AN APPROACH TO THE MODELING OF THE COGNITIVE ABILITY MANAGING THE FOCUS OF ATTENTION ON THE BASIS OF THE REFLEXIVE MECHANISM OF THE SYSTEM

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***Abstract**: The article reveals an approach to modelling of the cognitive ability managing the focus of attention (an ability to switch one's attention) which is based on the reflexive mechanisms developed in “OntoIntegrator” system. There were considered basic experiments to classify the mathematical texts, and demonstrated the reflection mechanisms for the solution of a set task.*

***Keywords:** ontology, reflection, attention switch, ontological mark-up of the text*

***ACM Classification Keywords:** H.3 INFORMATION STORAGE AND RETRIEVAL H.3.1 Content Analysis and Indexing - Linguistic processing*

Introduction

In the modern researches the problem of a reflection is considered, at least, in three directions: when studying thought, self-awareness of the personality, and also communication and cooperation processes. The study of reflection when solving different problems of the cogitative activity is aimed to detect the structure of system of knowledge and the organization of the thinking process. The article presents the reflection in terms of thinking processes, self-awareness by the system of structures of the knowledge representation and thinking mechanisms. In order to develop the ontological reflection it is necessary to work out the mechanism allowing tracing internal logic of the content of knowledge, including models of knowledge representation and knowledge processing.

The article suggests a way to model the cognitive ability to control the focus of the attention, considered in a context of the problems of the psychology of thinking. By [Gippenreyter, 2001] the attention is described as the most important component of the different psychical processes, and basic properties of attention, such as concentration, range, distraction, short span of attention, intensity, stability and refocusing (Figure 1) are distinguished.

This article examines the mechanisms of the attention switch, executed on the basis the reflection mechanisms of the “OntoIntegrator” system [Nevzorova et. al., 2013]. In the system the ontology-linguistic approach [Nevzorova, 2007] integrating conceptual and technological decisions, allowing designing the solutions of complex tasks of the texts processing in the semantic space of knowledge, represented as a system of ontological models, is consequently executed. On one hand, the system of ontological models structures the semantic space on the other hand it controls the solution of applied linguistic tasks.

Developed tools in the "OntoIntegrator" system are intended for processing of texts in Russian language and contain a number of specialized databases built on the basis of processing of the corpuses in Russian language. On one hand, the system of ontological models structures the semantic space on the other hand it controls the solution of applied linguistic tasks.

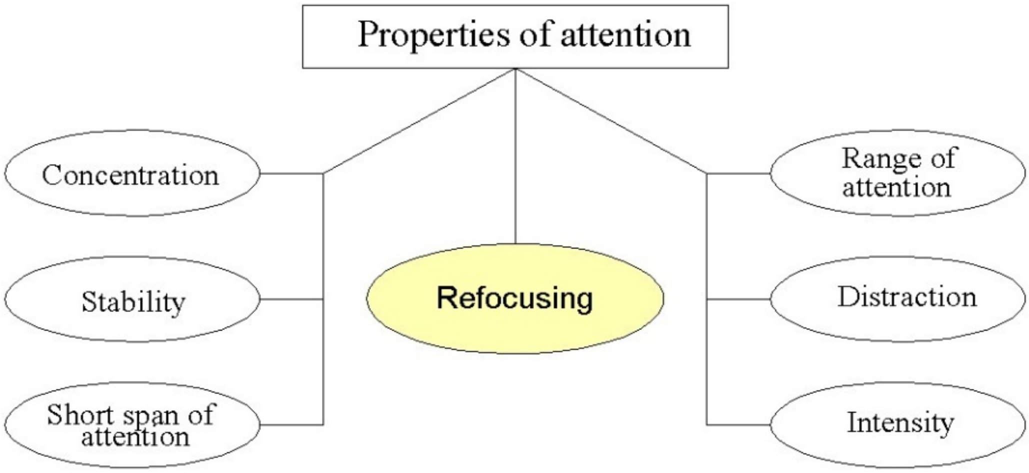

Figure 1. Basic properties of attention

In psychology under the attention switch it is meant the conscious and knowledgeable, willful and purposeful change of the direction of thinking from one object to another caused by the setting of a new goal. In our experiments, there will be considered the task of automatic switch of the focus of attention in order to classify mathematical texts according to their the areas of knowledge. «The attention switch» of the system will be performed on the basis of specified criteria, and by the focus change during the process of the mathematical document analysis various resources of the system, providing relevant text processing, will automatically connect.

