Architecture and Working Principles of the Concept Map Based Knowledge Assessment System

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Abstract

The paper describes the concept map based knowledge assessment demonstrating its main functionality on the basis of screenshots and presenting the three-tier client-server architecture of the system in terms of components, their functions and interaction. Underlying conceptions and current development directions related to the implementation of learner's supports are discussed as well.

Keywords: Concept map, Assessment system, Learner's support

1. Introduction

Rapid development of information and communication technologies has led to the appearance of a new generation of young people who cannot imagine their life without the use of computers. The computer serves not only as an instrument of acquisition of necessary information or as an environment for communication and entertainment, but also as a tool for learning. This is a reason why the great part of educational institutions all over the world introduce different information and communication technologies, such as e-learning environments, videoconferences, intelligent tutoring systems, etc., in the process of teaching and learning.

The Department of Systems Theory and Design of the Faculty of Computer Science and Information Technology of Riga Technical University has been developing the concept map based knowledge assessment system since the year 2005. The system has twofold goals in the context of the integration of technology into the traditional educational process: 1) to promote learners' knowledge self-assessment, and 2) to support the teacher in the improvement of the learning course through systematic assessment of learners' knowledge and analysis of its results. The goals are reached by the use of concept maps as an assessment tool. At the moment the system has reached the certain level of maturity concerning its architecture and working principles which are presented in this paper.

The paper is organized as follows. Section 2 gives an overview of the system. The architecture of the system presenting its main components and technologies is described in Section 3. Section 4 demonstrates an example of the system's operation by means of

screenshots. The current development directions related to the implementation of learner's support are discussed in Section 5. The paper ends with Conclusions.

2. Overview of the System

As it was mentioned in Introduction concept maps are used as an assessment tool in the developed system. According to (Cañas, 2003) they can foster the learning of well-integrated structural knowledge as opposed to the memorization of fragmentary, unintegrated facts and externalize the conceptual knowledge (both correct and erroneous) that learners hold in a knowledge domain. Concept maps are a kind of mental models based on a graph with labeled nodes corresponding to concepts in a problem domain and with arcs indicating relationships between pairs of concepts. Arcs can be directed or undirected and with or without linking phrases on them. A linking phrase specifies the kind of a relationship between concepts. A semantic unit of a concept map is a proposition. Propositions are concept-link-concept triples which are meaningful statements about some object or event in the problem domain (Cañas, 2003). Concept map based tasks can be divided in 1) "fill-in" tasks, where the structure of the concept map is given to the learner and he/she must fill it using the provided set of concepts and/or linking phrases, and 2) "construct-a-map" tasks, where the learner must decide on the structure of the concept map and its content by him/herself.

In the context of the developed system both mentioned types of tasks are provided. Two kinds of relationships are used: 1) important relationships which show that relationships between the corresponding concepts are considered as important knowledge in the learning course, and 2) less important relationships which specify desirable knowledge. Arcs are directed and linking phrases are provided on them depending on the degree of task difficulty. Concepts are divided in 1) initial concepts which serve as a starting point for the learner in the filling or creation of the concept map, and 2) concepts, which the learner must insert or relate by him/herself.

The system is used in the following way. The teacher defines stages of knowledge assessment and creates concept maps for all of them. The process of the creation of a concept map consists from the specification of relevant concepts and relationships among them. Moreover, the concept map for each stage is nothing else then an extension of the previous one because new concepts and relationships are added at each stage. Thus, the concept map of the last stage includes all concepts and relationships among them. Teacher's created concept maps serve as a standard against which the learners' concept maps are compared. During knowledge assessment the learner solves a concept-map based task corresponding to the assessment stage. After the learner has submitted his/her solution, the system compares the concept maps of the learner and the teacher, calculates the score of the learner's result, gathers statistical information and generates feedback which is delivered back to the learner.

The system offers five concept-map based tasks, which are ranged from the easiest to the most difficult (Table 1) taking into account information given to the learner and workload needed to complete the task (Anohina et al., 2007). Eight transitions between

tasks are implemented allowing the learner to find a task which is the most suitable for his/her knowledge level. Four transitions increase the degree of task difficulty. They are carried out after the analysis of the learner's solution, taking into account whether the learner has reached the teacher's specified number of points in the current assessment stage without reducing the degree of difficulty of the original task. So, this is a system's adaptive reaction to the learner's behavior. Other four transitions reduce the degree of task difficulty and they are carried out by the voluntary request from the learner during the solving of the task.

