Semantically Compatible OSTIS Educational Automative Systems

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***Abstract*—A class of semantic electronic textbooks is proposed, which are based on the semantic structuring of educational material. Thanks to the semantic structuring of the educational and methodological material, the SEU acquires new opportunities compared to traditional electronic textbooks. A semantic electronic textbook is an interactive intellectual self-instruction manual for a certain subject area, containing detailed methodological recommendations for studying it and intended for a motivated, independent and active user who wants to acquire knowledge in the relevant discipline (subject area). The prospect of designing intelligent learning systems for specialties is considered on the example of the specialty Artificial Intelligence.**

***Keywords*—semantics, electronic textbooks, knowledge, hypertext semantic network, intelligent learning systems**

I. Introduction

The organization of educational activities today largely determines the level of development of any state and society. Therefore, we can fully explain the great interest in the use of telecommunications and computer technologies in order to increase the efficiency of this activity. In this regard, such a direction of research in the field of artificial intelligence as intelligent learning systems and automation of educational activities is of particular relevance. Many authors in our days consider the problems of transition to digital forms of education [1], [2], [3], [4].Intelligent learning systems (ILS) should become part of the specialist training complex. At the same time, such systems can be effectively used in the process of providing advanced training, in the implementation of continuous education. Also, one of the features of the intelligent learning systems development is that the users of such systems will be non-specialists in the field of computer and telecommunication technologies, people who are significantly different both in age and in the level of knowledge in a particular subject area. This is an incentive for the development of artificial intelligence technologies in various applied areas of human activity in order to realize the possibility of building an ILS for training specialists in various professional areas. The most promising from the point of view of the development and implementation of ILS in the educational process of universities is the use of the OSTIS ecosystem for the formation of both elements of learning and educational systems, and their integration into a single complex.

II. 1. Semantic electronic textbook as a new type of computer learning tools

Along with traditional sources of knowledge, such as teachers (lecturers and seminar leaders), books (teaching aids), family, acquaintances, the members of the study group, etc., today such sources, depersonalized in the sense of personal communication, as intellectual (computer) information systems, specialized data- and knowledge bases, electronic textbooks, including those prepared using hypermedia and multimedia tools, as well as Internet-based network sources. Thus, the ever-increasing requirements for the efficiency and practical orientation of training systems lead to the inevitable realization of the relevance of the problem of developing such computer training systems, that provide:

1) processing of large volumes of complexly structured information of various types;
2) flexibility and easy modifiability of the system;
3) integration of various models and mechanisms for solving problems;
4) support for various models of learning and user interaction management;
5) integration of various software systems within one system and management of their operation and interaction;
6) wide use of multimedia tools;
7) operation in real time.

An example of building such intelligent learning systems can be ILS based on semantic electronic textbooks (SET). An electronic textbook, as a rule, is used for independent study of an academic discipline. As far as the knowledge presented in the electronic textbook is well structured, their completeness and consistency, clarity and accessibility, the possibility of quick associative search are ensured, the effectiveness of the learning process increases. Semantic electronic textbook – a set of software tools built using methods and tools of artificial intelligence, in particular, OSTIS technology, in which the knowledge base of educational and educational material is presented in the form of a hypertext semantic network and the possibility of associative access to any fragment of this educational

material is provided. Feature of the semantic electronic textbook in comparison with the traditional electronic textbook:

1) SET is a software system designed both for the development of electronic textbooks of this type, and for the user (student) to work with this textbook.
2) The SET is based on a knowledge base, which integrates the formal presentation of educational material with ILS traditional hypertext and hypermedia presentation, while maintaining all the positive features of the latter.
3) Since the SET is based on the knowledge base, the electronic textbook turns into a fairly "reasonable" question-answer system for the specified material (i.e., into a system capable of finding answers to a fairly large number of questions related to the meaning, semantics of the relevant material). This means that the SET becomes a system that "understands"the meaning of the educational and teaching materials contained in it.
4) The SET provides the possibility of visualization (including three-dimensional) of the semantic structures of the educational material, presented in the form of semantic networks.

