Using Intelligent Agent-managers to Build Personal Learning Environments in the e-Learning System

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Abstract: The article focuses on the issues of developing the structure of a multi-agent environment for e-learning systems and proposes a computer technology to ensure student activities in e-learning modular systems. The relevance of the research topic is due to the low level of modern e-learning systems adaptation to the individual characteristics of the student, the lack of ability to predict learning outcomes. The technology enables to take into consideration the factors affecting the students' learning outcomes and to form an individual trajectory of the learning session from a holistic perspective.

1 INTRODUCTION

In modern e-learning systems, it is important to deliver dynamic learning materials, as well as manage the training course system in a prompt manner, that is, the e-learning system should provide the user with optimal content and encourage working in groups. An intelligent agent-manager should refer students to the most relevant community or knowledge communities, examining the materials that other community members look through, and connect students and experts (Al-Sakran, 2006).

The introduction of e-learning systems has also accelerated the evolution and the learning process in higher education institutions, given the constraints of non-adaptive systems, resulting in the introduction of new open intelligent systems that are used simultaneously with web technology. This is critical to the e-learning technology being implemented across the globe (Arif and Hussain, 2016).

Tutor agents and support systems play an important role in improving learning outcomes, as they provide continuous assistance to students in the learning process. Some of the existing learning support systems are used at the organizational level and integrated into the current organizational structure of the educational institution (Chen et al., 2003). Such learning support systems enable to connect existing users, share important information, improve the training of technical personnel, and improve organizational processes, making them more efficient. However, most existing learning support systems operate with a small number of functions that do not contribute to the development of the e-learning environment required for groups and students to achieve their learning goals in the corresponding fields (Hung and Nichani, 2001).

The main disadvantage of present-day learning management systems is the failure to provide students with assistance in the distance learning process, and therefore they are unable to replace the physical presence of a tutor, who generates the students' work progress. In fact, it is proposed to integrate for each student a metacognitive agent that would ensure metacognition assistance and reveal defects in the learning process and strategies. The goal is to encourage students to improve their learning outcomes measured against the learning goals and refine the learning method. The results show that there are relationships between different metacognitive attributes and student's academic excellence, that is, there is a dependence of metacognitive influence on learning outcomes, reflecting the degree of student's understanding of a particular training unit (Elbasri et al., 2018). There are certain difficulties associated with a large number of micro-modules and the need to form a learning trajectory tailored to the student's needs.

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One of the ways to overcome these obstacles may be the use of adaptation technology (Klašnja-Milićević et al., 2017).

Thus, the state of elaboration of this problem and current trends in the development of management systems for educational environments for e-learning are indicative of its theoretical and practical significance, and determine the urgency of the chosen theme. The goal of the research is to develop a functional architecture that supports the above goals of e-learning using mobile agent technology.

The introduction of multi-agent systems is one of the most promising areas for building virtual educational environments for distance education systems. The goal of this article is the possibility of illustrating the advantages of using intelligent agents to optimize the location and configuration of appropriate resources for distance learning courses and organizing collective collaboration in the e-learning environment.

The main objectives of the research are to develop the structure of the training service based on the use of a personal learning environment and intelligent agent-managers, which may be used to ensure individual learning. It uses a set of agents that may personalize learning based on previous requests from students (or groups of students), and improve learning and collaboration based on previous knowledge and learning styles.

2 RESULTS

As of today, the SCORM (Shareable Content Object Reference Model) standard that is a standard for sharing learning materials based on the IEEE 1484.12.1 standard model (IEEE, 2020) has been developed, and is currently being used. SCORM has been developed to ensure the multiple use of learning materials, support for and adaptation of training courses, introduction of information of individual training materials into training courses or disciplines in accordance with individual user requests. In June 2006, the United States Department of Defense established that all developments in the field of e-learning should meet the SCORM requirements. A promising direction for e-learning standardization has become the successor of SCORM – Tin Can API model (Romero, 2015), which enables to consider the types of learning activities that are not available in SCORM: mobile learning, simulations, informal learning, games; tracks events without using the Internet, and has a reliable system for maintaining the required level of security and user authentication.