Table 1

Tasks Offered in the Concept Map Based Knowledge Assessment System

The type of the task	The degree of task difficulty		The structure of a concept map	Linking phrases	Concepts
Fill-in	1	The easiest	Is given	Inserted into the structure	Must be inserted by the learner
	2		Is given	Not used	Must be inserted by the learner
	3		Is given	Must be inserted by the learner	Must be inserted by the learner
Construct-a- map	4		Not given	Not used	Must be related by the learner
	5	The most difficult	Not given	Must be inserted by the learner	Must be related by the learner

An algorithm has been developed for the comparison of learner's and teacher's concept maps (Anohina et al., 2007). It is not based only on the isomorphism of both graphs, but is sensitive to the arrangement and coherence of concepts taking into account such aspects as existence of a relationship, locations of both concepts, type and direction of a relationship, correctness of a linking phrase, etc.

Thus, the system supports knowledge self-assessment as it makes an analysis and evaluation of learners' concept maps, as well as provides feedback about the learner's errors. It promotes systematic knowledge assessment because it allows the extension of the initially created concept map for other assessment stages. Moreover, statistical information about differences between learners' concept maps and teacher's concept map is collected providing opportunities for the teacher to improve the learning course.

3. Architecture of the System

The system is implemented as a Web-based application which has three-tier client-server architecture (Lukashenko et al., 2008). It has the following architectural layers (Figure 1): 1) a data storage layer, which is represented by Data Base Management System (DBMS); 2) an application logics layer, which is composed of two parts: the application server and the server side code running on it; a special persistence and query framework is used to communicate with the DBMS; and 3) the representation layer or graphical user interface (GUI).

Logical principles of the system are based on the Model-View-Controller (MVC) pattern (eNode, 2002). The representation layer of the system is responsible not only for the displaying of data, which is the task of the View part, but also it acts as Model. View part consists of various GUI components (buttons, text input fields, combo boxes lists, etc.). View handles any events generated by the user, for instance, clicking on a button, and redirects it to Model, which is located in a separate logical piece. Model, in its turn, collects data from GUI controls and interacts with Controller (server) by sending and receiving data and remotely invoking server's services-methods, which signature is available on the client side. An action of Model depends on an event, which come from View. The representation layer is build using java open source graphical user interface library called swing. JGraph library is used for creation of concept maps. JGoodies library is included for building more complex GUI layouts.
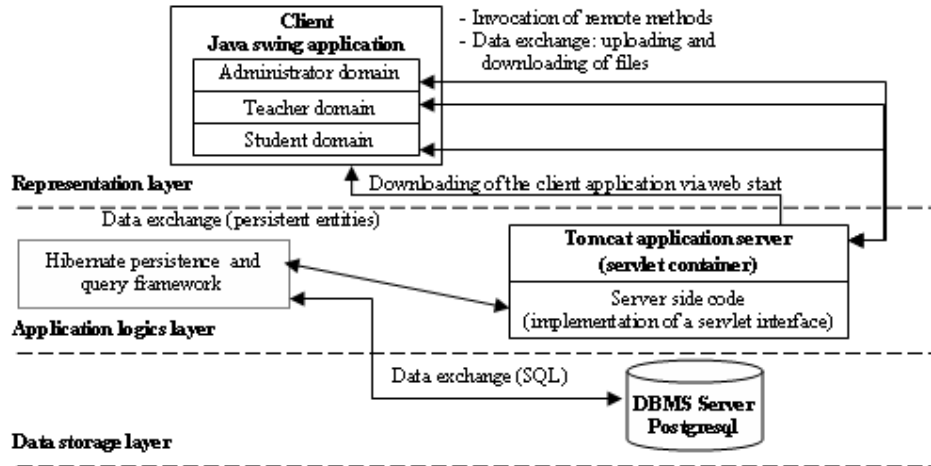

Figure 1. The Three-Tier Architecture of the System

The application logics layer is implemented as a controller for the entire application. Apache Tomcat is chosen as an application server. It is a container of servlets. A servlet is a Java interface, which could be launched by Web server. Servlets receive clients' requests and respond to them, usually across HyperText Transfer Protocol. There is a basic implementation of this interface (for example HttpServlet), but it can be extended by creating user's defined event handlers and data transformation for concrete business logic.

