BUILDING A DECISION SUPPORT SYSTEM FOR STUDENTS BY USING CONCEPT MAPS

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Keywords: Concept mapping, e-learning, decision support system.

Abstract: Concept maps are an effective way of representing organized knowledge (concepts) in hierarchical fashion regarding a person's understanding of a domain of knowledge. Within our custom developed e-Learning platform it was created a concept map for a chapter of a discipline. The obtained concept map has been used for creation the test and exam questions such that knowledge regarding each concept is tested by a certain number of quizzes. We present the architecture of a decision support system that assesses the accumulated knowledge of students. The architecture's business logic is based on a concept map of a chapter of a discipline. A custom algorithm has been designed and implemented to measure the coverage of the curriculum. The system may be generalized for entire discipline as long as for each chapter is set up a concept map and all other necessary settings.

1 INTRODUCTION

Every e-Learning platform has implemented a mechanism for assessing the quantity of accumulated knowledge for a certain discipline. A problem that frequently arises is that the system in place may not be fair regarding the ordering of learners according with accumulated knowledge. Usually, there are situations when the distributions of grades is not normal, such that many learners are clustered although there are differences regarding their accumulated knowledge.

The evaluation environment is represented by the setup put in place within an e-Learning platform for assessment of learners. The setup consists of course materials and test quizzes that are set up by course managers. Learner's activities are obtained by specific methods embedded in our e-Learning platform, called Tesys (Burdescu et. al., 2006). The main goal of the application is to give students the possibility to download course materials, take tests or sustain final examinations and communicate with all involved parties. To accomplish this, four different roles were defined for the platform: sysadmin, secretary, professor and student.

Concept maps are a result of Novak and Gowin's (1984) research into human learning and knowledge construction. Novak (1977) proposed that the primary elements of knowledge are *concepts* and relationships between *concepts* are *propositions*. Novak (1998) defined concepts as "perceived regularities in events or objects, or records of events or objects, designated by a label". Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit. Concept maps are a graphical two-dimensional display of concepts (usually represented within boxes or circles), connected by directed arcs encoding brief relationships (linking phrases) between pairs of concepts forming propositions. The simplest concept map consists of two nodes connected by an arc representing a simple sentence such as 'flower is red,' but they can also become quite intricate.

One of the powerful uses of concept maps is not only as a learning tool but also as an evaluation tool, thus encouraging students to use meaningful-mode learning patterns (Mintzes et al., 2000; Novak, 1990; Novak & Gowin, 1984). Concept maps are also effective in identifying both valid and invalid ideas

Dan Burdescu D., Cristian Mihaescu M. and Logofatu B. (2008).
BUILDING A DECISION SUPPORT SYSTEM FOR STUDENTS BY USING CONCEPT MAPS.
In *Proceedings of the Tenth International Conference on Enterprise Information Systems - AIDSS*, pages 130-135
DOI: 10.5220/0001673301300135

held by students, and this will be discussed further in another section. They can be as effective as more time-consuming clinical interviews for identifying the relevant knowledge a learner possesses before or after instruction (Edwards & Fraser, 1983).

Ausubel made the very important distinction between rote learning and meaningful learning. Meaningful learning requires three conditions: 1. The material to be learned must be conceptually clear and presented with language and examples relatable to the learner's prior knowledge. Concept maps can be helpful to meet this condition, both by identifying large general concepts held by the leaner prior to instruction of more specific concepts, and by assisting in the sequencing of learning tasks though progressively more explicit knowledge that can be anchored into developing conceptual frameworks; 2. The learner must possess relevant prior knowledge. This condition can be met after age 3 for virtually any domain of subject matter, but it is necessary to be careful and explicit in building concept frameworks if one hopes to present detailed specific knowledge in any field in subsequent lessons. We see, therefore, that conditions (1) and (2) are interrelated and both are important; 3. The learner must choose to learn meaningfully. The one condition over which the teacher or mentor has only indirect control is the motivation of students to choose to learn by attempting to incorporate new meanings into their prior knowledge, rather than simply memorizing concept definitions or propositional statements or computational procedures. The indirect control over this choice is primarily in instructional strategies used and the evaluation strategies used. Instructional strategies that emphasize relating new knowledge to the learner's existing knowledge foster meaningful learning. Evaluation strategies that encourage learners to relate ideas they possess with new ideas also encourage meaningful learning. Typical objective tests seldom require more than rote learning (Holden, 1992).