The formal basis for the representation of knowledge in the SET is hypertext semantic networks (HSN) [5]. The composition of the semantic electronic textbook, in addition to the actual educational material, includes:

1) Knowledge base of the subject area, which is a formal record of the semantics of educational material in the knowledge representation language, which also includes:
   - a set of links between the generated knowledge base and information sources for this knowledge base;
   - a description of the specifications of the fragments of educational material presented in one form or another (information about what software was used to develop this fragment, how this fragment is related to other fragments of educational material, etc.);
   - various kinds of systematization, structuring and meta-description of educational material.
2) Subsystem for the formation and editing of educational material. This subsystem is designed to acquire expert knowledge. The formation of the knowledge base takes place in the representation language of hypertext semantic networks (SCht) and ILS extension, specially oriented to describe educational material (both in linear and graph language specifications). This subsystem supports the possibility of further checking the syntactic and semantic correctness of the generated knowledge base.
3) Subsystem of navigation through educational material. As a language of dialogue with the user, a specialized query language or menu items are used.

The semantic electronic textbook is generally focused on working with such categories of users as the authors of educational material (subject expert, expert teacher, knowledge engineer, designer) and students. As practice shows, often one person often performs the functions of all the listed authors (developers) of an electronic textbook.

The SET operates in two modes: in the mode of formation of educational material (the mode of acquiring knowledge) and in the training mode (presenting the material to the end user-learner). The user interface of the SET includes:

- commands for the formation of the educational material of the SET;
- commands for editing the educational material of the SET;
- commands for navigation through the hypertext semantic network of the SET;
- the command for printing the hypertext semantic network of the SET;
- teams that ensure the integration of the SET;
- graphical modification of the universal language of semantic networks SC;
- linear modification of the universal language of semantic networks SC;
- ways to visualize various other forms of presentation of educational material (editors of traditional information structures).

III. Hypertext Semantic Networks as a Model of the SEU Subject Domain

The domain model is used to solve the problems of structuring and systematizing educational material, implementing navigation and search algorithms for educational material, generating information about the student and implementing adaptive learning management, etc. The knowledge representation model should combine traditional forms of presenting educational information with ILS formal presentation. In this paper, it is proposed to use hypertext semantic networks as a knowledge representation model [5]. Hypertext semantic networks (HSNs) are a class of knowledge representation models, the distinguishing feature of which is that various forms of information representation are integrated on their basis: traditional, for example, hypermedia, and formal – in the form of semantic networks, in fact, the knowledge base. Traditional forms of information presentation are focused primarily on the visualization of the information displayed to the user, in turn, the formalized presentation of this information in the knowledge representation language makes it a semantically interpreted system. The integration of these heterogeneous ways of presenting information is based on meta-relations (meta-descriptions) of this information. HSN is a knowledge representation model focused on a formal description of the syntax and semantics of information structures of any kind, as well as a description of the relationships between them.

A hypertext semantic web can also be called a semantically structured hypertext; the result of the integration of hypertext technologies and technologies based on semantic networks; semantically structured hypertext multimedia knowledge base. The following should be indicated as the main structures underlying hypertext semantic networks. The HSN node, which is a sign of some information structure, contains the information structure designated by it (the information structure is considered to be the content of the node of the hypertext semantic network that designates it). The set of input signs denoting a variety of objects (specific objects of a certain subject area, specific information structures, specific sets, connections, concepts, relations) of the HSN one-to-one correspond to a set of identifiers (names), which are a string

(linear-symbolic) version of the image of signs. A HSN node that denotes some information construct does not always need to explicitly "store"that information construct as ILS content. This information structure may be unknown (not formed), it may be broken into fragments, each of which is presented explicitly, and, therefore, there is no need to explicitly represent and store the entire original information structure. An information structure (in particular, a text information structure) may include identifiers (names) of some characters represented by GSS nodes. This is interpreted as a link to the corresponding sign (a node of the hypertext semantic network). Links can be multisets, since the same element can be included in the link multiple times, including under different attributes. A link whose elements have their roles (attributes) is a directed link, otherwise it is an undirected link. Hypertext semantic networks allow you to have links that connect not only objects, information structures, but also the links themselves. They also allow the formation of set signs, called set systems, including the signs of some other sets and their elements, as well as the corresponding signs of membership pairs. In this way, it is possible to describe connections not only between bundles, but also between entire structures (systems of sets). GSN are focused on the description of subject knowledge that has a complex hierarchical, multi-level structure. In hypertext semantic networks, the description of various types of links is supported: links between links, links between entire structures, links between various fragments of processed knowledge. The set of nodes of the GSN on the subject basis is divided into a set of nodes of the subject level, that is, those that can be semantically interpreted directly through the elements, structures and relationships of the described subject area, and the set of meta-level nodes denoting statements about objects and relations of the subject area, the connections between them. These structures allow for semantic and semantic compatibility both within a separate EMS, and in the future when integrating several EMS in a certain subject area, as well as when building an ILS for training specialists in a certain professional field.