The reflection mechanisms of the “OntoIntegrator” system

The process of solving of an applied linguistic problem in the "OntoIntegrator" system executed under the management of the ontological models system [Nevzorova et. al., 2013]. The system of ontological models includes different types of ontologies: the applied ontology, the ontology of models and the ontology of the task planning.

From the point of view of the structural organization the system of ontological model is a three-component associative system. The components of the system are the ontology of the task planning, the ontology of the models and the applied ontology. In the system the interpretation of the applied ontology as a set of ontologies of different problem domains (and, accordingly, of different semantic interpretations) is allowed: external, connected by a user, and internal, integrated into the “OntoIntegrator” system (with the possibility of the replenishment, editing and calculating support) to address a wide range of applied tasks. The examples of the built-in ontologies are the ontology of the generally accepted abbreviations, the ontology of the markers to annotate the output text according to the results of applied tasks solution, etc.

An important component of the ontological system is the “reflexive core” component of the ontology of models, which allows to model in a system the capacity to reflect. The reflexive core is the system-forming part in building of the ontological system, it contains the links to all types of the concepts and relations in the ontological system, as well as the set of admissible functions of the interpretation, defining the choice of the types of the concepts and relations used, and this information is presented as an internal model of the ontology of models. In other words, in the ontological system there is the knowledge about the structure of the system, organized as the domestic knowledge of the system. The reflexive core can be configured (redefined) by an "OntoIntegrator" system user based on their own interpretation of the concepts of the ontology of the models.

Let's consider one of the typical models of the reflection usage in the ontological system. In Figure 2 is shown an example of reflection, related to a change (redefinition) of the links in the structure of a concept-model. New model preserves the structural properties of the original model, but it changes the semantics of its links. All the transformations are performed on the level of the reflective core.

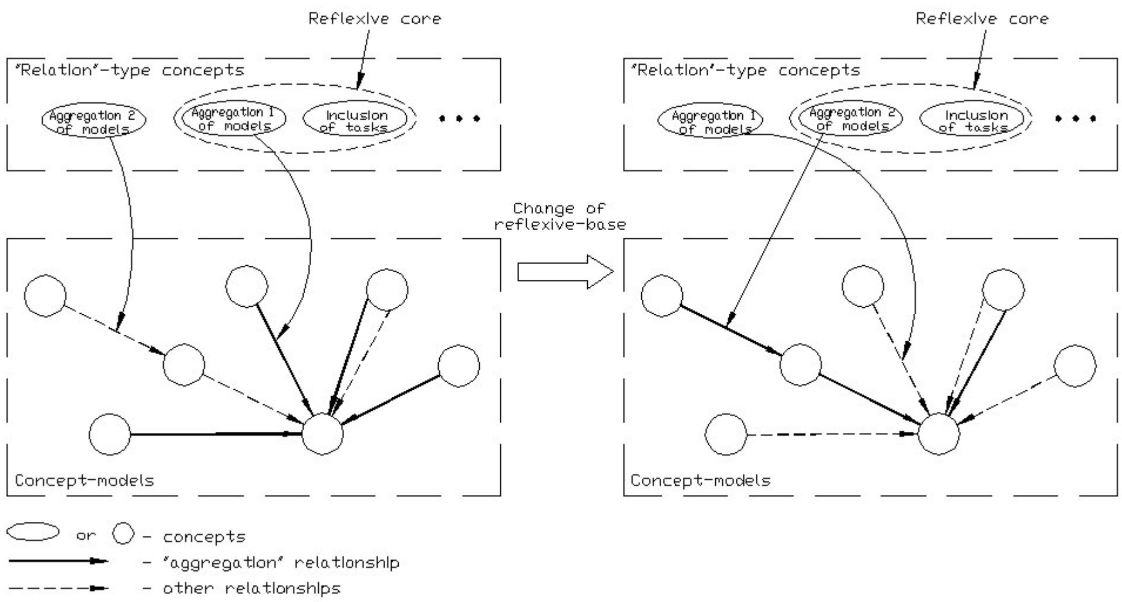

Figure 2. Reflection as a management tool of the structure of the model (tasks)

The OntoMath^{pro} ontology of the professional mathematics

The system of ontological models of the "OntoIntegrator" system contains different ontologies, including applied ontology relating to different subject domains. Replenishment of the applied ontology can be done through the development of the new ontologies by the means of the system and by the conversion of the public ontologies in OWL, XML/RDF formats. In recent years, the authors of the article together with the fellow mathematicians from Kazan Federal University participated in the development of the ontology of professional mathematics OntoMath^{pro}, used in experiments for the classification of mathematical texts, described in section 4.

