Approaches for Building an Agent-Oriented Model of the Competence Formation System

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Abstract. The paper describes intellectual system of the formation of professional competencies and the approaches to building an agent-oriented model of competence formation system. The diagram of the functioning of an intelligent system is shown in the article. The main functions and executive mechanisms of agents are summarized. It was concluded that agent-oriented approach has not yet become the leading paradigm for building corporate industrial applications and information systems, and requires the development of efficient and understandable and practical AOS programming architectures and methodologies, needs to be promoted among system engineers and software developers. An analysis of the scientific literature showed that the solution of the listed problems is carried out, as a rule, by non-formal methods, which reduces their practical value. The prospects of further research can be seen in the use of VR and AR to create models of complex distributed and heterogeneous systems.

Keywords: competency, education, agent-oriented model, competency-based approach, LMS moodle

1 Introduction

Modern approach to education dictates high-level requirements for the content of education materials, and the ability to apply received knowledge, skills and personal qualities in future professional activities.

This is ensured by competency-based training. The development of information technologies allows to organize individual trajectory in learning and provide adaptive educational content, to ensure a competency-based approach. Individual trajectory in learning helps student to choose educational tracks on the topics of content by their own, same as adaptive educational content tries to predict and choose the most suitable types of exercises, the complexity of the programs according to the student's level of knowledge. And competency-based approach is aimed at the formation of competencies and skills needed in future profession [1].

There are a lot of training computer systems which combine the properties of intelligent systems and adaptive control systems.

Adaptation technologies in these systems are borrowed either from the field of artificial intelligence (AI): adaptive planning, intelligent analysis of student's decisions, support for interactive problem solving, support for problem solving by examples and support for collaboration or from the field of adaptive hypermedia: support for adaptive presentation and adaptive navigation [2], [3].

2 Analysis of recent research

A general idea of intelligent learning systems was formulated back in 1970 by D. Won, P. Jansen and J. Carbonell [4], but real research and commercial ITS appeared already in the 80s of the XX century.

While studying Agent-based computing R. Abdalla and A. Mishra investigated the agent concepts, techniques, methods, and tools used in evolving Internet of Things systems. In their research scientists conducted a comprehensive analysis of selected agent-oriented software engineering methodologies. They have also provided a proposal of a draft unified approach that drives benefits of these methodologies towards advancement in the studied area [5].

Multi-Agent Programming was studied both by A.R. Panisson, P. McBurney, R.H. Bordini and by T. Ahlbrecht, J. Dix, N. Fiekas, T. Krausburg groups of scientists. The first one investigated mostly the advantages of using argumentation-based techniques in multi-agent systems. They also proposed an argumentation framework using the particular structure of argumentation schemes at its core [6], [7]. While the second group of researchers tried to find scenarios, where it pays off to use the tools of agent-oriented software engineering, and tried to encourage people to learn about those tools and instruments [8].

A. Croatti and A. Ricci studied programming agent-based mobile applications, namely the JaCa-Android framework. They described JaCa-Android framework and benefits of its use. They also highlighted that the impressive progress of technologies makes it possible to explore the use of agent-oriented programming languages and frameworks based on cognitive architectures [9].

E. Iotti, G. Petrosino, S. Monica, and F. Bergenti discussed two approaches to agent-oriented programming and compared them from a practical point of view. Thus, two considered languages were used to solve the same coordination problem, and obtained implementations were compared to discuss pluses and minuses of both approaches (Jadescript and Jason) [10].

The analyze on agent programming was conducted by R.H. Bordini, A. Fallah Seghrouchni, K. Hindriks, B. Logan, and A. Ricci. The researchers reviewed the state of the art in agent programming, focussing particularly on BDI-based agent programming languages [11].

Agent-oriented modeling was also the subject of research of Y. Ivashkin and M. Nikitina scientists. Their proposal was the agent-oriented simulation model of the

logistic system of the material flows. The results of their research led to optimization of material flows [12].

Agent-oriented methodology became a subject of scientific research of the group of scientists: C.W. Shiang, S.Y. Wai, N. Jalia and M. Bin Khairuddin.The adoption of such methodology was investigated. The researchers introduced a systematic way to model crime simulation in detail [13].

