Automated knowledge monitoring with intellectual handling of the students' answers in a natural language

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Abstract. A framework for design and developing the intelligent system of knowledge monitoring and evaluation using an answer in a natural language is suggested in the article. Using the conventional tests involves the answer selection based on a dual logic, only in case of the strictly formal questions asked. This results in quite simple questions. But acquiring knowledge includes not only (and not so much) remembering a priori true facts, but also the ability to understand the common phenomena and trends. The open test tasks (without any given answer) are more effective for managing the knowledge. Hence, we have presented an approach to analysing the ontology-based text for automatic evaluation of the students' answers in a natural language (the Kazakh language).

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1. Introduction

One of the important tasks of the continuing education system is to ensure the conformity of the education quality with the international standards. In the field of education there is a search for the new content and forms, such as e-learning, distance learning, a credit technology, rating monitoring of knowledge. All of these forms of learning are based on the preference use of the test procedure. In addition, the essential trend in implementing the task of improving the current education system is to improve the fairness of the students' knowledge assessment by reasoning and developing the effective procedures of assessing the test results. Hence, a framework for design and developing the intelligent system of knowledge monitoring and evaluation in a natural language is suggested in the article.

Training is carried out within an integrated system, which combines the tools for creating the electronic education materials, the knowledge monitoring subsystems and the subsystems for supporting the training process. The research analysis of the issue shows the trend in the extended use of tests as a tool for assessing the quality of the studied material [1]. The main advantage of the computer tests is the possibility to ask all the students questions under the equal conditions and in accordance with a scale of the equal ratings. This increases the fairness of knowledge monitoring, as compared with the traditional methods.

Currently, there are many testing systems in various fields of knowledge, for example OLAT [2], Moodle [3], Sakai [4] and AuthorWare [5]. Most of these tools provide the ability to create multimedia tests, testing for traditional learning and e-learning, saving and transfer of results to the teacher for administration of users and educational groups.

Moreover, in the world there are organizations involved in the test preparation and execution, such as ETS (Educational Testing Service) - a private, non-profit organization [6], established in the USA in 1947. It develops, prepares and annually centrally manages several million tests (the achievement and admission ones) in more than 180 world countries. During the change-over to the computer-based testing, ETS conducts numerous researches and experiments, prepares the information materials for the testees, parents, teachers, managers, while explaining the benefits from the new technology implementation, distributes the training and demonstration programs (ETS Computer-Based Testing Demo, ETS Next Frontier, One-on-One with SAT, PowerPrep, TOEFL Semple, AccuPlacer).

The similar student services are provided by the AST Corporation [7] - an independent, non-profit organization, founded in 1959 at the University of Iowa for supporting the program of testing the American college applicants (American College testing Program). Nowadays it serves the customers all over the world and supports more than 100 different test programs.

The world's largest network of more than 10,000 computer-based test centres in 160 world countries is held by Sylvan Prometric [8] - a division of the Sylvan Learning System Corporation, which specializes in the computer tests.

Subject to as aforesaid, in this article we propose the use of the artificial intelligence methods and tools, in particular, the ontological engineering in order to compensate for the lack of the knowledge assessment.

For texts of the geometric tasks solution ontological descriptions of the situations presented as a result of the transformation and evaluation of the concept's structures. It is shown that the use of ontology-based text mining can open the "anatomy" of the correct answer preparation that can be used in the analysis of a student's answer and the search for precisely that moment, which caused difficulties in their reasoning.

Results of research can be used at creation of intellectual testing systems on the base processing of the Kazakh language. The proposed concept testing system enables the use of intellectual evaluation results of the user level and provides a set of tests, tailored to the level of preparation of the test. The system distributes the issues in terms of complexity, based on data obtained during testing. This enables the construction of adaptive tests, which are self-correcting to the level of users.

2. Systems of the automated knowledge assessment

For many countries the e-learning theory emphasizes the importance of the specified cognitive process and personalized learning [9]. Knowledge monitoring and evaluation is an intellectual challenge, requiring the high-quality solutions, which will help to get to a new level in the teaching procedure, as it could allow implementing the concept of the individual approach to learning on a massive scale. Nowadays the automated knowledge test has become very popular, firstly, as it saves the teacher's working hours, relieves him from the routine work and ensures an objective evaluation of knowledge, the results of which do not depend on the subjective opinions of different teachers.

In [10] the newly developed computerized constructive multiple-choice testing system is introduced. The system combines short answer (SA) and multiple-choice (MC) formats by asking examinees to respond to the same question twice, first in the SA format, and then in the MC format.