Knowledge modeling methods and languages may be thought of as representation schemes that augment traditional data modeling by adding semantic content to the modeling language (Mineau et al. 2000). Knowledge modeling approaches lie on a continuum from informal (and potentially, easily understood by humans) to formal (and therefore, capable of being evaluated by machine). Chan and Johnston (1996) describe two categories of approaches to knowledge modeling: one group based upon problem solving methods and another based upon domain ontologies. These two approaches have significant overlap in the sense that, although problem solving methods are process oriented and ontological accounts start with characterizations of objects, at some point during knowledge model construction, process models must be created.

This paper presents a procedure for measuring learner's accumulated knowledge using concept mapping. The most important thing is to construct a good concept map. It is important to begin with a domain of knowledge that is very familiar to the person constructing the map. After concepts have been enumerated the concept map is build. For each concept there is created a pool of questions regarding that concept. At any point in time the concept map may be seen as a graph, such that a coverage function may be used to compute the learner's accumulated knowledge.

2 METHODS AND MATERIALS

2.1 Tesys e-Learning Platform

The main goal of the platform is to give students the possibility to download course materials, take tests or sustain final examinations and communicate with all involved parties. To accomplish this, four different roles were defined for the platform: sysadmin, secretary, professor and student.

The main task of sysadmin users is to manage secretaries. A sysadmin user may add or delete secretaries, or change their password. He may also view the actions performed by all other users of the platform. All actions performed by users are logged. In this way the sysadmin may check the activity that takes place on the application. The logging facility has some benefits. An audit may be performed for the application with the logs as witness. Security breaches may also be discovered.

Secretary users manage sections, professors, disciplines and students. On any of these a secretary may perform actions like add, delete or update.

These actions will finally set up the application such that professors and students may use it. As conclusion, the secretary manages a list of sections, a list of professors and a list of students. Each discipline is assigned to a section and has as attributes a name, a short name, the year of study and semester when it is studied and the list of professors that teach the discipline which may be maximum three. A student may be enrolled to one or more sections.

Tesys application offers students the possibility to download course materials, take tests and exams and communicate with other involved parties like professors and secretaries.

Students may download only course materials for the disciplines that belong to sections where they are enrolled. They can take tests and exams with constraints that were set up by the secretary through the year structure facility.

2.2 Sample Concept Maps

Concept mapping may be used as a tool for understanding, collaborating, validating, and integrating curriculum content that is designed to develop specific competencies. Concept mapping, a tool originally developed to facilitate student learning by organizing key and supporting concepts into visual frameworks, can also facilitate communication among faculty and administrators about curricular structures, complex cognitive frameworks, and competency-based learning outcomes. To validate the relationships among the competencies articulated by specialized accrediting agencies, certification boards, and professional associations, faculty may find the concept mapping tool beneficial in illustrating relationships among, approaches to, and compliance with competencies (McDaniel et. al.).

According to this approach, the responsibility for failure at school was to be attributed exclusively to the innate (and, therefore, unalterable) intellectual capacities of the pupil. The learning/ teaching process was, then, looked upon in a simplistic, linear way: the teacher transmits (and is the repository of) knowledge, while the learner is required to comply with the teacher and store the ideas being imparted. (Vecchia, L, et. al.)

2.3 Knowledge Evaluation Methodology

Knowledge evaluation is closely related with cognitive processes performed by an individual. After an initial step of goal setting a student has at first to identify task-relevant knowledge and to evaluate it with respect to his own knowledge regarding that goal. Self-evaluation of individual knowledge is a step that should be performed before any learning process. For example, if the task is to acquire expert knowledge, the structure of an individuals' knowledge as represented in an individual knowledge map may be compared with the knowledge structure of an expert as represented in an expert map. The potential of knowledge maps as means for diagnosing individual structures of knowledge has been shown in a variety of empirical studies (a.o. Jonassen et al., 1997). In self-regulated learning scenarios the particular contribution of computer-based concept maps is that they may support self-assessment (Shavelson, Lang, & Lewin, 1994; Kommers & Lanzing, 1997).

A concept map may be seen as an oriented graph where vertexes are represented by concepts and edges are represented by verbs. Within e-Learning platform for each proposition from the concept map may will be represented by an weighted edge and will have associated a number of quiz questions. Under these circumstances we have created an algorithms for building the associated graph of a concept map. The parameters of edges are continuously updated as the student answers quizzes. In the experimental part of the paper there will be presented the obtained graph. Each edge in the graph will have four parameters: the weight, the total number of questions, the correctly answered questions and the wrong answered questions.