When creating complicated and distributed systems, multi-agent systems (MAS) can offer a variety of solutions, especially in the field of distance learning. The combining of agent technology with other methods such as the Educational Data Mining (EDM) and Case-Based Reasoning (CBR), which in turn are based on cloud technology, is important in taking the learning process to the next level. The three-level multi-agent management architecture for distance learning in the e-learning system, which contains the following set of intelligent agents, is proposed to meet the above functional requirements (figure 1):

- Tutor Agent is a set of tools for creating rules that enable tutors to adapt the selection of learning material, define appropriate search terms for finding learning materials based on certain learning styles, and to communicate with other agents for collaboration and establish interaction between tutors and students in a distance learning system.
- Lesson Planning Agent is designed to collect information and complicated reasoning required for defining and developing a curriculum (Woolf and Eliot, 2005).
- Learner Agents are required to organize the effective interaction of students with the e-learning environment, and enable to unite various learning resources into a single whole and constantly monitor learning outcomes.
- Personalization Agents are responsible for customizing training materials based on the preferred learning style of each individual student or workgroup (Wilson, 2000).

The greatest interest for implementing LMS is represented by learning agents, which in some literature are also referred to as autonomous intelligent agents that determines their independence and ability to learn. Figure 2 shows the flow of work of an agent-manager as part of LMS, which meets the following requirements: to work in real-time mode; learn based on a large amount of data; analyze oneself in terms of behavior, mistakes and success; contain a database of examples with the possibility of replenishing it, as well as learn and develop in the process of interaction with the environment.

The objective of formalized description of modular e-learning systems to ensure the ergonomic quality of human-machine interaction has been solved. As a result, a complex of component and morphological models, which is the basis for the formation of information support to adaptive e-learning as the “man – technology – environment” classical systems and contribute to the search for ergonomic reserves of com-

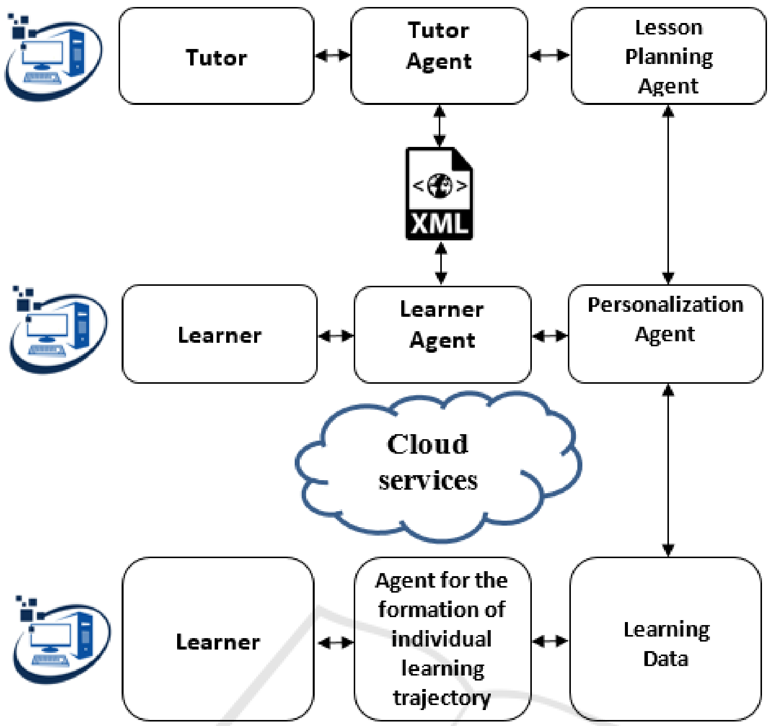

Figure 1: Architecture of distance learning multi-agent management in e-learning systems.