The authors of [11] have developed the software tool that allows to prepare test questions and conduct testing using any of the suggested types of questions below. Description of this software tool and the intellectual algorithms for evaluation of knowledge is presented in the previous paper of the authors [12].

The papers [13, 14] describe methods of implementation of a control mechanism of student knowledge with the help of fuzzy set theory combined with neural network technology. The papers apply some serious improvements in the logic of evaluation of knowledge, and methodologies of data interpretation of student responses. The presented architecture is typical of the configuration of hardware and software in an intranet environment of educational institutions.

Analysis of the aforementioned work shows that ordinary linear tests with simple forms of the answer do not quite meet the requirements of comprehensive control of students' knowledge. Most of all it concerns natural and mathematical sciences, a feature which is the close relationship of concepts, themes and sections of the course, as the main criterion for learning - the ability to solve tasks of different nature and level of complexity. Therefore development of the adaptive, nonlinear, and intellectual testing methods with more different types of tasks and answers' forms are needed. At the same time, new testing systems should incorporate all the achievements of previous generations of the knowledge control tools.

2.1.Ontologies

In order to build ontology of Geometry, it is beneficial to understand the need of ontology and some works concerned of the ontology-based text mining.

Ontology is an explicit formal specification of the terms in explicit specification the domain and relations among them [15]. Ontologies are useful as means to support sharing and reutilization of knowledge [16]. This reusability approach is based on the assumption that if a modeling scheme, i.e., ontology, is explicitly specified and mutually agreed upon by the parties involved, and then it is possible to share, reutilize and extend knowledge. Many disciplines now develop standardized ontologies that domain experts can use to share and annotate information in their fields. Problem-solving methods, domain-independent applications, and software agents use ontologies and knowledge bases built on ontologies as data [17].

Reusing existing ontologies may be a requirement if our system needs to interact with other applications that have already committed to particular ontologies or controlled vocabularies [17]. There are libraries of reusable ontologies on the Web and in the literature, for example, the Ontolingua ontology library [18], or the DAML ontology library [19].

The need of ontologies is connected with the inability of the existing methods to adequately automatically process native-language texts. For high-quality word processing, you must have a detailed description of the problem area with a lot of logical links that show the relationships between the terms field. The use of ontologies can provide a native language text in such a way that when it becomes available-for-automatic processing [20].

Within the OSTIS project (The Open Semantic Technologies for Designing the Intelligent Systems) the "Variational Geometric Solver" help system has been generated. On the basis of the Geometry domain ontology. The system operation is organized so, as to answer the questions asked by a user and to give him answers to the questions, as well as to complete the geometric tasks. In the work "The Semantic Technology for the Component Design of the Intelligent Task Solvers" the authors [21] have presented the features of the help system of the intelligent geometric solver.

In this paper we develop the Geometry ontology and this ontology is used as a basis for the automatic verification of geometric task solution. The authors of [22] have developed the similar ontology for automatic synthesis of structural images of the geometric figures.

3. Geometry ontology

An ontology is a formal explicit description of concepts in a domain of discourse (*classes* (sometimes called *concepts*)), properties of each concept describing various features and attributes of the concept (*slots* (sometimes called *roles* or *properties*)), and restrictions on slots (facets (sometimes called *role restrictions*)) [17]. Ontology together with a set of individual instances of classes constitutes a knowledge base.

Development of ontology includes [17]:

– defining classes in the ontology,

– arranging the classes in a taxonomic (subclass– superclass) hierarchy,

– defining slots and describing allowed values for these slots,

– filling in the values for slots for instances.

Our ontology consists of the several levels. The first level contains the classes, which instances could not be received from the other classes. The Right Class Shape represents all the entities of the outline shapes. The Specific Right Shapes - are the instances of this class.

The front levels are generated by the reasoning process, i.e. using the ontology reasoning block or by various modules, opened by the Reasoning Manager. The higher the level is, the more detailed the information is, for example, on the third level a figure is classified as a two-dimensional one, and in turn, it is classified as a polygon, the polygon - as a convex polygon, the convex polygon - as a quadrilateral, the quadrilateral - as a parallelogram, the parallelogram - as a rectangle or a diamond, the rectangle or the diamond - as a square respectively (ref. Figure 1).

We arrange classes in a hierarchical taxonomy with a question if, when being an instance of one class, the entity is always (that is, by definition) an instance of another class. If the A class is a superclass of the B class, then every instance of the B class is also the instance of the A superclass.

