Ontology-Based Design of Intelligent Systems for Educational Purposes

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***Abstract*—Application of the ontological approach to the design of intelligent systems for educational purposes is considered in the paper.**

***Keywords*—information; knowledge; informatization of education; academic discipline.**

I. INTRODUCTION

The key problem of higher education is a mismatch between the capabilities of the traditional approaches to teaching and the actual volume of knowledge and skills, which a modern school graduate must have.

Further development of education is impossible without improving the methods and means of informatization. As before, there are problems of a reasoned attitude towards learning, the formation of self-learning skills, coordination of educational materials. One of the solutions of these problems is the use of methods and means of artificial intelligence for the development of computer systems for educational purposes. Intellectualization of computer systems for educational purposes is carried out in the following areas:

- logical-semantic structuring of the educational material with an explicit semantic interdisciplinary connections and links between modules disciplines within each subject;
- development of computer systems for educational purposes, which know good enough and can do everything what they were taught, ie, which can answer all questions and solve all the problems on the relevant training materials;
- not only significant expansion of consulting capabilities of computer systems for educational purposes according to training material, and also possibility (1) to request the analysis of the correctness and completeness of the proposed student response to specified question, (2) to request the analysis of correctness and elegance of the specified task solution, proposed by student, (3) to request justification of correctness of this fragment of educational material specified by student, (4) to request the similarities and differences specified objects or fragments of educational material, (5) to request analogs or antipodes of the object, or a fragment of material (6) to request information about the logical-semantic structure of educational material;
- adaptive management of individual activities of the student based on continuously refines formal model of the student it takes the form of recommendations addressed to the student, indicating either a fragment of educational material that is useful to study (perhaps repeatedly), or a question that it is expedient to respond and report the response to system or problem, that it is advisable to solve and to report the response to system;
- constant refinement of the formal student model to improve the efficiency of the adaptive control of his training. This update is based on (1) the analysis of control the student - analysis ignored recommendations of the system, (2) the analysis of the student's answers to the questions, which are recommended to him by the system or chosen by his initiative, (3) the analysis of problem-solving options that are recommended to the user system, or selected on their own initiative;
- Automatization of project management, which are carried out by teams of students and aimed at development of skills of *collective* problem solving within the relevant subject or group of subjects or specialty in general.

Ontological approach to the design of intelligent systems for educational purposes, proposed in this paper, is based on the following principles:

- Training material, studied by using educational purpose intelligent system, is formalized as a section of knowledge base of the system. Logical-semantic structuring of the formal educational material presented in a hierarchical system of *subject domains* corresponding to *ontologies*. It can be one subject domain with a corresponding ontology for the *module of the subject*. But for *academic subject*, for the *group of academic subjects* and even more so for the *speciality* in general is always a system consisting of a sufficiently of a great number of subject domains and ontologies. It is very important to clearly specify

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the connections between these domains and ontologies in this hierarchy of subject domain and ontologies, in particular, *interdisciplinary connections*, which allow the student to form a *complete picture of the world* in which everything is interconnected. During structuring of *formal educational material* is very important to decompose it into *subject domains* and *ontologies* to not go beyond the borders of each subject domain and its corresponding ontology for possibility to solve a lot of problems.

- The internal representation of the knowledge base of intelligent system for educational purposes is carried out in the language of *SC-code*, which is the universal language of semantic knowledge representation, the base semantics of which is defined by *Ontology of entities*, which is a top-level ontology. This SC-code provides representation of any *ontologies*, any *subject domains* and connections between them. The concepts, which provide such representation, are given by (specified by) using *Ontology of ontologies* and *Ontology of subject domains*.
- Beside *subject domains* and *ontologies*, providing formalization of educational material in the knowledge base of intelligent systems for educational purpose include a variety of other subject domains, and ontologies, for example, (1) *Subject domain* and *ontology of student*, within *formal models of student* forms, (2) *General subject domain* and *ontology of actions and tasks for user training*, which is a formal model of the general methods of adaptive learning management, (3) family of particular subject domains and ontologies of actions and tasks to teach the user knowledge and skills of solving problems within relevant subject domains and ontologies, which are formal models of particular methods of adaptive learning management within relevant subject domains and ontologies.
- Unification of all the ontologies that can be used in intelligent systems for educational purposes (first of all - it is *Ontology of subject domains* and *Ontology of ontologies*). It provides (1) compatibility of knowledge bases of intelligent systems for educational purposes, in particular, the compatibility of formal ontological models of studying materials of different subjects and (2) component (modular) design of knowledge bases, because specified ontologies become reusable components of knowledge bases.