puter human dialogue interaction has been obtained (Lavrov et al., 2017b) (figure 1). The set of models is given by the scheme shown in figure 3, and is described by structural formula (1). The description of the designations accepted in the formula is given in figure 3.

$$MMS =< EE, OT, PO, MODUL, KPKT, SPF, SVP, SVFS, SGOT, SMT, EREM, KvPEE, KvNpEE, KvOT, KvPKT, KvPT, MKvHEE, MFSEE, MKvMODUL, MKvMOD, ProgPPR, MDV, MUT > \quad (1)$$

Here are the structures of some models.

Component model of elements of module. It describes the structure of educational module.

$$MODUL =< [idmod_i, [PO_k, [tema_{kj}]| j \in [1,2,...,KT_k]|k \in [1,2,...,KPO], [PMod_{il}, [Srmod_{iln}]||n \in [1,2,...,KSr_{il}], [Sdmodilk]|z \in [1,2,...,KSd_{il}], Pruk_{il}]|l \in [1,2,...,KPmod_i] > \quad (2)$$

where $idmod_i$ is the identification of the i-th module;

PO_k is the k-th subject area;

$tema_{kj}$ is the j-th theme of the k-th subject area;

KT_k is the number of themes of the k-th subject area;

$PMod_{il}$ is the first sub-module of the i-th module;

$Srmod_{iln}$ is the n-th self-control of the first sub-module of the i-th module;

KSr_{il} is the number of variants of self-control of the first sub-module of the i-th module;

$Sdmod_{ilk}$ is the z-th means of “finishing” of additional learning (in terms of (Adamenko et al., 1993) – “finishing”) of the first sub-module of the i-th module;

KSd_{il} is the number of means of “additional learning” of the first sub-module of the i-th module;

$KPmod_i$ is the number of sub-modules of the i-th module;

$Pruk_{il}$ is a sign of existence of means of controlling the quality level (provides a possibility of changing learning technologies depending on the current level of the learning quality) of the first sub-module of the i-th module, $Pruk_{il}$ [0,1].

Component model of the means of revealing motivation levels. The model gives enumeration of means for revealing motivation levels of EE.

$$SMT =< [INSmt_i, NameSmt_i, [PSmt_{ij}] |j \in [1,2,...,KPMT_i]|i \in [1,2,...,KMT]] > \quad (3)$$

where $INSmt_i$ is the identifier of the i-th means of defining motivation of EE;

$NameSmt_i$ is the name of the i-th means of defining motivation of EE;