IV. Systematization of educational material in the SET

The main task of the learning process is the formation of a system of knowledge in the student on the subject being studied. In a semantic electronic textbook, this problem is solved through an explicit, visual representation of the semantic structures of the educational material. The formal model of the content structure of the information support of the EMS is presented as a set of sets and structures. For example, a set of semantically elementary information structures of educational and educational material; a set of knowledge base constructions, which are a formalized record of some elementary information construction in the knowledge representation language; set of relationships between the above sets. Such constructions, in particular, include relations that define the description of bibliographic attributes for information constructions, a set of semantic equivalence links between source text fragments and their formalized record, specifications of educational material fragments, and a meta description of educational material. When describing the educational material, one can consider as the main set of objects of study (concepts) of the SEU subject area; a set of statements (such as axioms, theorems, lemmas, etc.) that describe the main properties of the objects of study; a set of relations describing the relationship between the main objects of study. The latter include in particular:

- relations defining the typology of the main objects of research (“subset”, “genus – species”, membership relations, relations “general concept – particular concept”, etc.);
- relations describing the system of concepts of the subject area, based on the hierarchical structure of their definitions (defined concept-defining concepts), etc.

Each concept from the set of objects of the subject area is assigned a knowledge model of the SEU, called the semantic neighborhood of the concept, which is given, in turn, by the formulation from the textbook, as well as the formalized definition of the concept, the relationship between the text of the definition in natural language and the formalized record of the definition); synonyms, homonyms for a given concept; examples - elements of the set denoted by this concept; determining the place of a given concept in the hierarchy of concepts of the theory; a set of relations that are defined on a set of specified concepts; set of the most important statements that describe the properties of this concept. These semantic structures of educational material in the SEU can be used in the following access options:

- Query drafting option: the user generates a query to the system in a specialized query language, or initiates the navigation and search command of the EMS presented in the system menu, in response the system searches for relevant information, for example, searches for the semantic neighborhood of a concept or a section of a textbook;
- a variant of navigation through semantic links, when the student or the system forms a certain path, reveals a feature, moves to the next feature, and so on through the learning material.

V. Knowledge Representation Languages in Semantic Electronic Textbooks and Intelligent Learning Systems

The tools for creating an SET include knowledge representation languages:

1) Basic semantic language SC.
2) Language SCht for representation of hypertext semantic networks. The key nodes of this language are divided into two classes:
   - key nodes that determine the typology of information structures of the hypertext semantic network;
   - key nodes, which are signs of relations, the scope of which includes the specified information constructions.

The SET knowledge representation language is focused on ILS use by both the authors of the educational material and the end users (students), i.e. the language with which

the developer structures, systematizes, marks out the educational material and the language of presentation of this material to the student is one and the same language. Accordingly, the means of searching and navigating through the educational material are the same for all categories of users. For navigation and search within the framework of a semantic electronic textbook, special navigation and search tools can be used, which are based on associative access to stored information. The essence of search in graph-dynamic models is to compare the graph-query and fragments of the semantic network. The output to the user of the search results of this or that information about the subject area occurs through the implementation of the corresponding search operations. The execution of each navigation and search operation occurs when the task (request) corresponding to this operation enters the knowledge base. To control the methods for displaying fragments of the hypertext semantic network, it is necessary to introduce the concept of display (reproduction) style and special relationships between the playback style and reproducible fragments. Displaying responses to user requests should be focused on adapting the style of visualization of educational material to the individual characteristics of the student.

The process of designing applied SET should include such stages as the formation of a knowledge base of educational material, test debugging of the system, trial operation.

A semantic electronic textbook, like any other textbook or any book, must contain a description of the structure of the educational material presented, which is reflected in the form of content. Educational material is a structured set of information components of various types. The task of the developer is to isolate these components and describe their order. The presentation of the educational material and, accordingly, the structure of the training course can be linear, or it can also have a branched reading structure.

