Ranking the Difficulty Level of the Knowledge Units Based on Learning Dependency

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ABSTRACT
Assigning difficulty level indicators to the knowledge units helps the learners plan their learning activities more efficiently. This paper focuses on how to use the topology of a knowledge map to compute and rank the difficulty levels of knowledge units. Firstly, the authors present the hierarchical structure and properties of the knowledge map. Then they propose three hypotheses of factors influencing difficulty based on the correlation between the difficulty level of knowledge units and the learning dependency. Finally, the authors provide algorithms for ranking the knowledge units with objective and subjective difficulty scores. The experiment on the knowledge map of the “plane geometry” course shows that our algorithm can precisely calculate the difficulty level of knowledge units.

Keywords: Difficulty Level, Knowledge Map, Knowledge Units, Objective Difficulty, Subjective Difficulty

INTRODUCTION
Learning is an incremental process that depends on what a learner has mastered (Gordon, 2000). When a learner wants to master a new knowledge unit, he or she must completely grasp all the prerequisite knowledge units related to the knowledge unit to be learned. The knowledge unit is defined as the smallest integral knowledge object in a given domain, such as definition, theorem, rule, or algorithm (Jeschke & Richter, 2006). The following is an example of a definition type knowledge unit: “Definition of triangle: the plane figure formed by connecting three points not in a straight line by straight line segments”. An example of a theoric knowledge unit is as follows: “Triangle interior angles sum theorem: the sum of the measures of the interior angles of a triangle is 180°.” The knowledge unit “Triangle interior angles sum theorem” has a learning dependency on the knowledge unit “Definition of triangle”. This dependency means that “Definition of triangle” must be learned before the “Triangle interior angles...
sum theorem”. A knowledge map is defined as a directed graph composed of knowledge units and learning dependency relationships (Gordon, 2000; Lin & Hsueh, 2006).

Knowledge maps have been employed in navigational learning as a knowledge representation tool (Lin et al., 2006; Han & Kim, 2005). A navigational learning path can be visually presented by making use of the knowledge map based on the learner’s cognition level. Personalized learning content and services can also be offered adaptively to avoid the learning disorientation problems (Adomavicius, 2005). In navigational learning, each knowledge unit has two properties (objective difficulty and subjective difficulty) that affect the efficiency of learning the objective difficulty level and the subjective difficulty level. Computing and ranking these properties are helpful in guiding learners to allocate their efforts and time appropriately. Currently, the navigational learning model does not have a standard to identify the difficulty level properties. Therefore, the efficiency of navigation learning is limited. This paper will address this problem by studying on how to rank the difficulty levels of the knowledge units based on these units’ learning dependencies.

The difficult level of a knowledge unit correlates to the knowledge unit itself, and also is influenced by the learner’s cognition level (Cant, Jeffery, & Henderson-Sellers, 1995). We define the objective difficulty level as the complexity of the knowledge unit itself, and the subjective difficulty level as the degree to which an individual learner’s cognitive level affects the objective difficulty.

We identified the correlations between a knowledge map’s topological properties and the objective difficulty levels of its knowledge units by building the knowledge maps of eight courses, including “Plane Geometry,” “Data Structure,” “Computer System Architecture”, “Principles of Computer Composition,” and others. We reached to three hypotheses after analyzing these correlations. According to these hypotheses, we propose an algorithm of ranking the objective and subjective difficulty level of the knowledge units. The algorithm is based on the learning dependency relationships among the knowledge units.

The rest of the paper is organized as follows: we review the related researches in difficulty ranking; we elaborate on the hierarchical structure of the knowledge map, and presents the algorithm for ranking the difficulty level of the knowledge units; we then provide the experimental results of the proposed ranking algorithm; and end the paper with the conclusion and future work.

**RELATED WORK**

Existing researches on the difficulty level calculation mainly focus on two areas.

The first area investigates the mechanism of human cognition. Learning difficulty and cognitive complexity are quantified by analyzing the impact of a learner’s cognitive status and the attributes of cognitive objects on cognitive processes. Here is an example of a typical study in this area. Based on the finding of one’s short term memory (STM) capacity is only 7±2 information chunks, Kellett asserted that the more information chunks that one needed to store in STM, the more difficult the cognitive process would be. Kellett (1979) used the number of information chunks as a quantification indicator for a knowledge unit’s difficulty. Kellett found the learner’s cognitive understanding of the object-related concept would influence the number of information chunks used in STM. The higher the learner’s level of understanding was, the lower the number of information chunks one would use. This study shows the number of information chunks used reflects a knowledge unit’s subjective difficulty.

The second area of the knowledge difficulty level study focuses on how objective and subjective factors can influence difficulty levels during the problem-solving process. Kuo et al. (2004) analyzed the factors that affect the level of difficulty in the following four stages of the problem solving process: problem identification, establishment, planning, and execution.
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