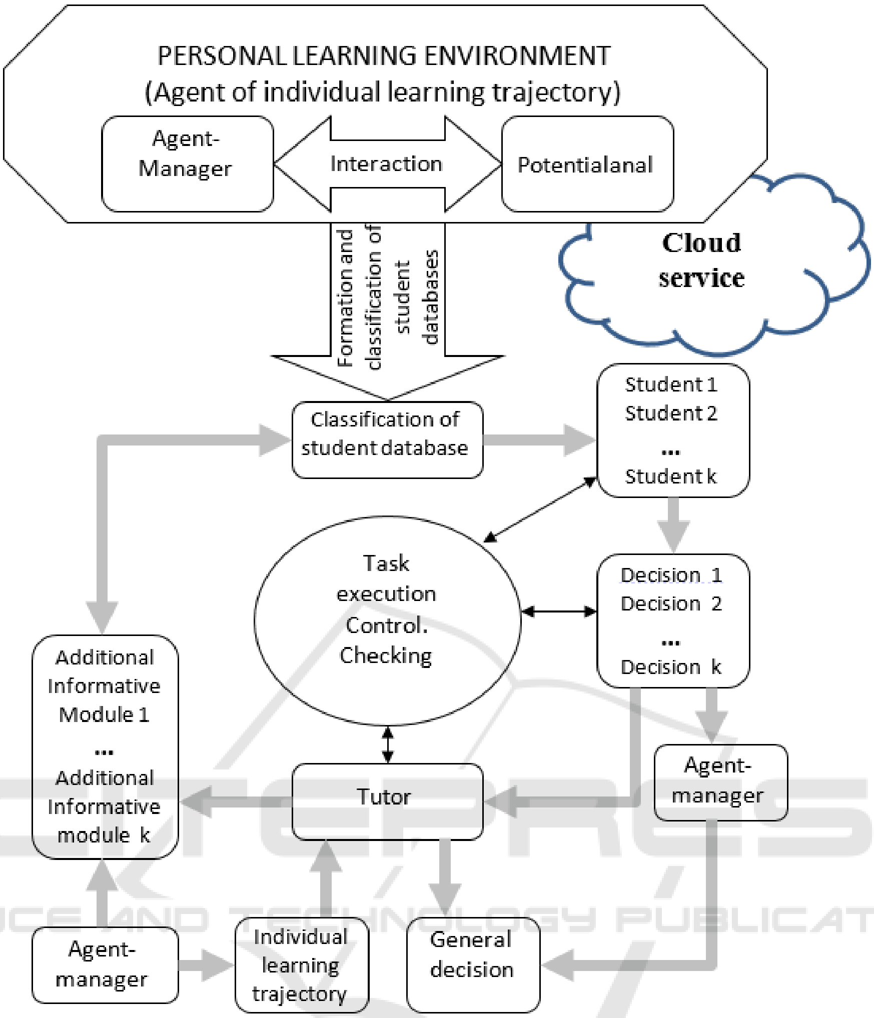

Figure 2: Flow of work of an agent-manager as part of LMS.

$PSmt_{ij}$ is the j-th indicator for the i-th means, $PSmt_{ij} \in MMT$;

$KPMT_i$ is the number of all indicators of motivation for the i-th means;

KMT is the number of means of defining the motivation level of EE.

Component model of means of revealing preferences of EE. The model describes the means for revealing preferences and indicators of EE and preference indicators of the EE, revealed by this means.

$$SVP = < INSvp_i, NameVp_i, [PSvp_{ij}] \\ |j \in [1,2,...,KPVP_i]|i \in [1,2,...,KVP] > \quad (4)$$

where $INSVp_i$ is the identifier of the i-th means of revealing the EE preferences;

$NameVp_i$ is the name of the i-th means of revealing the EE preferences;

$PSvp_{ij}$ is the j-th indicator for the i-th means, $PSvp_{ij} \in [PMOD]$;

$KPVP_i$ is the number of all indicators of the EE preferences, revealed by the i-th means;

KVP is the number of means of revealing the EE preferences.

Component-qualitative model of non-pragmatic indicators of EE. The model defines the composition of the EE characteristics, which are revealed for defining individual preferences, psycho-physiological characteristics, functional state, motivation and level of readiness for learning.

$$KvNpEE = < [PMOD, PFH, [PFS, VPfs], \\ [MMT, VMmt], [InUGot, VUGot]] > \quad (5)$$

where $PMOD$ is the set of characteristics of preferable modalities of the EE;