The application server receives remote calls from the client and redirects them to the appropriate servlet. The information about a servlet is included in the remote call. The servlet handles a call and launches the appropriate method needed for the communication with the database or for the execution of business logic. The application server does not use SQL queries to perform data manipulations. Instead of that, Java object oriented framework, namely Hibernate, is used.

Hibernate is a high performance object/relational persistence and query framework. It allows programmers to develop persistent classes following object-oriented paradigm, including associations, inheritance, polymorphism, composition and collections. Hibernate provides opportunities to create queries by using SQL extension HQL, native SQL, or object-oriented criteria (Red Hat, 2006).

To start working with Hibernate, it is necessary to define two major things: an entity and its xml mapping or annotation. The file "hibernate.properties" with the extension .xml describes a basic configuration, that is, how and with which database Hibernate will work: URL of a database, a user name, a password, presented entities, and so on. An entity represents a real world object with the set of simple attributes. Xml mapping represents this entity as a relational table in the database, and describes metadata of entity's attributes and relations with other entities. Entities can reference each other, can have child collections of other entities, and so on. The structure and relations of an entity might be as complex and sophisticated, as it is needed for the modeling of real world objects.

Hibernate provides handy and flexible API for any manipulations with persistent entities. So a programmer works with DBMS via Hibernate as with Java classes (tables) and objects (rows). The one of the most powerful feature of Hibernate is lazy loading. Lazy loading is a mechanism for comfortable work with large amounts of data even without loading them into computer memory, excepting cases, when it is necessary to perform some actions with a definite piece of data (Red Hat, 2006).

There is one more thing to add about communication between Hibernate and DBMS. The framework performs any loading/saving/updating operations with data using its own generated SQL, because DBMS "understands" only this language.

For the implementation of the data storage layer the Data Base Management System Postgresql is chosen. This software is open source and supports PL/SQL.

As it is shown in Figure 1 the concept map based knowledge assessment system can be divided into three logical domains: administrator, teacher and student. Each domain has its own goal, but they are strictly linked together. Functionality of each domain can be used by one of three user roles which names correspond to the names of the domains. An administrator is responsible for the administration and maintenance of the whole system using such functions as input, editing and deleting of data about users (teachers and students), courses and student groups. Teacher domain provides all necessary functions for the creation of concept maps for any course and defining of their attributes, as well as for the viewing of learners' results. Functionality of the student domain includes all things related to the completion of the concept map based tasks by learners and providing of feedback after the completion of the task.

4. Example of the System's Operation

First of all the teacher creates concept maps for chosen stages of knowledge assessment by defining relevant concepts and relationships among them. Figure 2 displays the partly created teacher's concept map for the first assessment stage and a

dialogue window where data of a new concept must be provided. Only one concept, that is, New Year, is defined as an initial concept and its color differs from the color of other concepts. Three relationships (marked by thick line) are important relationships, and one marked by thin line is a less important relationship.

After the creation of the concept map the teacher must define the publication data of the concept map, the initial degree of task difficulty, the relative number of points needed to move the learner to the higher degree of task difficulty and time for the completion of the task (if necessary). Let's consider that the initial degree of task difficulty is the fourth degree, the relative number of points is 75%, and time for the task completion is not provided.

The concept map presented to learners at the first assessment stage is displayed in Figure 3. During the solving of the task of the fourth degree of difficulty learners must create their own concept maps using the offered set of concepts. The technique of drag-and-drop must be used to move concepts from the concept palette to the working space. In order to relate concepts two buttons are provided at the top of the window.