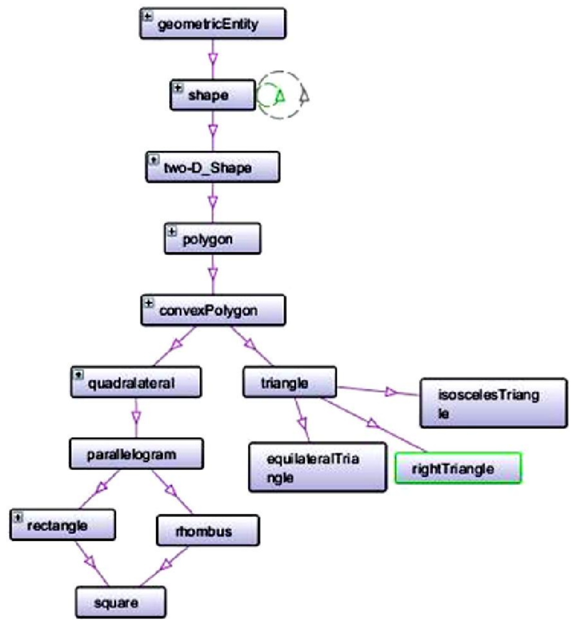

Fig. 1. Ontology fragment geometry

The ontology fragments, including the concept structures and properties are the basis for describing the situation, which is determined by the input data for completing the geometric tasks. The concepts and relationship are determined by the preconditions (a text of the geometric tasks) and introduced in addition to these ontology fragments.

4. A system of the students' knowledge monitoring based on analysing a text in a natural language

As compared with the traditional forms of learning, the distance learning has several advantages: adjustment to the students' individual peculiarities, a free choice of time, a place and an education level, the use of the new training methods, the modern means of communication and the information transmition between the students and teachers. Nevertheless, knowledge monitoring is particularly important due to the absence of the direct contact of students and professors.

Managing the knowledge monitoring is closely related to the issue of selecting the questions type, the method of generating the test path and the answer validation method.

For the purpose of solving these problems, we offer the concept of the intelligent test system based on the Geometry domain ontology.

The following types of questions for the knowledge quality supervision are suggested:

- the closed-ended test questions, i.e. when the multiple choice questions are suggested, and one of the answers to the question is right and should be chosen;
- the open-ended test questions, i.e. the questions without the proposed alternate answers (these questions are useful for evaluating the knowledge of terms, definitions, concepts, etc.);
- the situation tests, i.e. a set of the test tasks designed for solving the problematic situations (the geometric tasks).

A special method for selecting the mode of the test path is suggested, the test set is not generated by the random samples from the test database. The question selection is based on analysing the answers to the previous questions. This algorithm is based on the unique procedure of selecting the questions in accordance with the system, which corresponds to the current level of the students' knowledge [14].

One of the artificial intelligence methods for representing knowledge in a natural language is the semantic network. A semantic network – is an information model,of the domain, which is of the form of the directed graph, which nodes correspond to the domain entities, and the arcs (edges) set the relationship between them. Concepts, events, properties, processes could be the entities. Thus, the semantic networks are one of the ways to represent knowledge in a natural language. Over the last years in the works of many scientists the special graph-dynamic models - the semantic models of representing and processing the knowledge based on **the semantic networks** [23, 24, 25, 26, 27, 28] have been suggested to use as a formal framework for the designed intelligent systems, the abstract logical semantic models of the intelligent systems.

In his work [29] he suggested to generate the formal tools for describing the semantics of different knowledge types, as well as the formal tools for describing knowledge processing on the semantic level. A system of the intelligent evaluation of the students' knowledge in the case of the Geometry domain could be developed upon the proposed principles.

The text analysis in a natural language is suggested for analysing and examining the students' answers to the open-ended test questions. The knowledge description in the Geometry domain was presented as ontology [30].

Let's give a brief description of the proposed method of checking the geometric task solution based on the ontologies. The texts of the geometric task are a set of the coherent sentences. They include simple and complex sentences, incomplete sentences (with anaphora and ellipses). Formal understanding of a text of the geometric tasks is representing knowledge by them in the language in the Geometry domain ontology. This representation should be connected and extended by filling the slot value for the cases, which describe the situation presented by the text.

Reviewing the whole process of analysing the geometric tasks seems to be impossible in this article. Therefore, let us consider the structure of the situation, which should be resulted from the ontology based on the linguistic analysis for a geometric task.

