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Personalized curriculum sequencing utilizing modified item response theory for web-based instruction

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Abstract

Curriculum sequencing is an important research issue for Web-based instruction systems because no fixed learning pathway will be appropriate for all learners. Therefore, many researchers focused on developing e-learning systems with personalized learning mechanism to assist on-line Web-based learning and adaptively provide learning pathways. However, although most personalized systems consider learner preferences, interests and browsing behavior in providing personalized curriculum sequencing services, these systems usually neglect to consider whether learner ability and the difficulty level of the recommended courseware are matched to each other or not. Generally, inappropriate courseware leads to learner cognitive overload or disorientation during learning, thus reducing learning effect. Besides, the problem of concept continuity of learning pathways also needs to be considered while implementing personalized curriculum sequencing. Smoother learning pathways increase learning effect, avoiding unnecessarily difficult concepts. This paper presents a prototype of personalized Web-based instruction system (PWIS) based on the proposed modified Item Response Theory (IRT) to perform personalized curriculum sequencing through simultaneously considering courseware difficulty level, learner's ability and the concept continuity of learning pathways during learning. In the proposed modified IRT, the information function is revised to consider the concept continuity of learning pathway as well as considering the difficulty level of courseware and individual learner ability. Experiment results indicate that applying the proposed modified IRT for Web-based learning can construct suitable learning pathway to learners for personalized learning, and help them to learn more effectively.

Keywords: Item response theory (IRT); Computerized adaptive testing (CAT); Intelligent tutoring system; Personalization; Learning pathway

1. Introduction

Traditional teaching resources, such as textbooks, typically guide the learners to follow fixed sequence to other subject-related sections related to the current one during learning processes. Web-based instruction researchers have given considerable attention to flexible curriculum sequencing control to provide adaptable, personalized learning programs (Mia and Woolf, 1998; Lin and Hsieh, 2001; Lee, 2001; Tang and Mccalla, 2003; Papanikolaou and Grigoriadou, 2002; Jih, 1996; Tang et al., 2000; Brusilovsky et al., 1998). Curriculum sequencing aims to provide an optimal learning pathway to individual learner since every learner has different prior background knowledge, preferences, and often various learning goals (Hübscher, 2000; Weber and Specht, 1997; Brusilovsky and Vassileva, 2003). In an educational adaptive hypermedia system, an optimal learning pathway aims to maximize a combination of the learner's understanding of courseware and the efficiency of learning the courseware (Hübscher, 2000). Curriculum sequencing can generally be distinguished as either knowledge sequencing or task sequencing. Knowledge sequencing determines next teaching concept or topic (Brusilovsky, 1999). Task sequencing determines the next learning task (problem, example, test) within a current topic (Brusilovsky, 1999). However, finding an optimal learning pathway for individual learner is difficult and non-meaningful for tutoring systems because no measure exists by which to evaluate the success of an optimal learning pathway. Therefore, to provide adaptable learning pathway for individual learner is a more practicable in Web-based tutoring systems.

Moreover, as numerous Web-based tutoring systems have been developed, a great quantity of hypermedia in

