Ontological Model of Representation of University Resources

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Abstract. The article substantiates the expediency of using the ontological model of presentation of knowledge, which combines the properties and advantages of other models of presentation of knowledge and data in the process of construction, development, processing and application of ontologies. The analysis of application of systems of computer ontologies has been analyzed and the criteria of their selection are selected: software architecture and tools development; functional compatibility; intuitive interface. Determined to be the most optimal with regards to the training of future pedagogical engineers in the field of computer technology Protege OWL. The requirements, which are put in the process of designing an ontological model of representation of educational resources of the university, are singled out. The ontological model of representation of university resources used for unified description of knowledge bases from the point of view of competency requirements (knowledge, skills, skills) to student learning outcomes with the possibility of constructing repositories of electronic and educational resources was designed. The set of concepts and set of relations of computer ontology are presented. The method of filling the ontological base of knowledge of educational resources of the University is proposed. Experimentally, the efficiency of using the proposed ontological model for representing the University's learning resources in the process of training future engineers-educators in the field of computer technologies has been proved by the indicators: speed of construction under ontologies; number of defects.

Keywords: computer ontologies, knowledge representation, ontological model of university resources, designing.

1 Introduction

1.1 Setting of a problem

An analysis of the development of modern educational systems suggests that the amount of human knowledge accumulated today has a tendency to exponential growth and has long gone beyond the reach of one encyclopedia specialist, even for a particular part of one branch of science. The paradoxical consequence of such a spe-

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cialization could be the slowdown in the development of science and technology in general, therefore, there is a need for the emergence of cognitive sciences and the corresponding knowledge engineering, the achievements of which enable the formalization of a certain field of knowledge through an appropriate information model that takes into account all objects, their attitude, proven statements about them, and so on. The answer to these needs is ontology simulation and computer ontology.

1.2 Analysis of recent research and publications

According to most studies in this area, the problem of ontological modeling and the use of computer ontologies in higher education institutions is very relevant. However, most scholars focus on using computer ontologies, such as: N. Noy [15], B. A. Lapshyn [10], O. S. Narinyany [13], O. G. Yevseyev [22], V. V. Lyubchenko [11]. The process of developing and using computer ontologies is considered in the works of T. Gruber [6], T. Jeffrey [7], Y. Ding [3], S. Nirenburg [14], J. Zura [19]. A general review of the instruments of ontology engineering was undertaken only by O. M. Ovdey and H. Y. Proskudina [16]. The modeling of the ontology of the educational subject-based industry as a means of integrating knowledge was studied by O. H. Yevseyeva [22], V. V.Lyubchenko [11], O. E. Stryzhak [18], I. M. Tsidylo [21]. Modeling the categorical level of the language and ontological picture of the world – O. V. Palahin and M. G. Petrenko [17]. Ontological representation of the decision-making processes is Y. P. Chaplynskyy [2]. Using the ontology of the subject area to eliminate ambiguities in the computer translation of technical texts – A. V. Morentsova [12] etc.

The works of the above mentioned authors contributed to the accumulation and systematization of knowledge for improving the practical training of students on the creation and use of computer ontology. However, they do not fully disclose the specialty of ontological modeling in the context of studying in institutions of higher education and the creation of ontology of a certain subject field of educational resources of these institutions.

1.3 Purpose

The purpose of this study is to develop an ontological model for representing university resources in the process of training future engineering teachers in the field of computer technologies.

2 Results of the study

2.1 Prerequisites for ontological modeling

The modern stage in the development of science, education and production is characterized by the development and the use of information technologies based on knowledge, on the basis of computer technology, the relation of artificial intelligence

methods in the design of information systems. Currently, one of the prior directions of the development of information technologies is the transition to working with the semantics of information [1, p. 221]. In the process of working with semantic data, based on the facts obtained from the database, users can use logical rules to obtain new information (new statement). The possibilities and areas of relation of work with knowledge are expanding.