II. Classification of Intelligent Systems for Educational Purposes

Let's classify intelligent systems for educational purposes on the following grounds. Firstly, the volume of acquired knowledge and skills of a student, secondly, by the form of training. According to the first aspect of intelligent systems for educational purpose can be:

- module of subject;
- academic subject;
- a group of academic subjects;
- all academic subjects in the specialty.

It requires the greatest possible independence of each level of these systems for the hierarchy of intelligent systems for educational purposes to be effective. To do this, you should develop an ontology corresponding to the training material, which primarily depends on the teacher, his knowledge and interest in the final result.

According to the second aspect four levels of learning activities can be distinguished:

- individual self-study;
- management of individual training;
- management of collective learning;
- management of the training activities of the organization.

III. Semantic Electronic Textbooks

Semantic electronic textbook (SET) is an interactive intelligent tutorial that contains detailed guidelines for educational material for it's studies and intended for motivated, independent and active user who wants to master the relevant knowledge and skills.

Semantic electronic textbook - an electronic textbook which is based on a semantically structured educational and methodological materials. Through semantic structuring of educational and methodological materials SET gains entirely new possibilities compared to traditional electronic textbooks [3], [4].

Semantic electronic textbook can:

- Understand the wording of the addressed problems to it, to look for ways to solve them, and solve problems;
- Analyze freely constructed response and semantics of user errors;
- Identify semantic errors in own information resources (for example, correctness of definitions and statements, correctness of the concepts, correctness of proofs of theorems);
- To provide users with the freedom to use any aliases registered in the system.

Semantic electronic textbook provides automationzation of all forms of studies: lectures, tutorials, practical classes, laboratory work, tests and examinations.

Semantic electronic textbook in general consists of the following components:

- Formal model of semantically structured information resources;
- Formal model of processing of semantically structured information resources and its implementation;
- Semantic model of user interface;
- Semantic knowledge base;
- Consultant (semantic navigation and intelligent problem solver);

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- Tutor (tutor for specific tasks and virtual learning laboratory - tutor for laboratory work).

Besides possibility to read texts and illustrative materials of textbook there is opportunity to navigate in the semantic space of educational material.

There is an opportunity for user to ask any questions and the task of the study subject domain. This is achieved by the inclusion problems solver to SET, ability to solve problems by formulations, including which are entered by the user. In this case the specified problems solver can find a way of solving the problem, even if the appropriate way (eg, algorithm) it is unknown.

There is an opportunity for user to train under the supervision of the system (to acquire practical skills) in dealing with a wide variety of tasks in the studied subject domain. The system performs a semantic analysis of the correctness of the solution of problems both in easy constructible results and solutions protocols; locates user's errors in solving problems, determine their reason and issues appropriate recommendations to the user.

IV. Intelligent Training Systems

Due to the increasing complexity and the information richness of learning software it is necessary to implement management of the process of learning and interaction with user. Since the training system becomes more complex, feature-rich and designed for different categories of users, it's necessary to adapt to the individual needs of each user. The ability of the training system to adapt to the user is an indicator of its performance and, as a result, of intelligence.

Intelligent training systems (ITS) [3], [6], [7] is a complex hierarchical system consisting of a plurality of interacting subsystems, each of which solves a specific class of problems. As a basic component of the intelligent tutoring systems using semantic electronic textbook. The main functions of intelligent tutoring systems are:

- Monitor the activities of students and the constant refinement of the knowledge base about students (students analysis subsystem of actions);
- Selection of the recommended sequence of study teaching material (learning management subsystem);
- Selection of the recommended sequence specified by the student questions, problems and laboratory tasks (learning management subsystem);
- Testing of knowledge of students (subsystem of knowledge testing);
- Tracking interruptions in the learning process of each student and ensuring the possibility of a return to the interrupted state (subsystem trainee action analysis, learning management subsystem);
- Managing the transition between modes of learning (learning management subsystem).

