Computers & Education 88 (2015) 215–226

Contents lists available at ScienceDirect

Computers & Education

journal homepage: www.elsevier.com/locate/compedu

Negotiation based adaptive learning sequences: Combining adaptivity and adaptability

Chih-Yueh Chou [a, d], K. Robert Lai [a, d, *], Po-Yao Chao [b, d], Chung Hsien Lan [c], Tsung-Hsin Chen [a]

[a] Department of Computer Science and Engineering, Yuan Ze University, Taiwan, ROC
[b] Department of Information Communication, Yuan Ze University, Taiwan, ROC
[c] Department of Information Management, Taoyuan Innovation Institute of Technology, Taiwan, ROC
[d] Innovation Center for Big Data and Digital Convergence, Yuan Ze University, Taiwan, ROC

A R T I C L E I N F O

Article history:
Received 20 September 2014
Received in revised form
29 May 2015
Accepted 30 May 2015
Available online 12 June 2015

Keywords:
Architectures for educational technology system
Evaluation of CAL systems
Intelligent tutoring systems
Interactive learning environments

A B S T R A C T

This study proposes a negotiation-based approach to combine the notion of adaptivity (system-controlled adaptation) and adaptability (user-controlled adaptation) for an adaptive learning system. The system suggests adaptations and the student also submits his/her adaptation preference. When the student preference opposes the system suggestion, the student then negotiates with the system to reach an agreement of adaptation. A negotiation-based adaptive learning system (NALS) is implemented to support the generation of personalized adaptive learning sequences by system negotiations with students regarding assessments of learning performance (i.e. negotiated open student model) of the current content and choices of the next learning content (i.e. negotiation of adaptation). Students require two metacognitions in deciding adaptive learning sequences: self-assessment for evaluating their understanding of the current content and regulation for choosing appropriate learning content. Negotiated open student model are used for assist student self-assessment and negotiation of adaptation are used for assist student regulation of content choices. An experiment was conducted to compare a system-controlled adaptive learning system (SALS, adaptivity), a user-controlled adaptive learning system (UALS, adaptability), and a NALS. The results revealed that NALS promoted better metacognitions in student calibration (i.e. self-assessment) accuracy and learning content choices (i.e. regulation). Preliminary evidences also showed that NALS promoted better student performance in a delay test. The results further suggested that students with poor calibration accuracy and inappropriate content choices were not suitable to use UALS and were suitable to use SALS. The NALS can also be used for training students to make appropriate adaptation for learning.

1. Introduction

Individual instruction is an effective learning method, which provides individual students with individual/personalized learning supports, such as content, tutoring, tools, environments (Bloom, 1984). Researchers found that students have individual differences, such as gender, prior knowledge, cognitive styles, learning styles, preferences, and that these differences may lead to different learning outcomes, such as performance, behaviors, and motivation (Cassidy, 2012; Chen, 2010; Chen & Macredie, 2010; Chen & Sun, 2012; Jonassen & Grabowski, 1993). Therefore, research has investigated the impacts of individual differences on learning outcomes, in order to design appropriate learning supports for specific students, and for the purpose of developing approaches for providing individual instruction. To cope with the research issue of providing individual instruction, many learning systems have been developed and termed as personalized, intelligent, or adaptive systems (Brusilovsky, 2001; Dolenc & Aberšek, 2015; Kenny & Pahl, 2009; Klašnja-Milićević, Vesin, Ivanović, & Budimac, 2011; Papanikolaou, Grigoriadou, Kornilakis, & Magoulas, 2003; Sleeman & Brown, 1982; Yang, Hwang, & Yang, 2013).

* Corresponding author. Department of Computer Science and Engineering, Yuan Ze University, Taiwan, ROC. Tel.: +886 3 463800x2353; fax: +886 3 4638850.
E-mail address: krlai@saturn.yzu.edu.tw (K.R. Lai).

http://dx.doi.org/10.1016/j.compedu.2015.05.007

In general, learning systems adopt two adaptation approaches to provide individual learning supports, which are adaptivity (also called program control or system control) and adaptability (also called learner control or user control) (Frias-Martinez, Chen, & Liu, 2009; Lin & Hsieh, 2001; Oppermann, 1994; Papanikolaou et al., 2003). The adaptivity approach indicates that the system controls the adaptation; this means that the system detects the student, builds a student model to represent the system beliefs of the student, and provides the student with adaptive learning supports, such as learning materials, learning sequences, peers, tools, feedback, tutoring, interface, and presentation (Akbulut & Cardak, 2012; Brusilovsky, 2001; Kenny & Pahl, 2009; Magoulas, Papanikolaou, & Grigoriadou, 2003; Mampadi, Chen, Ghinea, & Chen, 2011; Papanikolaou et al., 2003; Truong, 2015). The approach involves many artificial intelligence techniques and issues, such as knowledge representation, student modeling, and intelligent tutoring (Klašnja-Milićević et al. 2011; Sleeman & Brown, 1982; Tseng, Chu Hwang, & Tsai, 2008; Wenger, 1987; Woolf, 2008). Adaptive learning systems are shown to be more effective than non-adaptive learning systems (Fletcher, 2003). However, building a student model is complex and intractable (Brusilovsky & Millán, 2007; Chrysafiadi & Virvou, 2013; Desmarais & Baker, 2012; Holt, Dubs, Jones, & Greer, 1994; Self, 1988) and developing such an adaptive learning system is difficult and labor-intensive (Murray, 1999).