At the beginning of this century such processes are observed in the development of the theology associated with ontological modeling. Most research has already formed an understanding that the use of ontology libraries in the organization of information processes in the near future will be as widespread as the use of databases now. Therefore, ontological modeling is the answer to this need, because it allows to look at the process of designing, development, processing and use of the ontology of the predominant industry, and the development of an ontological model of presentation of university resources will allow: simulation of processes in order to optimize them; rapid receipt of logical conclusions based on a large amount of information in order to support decision-making; ensuring accessibility for users of large volumes of highly structured information; solving a number of technical problems, especially in the field of integration of information systems; automating the annotation of the learning resource and reducing the complexity of this process, to accumulate learning resources and further automate processing in the process of solving search and integration problems by means of computer ontology systems (COS); designing computer ontologies of personalized electronic didactic materials describing a plurality of university resources selected on the basis of the student profile, the relations between them, which specify the order of learning the study material included in the collection, and include in self-semantic rules for designing didactic materials based on ontology.

In addition, the training of engineering teachers in the profile "Professional Education. Computer Technologies" is becoming especially important in the current conditions of social and economic development of the country, which can be explained by the shortage of competent specialists of the new formation. However, the specifics of the training of future engineers and eductors of the computer profile is that all disciplines of the curriculum can be traced to two interrelated areas of training related to the field of computer technology: pedagogical and engineering. The practice convinces that the prospective direction of professional training of future engineering teachers are ontologically managed information systems, the design of which is essential choice such as a formally-logical representation of knowledge, and sources of acquisition and renew of knowledge [4, p. 9].

In recent years, the number of tools for working with computer ontologies has sharply increased (more than 50 editing tools) [10, p. 101]. Therefore, in order to further design computer ontologies for representing the University learning resources in the context of training future engineering teachers in the field of computer technologies, it is advisable to use systemic computer ontologies (COS) [9, p. 61]. Their use is much to rapid and accelerate the process of designing computer ontologies on the basis of the proposed model.

In order to decide on the choice of a specific COS, having analyzed the skills of an engineer and educator and the use of computer ontologies in various fields, we distin-

guish three main criteria for choosing the COS [10, p. 178–179]: software architecture and tool development; interoperability covers; intuitive interface.
The choice of the most convenient COS depends first and foremost on the goals of the developer and the ontology developed, therefore, in the process of choosing COS for the training of future engineering teachers, Protégé, which meets all the necessary criteria for their successful practical activity, is the most appropriate means [8, p. 180].

It is based on a logical model that is designed to create definitions that are relevant to the informal description. Thus, the definition of complex concepts can be designed on the basis of simpler definitions. In addition, the logical model allows to find out which concepts correspond to the given definition and check that concepts and definitions in the ontology are mutually consistent [7, p. 233].

2.2 The justification of the ontological model of representing the university educational resources knowledge

To implement a model of presentation of knowledge and data, it is expedient to use the ontological model of presentation of knowledge, which combines the properties and advantages of other models of representation of knowledge and data (graph model, tree-based model, relational model, semantic network, framing, logic model, etc.).

Solving the tasks of searching and integrating educational material in a person-made educational collection can be implemented in the ontological model as a result of the development and inclusion of the corresponding semantic rules in computer ontology [9, p. 99].

The ontological model of presentation of university resources (see Figure 1) used to unify the description of knowledge bases from the point of view of competency requirements (knowledge, skills) to the results of training students with the ability to build electronic repositories of the resources will look like:

$$O_{NR} = <C_{NR}, Inst_{NR}, R_{NR}, I_{NR}>,$$

where: C_{NR} – the final set of concepts of subontology of university resources; $Inst_{NR}$ – a set of instances of classes of subontology, annotated on the ontology of learning resources, which form a repository of learning resources; R_{NR} is the set of relations of subontology of learning resources. I_{NR} is the set of rules of interpretation, $I_{NR} = ø$.

The learning resources described in the ontological model may belong simultaneously to several concepts of the ontology of the university educational resources and inherit the corresponding properties (attitudes). In the process of describing the contents of the teaching resources of future engineering teachers in the field of IT, the concepts of the ontology of the subject discipline of the discipline are used, which allows describing different learning resources in terms defined in the general domain.

