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AN INTELLIGENT APPROACH TO ELECTRONIC TEST RESULTS EVALUATION*

Daniela Orozova, Veselina Jecheva

The present paper examines an approach to automated test units evaluation, based on preliminarily created ontologies. Each test element is described by metadata, according to LOM standard. The learners' results are evaluated by intelligent agents, using ontologies.

1. Introduction. Knowledge representation and reuse is among the key areas in the contemporary e-learning techniques. The purpose is to create and use digital libraries, which not only contain documents, but could be accessed by learners in a customized and personalized way. E-learning increases productivity in education in that it provides access to learning materials at any time and at any place. The Internet and the World Wide Web are part of everyday life of students and teachers at any level all over the world [12]. Incorporating semantic web techniques, namely ontologies, within e-learning systems has been accepted as a widely used and viable approach [13]. Ontologies have been applied as a method of knowledge representation, which combines data representation with relations and concepts, describing the specific domain. One of the most cited definition defines an ontology as an explicit specification of a conceptualization [8]. The purposes of ontology application in e-learning environments vary from simple terms and concepts representation to user personalization and customization in dynamic e-learning environments [3].

There are four basic different types of ontologies, according to the subject of the conceptualization, defined by Van Heijst et al. [15]: generic ontologies, domain ontologies, application ontologies and representation ontologies (meta-ontologies). For the purposes of the present research domain ontologies were examined as a knowledge description in the field of information security.

On the other hand, agent technologies have been broadly applied in the field of e-learning. They have various functions: virtual student advisors, assisting the learners to successfully organize and perform their studies [4]; to perform specific tasks on behalf of students, instructors, and other members of the educational community including parents and alumni [1]; to facilitate the location and customization of appropriate e-learning resources and to foster collaboration in e-learning environments [7]; to create animated characters with speaking abilities and many others.

There is a variety of e-learning systems, which contain modules for creation of tools for automatic monitoring and assessment of learners' progress. The most common elements

*Key words: electronic tests, test elements, ontology, software agent.

are tests, which may contain various types of questions: multiple choice, true-false, matching answers, crossword puzzles, etc. However, in many cases the tests, where the learner can only select the correct answer(s), do not allow the lecturer to evaluate the real level of learners' knowledge. The tests, described above, give the learners the opportunity to guess the correct answer, and even to cheat in some cases. These drawbacks can be avoided using the questions, which require answer, completely worked out by the learner. This answer may contain just a few words, one or two sentences and even a whole essay, that the learner should input to the system. Most systems require the lecturer to evaluate such tests manually; nevertheless, many have some abilities to evaluate short answers, given by the learner, for example alternate answers, regular expressions, etc. Unfortunately, manual tests evaluation is a difficult and time-consuming task for the lecturer and systems that adequately provide automated "open" questions evaluation are still to come. This problem can be solved by creation of tools, which can automatically evaluate the learners' answers to the tests, comparing them to a preliminarily created knowledge database in a specific domain.

The purpose of the present paper is to create an e-learning system, which automatically evaluates a short answer or an essay in a specific topic. The presented methodology is announced in a previous work [10]. The proposed approach consists of the following stages: the first one is to represent the knowledge data by OWL domain ontology [11], and the second one is the agent-based system, which accesses the ontology and evaluates the user input.

2. Description of the methodology.

2.1. The ontology. The presented methodology uses a domain ontology, which describes the organization of theoretical concepts and notions in a specific field, namely information security. There are four different OWL-ontologies, described in [9]: main security ontology, security views ontology, source code analysis ontology and memory protection ontology. The first one was examined for the purposes of the class "Information security" for the Computer science bachelor program in Burgas Free University. This ontology models the major concepts: assets, threats, vulnerabilities, countermeasures and their relations. It contains 88 threat classes, 79 asset classes, 133 countermeasure classes and 34 relations between them. Each term has one or more text descriptions; one or more categories it belongs to, referred to as superclasses; one or more equivalent classes, if any; and the relations with other classes, defined as ontology properties. In the present paper we draw attention to the logical structure of the ontology, as well as the text definitions of the terms.