The main objective of the OntoMath^{pro} ontology is to provide an informative terminological resource for the automatized processing of the electronic professional mathematical publications in Russian language. The OntoMath^{pro} ontology contains definitions of generally accepted mathematical concepts as well as evolving terminology, mainly in the following areas of mathematics: the theory of numbers, the theory of sets, algebra, geometry, mathematical logic, discrete mathematics, the theory of algorithms, mathematical analysis, differential equations, numerical techniques, the theory of probability and mathematical statistics.

The above-mentioned classic and applied mathematical sections are selected as basic from the positions of the traditional mathematics teaching, and on the basis of requirements of word-processing tasks from the collection of mathematical scientific publications of the journal "The Proceedings of higher education institutions Mathematics".

The sources for determination of the concepts of the semantics for the OntoMath^{pro} were: classical textbooks of the relevant sections of mathematics, electronic resources such as Wikipedia and Cambridge Mathematical Thesaurus, scientific articles from the journal "The Proceedings of higher education institutions Mathematics", and also the professional knowledge of the ontology developers. As OntoMath^{pro} representation languages were chosen OWL-DL/RDFS languages, which are high logical expressive means and algorithmically solvable not only theoretically but practically with the help of such tools of the logic output, as Pellet and Fact++. Let us note the principles of modeling, adopted in OntoMath^{pro} ontology. Regarding “subclass – class” they distinguish two hierarchies in OntoMath^{pro}: hierarchy of the sections of mathematics and the hierarchy of the elements of the mathematical knowledge. The first hierarchy presents taxonomy of the main sections of mathematics. The most fundamental sections are geometry and analysis are developed in more detail, for example, they highlight such sections of geometry as analytical geometry, differential geometry, fractal geometry and others, as well as sections of the analysis that is functional analysis and complex analysis.

The top level of the hierarchy of the elements of the mathematical knowledge is represented by three types of classes: i) basic mathematical concepts (for example, set, operator, function, tensor); ii) root elements of the relevant sections of mathematics (for example, an element of the mathematical analysis theory, the element of the theory of numbers); iii) general scientific notions (for example, theorem, task, method, formula, statement). It is acceptable for a class to be in different hierarchies (the mechanism of a multiple inheritance is supported). For example, the class of “Chernov's Theorem” is a subclass of the “Theorem” class and is a subclass of “An element of the theory of differential equations” class.

Fragment of the hierarchy of the OntoMath^{pro} ontology is in Figure 3.

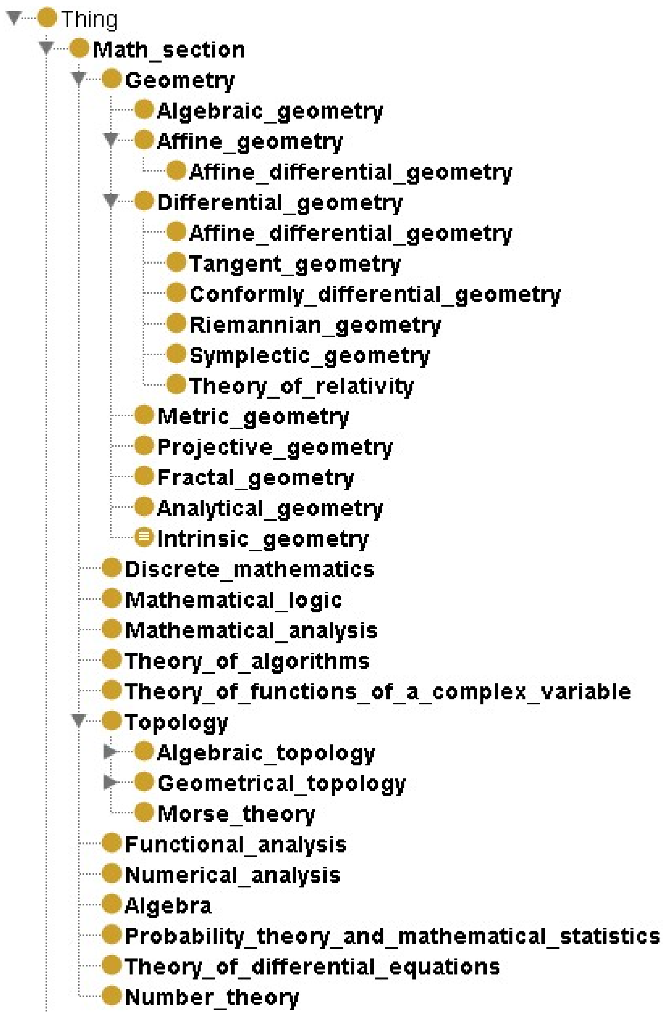

Figure 3. The hierarchy of the sections of mathematics in OntoMath^{pro} ontology