Feature of the implementation of the learning process in ITS is that beside representation and processing of knowledge of subject domain system should contain information about their users, to be able to handle it, and thus adapt to the individual needs of each user. In addition, one of the most important issues in the design of the training system is to control the feedback (usually untrained in the field of computer technology). Interaction with the user, unlike the interaction of the subsystems in the computer system is a more complex process, since it is present in an element of unpredictability. The user exerts its influence on the work of ITS, i.e functioning of the system in terms of interaction with them becomes manageable both system and user. In this regard, there is a problem processing the external user actions, as well as the description and implementation of the system of control mechanisms in general. Systems of this class are classified as complicated and their design requires appropriate technology and design techniques. Instrumental ITS design tools are discussed in [3], [4].

To adapt to the individual characteristics of user intelligent system can accumulate knowledge about hi or she, that reflects how the system imagine user. Description is situational structure containing information about how the system imagine user (may take into account the likelihood that the system may be wrong).

For the structuring and systematizing description the user enters *Subject domain of users of ostis-systems*. The maximum class of objects related to the field of research is enters *Subject domain of users of ostis-systems* is the concept of *user of ostis-system*. Set of *user of ostis-system* includes *signs* of all those interacting with *ostis-system* with a purpose and solve certain problems. In terms of knowledge processing *user ostis-system* acts as an external agent, which forms message by performing basic actions provided by user interface in *sc-memory*.

Variety of *users of ostis-system* is divided into a set of *non-registered users of ostis-system* and a set of *registered users of ostis-system*.

Executable specification of currently executed actions and interaction history stores in *sc-memory* for each *user of ostis-system*. Links of relation *current activities** connect sc-node, denoting the user, and a set of specifications of these actions. For *registered users of ostis-system* after the completion of the steps by past entities and their specifications are transferred to the *history of interaction**. Sequence of actions a result, execution time and execution time, etc. can be included into specification Within the domain user specification includes:

- *description of the state of user of ostis-system characteristics*;
- *the role within the system*;
- *relationships with other users*.

Description of state characteristics can be displayed based on the *history of interaction** or included in knowledge base explicit. In the first case sc-agents make a logical inference, based on which the assumption of the system about description of the different characteristics of the user build. In the second case, the *user's knowledge**, *user's interests**, a *description of previous experience** include into knowledge base.

Links of relation *user's knowledge** connect *sc-node* denoting the user, sign of *subject domain*, and sign of a generalized *structure*, which is a subset of the *sc-elements* (concepts) *of*

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subject domain and reflects the state of knowledge of the user within a given *subject domain*. The level of assimilation of the concepts defined by role relations: *formed image of the concept'*, *concept was understood'*, *concept was assimilated'*.

Links of relation *user's interests** connect *sc-node* indicating the user, sign of *subject domain*, and a sign of the set of *sc-elements*, which are a subset of the objects of *subject domain* and representing interests within the *subject domain*.

As part of the subject domain the classes of users specifications are selected, reflecting:

- *characteristics of the target state of user of ostis-system*,
- *the current state of the characteristics of user of ostis-system*.

Performed roles within the system determines the set of feasible objectives and types of actions performed. Roles are defined by binary oriented relations: *developer of ostis-system** and *end user of ostis-system**. Among *developers of ostis-system** is distinguished *administrator**, *manager**, *expert**. Among the *end users of ostis-system** sub roles selection depends on the type of ostis-system. For example, intelligent tutoring systems are distinguished *expert**, *teacher**, *student**.

V. Complex of Intelligent Systems for Automation of Training of Engineers

The most important contingent of university graduates are engineers of various profiles. Training of Engineers has its own specifics. The basic method of preparation of young professionals is to create conditions that allow (1) to accumulate real design experience in the development of technical systems of the relevant class and (2) to link closely knowledge and skills acquired in the study of all subjects with the specified project activities. At the same time the young specialist will acquire high level of mathematical, system, technology, and corporate-team culture. In addition, he must learn not only how to develop technical systems of the relevant class, but also how to improve the technology of development of such systems.