The Task. A rectangular quadrilateral, which sides are 8 cm and 18 cm, is given. The areas of the rectangular quadrilateral and the square are equal. Find the square side.

The result:

The task solution procedure is presented in a natural language (the Kazakh language). Under the task conditions the quadrilateral sides are given, as well as the areas of the rectangular quadrilateral and the square are equal. Hence, let's find the rectangular quadrilateral area. I.e. when multiplying the quadrilateral sides we will find 8*18=144. When we know, that all the square sides are equal, then while extracting the square root of 144 we find the square side. The square side is 12.

In the test system the reference knowledge for the student's knowledge evaluation should be laid. The knowledge pattern is suggested by an expert (in this case, a teacher). The test system will assess the student's knowledge using the reference knowledge.

Knowledge pattern:

1) Task (question) handling:

1.1 Morphological Analysis: in order to find the task-related keywords in the Geometry domain ontology. In our case - it is a rectangular quadrangle, a side, a square, an area.

1.2 Syntactic Analysis: in order to determine which property belongs to which class. Loading equations from the database in order to complete the task. In order to draw up a list of the required variables and to assign the values selected from the task text while analysing the task.

1.3 Determining the number and sequence of the task solution levels (here a teacher could indicate the validity of the task solution procedure, which will be considered upon the student's knowledge evaluation in future).

The test will be organized and executed with a teacher in attendance in order to expand on and to improve the basic ontology on a particular issue (it includes introducing the equations, supplementary descriptions, etc.). The unhandled questions, on which the reference knowledge has not been generated, are not passes for the students' knowledge monitoring. All the handled questions and tasks should be stored in the knowledge base for the students' knowledge monitoring. This approach provides a qualitative selection of questions and its complexity level.

The mathematical equation markup language MathML is used for soluting the tasks in the intelligent system. The input and storage of the equations required for soluting the tasks will be carried out in the mathematical equation markup language MathML. In the intelligent system there is a support for editing, viewing and soluting the mathematical tasks in the mathematical equation markup language MathML. The generated universal mathematical equation editor MathML could be used for soluting the mathematical tasks, computing. The mathematical equation editor is represented in the Fig. 2.

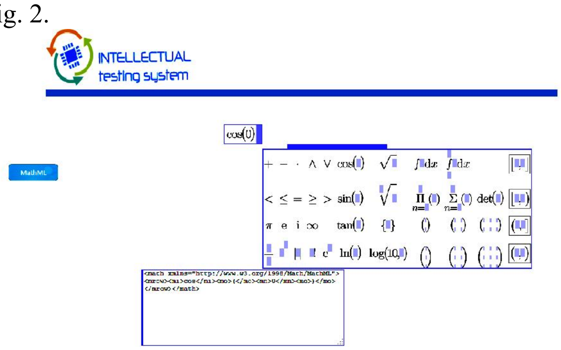

Fig. 2. Mathematical equation editor

2) Students' answer handling:

2.1 Morphological and Syntactic Analysis: in order to convert the student's answer given in a natural language to the mathematical language in the mathematical equation markup language (MathML).

2.2. in order to conduct an analyse on the level, the task solution procedure, specified upon the question introduction and to assess their implementation in the student's answer, as well as to evaluate each level of the solution procedure, specified by a teacher on its validity. In other words, a task is divided into subtasks. In order to assess the student's knowledge, not the answer. As it often occurs when using the closed-ended tests or the multiple choice tests.

In our view, the operation of the automated intelligent system of knowledge monitoring which has been designed in such a way will give the expected objective result of the students' knowledge evaluation.

5. Conclusions and succeeding activity

In this article we have presented an approach to analysing the ontology-based text for automatic evaluation of the students' answers in a natural language (the Kazakh language). Using the intelligent algorithms could also rapidly change the system of evaluation and the reference circuit, what significantly increases the test quality and rate. Our concept of the knowledge monitoring system uses the results of the intelligent assessment of the user's level and provides a set of the tasks adapted to the student's training level. The knowledge monitoring system distributes the questions based on the data obtained during the test by its complexity. This makes it possible to build the adaptive tests, which do not require the correction on the user level.

In future the required system of testing the intelligent evaluation of the students' knowledge will provide a prerequisite for the further application of the research results to develop an automated on-line test system, in order to organize and execute such outstanding events, as CNT (the common national testing) of school leavers and CTA (the complex testing of applicants), who enter the Kazakhstan universities.

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