The set of concepts of the ontological basis of university resource knowledge of learning resources is presented in Table 1, and the set of relations is given in Table 2. The defining areas and the domains of relations of values can be both defined concepts and their daughter concepts within the framework of ontology.

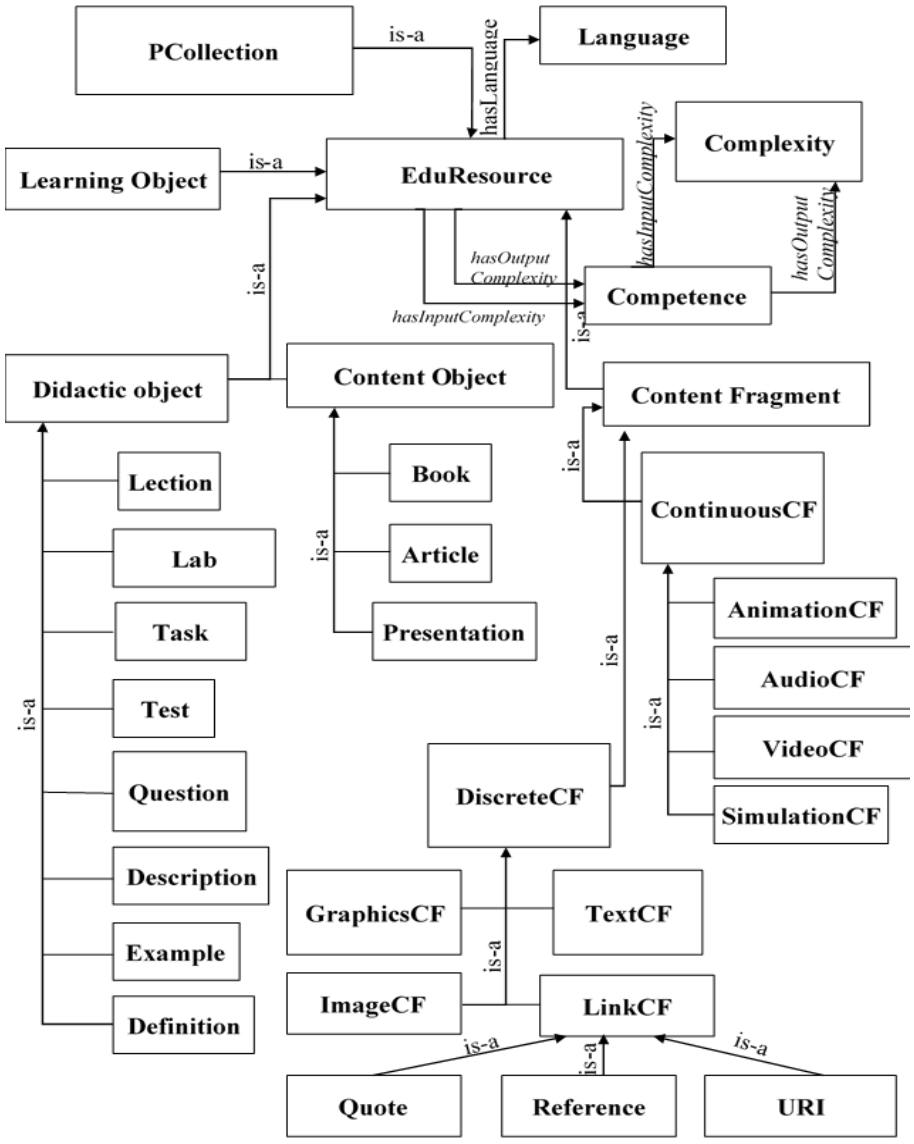

Fig. 1. Ontological model of educational resources of the university

Table 1. A set of concepts of computer ontology representing the learning resources of the university