The high technology development of intelligent systems has special *requirements* for young professionals in the field of intelligent systems engineering. Effective training of such specialists is only possible based on the *project method* of training. Comprehensive support for the project method of teaching of engineers of intelligent systems are supposed to implement in the form of built-in intelligence system that (1) is built on the same technology, on which intelligent systems designed; (2) directly included in the designed intelligent system (a subsystem). Built-in intelligent system of design method of teaching intelligent systems engineers is an intelligent system of management of intelligent system design with additional function of management of qualification development of intelligent systems developers.

As an example, consider organization of the preparation of intelligent systems engineering at the Department of Intelligent Information Technologies of Belarusian State University of Informatics and Radioelectronics. The range of intelligent systems, providing training automatization includes:

- semantic electronic textbooks and smart learning systems for all academic subjects of the specialty «Artificial Intelligence»;
- integrated semantic electronic textbooks and an integrated intelligent tutoring system in «Artificial Intelligence»;
- Intelligent metasystem IMS (Intelligent MetaSystem), which is ostis-system of a design automatization of ostis-systems and contains all the information about the current state OSTIS technology, provides comprehensive information service development;
- Intelligent system of support tool for design ostis-systems and control their design, built-in developed ostis-systems;
- ostis-systems, developed by a team consisted of students of different courses, master students and post-graduate students;
- Corporate intelligence system of the department, which provides automation and management for the different activities of department staff. First of all, an organization of continuous improvement of the whole complex of intelligent systems to provide automation of activities of the department;
- intellectual support system of preparation and holding of OSTIS conference as one of the most important activities of the department.

There are a variety of educational management techniques in intelligent tutoring systems. In general, training management methods can be divided into two classes: methods without forming a strategy and training methods with the formation of learning strategies.

In the first case of the training activity is controlled by user commands. In this case, subject of the training management is the user. The system can implicitly interfere in this process, giving certain recommendations.

In a second case, form of learning strategies as a plan of implementation of educational activities. Strategy of training can be divided into stationary training strategy, formed on a predetermined path, and non- stationary learning strategies. Depending on the method used and the situation on the control object to the plan of educational activity can get those or other actions.

Consider the formal typology of classes of actions aimed at solving the problem of educational management.

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educational action
*<= decomposition**

{

- *action. select properties of learning activities required to achieve the goal*
- *action. process the situation*
- *action. form a plan of training activities*
- *action. select methods for checking relevance with the plan (select the relevance criteria)*
- *action. select methods of correlating product activities and the goal*

}

act. process the situation
*<= decomposition**

{

- *action. Compare the current and target situation*
- *action. find context of the situation*
- *action. structurize description of situations*
- *action. classify the situation (to summarize the situation)*
- *action. transform the situation*
- *action. develop a hypothesis about the relationships in situations*

}

The result of the action of this class is a more detailed of the proposed executed *action. learn course material*, i.e, implementation plan forms. Formation of the plan depends on the context of the conditions under which the activity should be carried out.

VI. Conclusion

Development of a multi-level educational management model allows phased design of relevant intelligent system of management and reuse of its components.

Design of this model is based on the proposed system of subject domains and allows ontologies allows different approaches to the design of learning management systems.

Ontological design makes it possible to implement the agreement between the subject domains of each individual subject, and thus allows to build a system of interdisciplinary connections and provides the integrity of the knowledge of the speciality.

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ОНТОЛОГИЧЕСКОЕ ПРОЕКТИРОВАНИЕ ИНТЕЛЛЕКТУАЛЬНЫХ СИСТЕМ УЧЕБНОГО НАЗНАЧЕНИЯ

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Ключевой проблемой высшего образования является несоответствие между возможностями традиционных подходов к обучению и тем объёмом фактических знаний и навыков, которыми должен обладать современный выпускник учебного заведения.