Research of S. François, J. Ferber, T. Stratulat, F. Michel was devoted to the original methods for describing reactive agents. Thus, the "eco-resolution" method proposed by them is based on solving a problem by a set of agents that communicate by exchanging messages. Here, the solution of the problem is understood as the evolution of a dynamical system until it reaches stable stationary states. These stationary states correspond to the satisfaction of the goals of various agents.

It is also actively conducting researches on the development of Internet education. The informational systems are a software shell that not only provides distance learning and testing of student's, but also allows to manage the activities of a virtual educational institution.

Meanwhile, the disadvantage of these systems is the processing of limited individual knowledge about the student [14].

3 Results

For example, such automated learning systems as ELM-ART-II, AST, ADI, ART-Web, ACE, KBS-Hyperbook and ILESA allow to develop intelligently a learning sequence in the form of a frame script. The interactive learning system "Learning Space" (of the firm LOTUS) provides an opportunity for a tutor to place educational material on a server, to create discussion seminars for discussing individual topics with students. Students can study the material, participate in discussions on topics.

Connection between participants of the training (teachers and student's) is carried out using e-mail, which is a part of the DOMINO services. However, the key role in this system is played by the human factor, which does not allow to classify it as intellectual.

Agent-based systems are being developed and implemented. They are the following:

- Math Tutor, which provides dynamic, interactive teaching aids for learning mathematics;
- OLAT web application which implements a learning management system that supports any kind of online learning, teaching and learning with few educational limitations.

However, despite the variety of information systems and software, intelligent learning systems require improvement in the following directions:

1. Diagnostics and expert assessment of the student's competencies.
2. Planning and analysis of the learning trajectory, the ability to adapt to learning goals.
3. Development and implementation of the programs' interface that correspond to the personal qualities of the student and his emotionality.

The intellectual system of the formation of professional competencies should provide a full cycle of management (reaction to events; dynamic planning; coordination and revision of plans; monitoring and control).

Let define the main functions of such system:

- Administration;
- Formation of an individual training program based on the results of primary control and questioning;
- Implementation of diagnostics by means of testing at various stages of training;
- Formation of the current assessment of the structure`s state and parameters of professional competencies;
- Analysis of the results of diagnostics to form an adequate control action;
- Decision making on the formation of control actions at various stages of education;
- Providing educational content which adapted to the individual abilities and needs of learners;
- Support functions for the formation of educational materials;
- Communication functions.

Figure 1 shows a diagram of the functioning of an intelligent system, a feature of which is the presence of two correction blocks that allows to form control actions at various stages of training.

Automation of the intellectual system will allow not only to exercise control at various stages of education, but also to modify educational programs based on the results of knowledge control. At the same time, individual sets of modules are determined not only by the standard of the specialty, but also by the student's choice. And the set of educational elements of the module program may vary, depending on the individual trainees' abilities and the need for an intensity of study of the material in further education.

The process of forming of professional competencies is a complex action that includes several stages.

The solution of the problem of managing a complex deterministic process is proposed to be considered as the result of the interaction of many independent purposeful program modules – the so-called agents, while the agent can act on behalf of and in the interests of a person.

The field of multi-agent systems is described in [15].

These systems include:

1. open systems – systems whose structure can change in the course of their operation;
2. complex systems – systems that include many modules (subsystems);
3. interactive systems – systems that accept user commands and interact intelligently with him.

The use of multi-agent systems is most common in the automation of complex systems management, in systems for collecting and processing information; games [16].