Ontology concept	Parent Concept	Description of the concept
EduResource	Thing	University learning resources
PCollection	EduResource	Personalized learning materials
Learning Object	EduResource	Educational facilities currently available at an educational institution

Content Object	EduResource	Information resources of the University academic resources
Book	Content Object	List of available books from various subject areas
Article	Content Object	List of scientific articles from various subject areas
Presentation	Content Object	A variety of presentations from various subject areas
Content Fragment	EduResource	Information fragments of university resources
ContinuousCF	Content Fragment	Dynamic information fragments of university resources
DiscreteCF	Content Fragment	Static information fragments of university resources
GraphicsCF	DiscreteCF	Graphic elements of the University learning Resources
ImageCF	DiscreteCF	Image
TextCF	DiscreteCF	Text fragments of university learning resources
LinkCF	DiscreteCF	Links to other training resources
Quote	LinkCF	Quotes
Reference	LinkCF	Link to additional information
URI	LinkCF	Hyperlinks
AnimationCF	ContinuousCF	Animation elements of university learning resources
AudioCF	ContinuousCF	Audio elements of university learning resources
VideoCF	ContinuousCF	Video elements of university learning resources
SimulationCF	ContinuousCF	Simulation models and simulation learning resources of the university
Didactic object	EduResource	Didactic objects of learning resources of the university
Lection	Didactic object	Lectures on all disciplines
Lab	Didactic object	Laboratory work on all disciplines
Task	Didactic object	Tasks from all disciplines
Test	Didactic object	Tests on all disciplines
Question	Didactic object	Test questions from all disciplines
Description	Didactic object	Descriptions of all academic disciplines
Example	Didactic object	Examples of tasks
Definition	Didactic object	Definitions
Competence	Thing	Competences that are formed when studying one or another discipline
Complexity	Competence	Level of mastery of each competency
Language	Thing	Language of presentation of information

Table 2. The set of relations of the computer ontology of the representation of the university learning resources

Peculiarity	Definition area	Competence area	Description
hasInput-Competence	EduResource	Competence	The ratio that gives competence is needed to study this learning resource
hasOutput-Competence	EduResource	Competence	The ratio of competence, obtained as a result of the study of this learning resource
hasLanguage	EduResource	Language	Information presentation language
hasInput-Complexity	Competence	Complexity	Input level of mastering of competencies
hasOutput-Complexity	Competence	Complexity	Initial level of development of competencies
hasTitle	EduResource	string	The ratio that specifies the name of the learning resource
hasURI	EduResource	string	The ratio that specifies the storage location of the learning resource (for example, URI)
hasBibRefer-ence	EduResource	string	Bibliographic description

2.3 Methodology of filling the computer ontology of university learning resources

In addition to designing the ontological model of presentation of university learning resources, we conducted a research on the study and relation of computer ontologies by future engineering teachers in the field of computer technologies, which covers both cognitive knowledge of knowledge database and their engineering tools, as well as the structure of information (a list of its types and interconnections), necessary for a decision, means of receiving and preparing this information, the procedure for setting tasks for the design of computer ontologies, solving these problems and getting results. For the implementation of this ontological model, future engineering teachers need for each annotated learning resource to follow the methods of filling it by following the next steps:

– Identify the possibility of decomposition of the learning resource. For methodical instructions for individual laboratory works, presentations for lectures, other educational resources, the use of which is limited by separate modules of the work program on a academic discipline, annotation is conducted for the entire resource as a whole. For teaching manuals and other educational resources, the use of which is possible in several modules of the work program of the discipline, which have a large volume and complex structure, it is expedient to decompose such resources into separate elements (sections) and annotate them as a separate educational resource.

- Create a representation of the annotated learning resource as an instance of the class of computer ontology of the University academic resources, the corresponding type (Course, Lection, Lab, Task, etc.).
- Describe the name of the learning resource and the language (s) of the information submission using the hasTitle and hasLanguage relations.
- Describe the bibliographic link for the annotated resource, in accordance with the references to bibliographic references using the hasBibReference relation.
- On the basis of the analysis of the learning resource and the first stage of the computer ontology of the discipline developed, identify the competencies gained in the process of learning about the other learning resource and the level of mastering them (high, necessary, critical or low). Describe them as instances of the Competence classes, linking the created instances to the relation with the corresponding instances of the description of the discipline and the relation isOutputCompetence in the computer ontology of the university learning resources. The level of possession of each competence as a result of studying the resource is determined by the relation hasOutputComplexity.