In the OntoMath^{pro} ontology there are defined four types of relations between classes:

- "The subclass - the class" relations (or 'ISA relations");
- Directed object relation of ownership between an element of the mathematical knowledge and the mathematic section;
- Directed object relation of the logical dependency between the elements of the mathematical knowledge, i.e. when one term participates in at least one of the options of another term definition;
- Symmetric object relation of associativity, i.e. it is used when the terms are logically related to each other, but one cannot clearly establish the direction of logical dependency.

The ontology is executed in the popular language OWL-DL of ontology and is available in the file form in a standard RDF/XML format, so it can be used by various modern means of work with ontologies, such as the Protégé editor and Jena software library.

Experiments with the mathematical texts

For experiments on simulation of the mechanism of the attention switch on the basis of the reflexive mechanisms of the "OntoIntegrator" system there was selected a task of the mathematical texts classification based on the mathematical ontology system related to various sections of mathematics. The system of mathematical ontologies was built on the basis of the OntoMath^{pro} ontology of professional mathematics and it included ontologies related to sections of the differential equations, numerical analysis, algebra, the probability theory and mathematical statistics. In the experiments following below, we treat (conditional) mathematical terms as multivalued that relate simultaneously to different mathematical ontologies.

This method of reasoning may be transferred in the same manner to the situation of a real multivaluedness with the same formulation of the classification task.

The article offers a spectral-ontological method of analysis of texts, containing multiple terms, based on the technology of the ontological marking in order to switch automatically the focus of the "Ontointegrator" system on the basis of the reflexive mechanism. Under the ontological range of the text it is understood the distribution of the number of ontological inputs into the text relating to different ontologies, according to its sentences (and/or paragraphs, sections). An example of ontological text spectrum of the lecture courses on differential equations of the 1st order is shown in Figure 4 [Russian University of Chemical Technology (RCTU), 2014]. Our attention is drawn to more dense distribution of the conceptual terms, relating to the problematic area of the lecture, in the beginning of the text for the courses.

In the "Ontointegrator" system there are two possibilities of ontological text processing with the multivalued terms usage:

1) "Simultaneous" ontological marking of the text with the help of several applied ontologies (external from the user and internal in-built), with multiple concepts in unambiguous interpretation;
2) Switch of the aggregation relation underlying the structuring of the applied ontology with the help of reflexive mechanism that allows one to choose specific interpretation of the multivalued concept in the ontology containing its multivalued interpretation.

In order to execute the first way, the system provides a mechanism to include the external applicable ontologies into the process of ontological marking by adding them into the special list (see Figure 5).