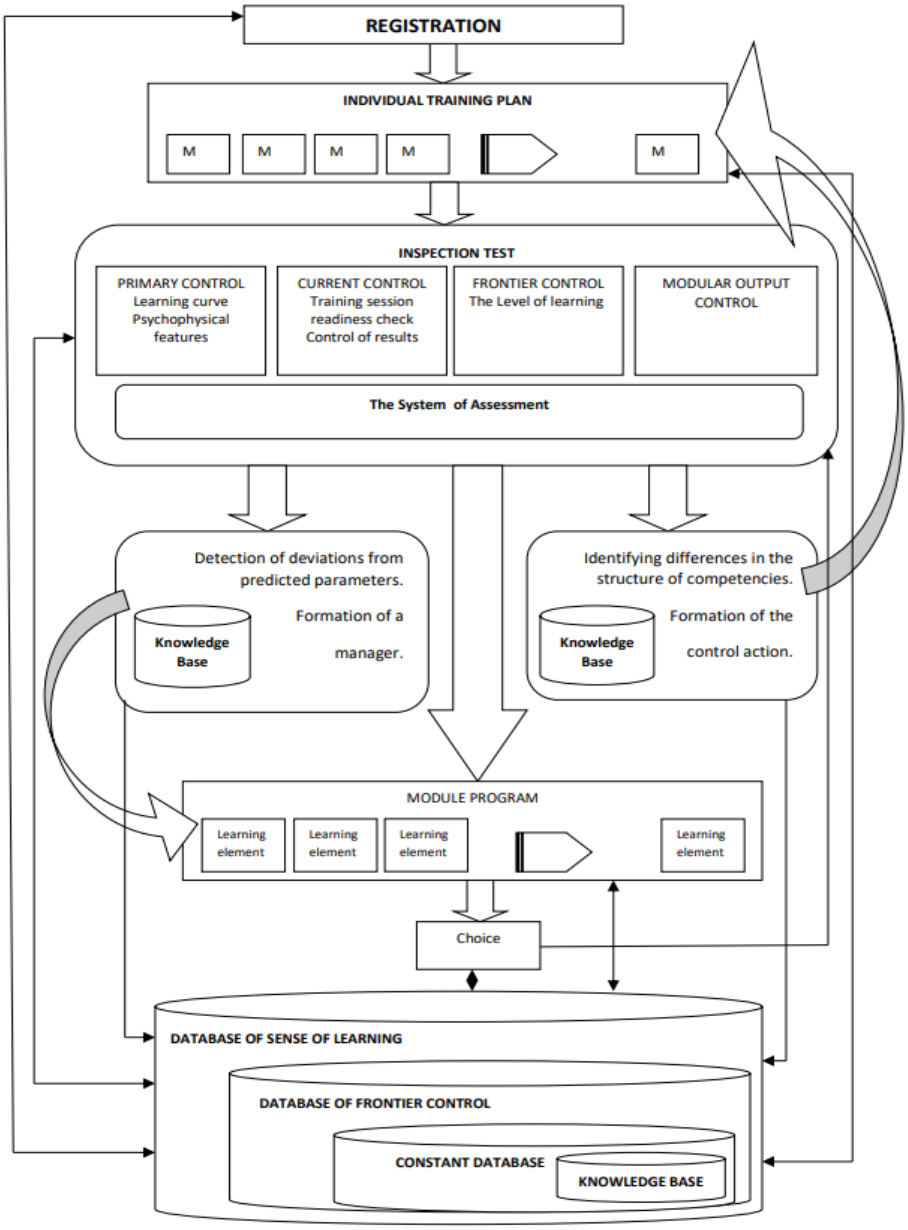

Fig. 1. Functional diagram of an intellectual system for the formation of professional competencies

According to the proposed scheme, the functions of the system are divided into separate modules (control and diagnostics, planning, analysis, blocks that provide communication channels) which, interacting, provide a flexible system of managing for the formation of professional competencies [17].

The operation of each module is provided by a software agent, the operation algorithm of which is determined by the script [18]. The relationship of the set of agents of the system is represented by an agent-oriented model in Figure 2.