2.2. Test units representation. As the purpose of the work is to increase the automated test assessment ability, using ontology-based approach, the system should contain a database with test units. In addition, the database should contain data, describing the test units, which is used during the students' answers evaluation. LOM (Learning Object Metadata) [5] is the basic standard for metadata of learning objects. According to this standard, the metadata are 58 in number and grouped into 9 different groups. Each group contains specific number of fields, which describe the groups in detail. The purpose of the metadata is to describe the corresponding learning unit content and the relationships among the units. For that reason they can serve the purpose of units search and exchange.

The examined test units are described by metadata, which contain keywords, applied

for learners' answers evaluation, using specific search query results from the ontology. Except the keywords, each test unit can be in possession of metadata, which describe its difficulty, domain, average time, necessary for its solving, etc. These metadata could be used for flexible evaluation of the test unit.

The test unit metadata could be defined in the following way:

Test_ element([*test_ element_ id:* <*test element number*>,
key_ words: <*keywords list*>,. . .]).

2.3. Basic elements of the solution realization. The major stage of the proposed methodology is the test evaluation itself. The system input is the learner's answer to the "open" test question, which is created by the student themselves. It may contain one or more sentences, some terms enumerated, or an essay. The system input contains metadata, describing the expected answer, except the user input. Then the system creates SPARQL queries with the metadata as their arguments to the ontology, which contains the domain knowledge. The results contain the relations and concepts, related to the question keywords. This search could be optimized by maintaining a temporal cache, containing the results, generated during the search of the last k test units in the knowledge database. Then, the system should perform an initial search in the cache if there exists a previously generated result for the specific unit. If so, this result should be used for a comparison with the learner's answer, otherwise the ontology should be searched with a SPARQL query.

The proposed system is based on software agents. The 'software agent' is a software package that supports the programming tasks of other objects autonomously, without the direct intervention of their author. Its major characteristics are defined: autonomy, reactivity, and communication abilities. Autonomy is expressed in the agent's ability to fully control its actions and state, without external software control. Reactivity is related to sending and obtaining information from the outer environment and appropriately reacting in response. All software agents are able to communicate with the other components in the system (users, other software agents, or objects), providing them with decision making information.

Students discuss the agent's mobility according to the need of visiting different Internet addresses makes mobility an especially significant feature of the software agents. The feature intelligence has been introduced. Intelligence is the characteristic needed for the agents' decision making and independence in interacting with users and/or other agents in the environment. In Fig. 1 we propose a scheme of the concrete realization of the system for e-learning evaluation, using Java-agents.

The application's main interface creates a BasicAgent, which communicates with the other agents. The information about keywords linked with test element is handled as a parameter in the newly created mobile agent that is sent to the servers. On every server, the mobile agent creates a ServerAgent which receives the search information, while the mobile agent continues its way to the successive server. This initialization happens only for the first search. For each subsequent search the mobile agent relies on the already established ServerAgent to activate the search with new parameters (keywords).

Correspondingly, the ServerAgents retrieve all the relevant information and dispatch it to the BasicAgent that filtrates data and generates evaluation on test element. When the consumer stop working with the program, then it takes care to remove all agents,

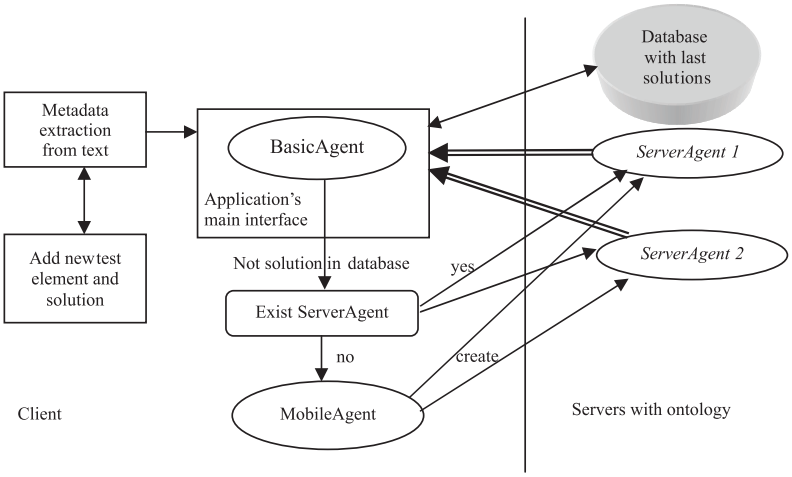

Fig. 1. Scheme of the proposed realization of the system for e-learning tests evaluation