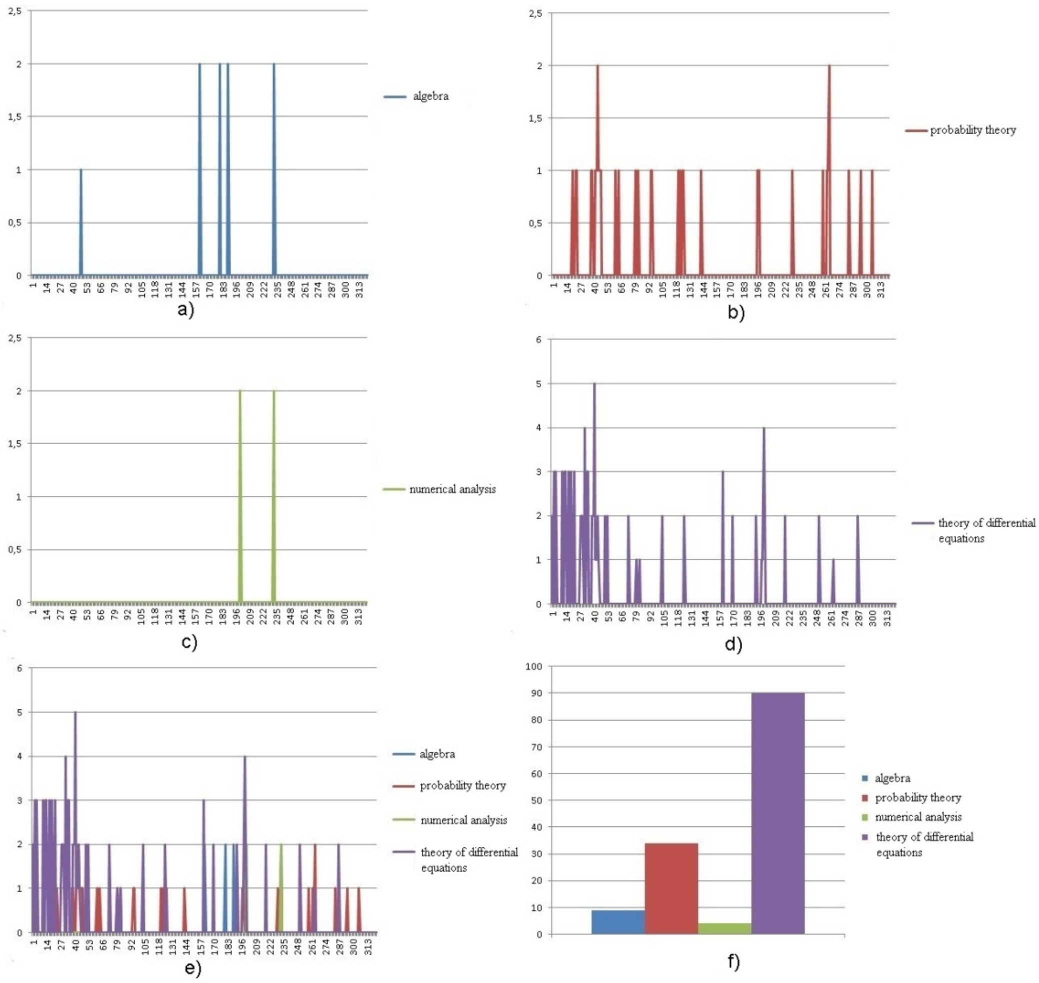

Figure 4. Example of the ontological text spectrum - On the x-axis there is a number of a sentence and on the y-axis is the number of objects of text that are marked by the ontological inputs: a) for ontology "Elements of the theory of algebras"; b) for the ontology “Elements of the probability theory and mathematical statistics"; c) for the ontology "Elements of the numerical analysis theory"; d) for the ontology "The differential equations theory"; e) the combined ontological spectrum for 4 ontologies; f) a histogram of the total number of the marked text objects for each ontology.

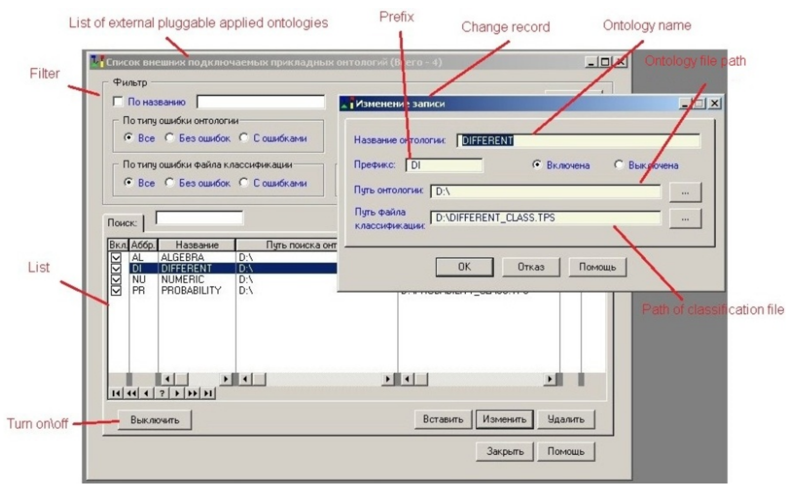

Figure 5. Connection of the external applied ontologies to the process of ontological marking

In the list there are: the place of localization of the connected ontology as well as its classification file corresponding to the current ontology of the models; the mode of ontology usage in the ontological marking: enabled or disabled. Besides, there is an option in the analyzer settings of text to change the global configuration of the ontological marking mode (see Figure 6). These settings determine which ontologies will be used in the process of the ontological text marking.

