ADAPTIVE LEARNING SYSTEMS

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Contents

Summary

The exponential growth of Internet technologies in recent years, increasing availability of high bandwidth network infrastructures and advances in mobile and wireless technologies have opened up new opportunities for education. The true potential of online learning as anytime and anywhere has put the learner at the centre of learning process by questioning and challenging the century-old teacher-centric instructional paradigm. Research is advancing rapidly on finding ways to customize education to suit individual learners. While creation of personal profiles of the learners has been part of research agenda for quite some time, recent advances in computational areas such as data mining and location-based context adaptation have received much attention recently to provide real-time adaptivity in the learning process. This chapter introduces systems that use learner profile information to provide adaptive and personalized learning in real time. Four major directions of adaptivity are discussed, namely adaptivity based on learning styles, cognitive abilities, affective states, and context and situation.

While the field of adaptive learning systems is still evolving, research till date has shown great potential for changing the education as perceived now, by enabling

seamless integration of learning process in work environments, information learning situations and non-formal learning contexts. Further advances in tracking technologies and improved understanding of human cognition should pave the way for emergence of adaptive learning systems of future that are capable of providing always-on learning, in such small chunks and so much in tune with learners' context that no conscious effort is needed during learning process.

1. Introduction

Technological advancements in Internet and web technologies over the past decades have made tremendous changes in education. This has also resulted in changes in educational pedagogy, with learning process moving from teacher-centric classroom environments to learner-centric anytime and anywhere approach favored by constructivist paradigm. There is a growing sense of need for supporting learners in their learning process in the way that each learner can experience the optimal learning experience and achieve the best possible outcomes. Research is continuing to design such adaptive learning systems, even though adoption at mass-scale is yet to be seen.

In this chapter, we first introduce the basic concepts of adaptive learning systems. Secondly, adaptivity based on individual differences is examined from four different methods including learners' learning styles, cognitive abilities, affective states and context/situation. A concrete example demonstrating how each method can be applied in designing an adaptive learning system is also described.

2. Adaptive Learning Systems

Different learners have different learning styles, and also have different cognitive abilities. In traditional instructional environments, meeting different needs of all students is difficult, especially in classes with a large number of students. In web-based educational systems, lots of research works have therefore emerged in the area of adaptive instruction (Brusilovsky, 1996). Adaptive systems have been developed which aim at providing courses that fit the needs of learners.

Learning systems, which are implemented on the web, can often be classified as part of hypermedia systems. Addition of adaptivity into hypermedia systems qualifies them into a group of systems called adaptive (educational) hypermedia systems (AHSs) (e.g. Karampiperis and Sampson, 2005). Hypermedia systems are inherently information systems with visual navigational aids that can be used to move through a hyper-linked information space. Hypermedia systems are in themselves good tools for information dissemination – they allow access to great amount of information from different locations at different times. Students are no longer bound to come to a particular space in a particular time (e.g. attending a lecture) in order to access the information. If portable devices could be employed for educational purpose, there is even greater mobility in the learning process (e.g. Chan et al, 2006).

However, static hypermedia systems are often criticized for their direct transplantation of learning materials from traditional media (e.g. text books) to the Internet (Forbus, & Feltovich, 2001). The great amount of information in hypermedia system could also cause cognitive overload on the students (Kinshuk et al., 1999). Adaptive hypermedia systems try to overcome the limitation of static hypermedia system by providing customization. The terms customization, personalization, and adaptation all express a similar goal – to transform the information or learning material to a presentation that best meet the needs of the learners (Kinshuk et al., 1999). The adaptive characteristics improve the usability of the hypermedia systems. Without adaptivity, the hypermedia systems would present the same material, with the same set of links, to all learners. It could work well if the intended user group has the same/similar learning characteristics, but it is rarely the case in real learning environments. Examples of adaptive hypermedia systems include HYLITE (Bontcheva, and Wilks, 2005), AHA (De Bra, 2002), InterSim (Kinshuk et al., 1999) and ELM-ART II (Specht et al., 1997).

Adaptive hypermedia systems, with the ability to change the content according to the student's needs, provide similar situation as if there were many instructors available for each individual student, and therefore "the learner's chances of doing well in this classroom would appear to be significantly better than in a classroom with one instructor because each learner would need to adapt to the instructor(s) that would facilitate his/her learning style" (Glibert and Han, 1999, p.2). Learning therefore becomes a personalized experience (Kabassi, and Virvou, 2003; Dagger, Wade, and Conlan, 2005).

3. Adaptivity Based on Individual Differences

3.1. Learning Styles

The field of learning styles is complex, and although lot of research has been conducted, some important questions are still open. Coffield, Moseley, Hall, and Ecclestone (2004) pointed out several controversial issues, including the existence of many different views, definitions, and models of learning styles, the reliability and validity of instruments for identifying learning styles, the feasibility and effectiveness of incorporating learning styles in education, and the way learning styles should be used in education. While Coffield et al. (2004) concluded that learning styles are often misused and are limited in what they can achieve, many other researchers argue that the consideration of learning styles is an important factor in education (Felder & Silverman, 1988; Graf, 2007; Lu, Jia, Gong, & Clark, 2007). Especially in the last few years, several research works have been conducted that support this argument. Examples are the development of adaptive systems such as TSAL (Tseng, Chu, Hwang, & Tsai, 2008), WELSA (Popescu, 2010) and an adaptive mechanism for extending learning management systems (Graf & Kinshuk, 2007). The evaluation of these systems showed that considering learning styles can decrease learners' effort in terms of time required for learning and increase overall learner satisfaction.