Knowledge evaluation procedure takes into account the parameters of edges from the associated graph of concept map. The weight of an edge is set by the domain knowledge expert from a scale from 1 to 10 where 1 means very simple proposition and 10 means very hard proposition. All other parameters take different values according with learner's experience. In the experimental part there will be presented the formulas that synthesize the knowledge level of the learner.

The analysis of concept's map associated graph represents the core part of decision support system that runs along the e-Learning platform. The architecture of the decision support system is presented in figure 1.

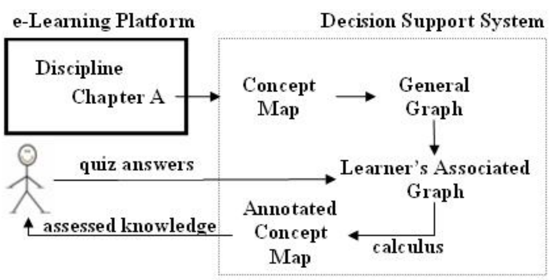

Figure 1: Functionality of Decision Support System.

Chapter A has associated a concept map build by a domain expert. From the concept map a transformation procedure creates the general graph of the chapter. In this graph, each sentence becomes an edge, weighted by the domain expert. Besides the associated weight, each proposition has associated a set of quiz questions that are to be answered by learners.

When the learner starts answering questions, the Decision Support System starts building learner’s associated graph. This graph represents the input data for the calculus procedure that assesses the knowledge of the students regarding chapter A.

Whenever a student logs in the Decision Support System builds the learner’s associated graph such that at request the knowledge status will be delivered in the form of an annotated concept map.

3 EXPERIMENTAL RESULTS

The experimental results were obtained on Tesys e-Learning platform (Burdescu and Mihaescu, 2006). On this platform there was set an Algorithms and Data Structures discipline. The tests were performed for the chapter named Binary Search Trees.

The concept map for Binary Search Trees is presented in figure 2. It contains 16 concepts, 11 linking phrases and 16 propositions.

The concepts are presented in table 1.

Table 1: List of Concepts.

Id	Concept	Id	Concept
C1	BST	C9	Right child
C2	Dynamic Structure	C10	No child
C3	Node(s)	C11	Root
C4	Traversed	C12	Leaf
C5	Key	C13	Preorder
C6	Parent	C14	Inorder
C7	Child	C15	Postorder
C8	Left child	C16	Ascending order

The list of propositions with two concepts and one linking phrase is presented in table 2. The list of propositions with three concepts and two linking phrases is presented in table 3.

Table 2: List of propositions with two concepts and one linking phrase.

Id	Concept	Linking phrase	Concept
P1	BST	is	Dynamic Structure
P2	BST	is made of	Node(s)
P3	Node	has	key
P4	Node	is	Parent
P5	Node	is	Child
P6	Parent	is greater than	Left child
P7	Parent	is smaller than	Right child
P8	Node	may have	Left child
P9	Node	may have	Right child
P10	Node	may have	No child

There is one proposition with five concepts and four linking phrases:

“BST” *may be* **“Traversed”** *in* **“Preorder”** *determines* **“Key”** *in* **“Ascending Order”**. The concepts are bolded and put between quotation marks, while linking phrases are italic and underlined.

Table 3: List of propositions with three concepts and two linking phrase.

Id	C	LP	C	LP	C
P11	Node	without	parent	is	root
P12	BST	may be	traversed	in	Preorder
P13	BST	may be	traversed	in	Inorder
P14	BST	may be	traversed	in	Postorder

Once the concept map has been built the general graph of the chapter may be created. In this graph, each proposition will become an edge that links the first concept and the last concept. The domain knowledge expert will assign a weight for each edge. While the students answers questions the number of correct and wrong answers will determine the knowledge weight of that edge.

If:

W- is the weight of the edge
CA – is the number of correct answers
WA – is the number of wrong answers
N – the number of questions

Than

KW – is the knowledge weight of the edge

and

$$KW = \frac{CA - WA}{N} \frac{1}{W} * 100$$

Under these circumstances the knowledge weight may also be negative. At any time there may be estimated the overall knowledge level of the learner as the ratio between overall knowledge weight and overall weight.

Figure 2 presents the general graph associated with the concept map.

The algorithm transforming the Concept Map into General Graph is strait forward. Each proposition becomes an edge with an weight assigned by domain knowledge expert. In this way it was obtained the Binary Search Tree General Graph.

