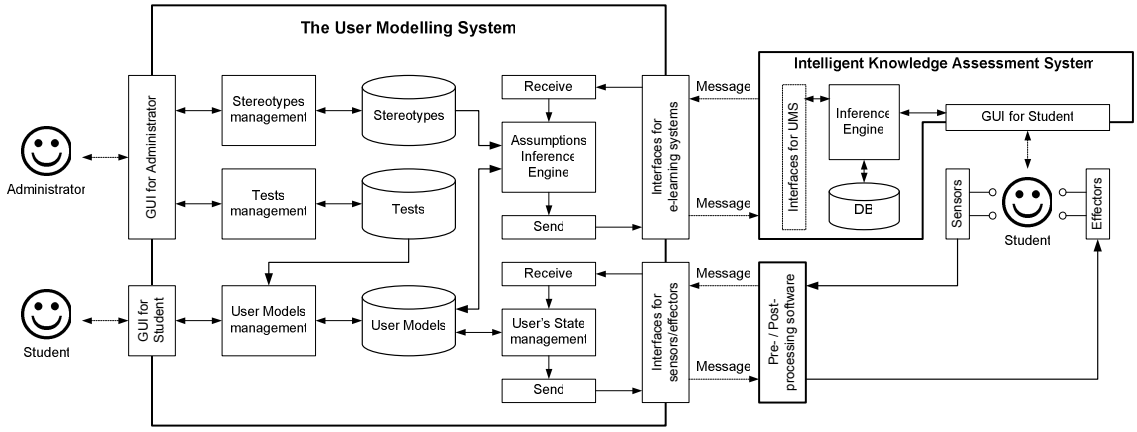

Figure 4. Architecture of the AGENT-UM shell at the component level

As it is mentioned before, software agents are used in implementation of modern user modelling shells. Therefore, we have defined agents-based architecture of the AGENT-UM shell as well (Figure 5). During review of available literature on user modelling shells and servers we didn't find any real user modelling system which is based on software agents. Therefore to the extent of our knowledge, the AGENT-UM shell potentially could be the first user modelling system which is agents-based.

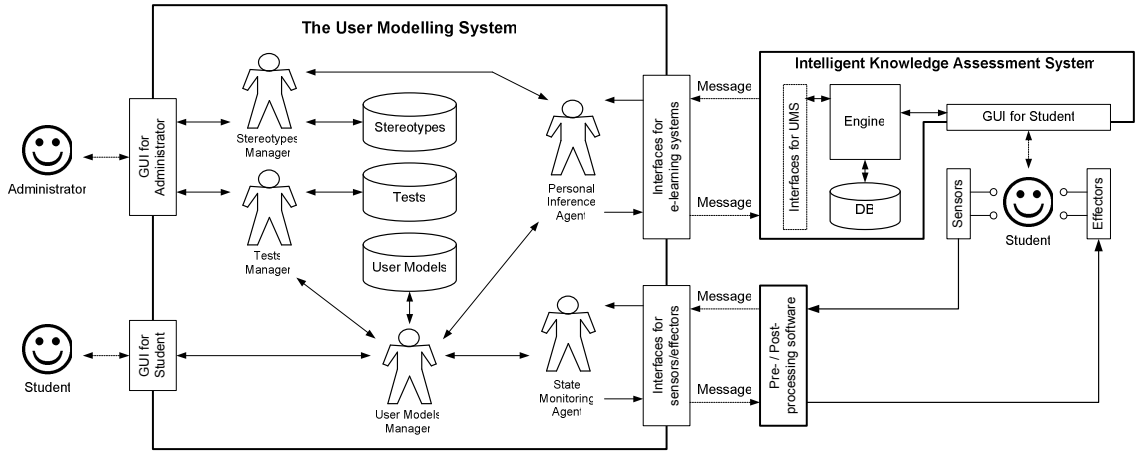

Figure 5. Agents-based architecture of the AGENT-UM shell

So, the AGENT-UM shell consists of five agents – a stereotypes manager, a tests manager, an user models manager, a personal inference agent and a state monitoring agent. Main functions of these agents are given in Table 1.