Assume that one of learners has related all concepts and submitted his/her solution without reducing the degree of task difficulty. Figure 4 shows the learner's created concept map and an example of feedback provided for each relationship. Different colors are used to display different degrees of correctness of relationships.
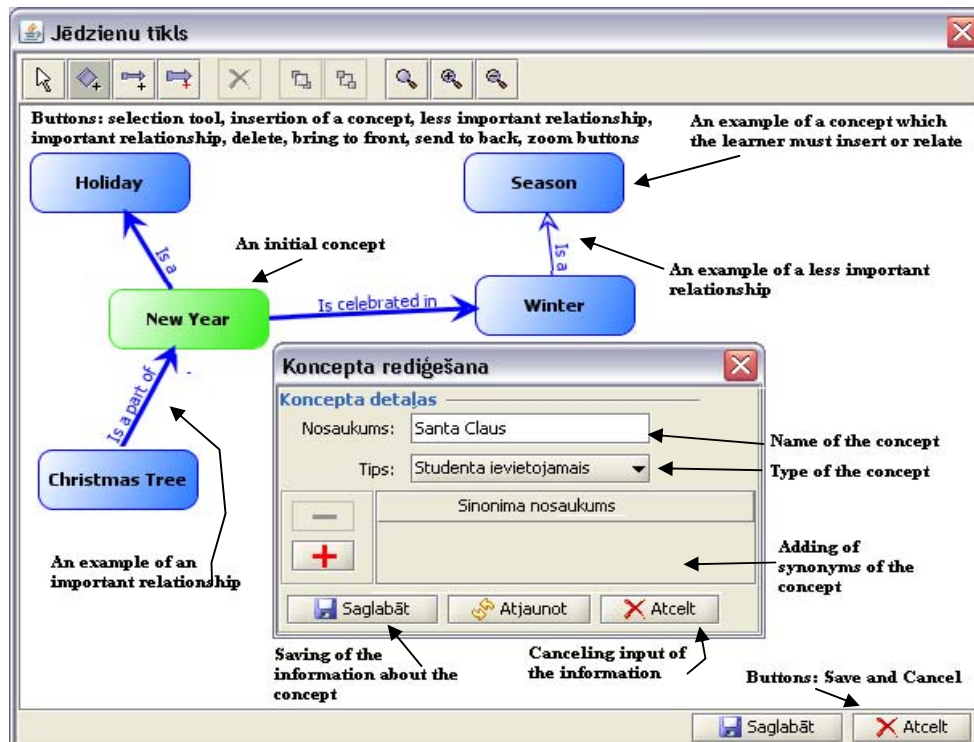

Figure 2. The Teacher's Created Concept Map for the First Assessment Stage

Figure 3. The Task of the Fourth Degree of Difficulty

Now, assume that another learner had partly created his/her concept map at the fourth degree of task difficulty and after that asked the system to reduce the degree of task difficulty. The learner receives the task of the third degree of task difficultly where the structure of the concept map is given and it is necessary to insert given concepts and to provide linking phrases (Figure 5). However, all propositions created by the learner at the fourth degree of task difficulty are kept. After the completion of the task this learner will receive the same form of feedback which is presented in Figure 4, but at the next assessment stage she/he will start to solve the task on the third degree of task difficulty because of the reduction of task difficulty of the original task.
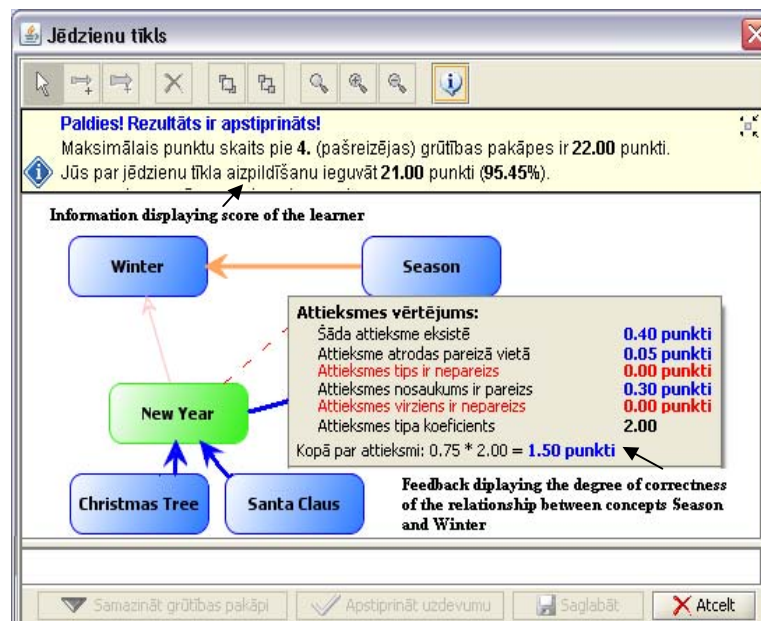