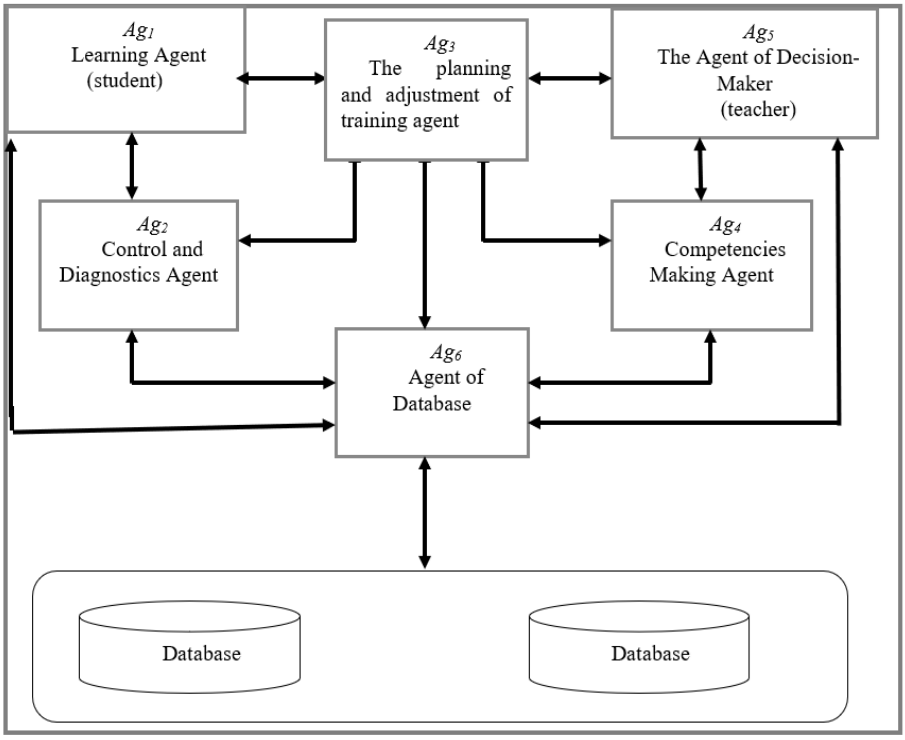

Fig. 2. Agent-based model of the system for the formation of professional competences

At each step, agents consider system inputs and react to unpredictable events (delays, failures, changes). The reaction can be independent, or carried out in cooperation with the trainee.

Databases contain a formalized representation of objects in the subject area and their relationships, as well as actions on objects. The main functions and executive mechanisms of agents are summarized in Table 1.

Table 1. The main functions and executive mechanisms of agents

	Main functions	**Environment**	**Actuating Mechanism**	**Detectors**
Learning agent (student)	Organization of procedures for issuing educational material, recording events in the process.	Student, data channels between agents.	Display of dialog boxes.	Keyboard input
Control and diagnostics agent	Organization of diagnostics and control of student's knowledge. Recording events during diagnostics.	Student, data channels between agents.	Formation of data. Transfer of data to agents at their request.	Agent Requests
The planning and adjustment of training agent	Implementation of control. Formation of control actions. Optimization of the educational program. Fixing events.	Data transmission channels between agents, taxonomy of the educational program, methodological and didactic technologies.	Deciding on the form of control action. Organization of decision implementation.	Agent requests
The agent of Decision-Maker (teacher)	Organization of procedures for the formation of a reference model of professional competencies.	User, data transmission channels between agents.	Display of dialog boxes.	Keyboard input. Agent requests
Competencies making agent	Formation of the current model of the state of professional competencies.	Data transmission channels between agents, reference models of professional competencies.	Formation and display of a histogram of training and a diagram of the formation of competencies.	Agent Requests
Agent without database	Providing a communication channel.	Data transfer channels between agents, knowledge bases, databases.	Single-tier and multi-tier database applications.	Agent Requests

4 Discussion

The analysis of scientific knowledge and pedagogical practice demonstrates that the student's tests can be effective. Pedagogical experiment was conducted at Maritime Professional College of Kherson State Maritime Academy (Ukraine) to check the results on implementation of tests in the agent-based model of the system for the formation of professional competences in subject "Ship electric power systems" [19]. 75 cadets participated in the experiment. They all study at ship engineering department, male, aged 17–18, 3rd year of study. Participants were divided into two groups: control group (38 cadets) and experimental group (37 cadets).