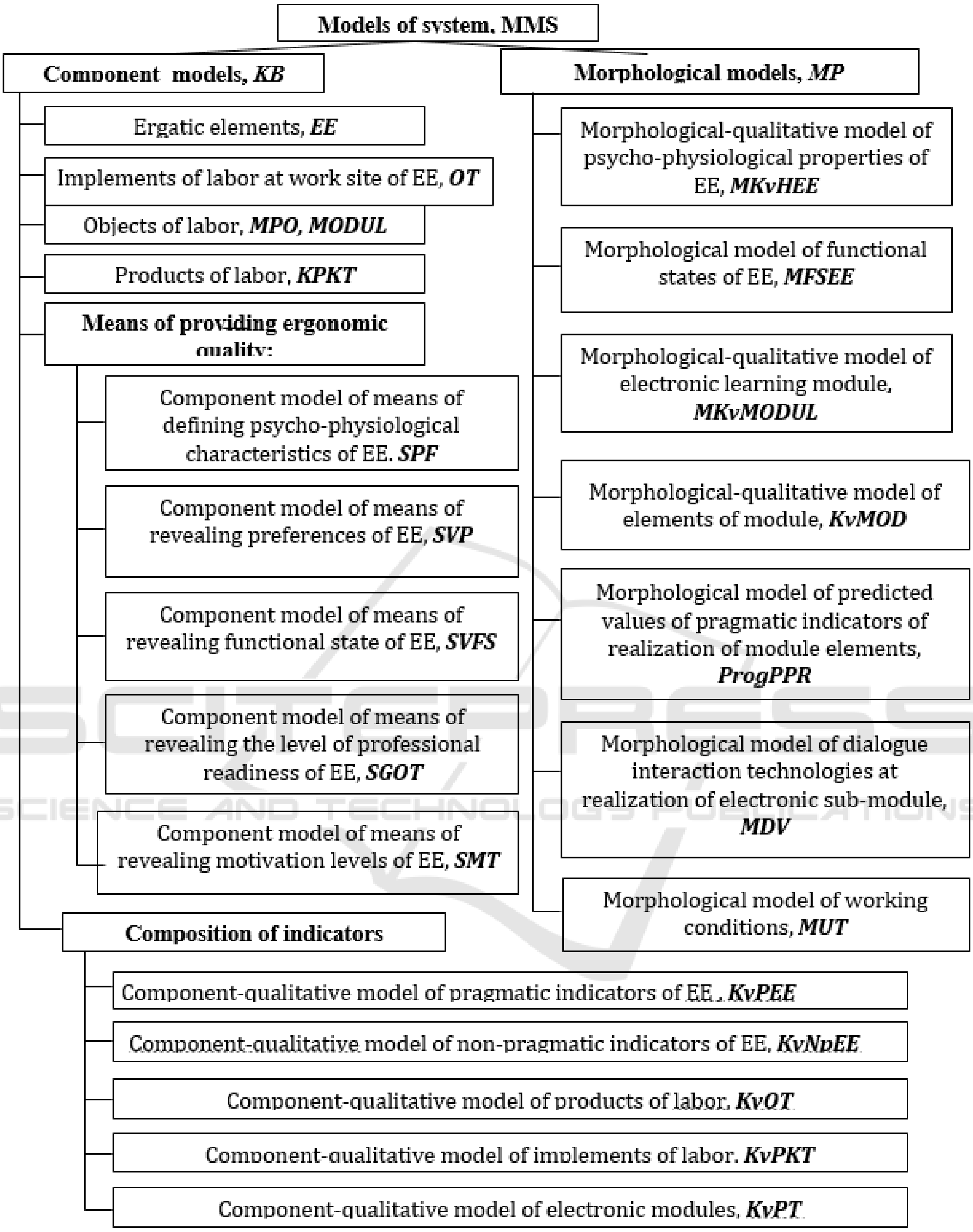

Figure 3: Structure of complex of models of systems ergonomic analysis.

PFH is the set of psycho-physiological characteristics of the EE;

PFS is the indicator of functional state;

$VPfs$ is the range of values of functional state;

MMT is the level of the EE motivations;

$VMmt$ is the range of values of motivation level;

$InUGot$ is the integral level of professional readiness for learning of EE;

$VUGot$ is the range of values of the level of professional readiness for learning of EE.

The set of characteristics of preferable modalities of the EE are determined by formula:

$$PMOD =< [Pmod_j, VPmod_j] | j \in [1,2,3,4] >$$

where $Pmod_j$ is the name of the j-th characteristic of preferable modalities of EE;

$VPmod_j$ is the range of values of the j-th characteristic of preferable modalities of the EE.