When writing a textbook, the author immediately focuses on the development of a semantic electronic textbook. A traditional textbook can become part of a semantic electronic textbook (as part of a hypertext semantic network). The construction of a semantic electronic textbook requires the construction of a strict formal presentation of educational material, the systematization and structuring of educational material, a clear consistency of the system of concepts of the subject area, which makes it possible to avoid ambiguity in the understanding of some concepts.

An adaptive approach to designing a user interface in learning systems is one of the promising areas for the development of intelligent learning systems. This approach provides for the creation of a flexible structure of the dialogue between the system and the user in accordance with a number of such individual characteristics of the user as readiness to work with the system, characteristics of interaction with the system, interface preferences, individual psychological characteristics, etc.

VI. The Artificial Intelligence specialty education in the context of creating intelligent training systems in the specialty

The most important direction of improving engineering education, in particular, in the direction of Artificial Intelligence, is the destruction of often artificially created barriers between various academic disciplines, which leads to a "mosaic unsystematic perception of the educational material of the specialty as a whole. Therefore, it is very relevant:

- the transition from programs for individual academic disciplines to comprehensive unified programs for each specialty, where the structuring and systematization of educational material is carried out not on the basis of the conditional division of this material into academic disciplines, but on the basis of ILS semantics;
- transition from textbooks for individual academic disciplines to comprehensive textbooks for each specialty;
- transition from electronic textbooks for individual academic disciplines to complex electronic textbooks and, in general, to intelligent teaching systems for each specialty.

In this regard, it is very important to provide technological means of "transition"of boundaries between educational materials of different academic disciplines. Ideally, the trainee should be able to work with educational material not on the scale of a separate academic discipline, but on the scale of the entire specialty, when solving a number of problems. The principles underlying the consideration of integration issues are based on the general theory of the interaction of scientific and technical disciplines. The SET technology supports the possibility of further mutual integration of the SET in several academic disciplines into a single integrated ILS. Moreover, integration in this case means integration at the content (semantic, semantic) level. The possibility of such integration is primarily provided by the basic language for representing the knowledge of educational material in each individual EMS and in the system as a whole, which makes it possible to describe information at various structural levels, move from level to level and to a meta level, which makes it possible to describe the links between atomic fragments of academic disciplines, between sections of academic disciplines, between the academic disciplines themselves, etc. The integration of many heterogeneous sources of knowledge is carried out on the basis of a single knowledge system, represented as a single conceptual scheme, or ontology. Sources of knowledge can be presented in documentary form (texts), in the form of formatted data (statistical data files), graphic diagrams, expert knowledge (knowledge of specialists). The main requirement for knowledge sources is to prevent the loss and increase the availability of all types of corporate knowledge by providing a centralized, well-structured information repository that meets the requirement of

semantic interoperability across disciplines. The structuring of an information warehouse involves the creation and description of a unified knowledge system based on a taxonomy of conceptual concepts, a meta-knowledge base or ontology, through which you can access various sources of knowledge. A number of authors work on this issue within the last decade [6], [7], [8], [9] The integration of SETs in several academic disciplines consists in the integration of hypertext semantic networks of these textbooks and involves:

- coordination of objects of study of these academic disciplines;
- harmonization of the subjects of study of these academic disciplines;
- harmonization of the "foundation"of integrable academic disciplines (basic (undefined) concepts and systems of axioms);
- building interdisciplinary links, which includes the coordination of conceptual systems of integrated academic disciplines; harmonization and integration of the typology of the main objects of research; coordination and integration of the system of statements, about the main objects of research and the relationship between them, etc.;
- integration of relevant scht-constructions;
- pasting of synonymous scht-nodes of the semantic network.

The hypertext semantic network, obtained as a result of the integration of individual SET, will make it possible to localize quite well those groups of concepts that require clarification. With the mutual integration of semantic electronic textbooks, the following problems are solved:

- search for contradictions in the integrated knowledge base;
- maintaining the consistency of constituent elements.