By analyzing the data after the experiment, namely – the test on LMS MOODLE of education establishment, one can observe that the current state of formation of the professional competence of future ship engineers changed positively in experimental group mainly.

During the work in two groups the teacher monitored each group dynamic and individual activity of each student. After the tests, by the end of each module, a considerable increase in the high level of professional competence was shown in experimental group, while the level of professional competence in control group changed slightly [20].

The part of e-course "Ship electric power systems" on LMS Moodle with test by the end of the module is shown in figure 3.

Fig. 3. Part of e-course "Ship electric power systems" with the test by the end of module

Results of five test according to number of modules per semester were taken to find out each student's level of professional competence. According to results after pedagogical experiment control group participants have following levels: low – 16 cadets (37.5 %); medium – 13 cadets (34%); sufficient – 9 cadets (24.5%). While experimental group participants have: low level – 5 cadets (13.5%); medium level – 20 cadets (54%); sufficient level – 12 cadets (32.5%).

Detailed graphical representation of results before and after pedagogical experiment can be seen in figure 4.

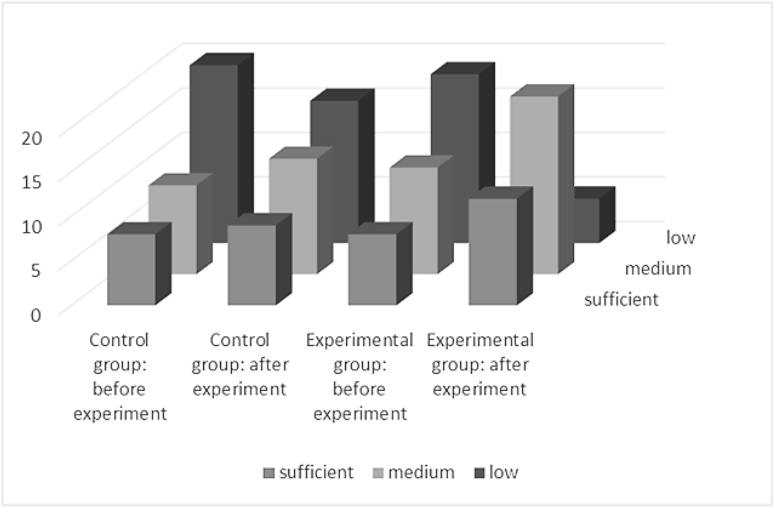

Fig. 4. Results on the levels of professional competence of future ship engineers before and after pedagogical experiment

In order to get feedback from the participants of experimental group LMS MOODLE Module Survey was created. The results of survey have shown student's positive assessment of studying. Gathered data reflected student's attitude to experimental learning which they found stimulating.

5 Conclusions

The development of information and communication technologies goes not only along the way of expanding the field and diversity of their application, but also leads to the emergence of a new multi-level hierarchy of hardware, software, conceptual entities that require new concepts, methods and tools for understanding and managing in the heterogeneous structure of the global information space. Agent-oriented approach allows to rise to a new level of conceptualization and intellectualization of modern information and communication systems. The achievements of the agent-oriented ap-

proach are various mathematical models of agents and MAS, concepts and methodologies of multi-agent design and programming, agent programming languages, and sufficiently developed tools and platforms for implementing multi-agent applications.

At the same time, the agent-oriented approach has not yet become the leading paradigm for building corporate industrial applications and information systems, and requires the development of efficient and understandable and practical AOS programming architectures and methodologies, needs to be promoted among system engineers and software developers.

Forecasting learning outcomes will make it possible to analyze the quality of education, to see the degree of assimilation of educational material by students, to detect a discrepancy in competencies between the discipline and the requirements of firms, and to assess the possibility of employment of graduates. An analysis of the literature shows that the solution of the listed problems is carried out, as a rule, by non-formal methods, which reduces their practical value. The modern level of information technology makes it possible to develop qualitatively new models that combine the advantages of mathematical methods, statistics, theory of neural networks, and programming. With the advent of the theory of multi-agent systems, it became possible to create models of complex distributed and heterogeneous systems, the class of which is the object under the study.

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