Ontological approach for the organization of intelligent tutoring on the basis of tutoring integrated expert systems*

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Abstract. Analysis of the experience of developing and using tutoring integrated expert system in the educational process and creating a single ontological space in the context of solving basic intelligent tutoring problems are discussed. Ontological model is described the methods of courses/disciplines ontologies integration with other components of the architecture of the tutoring integrated expert system, like an individual network student model and adaptive tutoring model are briefly shown.

Keywords: problem-oriented methodology, tutoring integrated expert systems, student model, ontology model, tutoring model, reusable components, AT-TECHNOLOGY workbench

1 Introduction

One of the major trends in the development of modern intelligent systems with different architectures typology is using of the ontological approach as an effective method for the detailed and uncontroversial description of the problem domain that use vast volumes of diverse data and knowledge [1–3]. As shown in [4, 5], ontologies and ontological engineering become particularly relevant in the integrated intelligent systems, in particular in the integrated expert system (IES), intelligent decision support system (IDSS) and intelligent tutoring systems (ITS).

The primary focus of this work are questions of modeling of educational activities, in particular the educational process in higher educational institutions, with ontological approach. It is largely attributed to the current stage of the evolution methods of intelligent tutoring and the creation of new ITS architectures based on the ideas of tutoring IES, when development of which is based on the problem-oriented methodology [4] and supporting it AT-TECHNOLOGY workbench. Models and methods for constructing of tutoring IES and web-based

* The work was supported by the Russian Foundation for Basic Research support (project 15-01-04696) and the Competitiveness Program of NRNU "MEPhI" (M.H.U.).

IES (web-IES) on the basis of the problem-oriented methodology and the AT-TECHNOLOGY workbench that supports this methodology are described in detail in two monographs [4, 5].

The experience of developing and using tutoring IES in the educational process and creating a single ontological space in the context of solving basic intelligent tutoring problems is analized. Today tutoring IES and web-IES, developed in the laboratory "Intelligent Systems and Technologies" of the department "Cybernetics" of NRNU MEPhI, operate on the basis of generalized ontology [5, 6] "Intelligent Systems and Technologies" of "Software Engineering" degree program and a set of ontologies for specific courses/disciplines. They were created with help of special tools of AT-TECHNOLOGY workbench and basic educational materials provided by the FSES (Federal State Educational Standards). Tutoring IES and web-IES are fully functional ITS of the new generation, ensuring the implementation of all the basic models of the ITS (student model, tutoring model, model of the problem domain, ontologies of several types, etc.), as well as the solution of the complex basic intelligent tutoring problems, containing [5, 7]: individual planning of course/discipline study; intelligent analysis of the solution of tutoring tasks; intelligent decision support.

This paper is focused on the methods of integration of ontologies of particular courses/disciplines with other components of the architecture of the tutoring IES, like an individual network student model and adaptive tutoring model. Their construction is carried out in the context of the requirements of a heuristic model of the solution of the typical education problem, as well as the methods of its implementation by AT-TECHNOLOGY workbench [4, 5].

2 Basic model of ontology of course/discipline

As was repeatedly noted in [4, 5] and other works, an important feature of the tutoring IES, developed on the basis of the problem-oriented methodology and AT-TECHNOLOGY workbench, is the possibility of flexible formation of applied ontology of each course/discipline based on the use of already built hierarchical structures of relevant courses/disciplines, which reflect the level of knowledge of the teacher [5]. Model ontology of the course/discipline is defined as a semantic network where each element of the course/discipline is the node, and the relations between the elements are arcs:

$$M_e = \langle V_e, U_e, C, K_e, RK, I_e, S_e \rangle \quad (1)$$

where V_e is a set of course/discipline elements (sections, topics, sub-topics, etc.) that are presented as $V_e = \{v_1, , v_n\}$, n is a number of course/discipline elements, and each element v_i is a set of three $v_i = \langle T_i, W_i, Q_i \rangle, i = 1...n$, where T_i is an element name of the structure of the course/discipline, $W_i = [0...10]$ is a node weight v_{ei}, Q_i is a set of questions presented in the form $Q_i = \langle F_{ij}, S_{ij}, I_{ij} \rangle, j = 1...q$, where F_{ij} is a enunciation of the question, $S_{ij} = \{s_{ij1\},...,s_{ije}}$ is a set of answers, I_{ij} is an identifier of the correct answer.

A set of links between the elements of the course/discipline is defined as $U_e = \{u_j\} = \langle V_{kj}, V_{lj}, R_j \rangle, j = 1...m$, where V_{kj} is a patent node, V_{lj} is a child node, R_j is a type of a link, at that $R = \{R_z\}$, where z = 1,...,Z, $R1$ is a part-to-whole relationship (aggregation) means that the child node is a part of the parent vertex; $R2$ is a link of the type of "association", means that to know the concept of the parent node, you need to know the notion of a child node; $R3$ is a "weak" link, means that for possession of the concept of the parent node, possession of the concept of a child node is desirable, but not necessary.

