Chapter XXXIII
Knowledge-Based Characterization of Test Questions

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ABSTRACT

The recent advances in knowledge engineering entail us to represent knowledge associated with a course in an expressive yet computable format as a hierarchical prerequisite relation-based weighted ontology. A schema called the course concept dependency schema written in Web ontology language (OWL) is designed to represent the prerequisite concept dependency. The knowledge associated with educational resources, like the knowledge required for answering a particular test question correctly, can be mapped to subgraphs in the course ontology. A novel approach for selectively extracting these subgraphs is given and some interesting inferences are made by observing the clustering of knowledge associated with test questions. We argue that the difficulty of a question is not only dependent on the knowledge it tests but also the structure of the knowledge it tests. Some assessment parameters are defined to quantify these properties of the knowledge associated with a test question. It is observed that the parameters are very good indicators of question difficulty.

INTRODUCTION AND BACKGROUND

Traditionally, concepts maps are used to represent the backend context for the course knowledge. Many efforts (Edmondson, 1993; Lee & Heyworth, 2000; Li & Sambasivam, 2003; Heinze-Fry & Novak, 1990) have gone into representing course knowledge using concept maps and using them to evaluate educational resources. In the recent past ontologies were being used to represent structured information in a hierarchical format. Concept maps offer a means to represent hierarchical knowledge; however, they are too expressive and consequently contain more information and semantic relationships than necessary for effective computation.

Ontologies provide a means to effectively map this knowledge into concept hierarchies. Course ontology, particularly, can be roughly defined as a hierarchical representation of the topics involved in the course, connected by relationships with specific semantic significance. Using ontologies for course concept hierarchies in the domain of education is only obvious. It seems such entailment can lead to several important pedagogical applications.

Testing is an integral part of any teaching and learning process. The main pedagogical focus of this research is to objectify the process of testing by estimating the difficulty of a test question based on the depth, breadth, and the amount of conceptual knowledge it tests. Consequently effective testing is possible by subjectively designing the test using these parameter values. A problem/question is one type of educational resource. The commonly observed properties of testware are difficulty or simplicity, breadth and depth of knowledge required to answer, relevance of the question to the root topic, the semantic distance between the concepts tested, ability of the question to test varying groups of students, applicability of the topics taught to a problem, and so forth. While designing a test an educator always tries to come up with questions which have maximum coverage of desired topics, diversity among the topics, good testing capabilities with respect to student knowledge, relevance to the material taught, and so forth. It is important to understand these properties for better design and reengineering of test problems. In this research, we attempt to visualize and understand these properties of test problems by qualitative knowledge-based evaluation. Currently the process of designing of test problems is completely manual, based on human experience and cognition. Design of test problems also follows the basic principles of any engineering design process. The primary elements of design in this case are the information objects. Much effort has been put in the creation and reusability of these information objects called the learning objects, for example, learning object metadata (LOM). Semantic representation standards like RDF and OWL allow the concept knowledge space symbolized by ontologies to be represented consistently.

The main hypothesis for this work is that "*test questions*" can be qualitatively analyzed for their perceived difficulty, using a purely knowledge-based approach given a background course knowledge base. The main contributing factor to the difficulty of a question is the knowledge associated with the question, that is, the knowledge required to answer the question. Furthermore, the observed difficulty of a question is in positive correlation with the structural properties of the knowledge associated. We propose an assessment system which attempts to evaluate an educational resource like test problem for its "difficulty" based on its knowledge content. We define some parameters which are able to quantify these structural properties associated with the knowledge and observe that they are indeed very good indicators of question difficulty. These parameters can give guidelines for setting up a standard for test problem assessment. We also present an approach to course knowledge representation using ontology in an expressible and computable format using *has-prerequisite* relationships where concepts involved in teaching a course are arranged in a hierarchical order of learning. Another original method for specifically pointing out areas in ontologies of maximum relevance called *CSG extraction* is given.

Alternate educational approaches that exist do not have a concrete knowledge representation and depend too much on external psychological, cognitive, and syntactical parameters for calculating the perceived difficulty. We analyze test questions objectively from the point of view of the knowledge it tests rather than subjective external parameters. Some researches in cognition (e.g., Apted & Kay, 2002; Gruber, 1993; [18]) have identified other extrinsic parameters, like perceived number of difficult steps, steps required to finish the problem, number of operations in the problems expression, number of unknowns, and so forth which attribute difficulty to a question, but none of them are knowledge-based. The few knowledge-based approaches (Dean &

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