Based on functionality of agents described in the Table 1 division of agents to reactive agents and proactive agents can be made. The test manager and the user models manager are reactive agents, because these agents retrieve, send and store only specific objects by request of a user or other agents. No reasoning is performed by these agents. In contrast, the stereotypes manager, the personal inference agent and the state

monitoring agent are pure proactive agents due to their ability to reason and take appropriate actions on the basis of inferred decisions. For example, the stereotypes manager is able to analyze adequateness of stereotypes and modify them if necessary, the personal inference agent is able to infer a new assumption about a user, and the state monitoring agent is able to work out appropriate motivation strategy for a user.

Table 1. Main functions of agents within the AGENT-UM shell.

Agent	Functions
Stereotypes manager	– Send and display specific stereotypes to an administrator – Retrieve stereotypes from and store them in a database – Provide personal inference agent with specific stereotypes – Analyze adequateness of stereotypes and modify them if necessary
Tests manager	– Send and display specific tests to an administrator – Retrieve tests from and store them in a database – Provide user models manager with specific tests and questionnaires
User models manager	– Send and display specific user models to a user – Retrieve user models from and store them in a database – Provide personal inference agent with specific user models
Personal inference agent	– Receive information about user interaction with a target application – Ask user models manager for current assumptions about a user – Infer new assumptions about a user – Tell user models manager new assumptions about a user – Send current assumption about a user to a target application
State monitoring agent	– Receive data from sensors – Inform user models manager about temporary state of a user – Work out appropriate motivation strategy for a user – Send commands to effectors

All agents in the shell must have communication abilities exchanging information with other agents. In addition, the stereotype manager must demonstrate learning abilities. The stereotype manager must analyze efficiency of application of stereotypes time after time and must make necessary corrections into stereotype definitions if logical errors are detected. Thus, the AGENT-UM shell as a whole will demonstrate learning and adaptation capabilities.

The usage of the AGENT-UM shell will solve the tasks of student modelling which is the prerequisite for implementation of a cognitive diagnosis agent (Anohina and Grundspenkis 2007). The latter will collaborate with the agent-expert and the communication agent of the IKAS to ensure delivering of a concept map based tasks with the appropriate degree of task difficulty in accordance with the current state and knowledge level of each individual learner.

5. CONCLUSION

In this paper a conception of agents-based user modelling shell was described. The AGENT-UM shell is designed to incorporate the functionality for modelling users – observing user behaviour, inferring assumptions about users and supplying a target application with current assumptions about a user. The main consumer of services which will be provided by the AGENT-UM shell is already developed and tested the concept map based intelligent knowledge assessment system.

The architecture and working principles of the AGENT-UM shell in general are similar to those of other known user modelling shells. At the same time the AGENT-UM shell is designed to incorporate some features, which discriminates it from other user modelling shells. After implementation the AGENT-UM shell will have the following features. Firstly, the shell will have graphical interface for the end user in order to provide possibilities to view, fill and edit his/her model. Secondly, the shell will be equipped with biofeedback sensors and effectors to observe user's emotional and physiological state and will motivate the user when necessary. Thirdly, the shell's agent-based architecture will consist of five agents: a stereotypes manager, a tests manager, an user models manager, a personal inference agent and a state monitoring agent. Fourthly, the shell will have an ability to learn through adaptive modification of stereotypes.

Future work is related with specification of requirements and design of the AGENT-UM shell. After that analysis of existing technologies will be conducted in order to choose the most suitable tools for implementation of the AGENT-UM shell. After that the shell will be implemented and integrated with the IKAS taking into account that the current version of the IKAS has no interface for communication with the AGENT-UM shell. Finally, the AGENT-UM shell will be tested in different study courses for practical evaluation of its functionality and efficiency.

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