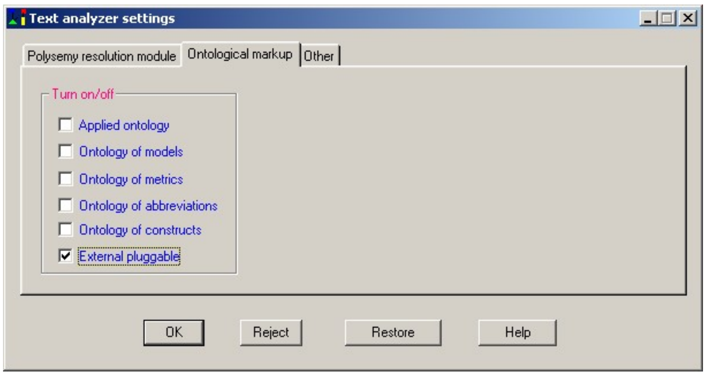

Figure 6. Setting of the ontological marking mode in the text analyzer

The second method is based on reflexive mechanism described in [Nevzorova et. al., 2013].

The ontology of the models of the system of ontologies is constructed as a three-level system of concepts, in which the concepts of the upper level determine the type of the concepts of the lower level (see Figure 7). The type of concept is connected with the model of interpretation and software support for processing of the text. Executive core of the "Ontointegrator" system is the “Processor” module that allows to choose any four concepts of the 2nd level, which are interpreted as a "property", "relation", "link" and "execution", and two concept of the third level out of the group of the concepts of the "relation" type, which are interpreted as the relationship of "aggregation of the models” in the ontology of models and "task integration" in the ontology of tasks planning.

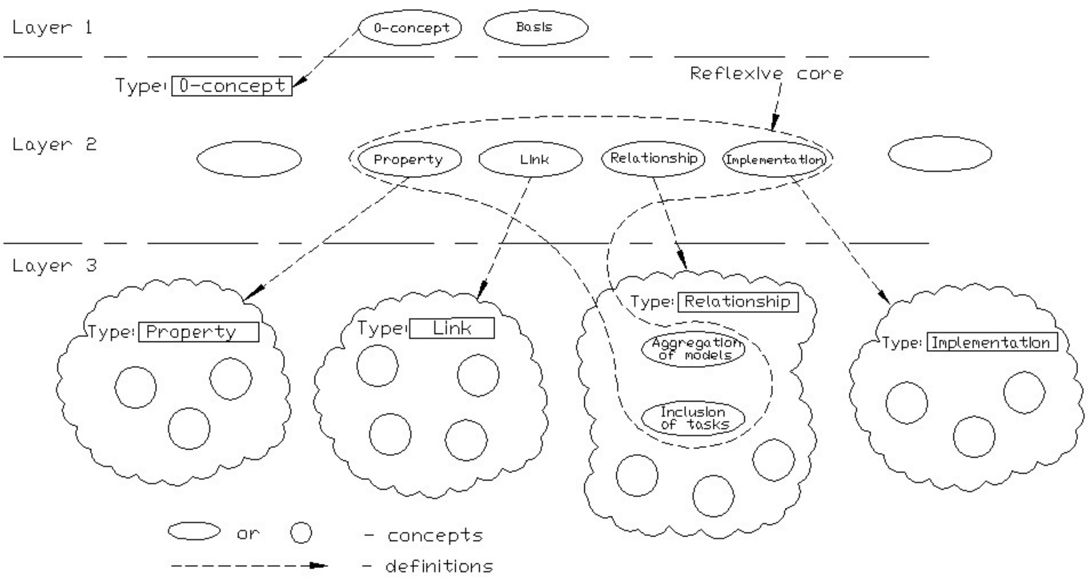

Figure 7. The three-level structure of the ontology of the models

Such a structure of the ontology of the models allows executing the mechanism of reflection by the dynamic substitution of some concepts of the reflexive core by the other during the text processing. In particular, the usage of some relations of the "aggregation of the models" (which can be given a typical for the problem domain names, for example, "algebraic interpretation") allows one to build an ontology, containing multivalued concepts with multivalued interpretation (see Figure 8).