Once the General Graph has been set up the professor has to set up the quiz questions for the chapter. For each edge in the graph it will correspond a certain number of quiz questions. There is no specification regarding the number of quiz questions but a minimum (e.g. five) number is still required. Once the quiz questions have been set up, for each student there may be constructed

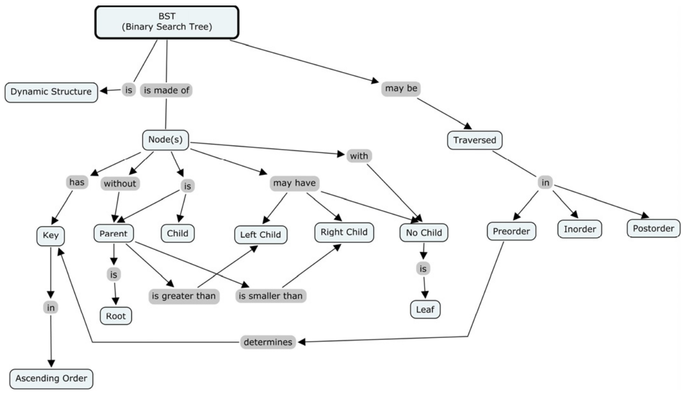

Figure 2: Binary Search Tree Concept Map.

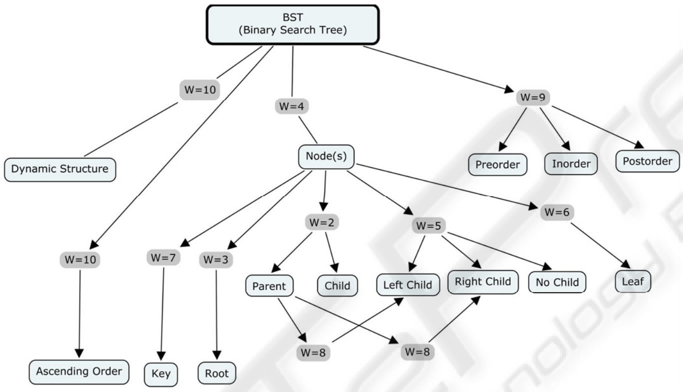

Figure 3: Binary Search Tree General Graph.

the learner's associated graph. This graph will have associated with the edges the history of correct and wrong answered questions. The Calculus engine will reconstruct an Annotated Concept Map which will present to the learner the current status of his knowledge level at Concept level. In this way, the learner will have an exact overview of his knowledge level regarding that chapter.

The Annotated Concept Map may represent the important information for learner in having a decision regarding which part of the chapter needs more study.

Table 4 presents a sample of the setup of the Binary Search Trees chapter.

Table 4: Sample setup of BST chapter.

Proposition	Weight	No. of questions
P1	10	8
P2	4	7
P3	7	6
P4	3	5
P5	2	7

Table 5 presents a sample of the of the values of the Learner's Associated Graph corresponding to BST chapter.

The values from table five are marked in an Annotated Concept Map that is finally presented to the learner. The Annotated Concept Map is the final outcome of the Decision Support System and is supposed to guide the learner regarding the necessary future efforts.

Table 5: Sample values for Learner's Associated Graph.

Proposition (Weight)	No. of questions	CA	WA	KW (%)
P1 (10)	8	3	2	1.25
P2 (4)	7	4	2	7.14
P3 (7)	6	1	3	-4.76
P4 (3)	5	3	1	13.3
P5 (2)	7	2	4	-14.2

4 CONCLUSIONS AND FUTURE WORK

The paper presents the structure and functionality of a Decision Support System that runs along Tesys e-Learning platform.

Tesys e-Learning platform has been designed such that on-line testing activities may me performed as they were set up by course managers.

It has been created a Concept Map for a Binary Search Trees chapter within Algorithms and Data Structures course. The Concept map has been the staring point in creating a set of quiz questions. Each quiz question refers to a certain proposition from the concept map.

For the designed Concept Map it has been derived a general graph in which edges are represented by the propositions from the Concept Map. For each edge the domain knowledge expert (i.e. course manager) assigned a specific weight.

After the setup has been put in place, the learners started using the platform. At request, from the general graph there was derived the learner's associated graph and on this one there may be performed calculus such that the level of knowledge regarding the chapter may be estimated at proposition level. These calculus represent the annotations in the original concept. The annotated concept map represents what the learner finally receives upon his request.

The calculus logic computes the knowledge of the student regarding the chapter as a knowledge weight. This weight is computed as a function of proposition's weight, number of questions assigned to that proposition, the number of correct answered questions and number of wrong answered questions.

This whole mechanism represents the functionality of a decision support system that runs along the Tesys e-Learning platform.

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