Several different techniques are used in adaptive learning systems to accommodate students' learning styles and adjust courses respectively. Some of the most often used techniques include changing the sequence of types of learning objects presented in each section of a course (e.g., Graf & Kinshuk, 2007; Paredes & Rodríguez, 2004; Popescu, 2010), hiding learning objects, elements of learning objects, or links to learning objects that do not fit students' learning styles well (e.g., Bajraktarevic, Hall, & Fullick, 2003;

Graf & Kinshuk, 2007; Tseng et al., 2008), and annotating learning objects in order to indicate how well they fit students' learning styles and therefore recommending the ones that fit best (e.g., Graf, Kinshuk, & Ives, 2010a; Popescu, 2010).

Identifying learning styles: self reported, inferred and dynamic approaches

In order to identify learners' learning styles, most adaptive systems use a static and collaborative student modeling approach, where learners are asked to fill out a questionnaire to determine their learning styles. These questionnaires are based on the assumption that learners are aware of how they learn. Jonassen and Grabowski (1993) pointed out that "because learning styles are based on self-reported measures, rather than ability tests, validity is one of their most significant problems" (p. 234). Similarly, Coffield et al. (2004) identified that many learning style questionnaires have problems with validity and reliability. In recent years, more and more research has been performed on investigating and developing automatic approaches for identifying learning style, where information about learners' behavior in an online course is used to infer their learning styles. For example, García, Amandi, Schiaffino, and Campo (2007) studied the use of Bayesian networks to detect students' learning styles based on their behavior in the educational system SAVER. In another study, Cha et al. (2006) investigated the usage of Hidden Markov Models and Decision Trees for identifying students' learning styles based on their behavior in a course. Furthermore, Özpolat and Akar (2009) used a NBTree classification algorithm in conjunction with Binary Relevance classifier in order to classify learners based on their interests and then inferred learning styles from these results. Besides using machine learning / data mining approaches to generate data-driven models which can then be used to calculate learning styles, Graf, Kinshuk and Liu (2009a) proposed a literature-based approach, where the calculation of learning styles is, similar to a learning style questionnaire, based on rules derived from literature. All abovementioned studies were applied to identify learning styles based on the Felder-Silverman learning style model (Felder & Silverman, 1988). However, they were developed for different systems or for learning management systems in general, and considered different behavior patterns of learners. Each of these approaches was evaluated by comparing the results of the approach with the results of the learning style questionnaire. Table 1 shows a comparison of the results for each of the four learning style dimensions of the Felder-Silverman learning style model. The four learning style dimensions are: active/reflective, sensing/intuitive, visual/verbal and sequential/global. Active learners learn better by working actively with the learning material, for example, working in groups, discussing the material, or applying it. Reflective learners prefer to think about and reflect on learning material. Learners with a sensing learning style like to learn facts and concrete learning material, using their sensory experiences of particular instances as a primary source. Intuitive learners prefer to learn abstract learning material, such as theories and their underlying meanings, with general principles rather than concrete information. Visual learners remember best what they have seen, e.g. pictures, diagrams and flow-charts, verbal learners who get more out of textual representations in written or spoken forms. Sequential learners learn in small incremental steps and therefore have a linear learning progress. Global learners use a holistic thinking process and learn in large leaps. The study by Cha et al. (2006) has not been included in this comparison since their experiment used only data from the learning style questionnaire indicating a strong or moderate preference on a specific learning style dimension rather than including all data, as has been done by the other studies. Among these four dimensions, visual/verbal dimension is considered to be not very practical as majority of people seem to be visual oriented.

	Participants	active/reflective	sensing/intuitive	visual/verbal	sequential/global
Garcia et al. (2007)	27	58%	77%	-	63%
Graf et al. (2009a)	75	79.33%	77.33%	76.67%	73.33%
Özpolat and Akar (2009)	30	70%	73.3%	53.3%	73.3%

Table 1. Accuracy of Learning Style Identification Approaches

The studies mentioned above focused on using behavior patterns such as the time a learner visited a particular type of learning object or the number of times such types of learning objects have been visited by learners. However, more complex behavioral patterns have been investigated as well. For example, Graf, Liu and Kinshuk (2010b) looked into navigational patterns, which indicate how learners navigate through the course and in which order they visit different types of learning objects and activities.

Several differences in the learners' navigational patterns were identified, indicating that students with different learning styles visit learning objects in different sequences. These differences can be used to improve the identification process of learning styles. Furthermore, Spada, Sánchez-Montañés, Paredes, and Carro (2008) investigated mouse movement patterns with respect to students‘ sequential/global dimension of Felder-Silverman learning style model and found a strong correlation between the maximum vertical speed and learners‘ sequential/global learning style. Again, these findings can contribute to the improvement of the detection process of learning styles.