including the ServerAgents on servers.

The system scans the learner's answer and performs a search of each sequence of n words in the ontology. The experiments were conducted with the values of $n = 1$ and $n = 2$. With purpose of comparing the learner's answer with the results, obtained from the ontology, the q-gram metrics [6] was applied.

A q-gram metrics is a character-based n-gram measure, which calculates the degree of similarity between two strings. Each q-gram is a short substring of length q of the ontology concepts and relations. The intuition behind the use of q-grams as a foundation for approximate string processing is that when two strings are within a small edit distance of each other, then they share a large number of q-grams in common [14].

The q-gram metric could be described as follows: let $\sum$ be a finite alphabet, and let $\sum^*$ be the set of all strings over $\sum$ and $\sum q$ be the set of all strings of length q over $\sum$ for $q = 1, 2, \ldots$. A q-gram is any string $v = a_1 a_2 \ldots a_q$ in $\sum q$.

The q-gram distance between two strings x and y is defined in the following way:

$$D_q(x, y) = \sum_{v \in \sum q} |G(x)[v] - G(y)[v]|, \tag{1}$$

where $G(x)[v]$ denotes the total number of the occurrences of v in x.

The proposed approach calculates the degree of closeness of the concepts and relations, retrieved from the ontology, to the preliminarily defined keywords and the data, retrieved from the learner's answer. Finally, an average score is calculated, measuring the overall similarity of the answer to the knowledge database.

3. Results. The described methodology was applied with a purpose to evaluate the students' progress in the elective course "Information security" for the students of the

Computer science bachelor program in Burgas Free University. The obtained results reveal that the proposed methodology evaluated the students' answers with 80.76% accuracy when $n = 1$ and 84.61% accuracy for $n = 2$. The number of students in the class was 26, and for 21 and 22 of them, respectively for $n = 1$ and $n = 2$, the evaluation was correct and showed no significant deviation from the manual evaluation, performed by the lecturer. This approach should be developed and improved further in order to achieve better evaluation accuracy.

4. Conclusion and future work. Various methods for comparison of the student's answer to the knowledge, represented in the ontology, could be applied and the obtained results could be compared to those, achieved by the methodology described above. As a result, an automated or semi-automated tool for students' answers evaluation will be obtained which reduces the lecturer's time and efforts and decreases the possibilities of any partiality in the students' results evaluation.

The electronic and Web-based assessments are novel types of learners' result evaluation, which can give an account of the learners' individual progress. They hold out some possibilities of automated result calculation, as well as data storage and analysis. The young people's interest to the new technologies, their curiosity and communication abilities could successfully be used in the process of their education.

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Daniela L. Orozova
Veselina G. Jecheva
Faculty for Computer Science and Engineering
Burgas Free University
62, San Stefano Str.
8001 Burgas, Bulgaria
e-mail: orozova@bfu.bg
e-mail: vessi@bfu.bg

ЕДИН ИНТЕЛИГЕНТЕН ПОДХОД ЗА ОЦЕНЯВАНЕ НА РЕЗУЛТАТИТЕ ОТ ЕЛЕКТРОННИ ТЕСТОВЕ

Даниела А. Орозова, Веселина Г. Жечева

Представен е подход за автоматично оценяване на тестови единици на базата на предварително съставени онтологии. С всеки тестов елемент са свързани метаданни в съответствие със стандарта LOM. Резултатите на обучаемите се оценяват от интелигентни агенти, използвайки онтологии.