Дальнейшее развитие образования невозможно без совершенствования методов и средств его информатизации. Как и раньше существуют проблемы развития мотивированного отношения к обучению, формирования навыков самообучения, согласования учебных материалов. Одним из направлений решения этих проблем является применение методов и средств искусственного интеллекта для разработки компьютерных систем учебного назначения. Интеллектуализация компьютерных систем учебного назначения осуществляется в следующих направлениях:

- логико-семантическая структуризация учебного материала с явным указанием семантических междисциплинарных связей, а также связей между модулями учебных дисциплин в рамках каждой дисциплины;

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- разработка таких компьютерных систем учебного назначения, которые достаточно глубоко знают и умеют все то, чему они учат, т.е. которые могут ответить на все вопросы и решить все задачи по соответствующему учебному материалу;
- не только существенное расширение консультационных возможностей компьютерных систем учебного назначения в соответствии с учебным материалом, но и возможность (1) запрашивать анализ корректности и полноты предложенного обучаемым ответа на конкретный указываемый вопрос, (2) запрашивать анализ корректности и элегантности предложенного обучаемыми варианта решения указываемой задачи, (3) запрашивать обоснование корректности указанного обучаемым фрагмента учебного материала, (4) запрашивать сходство и отличия указываемых объектов или фрагментов учебного материала, (5) запрашивать аналоги или противоположности указываемого объекта или фрагмента материала, (6) запрашивать информацию о логико-семантической структуре учебного материала;
- адаптивное управление индивидуальной деятельностью обучаемого на основе постоянно уточняемой формальной модели обучаемого, осуществляемое в форме адресованных обучаемому рекомендаций, указывающих либо фрагмент учебного материала, который целесообразно изучить (возможно повторно), либо вопрос, на который целесообразно ответить и сообщить ответ системе, либо задачу, которую целесообразно решить и сообщить вариант ответа системе;
- постоянное уточнение формальной модели обучаемого для повышения эффективности адаптивного управления его обучение. Такое уточнение осуществляется на основе (1) анализа управляемости обучаемого – анализа игнорируемых рекомендаций системы, (2) анализа ответов обучаемого на вопросы, которые рекомендованы ему системой, либо выбраны по его инициативе, (3) анализа вариантов решения задач, которые рекомендованы пользователю системой, либо выбраны по собственной инициативе;
- автоматизация управления проектами, которые выполняются коллективами обучаемых и которые направлены на формирование навыков коллективного решения задач в рамках соответствующей учебной дисциплины, или группы учебных дисциплин или специальности в целом.

Предлагаемый в данной работе онтологический подход к проектированию интеллектуальных систем учебного назначения основан на следующих принципах:

- Учебный материал, изучаемый с помощью интеллектуальной системы учебного назначения, представляется в формализованном виде в качестве раздела базы знаний этой системы. Логико-семантическая структуризация формализованного учебного материала представляется в виде иерархической системы предметных областей соответствующих им онтологий. Для модуля учебной дисциплины это может быть одна предметная область и соответствующая ей онтология. Но для учебной дисциплины, для группы учебных дисциплин и тем более для всей специальности в целом это всегда система, состоящая из достаточно большого количества предметных областей и онтологий.
- Внутреннее представление базы знаний интеллектуальной системы учебного назначения осуществляется на языке SC-код, который является универсальным языком смыслового представления знаний, базовая семантика которого задается Онтологией сущностей, являющейся онтологией самого верхнего уровня. При этом SC-код обеспечивает представление любых онтологий, любых предметных областей и связей между ними.
- Кроме предметных областей и онтологий, обеспечивающих формализацию учебного материала, в базе знаний интеллектуальных систем учебного назначения входит целый ряд других предметных областей и онтологий.
- Унификация всех онтологий, которые могут быть использованы в нескольких интеллектуальных системах учебного назначения (прежде всего – это Онтология предметных областей и Онтология онтологий). Это обеспечивает (1) совместимость баз знаний интеллектуальных систем учебного назначения, в частности, совместимость формальных онтологических моделей учебных материалов различных дисциплин и (2) компонентный характер (модульность) проектирования баз знаний, поскольку указанные обще употребляемые онтологии становятся многократно используемыми компонентами баз знаний.

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