While the above described approaches use a certain amount of data to identify learning styles in a static manner, investigations are also conducted on dynamic student modeling of learning styles, where the information about students' learning styles is updated frequently in the student model. Paredes and Rodríguez (2004) implemented a simple form of dynamic student modeling in their adaptive system TANGOW, which includes a mechanism that revises a students‘ learning style to its opposite if one particular behavior pattern has been detected.

Graf and Kinshuk (in press) investigated dynamic aspects of modeling learning styles in more complex settings and proposed a mathematical model to calculate how and when to revise information in the student model, assuming that new information about students' behavior is frequently added and therefore new information about students' learning styles is frequently gathered. Furthermore, they demonstrated how dynamic and automatic student modeling of learning styles can be integrated in learning management systems.

3.1.1. Examples: Adaptivity Based on the Felder–Silverman Learning Style Model

Felder and Silverman (1988) have given several examples on how to address the different needs of learners with respect to their learning styles in traditional education. Most of these suggestions can also be applied to provide adaptivity in learning systems. In the following paragraphs, two examples are given, showing how adaptivity can be provided for active and reflective as well as for sequential and global learning styles in typical learning systems.

A main characteristic of an active learning style is a preference for learning by doing. For this purpose, active learners can use exercises, where some practical questions/tasks are provided. On the other hand, reflective learners get more out from examples, observing how something can be done rather than doing it actively. One way to provide adaptivity for active and reflective learners is to vary the number of questions in an exercise and the number of examples, providing more questions or more comprehensive exercises for active learners and providing more examples for reflective learners.

A main characteristic of learners with global preferences is that they do not learn in incremental steps. Usually, they need a lot of time and much information until they get the ‘‘big picture” of a topic. Since these learners find it difficult to take any affirmative action without a complete picture, it is more suitable for them to first learn more about the whole topic, and do exercises and tests only after all information is learned and when they can see the ‘‘big picture”.

Therefore, one possibility to adapt to the needs of global and sequential learners in adaptive learning systems is to provide two different recommended sequences of learning. For sequential learners, it is suitable to learn a chapter, do exercises about this chapter, and then get tested on it. For global learners, it is more suitable to separate the exercises and tests from learning concepts and provide them after all concepts have been learned.

3.2. Cognitive Abilities

Humans have a number of cognitive abilities (Carroll, 1993). Several of these abilities are crucial for learning. These include abilities such as working memory capacity, inductive reasoning ability, information processing speed, associative learning skills, meta-cognitive skills, observation ability, analysis ability, abstraction ability, and so on. Very little research has been done on providing adaptivity based on cognitive abilities. Kinshuk and Lin (2003) provided suggestions for considering working memory capacity, inductive reasoning ability, information processing speed, and associative learning skills in online courses. These suggestions were based on the Exploration Space Control elements (Kashihara, Kinshuk, Oppermann, Rashev, & Simm, 2000) which are elements that can be changed to create different versions of courses to suit different needs. These elements include the number and relevance of paths, the amount, concreteness and structure of content, as well as the number of information resources. For example, for learners with low working memory capacity it is suggested to decrease the number of paths and increasing the relevance of paths in a course. Furthermore, less but more concrete content should be presented and the number of available media resources should increase. In contrast, for learners with high working memory capacity, less relevant paths can be presented with the amount of content as well as its abstractness being increased.

Jia, Zhong, Zheng, and Liu (2010) proposed the design of an adaptive learning system which is based on fuzzy set theory and can consider cognitive abilities such as induction ability, memory ability, observation ability, analysis ability, abstract ability, deductive ability, mathematic ability, association ability, imagination ability, and logic reasoning ability. These cognitive abilities, together with the students' knowledge level, goals and preferences, are taken into consideration when learning resources are suggested to the learners. Furthermore, Jia et al. (2010) proposed a student model which detects students' cognitive abilities based on test questions about the learned topics.

Another way of identifying students' cognitive abilities is to infer them from students' behavior in a course. Kinshuk and Lin (2004) introduced the Cognitive Trait Model (CTM), which is a student model that profiles learners according to their cognitive abilities. Four cognitive abilities, working memory capacity, inductive reasoning ability, processing speed, and associative learning skills are included in CTM. The CTM offers the role of 'learning companion', which can be consulted by and interacted with different learning environments about a particular learner. The CTM can still be valid after a long period of time due to the more or less persistent nature of cognitive abilities of human beings (Deary, Whiteman, Starr, Whalley, & Fox, 2004). When a student encounters a new learning environment, the learning environment can directly use the CTM of the particular student, and does not need to "re-learn the student." The identification of the cognitive abilities is based on the behavior of learners in the system. Various patterns, called Manifests of Traits (MOT), are defined for each cognitive ability. Each MOT is a piece of an interaction pattern that manifests a learner's characteristic. A neural network (Lin & Kinshuk, 2004) was used to calculate the cognitive traits of the learners based on the information of the MOTs.

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