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courseware has created information, cognitive overload and disorientation (Berghel, 1997; Borchers et al., 1998), such that learners are unable to learn very efficiently. To aid more efficient learning, many powerful personalized/adaptive guidance mechanisms, such as adaptive presentation, adaptive navigation support, curriculum sequencing, and intelligent analysis of student's solutions, have been proposed (Tang and Mccalla, 2003; Papanikolaou and Grigoriadou, 2002; Weber and Specht, 1997; Brusilovsky, 1999). Adaptation is particularly important in Web-based education for at least two general reasons (Brusilovsky, 1998). First, most Web-based applications are designed for a much wider variety of users than standalone application. That is, a Web application designed with a particular class of users in mind may not suit other users. Second, in many cases the user is alone working with a Web-based tutoring system. This is similar to a teacher typically providing adapted teaching content for an individual classroom student. Besides, personalized service has also received considerable attention (Mobasher et al., 2000) recently in Web application systems because of information needs differing among users. Examples of such systems include the Citeseer website for literature search (NEC Research Institute ResearchIndex) (Research), the Yahoo search engine for web page search (Yahoo! Search Engine) and product recommendation agents for e-commerce (Xiao et al., 2003). Currently, most adaptive/personalized tutoring systems (Lee, 2001; Tang and Mccalla, 2003; Papanikolaou and Grigoriadou, 2002) consider learner/user preferences, interests, and browsing behavior when investigating learner behavior for personalized services. However, these systems neglect the importance of learner ability when implementing personalized mechanisms. On the other hand, some researchers emphasized that personalization should consider levels of learner knowledge, especially in relation to learning (Papanikolaou and Grigoriadou, 2002; Brusilovsky, 1999). That is, the ability of individuals may be based on major fields and subjects. Therefore, considering learner ability can promote personalized learning performance.

The Item Response Theory (IRT) (Baker, 1992; Hambleton, 1985; Hulin et al., 1983) is a popular theory in education measurement. It is usually applied in computerized adaptive testing (CAT) (Horward, 1990; Hsu and Sadock, 1985) to select appropriate testing items for examinees based on individual ability. The computerized adaptive testing cannot only efficiently shorten the testing time and the number of testing items, but also precisely estimate examinee ability. Presently, the concept of CAT is applied to replace traditional measurement instruments (which are typically fixed-length, fixed-content and paper-pencil tests) in several real-world applications, such as TOEFL (TOEFL), GRE (GRE), and GMAT (GMAT).

To construct a personalized learning pathway based on simultaneously considering courseware difficulty level, learner ability and learning concept continuity during learning processes, a personalized Web-based instruction system based on the modified Item Response Theory is here presented to provide personalized curriculum sequencing services. The single parameter logistic model with difficulty parameter proposed by Georg Rasch (Baker, 1992; Hambleton, 1985; Hulin et al., 1983) is applied to model various difficulty levels of courseware. In addition, IRT with modified information function is presented to compute matched degree for appropriate course materials recommendations. This is because the original information function in Item Response Theory (Baker, 1992; Hambleton, 1985; Hulin et al., 1983) only considers the matched degree of difficulty level of courseware with the learner's ability to recommend courseware for learner. To recommend a learning pathway using the original information function for individual learner leads to the obstacle of the discontinued learning pathway, resulting in unnecessarily advanced concept learning. In modified Item Response Theory, the information function is revised in relation to concept continuity of the learning pathway. In this study, after the SCORM metadata of courseware in the courseware database is first processed by the Chinese natural language processing (NLP) technique, i.e. CKIP (CKIP), the cosine-measure (Frakes and Baeza-Yates, 1992; Chowdhury, 2004) is applied to calculate concept relation degrees among courseware. The concept relation degrees are applied to modify the original information function in IRT in order to obtain a smoother learning pathway for personalized curriculum sequencing. PWIS dynamically estimates learner ability based on the proposed modified IRT by collecting learner feedback after studying the recommended courseware. Based on the estimation of learner abilities, the system can recommend courseware with appropriate difficulty levels to learners using the modified information function. Restated, learner ability and the difficulties of course materials are simultaneously taken into account when implementing a personalization mechanism. Meanwhile, the problem of concept continuity of learning pathway is also considered while implementing personalized curriculum sequencing because the information function revision is based on concept relation degrees.

In summary, the proposed PWIS based on the modified IRT provides learning paths that can be adapted to various levels of difficulty of course materials and various abilities of learners. Meanwhile, the concept continuity of learning pathways is also integrated by analyzing concept relation degrees for all database courseware while applying personalized curriculum sequencing. To prevent the learner from becoming lost in course materials, the system provides personalized learning guidance, filters out unsuitable course materials to reduce cognitive loading, and provides a fine learning guidance based on individual user profile. Experimental results indicate that the proposed PWIS can recommend appropriate course materials to learners based