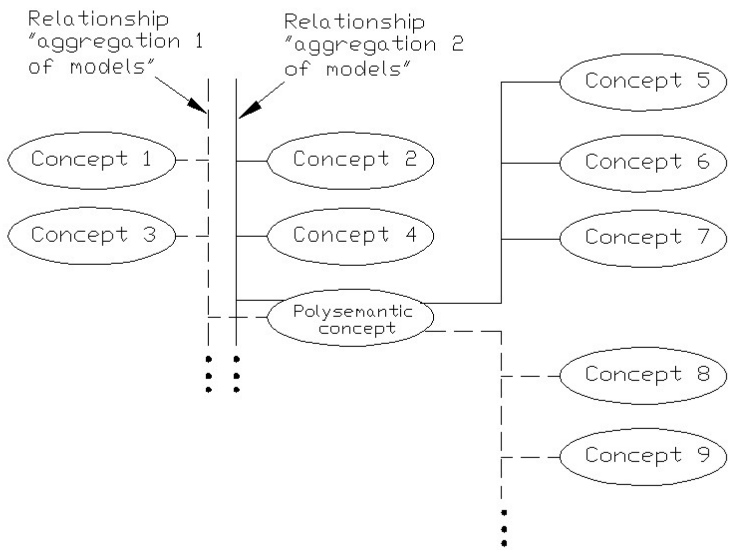

Figure 8. The structure of the ontology, containing multivalued concepts with a multivalued interpretation

Thus, the "Ontointegrator" system, equipped with the mechanisms of analysis and selection of the current text interpretation during its processing can automatically switch the "focus of attention" by a simple replacement in the dynamic mode, in the reflexive core one concept “an aggregation relation of a model N" with another concept of "an aggregation relation of a model M".

In this work there was made an attempts to use for these purposes the ontological range of the text received and analyzed during the process of its processing. For these experiments in the developed OntoMath^{pro} mathematical ontology, containing currently 3178 concepts, 4121 text equivalents (inputs) in the linguistic shell as well as 4321 links on the properties and relations, there were set aside into the independent ontologies four sub-ontologies related to various sections of the mathematical knowledge: "elements of the theory of algebras", "elements of the probability theory and mathematical statistics", "elements of numerical analysis theory" and "elements of the theory of differential equations" (the parameters of the specified ontologies are shown in Table 1).

Table 1

Ontology name	Number of concepts	
	Total	Unambiguous
Elements of the theory of algebras	222	221
Elements of the probability theory and of mathematical statistics	557	548
Elements of numerical analysis theory	469	461
Elements of the theory of differential equations	369	357

The texts for the experiments were taken from the collection of the mathematical articles in XML format [Nevzorova et al., 2013] and were downloaded from the Internet sites of the higher educational institutions. The text processing procedure included ontological marking and building of the ontological spectrum of text similar to figure 4.

The carried out experiments demonstrated stable operation of the reflection mechanism designed in the “Ontointegrator” system as a way of managing of the model structure. Primary analysis of the experimental results showed that the ontological spectra of the analyzed texts even on the basis of four used ontologies are individual (i.e. unique) in the framework of the considered problem area. Various typical sections of articles and lecture courses have a specific structure of the ontological spectra.

It can be assumed that the switching mechanism of the "focus of attention" can be based on the parametric analysis of the ontological spectrum of the current paragraph, and the spectral-ontological method itself can be used in various tasks of the analysis and the processed text classification. It should be noted that the spectral-ontological method of text analysis requires a more formal study and further development.

The usage of the reflexive mechanism of the "Ontointegrator" system allows carrying out the analysis of the text by the adequate to its content interpretations of multivalued concepts by simple replacement in the dynamic mode relations of the "aggregation models” that underlie the building of the ontologies with different interpretation of the multivalued concepts.

Conclusion

In the article was considered the approach to modeling of the cognitive ability to manage the focus of attention in text processing, which is based on reflexive mechanisms developed in the “OntoIntegrator” system. The process is carried out by a multi-level system of ontologies, including different types of ontologies: the applied ontologies, the ontology of models and ontology of tasks planning. An important component of the ontological system is a component of the ontology of models that is «the reflexive core”, which allows simulating in the system the capacity to reflect.

In order to switch automatically the focus of the "Ontointegrator" system on the basis of reflexive mechanism there was suggested a spectral-ontological method of texts analysis, containing multiple terms, based on the technology of ontological marking. The carried out experiments showed the stable work of the reflexive mechanism. The conclusion is drawn that the parametric analysis of the ontological spectrum of text can be used for switching of the focus of attention, and for solving of the problems of analysis and classification of the processed texts.

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