The set $C = \{C_i\}, i = 1...a$ contains hierarchical links between the elements of the course/discipline, where $C_i = \langle V_k, V_l \rangle$, where V_k is a parent element, V_l is a child element in the hierarchical structure of course/discipline (for example, V_k is a section, and V_l is a topic of that section);

In target competence model $K_e = \langle K, CK \rangle$ component $K = Ki, i = 1, ..., b$ is a set of target competence, at that $K_i = \langle N_i, S_i \rangle$, where N_i is a name, but S_i is a code of the attribution of K_i, $CK = \{CK_i\}$, $i = 1, ..., c$ is a set of hierarchical links between competence, at that $CK_i = \langle K_{ki}, K_{li} \rangle$, where K_{ki} is a parent-attribution from aggregate K, but K_{li} is a child-attribution from aggregate , $k = 1, ..., d$, $l = 1, ..., e$.

A set $RK = \{RK_i\}$, $RK_m = \left\langle V_{ki}, K_{li,W_{cj}} \right\rangle, m = 1...f$ represents elements of course/discipline links and competence, where V_{ki} is an element of V_e set, K_{lj} an element of K_e set, W_{cij} is a weight coefficient of attribution K_{lj} corresponding to the course/discipline element V_{ki}.

Element $I_e =< TR, CH >$ is a set of models of training impact [4, 5, 7]; $TR =< T_e, RT >$ is a educational-training tasks (ETT) model in accordance with [4], where $T_r = \{T_{ei}\}$, $i = 1, ..., c$ is a set of ETT, at that $T_{ei} =< D_a, C, V, V_u, O_v, P_a >$, where D_a is an initial data, C is limitations that must be taken into account when executing ETT, V is correct answers, $V_u = \{V_1, ..., V_n\}$ is a description of the method of input of the result, where V_1 is a numerical value or an interval, V_2 is a set of alternative options, V_3 is a set of options, V_4 is filling in blanks in the text, V_5 is selection of solution components from the list, V_6 is text labeling, V_7 is construction links between elements of the graphical representation; O_v is function of result evaluation $O_v\ (V_s, V) \rightarrow R$, where R is a set of estimates, V_s is an Input result; RT=$\{RT_i\}$, $i = 1...y$ is a set of links between the ontology of the course/discipline and the subset of the ETT; $H =< C_h, RC >$ is a model of HT-textbook, where $C_h = \{C_{hi}\}$, $i = 1...d$ is a set of chapters of the hypertext textbook (HT-textbook)[5, 6], at that $C_{hi} = \{M1, M2\}$, where 1 is a HTML-model of HT, 2 is a XML-model of H, and $RC = \{RC_i\}$, $i = 1, .., g$ is a set of links between the element of the course / discipline and the subset of the head of the textbook.

Component $S_e =< PA, FA, SA >$ is an aggregate of models for elicitation student skills/abilities, where PA is a model of the process of elicitation students abilities to simulate strategies of direct/reverse reasoning, FA is a model of the process of elicitation the students abilities to simulate the simplest situations of the problem domain with frames, SA is a model of the process of elicitation the students' abilities to simulate the situations of the problem domain with semantic networks. In its turn, $PA =< PS, PR >$, where PS is a production system in accordance with [6], $PR = \{PR_i\}$, $i = 1, ..., m$ is an aggregate of links between the ontology elements of the course/discipline and the components of PS; $FA = \langle F, FR \rangle$, where F is an aggregate of procedures and reference prototype frames in notation FRL [6], $FR = \{FR_j\}$, $j = 1, ..n$ is a set of links between the ontology elements of the course/discipline and the components F: $SA =< S, SR >$, where S is an aggregate of procedures and reference fragments of semantic networks [6], $SR = \{SR_k\}$, $k = 1, .., r$ is a set of links between the ontology elements of the course/discipline and the components S. In general, if it is a question of a specialty/specialization or a direction of preparation, in this case the ontology is realized as a generalized applied ontology $O = \{O_i\}$, $i = 1, ..., n$, integrating a set of individual ontologies of courses/disciplines O_i and determining the scope of the applicability of specific sections, subsections, themes, concepts used in the ontology of each course/discipline.

Accordingly, in the context of the development of tutoring IES, the model of the generalized ontology (M_o) is represented as: $M_o = \{M_{oi}\}$, where $M_{oi} = M_{ei}$, $i = 1, ..., n$, n is a number of of courses/disciplines of specialization, for which an ontology is constructed O_i.

According to [5], each ontology of the course/discipline i is represented as: $O_i = \langle M_e, F_e \rangle$, where M_e is the model ontology of the course/discipline described above; $F_e = \{F_s, F_q, F_{am}, F_k, F_{ke}\}$ set of operations (procedures) for construction an ontology (O_i) of course/discipline, where F_s are procedures for structuring the course/discipline; F_q are procedures for enunciating questions to selected elements of a course/discipline with a single level of hierarchy; F_{am} are procedures for realizing the adaptive method of repertory grids (RG) [4] for identifying the links between the elements of the course/discipline; F_k are procedures for constructing a model of target competence; F_{ke} are procedures for determining the relationship between attribution and elements of the course/discipline.