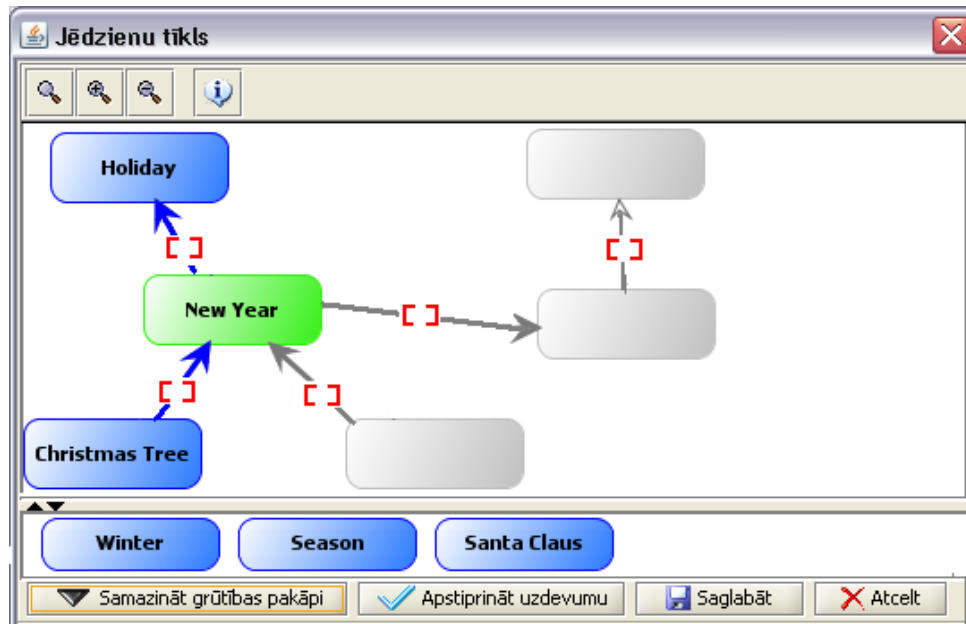*Figure 4.* Feedback Provided After the Completion of the Task

Figure 5. The Task of the Third Degree of Difficulty

5. Learner's support

The knowledge assessment system has been experimentally evaluated in 7 learning courses with participation of 149 students. The results show that students positively evaluate the functionality and the user interface of the system. However, a part of students (about 60%) experience difficulties during the solving of the concept map based tasks. One of the reasons mentioned by students is the lack of learner's support. Thus, the current directions in the development of the system are related to the implementation of different kinds of learner's support especially help and feedback. The purpose of help is to balance the degree of task difficulty and learner's knowledge level in order to help the learner to complete the task. In turn, feedback is aimed to give the learner information about the correctness of his/her actions and progress towards the goal, that is, towards the successful completion of the task.

Three kinds of learner's support (Table 2) are chosen for further implementation. In addition, there plans to use a student model for the provision of such type of explanations which are preferred by the learner or which the system recognizes as the most suitable for the learner taking into account learner's characteristics. This will make support more adaptive increasing its overall usefulness.

Table 2

Kinds of Learner's Support

Description of a support form	Kind of support	Helping nature	Tutoring nature
The system inserts the learner's selected concept into the right node within the structure of the concept map, thus, decreasing the number of concepts which the learner must insert by him/herself	Help	+	−
The system gives an explanation (definition of the concept, short description or example) of the learner's selected concept helping the learner to understand the concept and its relations with other concepts	Help	+	+
The system checks the correctness of the learner's created proposition and in case of its incorrectness provides appropriate explanations of both concepts involved in the proposition	Feedback	+	+

6. Conclusions

The paper presents the architecture and working principles of the concept map based knowledge assessment system developed at Riga Technical University. The main components and technologies used for the implementation of the system are described and an example of the system operation is demonstrated. Despite of fact that the system has already reached the certain level of maturity and has been used successfully in practice authors continue to improve its functionality. One of the significant development directions is the implementation of different kinds of learner's support inter alia adaptive mechanisms of help and feedback on the basis of a student model.

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