2.4 Results of the experiment on the feasibility of using the proposed ontological model

An experiment was conducted on the basis of the engineering faculty of the TNPU named after V. Hnatiuk in the process of realization of the designing method using the Prototype (COS), in which 50 future teachers in the field of computer technologies (25 experimental group and 25 control group). The assessment was carried out according to the following indicators: speed of designing subontologies; number of defects. For the students of the experimental group, the process of designing the computer ontology of university resources was carried out on the basis of the proposed ontological model and methodology based on the use of COS (in our case Protégé). The students of the control group carried out the design of the computer ontology of the University educational resources without using the model and using declarative programming languages.

The design of the computer ontology of the University learning resources, both in the control and experimental groups, was conducted modularly, that is, it was developed as a set of small modules (subontologies), which were later developed for the formation and use of one modular ontology. Like the learning process, the ontology design (ontology extraction, generation of ontologies or ontology acquisition) is an automatic or semi-automatic creation of ontologies, including obtaining the concepts of the corresponding domain and the relation between these concepts from the block of the natural language text and their coding with the ontology language for easy search. Therefore, each student (experimental and control group) built 1 subontology of educational resources for a particular discipline, which then were merged into the computer ontology of university resources. Therefore, as a result of the experiment, future engineering teachers in the field of computer technology built on one of the ontologies of the university academic resources for each of the groups.

In the process of designing subontologies, students use general concepts that are sufficiently defined in one ontology, while they are available from other ontologies, which avoids over-describing objects by reusing already-defined concepts. It will also make it possible to simplify semantic rules for the search of learning materials.

Comparison of the process of designing computer ontologies of university resources by students of experimental and control groups was carried out according to the following criteria:

- *The speed of design of subontologies*. Between the future engineering teachers of the control (students) and experimental groups (25students), 25 disciplines were distributed with the corresponding learning resources, on the basis of which students had to build ontologies, and the time taken for the students of each of the groups for these 25 subontologies, which should be included in the ontology of the university educational resources. The results show (Figure 2) that students of experimental groups cope with this task faster 2.5–3 times on average.

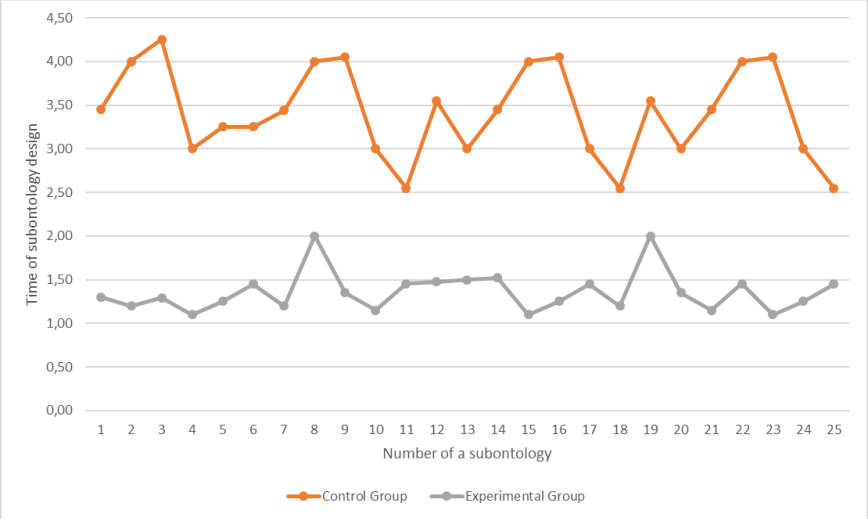

Fig. 2. Comparison of the speed of designing subontologies by students of control and experimental groups

- *Number of defects.* The study of this indicator took place on the basis of the analysis of 25 constructed subontologies, which, in aggregate, give an ontology of university resources. According to the results of the analysis (Figure 3), it has been found that future engineering teachers in the field of computer technologies of experimental groups, in the training of which the proposed ontological model of the representation of university resources and the method based on the use of COS (in particular, selected during the Protégé analysis) has considerably fewer defects (almost 3 times) than that by the students of the control groups who have been designing the computer ontology of the University academic resources without using the model and by means of declarative programming languages.