The set of psycho-physiological characteristics of the EE is determined by formula:

$$PFH =< [Npfh_j, Vpfh_j] | j \in [1,2,...,Kpfh] >$$

where $Npfh_j$ is the name of the j-th psycho-physiological characteristic of the EE;

$Vpfh_j$ is the range of values of the j-th psycho-physiological characteristic of the EE;

$Kpfh$ is the number of psycho-physiological characteristics of the EE.

Component-qualitative model of implements of labor. The model describes the characteristics of implements of labor, used in the system.

$$KvOT =< [idOt_i, NameOt_i, TipOt_i, [Pk_{ij}, Val_{ij}] \\ | j \in [1,2,...,KPK_i] | i \in [1,2,...,KOT]] > \quad (6)$$

where $idOt_i$ is the identifier of the i-th implement of labor;

$NameOt_i$ is the name of the i-th implement of labor;

$TipOt_i$ is the type of the i-th implement of labor;

Pk_{ij} is the j-th characteristic (quality indicator of the i-th implement of labor);

Val_{ij} is the value of the j-th characteristic of the i-th implement of labor;

KPK_i is the number of all quality indicators of the i-th implement of labor;

KOT is the number of implements of labor.

Morphological-qualitative model of electronic learning module. The model contains the values of the results of ergonomic assessment of learning module quality.

$$MKvMODUL =< idMod; [PO_k; [tema_{kj}] | \\ j \in [1,2,...,KT_k]; [px_i] | i = [1,2,3]; \\ [py_i] | = [1,2]; [pz_i] | i = [1,2]; [pv_i] | i = [1,2,3]; \\ [pm_i]; [mod_i] | i = [1,2,3,4]; e_i | i \in [1,2,3]] > \quad (7)$$

where $idMod$ is the identifier of a module;

PO_k is the k-th subject area;

$tema_{kj}$ is the j-th theme of the k-th subject area;

px_i is the $i-th$ indicator of the interface assessment;

py_i is the $i-th$ indicator of assessment of slide's parameters;

pz_i is the $i-th$ indicator of test assessment;

pv_i is the $i-th$ indicator of assessment of visual environment;

mod_i is the $i-th$ indicator of information modality;

e_j is the result of assessment (resolution on correspondence of a module to ergonomic requirements).

The developed models defined the concept of building databases and knowledge of the learning management system in the software package "Agent – Manager for e-learning" (Lavrov et al., 2017a). Each module can also be divided into parts (submodules), depending on the levels of complexity of the training material. The individual learning trajectory is a sequence of e-learning modules(ELM) and self-monitoring procedures. Individuality of the trajectory of learning is achieved through the use of different types of self-control procedures. Self-monitoring is a test procedure performed by a student after studying part of the module. UML-diagram of options for using the software package "Agent - Manager for e-learning" is shown in figure 4.

To study the effectiveness of the developed models and computer technology, the experiments were conducted on the basis of Sumy National Agrarian University. The quality expertise and evaluation of the parameters of electronic training modules "Informatics" for first-year students of the specialty "Agronomy" of the Bachelor's educational level were carried out.

The developed technology makes it possible to take into account the factors affecting the students' learning outcomes from a holistic perspective and form an individual trajectory of the learning session.

3 CONCLUSION

The proposed architecture of the training service based on the use of a personal learning environment and intelligent agent-managers provides users with the opportunity to collect, analyze, distribute and use knowledge in the e-learning system from various independent sources.

The computer technology that enables to automatize the processes of organizing high-quality human computer interaction in e-learning systems has been developed:

- ensuring a focus on comprehensive accounting of factors affecting the students learning outcomes;
- automatic selection of an individual training session trajectory.