Conversely, adaptability indicates that students control the adaptation; in this case, the system provides an adaptable framework, tools, or choices to enable students to adapt the content sequences, pacing, context, task difficulty, and learning supports per their needs and preferences (DeRouin, Fritzsche, & Salas, 2005; Kay, 2001). Adaptability offers promising possibilities for improved learning by giving students the control and responsibility for their own learning (Carolan, Hutchins, Wickens, & Cumming, 2014). Studies found that students prefer full control over their instructional options, but they often do not make good choices; particularly, novice students and students with low metacognitive skills (Clark & Mayer, 2008; Scheiter & Gerjets, 2007). Effective learning in student controlled learning, systems require students to have metacognitive skills and working memory capacity by conducting the two metacognitions of self-assessment and regulation in self-regulated learning process (Clark & Mayer, 2008; Kostons, Van Gog, & Paas, 2012; Vandewaetere & Clarebout, 2011; Winne, 2011; Zimmerman, 2001). Self-assessment (also termed as self-evaluation, monitoring, or judgments of learning) indicates that students assess their learning and regulation which means that students, based on their self-assessment, control the adaptation of learning pacing, sequence, and support to improve learning (Andrade & Valtcheva, 2009; Bourke, 2014; Griffin, Wiley, & Salas, 2013; Taras, 2010). However, studies revealed that novice students may lack of sufficient metacognitive skills and hence, hamper the effectiveness of student controlled learning systems (Corbalan, Kester, & van Merriënboer, 2009; Gay, 1986). Many students have poor calibration accuracy (poor correlations between student self-assessment and actual performance) and tend to be overconfident in their performance (Bol, Hacker, O'Shea, & Allen, 2005; Dunning, Heath, & Suls, 2004; Eva, Cunnington, Reiter, Keane, & Norman, 2004; Stone, 2000). In addition, students tend to select minimal support and may fail to gain adequate understanding of the content (Ross, Morrison, & O'Dell, 1989) and students with low self-regulatory skills learn less in student controlled e-lessons than in program controlled e-lessons (Young, 1996). Clark and Mayer (2008) argued that "*learners with poor metacognitive skills are prone to poor understanding of how they learn, which will lead to flawed decisions under conditions of high learner control*."

Some studies have tried to combine the approaches of adaptivity and adaptability to provide individual instruction; that is, the system controls the adaptation to provide adaptive supports and also allows students to control the adaptation. However, system controlled adaptation may conflict with student controlled adaptation and the issue needs to be resolved. Some researches prefer system control to student control, whereby the system limits the space of student control accordance with system adaptation. For instance, Corbalan et al. (2009) proposed a shared control approach to allow students to choose from a system pre-selection of suitable tasks. Some researchers prefer student control over system control, where the system plays the assisting job to suggest adaptive support and decisions for the student to either accept or reject the suggestions (Bell & Kozlowski, 2002; Bunt, Conati, & McGrenere, 2007; Fink, Kobsa, & Nill, 1998; Krogsaeter, Oppermann, & Thomas, 1994).

Researchers suggest that computer assisted learning systems could open student models (system assessment of student knowledge) to students in order to promote reflection, self-assessment, learning autonomy, independent learning, and metacognition (Bull, 2004; Bull & Kay, 2007, 2008, 2013; Mitrovic & Martin, 2007). Originally, a student model was a system assessment of student knowledge, which was commonly built inside in adaptive learning systems and was used for providing individualized instruction (Conati & Kardan, 2013; Holt et al., 1994; Pavlik, Brawner, Olney, & Mitrovic, 2013). Because students might slip or guess in performing learning tasks, building a student model deals with uncertainties; it is difficult to build an accurate, detailed student model (Self, 1988). Researchers suggested that a student model could be open to students by making inspectable, cooperative, and negotiable (Bull, 2004; Bull, Pain, & Brna, 1995; Self, 1988). An open student model enables students to collaborate with the system to build an accurate student model (Beck, Stem, & Woolf, 1997; Bull et al., 1995), improve communication between the system and student (Kay, Halin, Ottomann, & Razak, 1997), facilitate student reflection (Bull, Quigley, & Mabbott, 2006; Clayphan, Martinez-Maldonado, & Kay, 2013), promote more accurate self-assessment (Kerly & Bull, 2008; Mitrovic & Martin, 2007), further planning and independent learning (Bull, Gardner, Ahmad, Ting, & Clarke, 2009), and increase metacognition (Bull & Kay, 2008).

This study proposes a negotiation-based adaptation approach to combine adaptivity and adaptability by a student engaged negotiation of student model and adaptation. This study also applies the approach to provide adaptive learning sequences by resolving the conflict between the system and students in determining learning sequences through negotiation of performance assessment (negotiated open student model) and negotiation of learning content choices (adaptation). A learning sequence indicates the composition and the order of learning content, such as lessons, units, or topics. After studying a lesson, students might have many possible content options, such as re-studying the lesson, studying an additional lesson with the same knowledge for reinforcement, or studying a lesson with new knowledge. Many asynchronous e-learning systems enable students to control their learning pace and sequence, but students might lack of metacognitive skills to make appropriate control (Clark & Mayer, 2008). Students require two metacognitions in deciding adaptive learning sequences: self-assessment for evaluating their understanding of the current content and regulation for choosing appropriate learning content. This study applies negotiation in order to assist student in these two metacognitions. Negotiated open student model are used for assist student self-assessment and negotiation of adaptation are used for assist student regulation of content choice. First, the system asks students to self-assess their learning performance of the current lesson (i.e. self-assessment) and proposes system assessment of their performance (i.e. open student model). When a student's self-assessment is inconsistent with the system assessment, the student then is prompted to negotiate with the system to reach an agreement for his/her performance assessment (i.e. negotiated open student model).