Basic tools of AT-TECHNOLOGY workbench for supporting the construction of ontologies include tools for construction the ontology of the course/discipline, the means of constructing a generalized ontology and visualization component.

With the help of the aforementioned means, ontologies of all basic disciplines are currently implemented and supported generalized ontology [5, 6] "Intelligent Systems and Technologies". The unifying basis for basic intelligent tutoring problems [5, 7] is the use of IES of different architectural typology (tutoring IES, ITS on the basis of intellectual agents, etc.) are processes of elicitation knowledge (declarative knowledge of a specific course/discipline) and skills (procedural knowledge that allows to demonstrate how the declarative knowledge of the trainees is used in practice). When these processes are implemented in the tutoring IES (in the RunTime mode), the current competence-oriented model of the student [4] is dynamically formed, which is based on the analysis of answers to questions from special web tests. Generating of test case variants is performed before the beginning of web testing by applying the genetic algorithm to the specific ontology of the course/discipline or to its fragment [5] in accordance with the curriculum for carrying out control activities. Then the current student model is compared with the ontology of the course/discipline, as a result of which so-called "problem zones" are identified in the students knowledge of the individual sections and topics of the course/discipline and the corresponding current competence. Thus, ontologies of courses/disciplines be key in revealing the level of knowledge of students and construction competence-oriented student models.

Now consider the place and role of ontologies in the processes of computer-based identification of students abilities to solve tutoring problems. For tutoring of IES and web-IES that operate on the basis of the generalized ontologies "Intelligent systems and technologies" occupy an important place methods elicitation skills to solve tutoring problems is related to modeling the reasoning of the person (student), and other approaches are already required related, in particular, to the methods and means of traditional ES and IES. For example, the learning of special courses/disciplines in the areas of training "Applied Mathematics and Informatics" and "Software Engineering" is impossible today without inculcating the skills and abilities of students to solve following problems [4–8]: the ability to construct on the basis of the "self-expert" models of the simplest situations of the problem domain based on frames and semantic networks, modeling the strategies of direct/reverse reasoning in the expert system, construction the components of the linguistic model of the sublanguage of business prose, and others. The training tasks listed above are based on non-formalized expert methods, the experience of which has been accumulated in the technologies of traditional expert system and IES, in particular, in knowledge engineering [3, 6].

2.1 Integration between ontology elements of courses/disciplines with individual models of students and adaptive tutoring models

In the context of constructing tutoring IES on the basis of a problem-oriented methodology, special software tools of AT-TECHNOLOGY workbench were implemented and tested in practice at the NRNU MEPhI and other higher educational institutions implementing "manual" methods for solving various non-formalized tasks, in particular, presented in [5, 6, 8]. It is necessary to point out that all these software tools, in accordance with the concept of "intelligent software environment" [4] are designed as reusable components (RUC), used to implement the standard design procedure "Construction of tutoring IES" (described in [4, 5, 9]). For several years of experimental software research on several generations of students and continuous improvement of the methodical, algorithmic and software of all the above RUC, it was possible to create quite unique methods and software to elicitation and evaluate the skills of students to solve informal practical problems within the ontology of a specific subject area.

Since all RUCs were developed and operated autonomously without connection with the corresponding ontology of courses/disciplines, special algorithms and tools were developed to integrate the ontology elements of courses/disciplines with a variety of RUCs to elicitation the student's ability to solve tutoring tasks. Typically, in the context of the ontological approach, a conceptually close problem arose in the construction of an adaptive tutoring model that, in accordance with [4, 5], contains knowledge of the planning and organization of the tutoring process, depending on the individual tutoring models. An important feature is that each strategy (plan) of education consists of a certain sequence of learning impacts of different types, the application of which is completely determined by the state of the current model of the student (in particular, by "problem zones" and other parameters).

At the present time it were developed, decorated as a RUC [4, 5, 7, 8] and have undergone experimental testing such classes of training impact such as the solution of ETT of several types, reading sections of the hypertext textbook (HT-textbook) and "training with ES/IES". The greatest expansion of applied ontologies of courses/disciplines was associated with the implementation of the integration of ontology elements of courses/disciplines with a set of the following ETTs, designed as operational RUCs: "Arrangement of correspondences between blocks", "Filling in blanks in the text", "Marking or correction of the text", "Choosing answer options", "Arranging graphic images".

3 Conclusion

In this paper intelligent tutoring problems with use of onthological approach was discussed. Basic ontology model of course/discipline was defined. The properties of this model were analysed, in particular connection between ontology elements, student models and adaptive tutoring models. Some implementation details of the ontology model was given, and involved software components like different educational training tasks and skills evaluation components were listed.

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