The direction for future research:

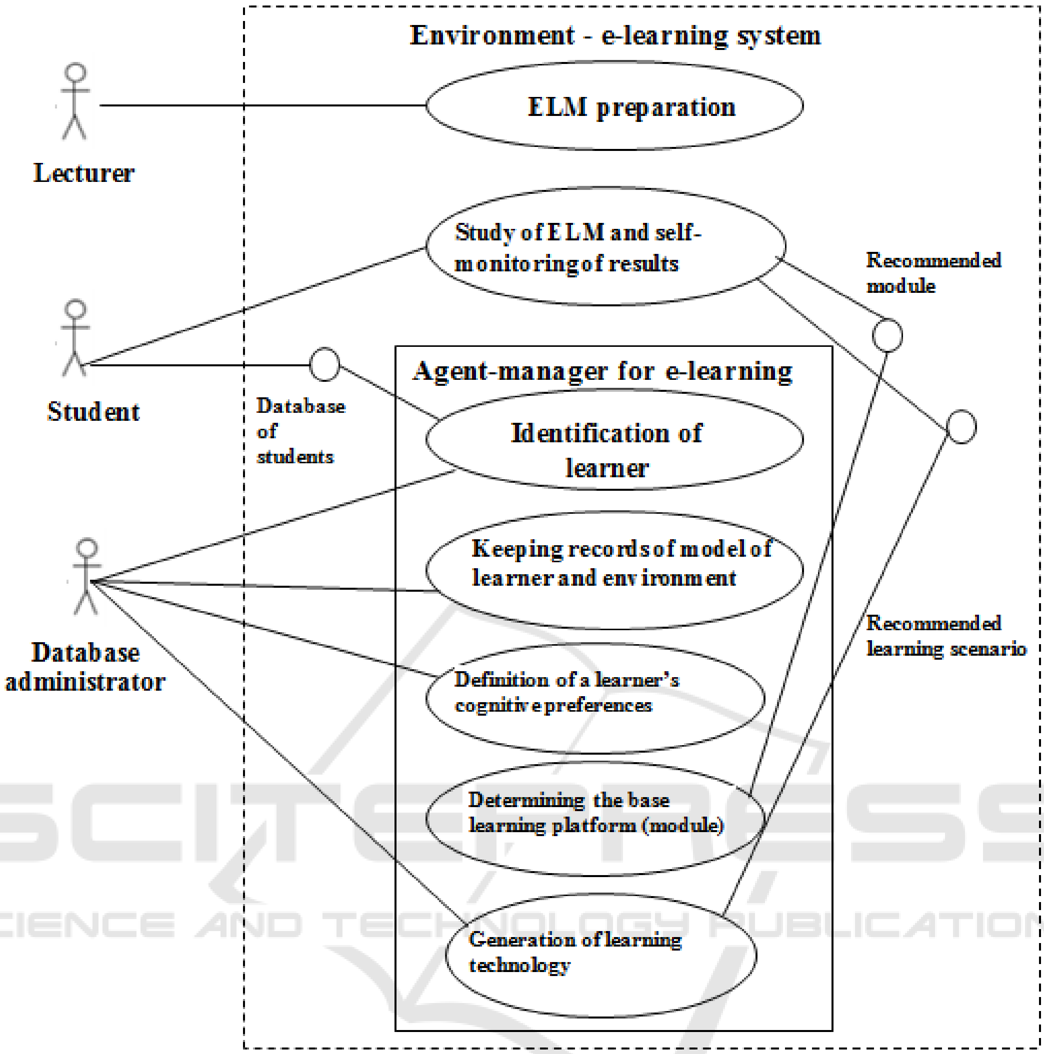

Figure 4: UML Use Case Diagram of agent-manager for e-learning.

- development of intelligent agent models based on dynamic data extraction rules and interaction with LMS;
- formation of intelligent agent operation algorithms that automatically detect the student's status, profile, and agent response in real time.

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