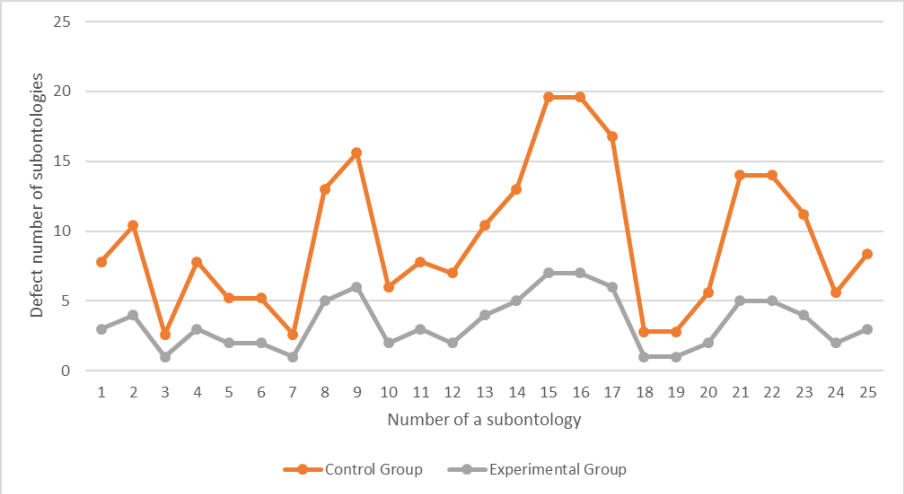

Fig. 3. Comparison of the number of defects in the subontologies constructed by students of control and experimental groups.

3 Conclusions and perspectives for further research

- The ontological model of representation of the university learning resources is proposed, on the basis of which future engineering teachers in the field of computer technologies will be able to automate the annotation of the learning resource and reduce the complexity of this process, to organize training resources and further automate processing in the process of solving search problems and integration by means of COS, which meets the requirements of the model of presentation of knowledge. It is appropriate to use this model for a unified description from the point of view of the competence requirements (knowledge, skills, abilities) to the results of training students with the ability to build repositories of electronic educational resources.
- In the process of analyzing the COS and selecting the methodology for designing computer ontology of university resources, it has been discovered that Protégé, which meets all the necessary criteria for their successful completion, is the most optimal means for the training of future engineering teachers in the field of computer technology practical activity. A methodology for filling this ontology is proposed, which includes: determining the possibility of decomposition of the learning resource; creating the presence of annotated learning resource as an instance of the class of computer ontology; creating a description, the names of the learning resource and the languages of the presentation of information; creating a description of the bibliographic reference for the annotated resource; the ability to identify and describe the computing skills gained in the process of learning about a learning resource and its level of mastery.

– We have experimentally verified the effectiveness of the proposed ontological model of representation of the University learning resources in the context of the training of future engineering teachers in the field of computer technology on the following indicators: 1) the speed of designing subontologies; 2) the number of defects. On the basis of the analysis of the results, it should be noted that according to all the criteria the students of the experimental group, where the process of designing the computer ontology of the university resources was carried out on the basis of the proposed ontological model and methodology based on the use of COS (in this case Protégé) higher, than the students of the control groups who carried out the design with the help of declarative programming languages.
– The continuation of scientific research on the given problem is expedient in the investigation of the dependence of constructed hierarchies of concepts and concepts in the computer ontology of university resources and the development of ontologically managed information systems on their basis.

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