Work on the logical organization of educational material within the specialty, which, in fact, is the preparation of a specialty curriculum, allows you to identify the links between academic disciplines, certain topics of these academic disciplines, their constituent fragments (theorems, definitions of concepts, etc.) with other academic disciplines, topics, fragments of educational material, subsequent and previous. It becomes possible to determine a more rational sequence for studying educational material. As a result, individual SETs in the disciplines of the specialty can be integrated into a complex, an intelligent learning system, which is a hypertext semantic network obtained as a result of the integration of hypertext semantic networks of the SES in all educational disciplines of the specialty. The construction of a semantic electronic textbook requires the construction of a strict formal presentation of educational material, the systematization and structuring of educational material, a clear consistency of the system of concepts of the subject area, which makes it possible to avoid ambiguity in the understanding of some concepts. The analysis of semantic correctness and editing of the knowledge base can be performed by the developer by navigating through the semantic links of the knowledge base of the SET. Explicit description of interdisciplinary links during the integration of SES will allow developing electronic textbooks for a complex of related academic disciplines, including a complex of academic disciplines for the entire specialty. Using the principles underlying the semantic electronic textbook and providing semantic structuring and systematization of stored information will also allow a new approach to solving the problems of intellectualization of computer educational resources and, in particular, educational sites in the open education system. An intellectual learning system (ILS) should be able to track the consistency and integrity of the picture of the world presented in it and presented to the student, teach through ILS own ability to solve problems, contain a system of assessments and decision-making on a learning strategy based on these assessments, i.e. should itself consist of a number of subsystems containing knowledge bases semantically correlated with each other. One of the necessary characteristics of any learning process and, of course, SET is the ability to intelligently assist the student. In educational practice, intellectual assistance means the automation of the teacher's consulting work, when the student independently solves problems with the support of an automated system. Thus, the IOS helps the user to make decisions by providing relevant information and decision rules in a particular situation. At the same time, in the process of searching for an answer, the user considers various options for solving the problem presented by the knowledge management system, modifies the problem statement or models the situation, choosing the most appropriate solutions. There may be another mode of solving the problem, when the user independently solves the problem, and evaluates the result of the solution with the help of the ILS for correctness and effectiveness based on comparison with the solution proposed by the system itself, or, for example, asking for help directly from the teacher. As specialists involved in filling the knowledge base of the entire ILS, as well as the knowledge bases of its subsystems, in building the subsystems of learning strategies, specialist models, problem solvers, and others, specialists in a particular field of knowledge, pedagogues, methodologists, knowledge engineers should be involved. The trainee, trainer and customer of personnel can act both as users and as conditionally developers of the SET, making adjustments to its work by their actions. The integration of heterogeneous knowledge sources, the interdisciplinary nature of their use, the need to attract additional sources of knowledge, the exchange of knowledge between users involves the development of a knowledge management system architecture based on a common information space in the form of an integrated memory of a virtual university and knowledge ontologies, i.e. based on the properties of

interoperability and convergence of systems and knowledge. An educational, educational, training organization or the structure and process of learning is not just a set of automated and intelligent learning systems in certain disciplines that have multimedia tools, flexible learning strategies, subsystems for adapting to the user, etc. For the effective use of all these tools, an infrastructure is needed in which information is processed, interaction between users and subsystems, joint problem solving, in which both users and subsystems are involved. Such a complex system, which combines many autonomous entities (or agents) serving users, solving problems, teaching students, etc., is a multi-agent system (MAS). Any organization that acts as a set of entities that perform certain functions in the interests of achieving the goals of the entire organization is a multi-agent system. All this becomes possible within the OSTIS ecosystem, as an association of structures, objects and their interaction with each other and with the external environment [10].

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Семантически совместимые OSTIS-системы автоматизации образовательной деятельности

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Предлагается класс смысловых электронных учебников, в основе которых лежит смысловое структурирование учебного материала. Благодаря смысловому структурированию учебно-методического материала СЭУ приобретает новые возможности по сравнению с традиционными электронными учебниками. Смысловой электронный учебник представляет собой интерактивный интеллектуальный самоучитель по определенной предметной области, содержащий подробные методические рекомендации по ее изучению и предназначенный для целеустремленного, самостоятельного и активного пользователя, желающего приобрести знания по соответствующей дисциплине (предметной области). На примере специальности «Искусственный интеллект» рассматривается перспектива проектирования интеллектуальных систем обучения для специальностей.

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