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A Heuristic Algorithm for planning personalized learning paths for context-aware ubiquitous learning

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ABSTRACT

In a context-aware ubiquitous learning environment, learning systems can detect students' learning behaviors in the real-world with the help of context-aware (sensor) technology; that is, students can be guided to observe or operate real-world objects with personalized support from the digital world. In this study, an optimization problem that models the objectives and criteria for determining personalized context-aware ubiquitous learning paths to maximize the learning efficacy for individual students is formulated by taking the meaningfulness of the learning paths and the number of simultaneous visitors to each learning object into account. Moreover, a Heuristic Algorithm is proposed to find a quality solution. Experimental results from the learning activities conducted in a natural science butterfly-ecology course of an elementary school are also given to depict the benefits of the innovative approach.

1. Background and motivation

With the rapid development of mobile, wireless communication and sensor technologies, opportunities for conducting new learning strategies by integrating authentic learning environments and the resources of the digital world have attracted much attention from researchers from both the fields of education and computer science (Chen, Kao, & Sheu, 2003; Hwang, 2003). A context-aware ubiquitous learning (u-learning) environment provides such a learning scenario that individual students are guided to learn in a real-world situation with supports or instructions from a computer system, using a mobile device to access the digital content via wireless communications; in the meantime, the learning system is able to detect and record the learning behaviors of the students in both the real-world and the virtual world with the help of the sensor technology (Ogata & Yano, 2004; Hwang, Tsai, & Yang, 2008). Such a new technology-enhanced learning model not only supports learners with an alternative way to deal with problems in the real-world, but also enables the learning system to more actively interact with the learners (Hwang, 2006; Murakami, 2003).

Although such technology-enhanced learning approaches have been proven to be effective, past experiences have also revealed the difficulties of applying them. In terms of technique, these difficulties are easy to overcome; however, in terms of education, it is difficult to arrange the learning activities so that the students will be guided to learn the right thing in the right place at the right time. Especially, in a u-learning environment which includes diverse context parameters, cognitive overloading and disorientation might become a problem while the students are being guided to learn content from both the real-world and the digital world (Hwang, Wu, & Chen, 2007). Therefore, it has become an important challenge to plan personalized u-learning paths for individual students to learn in a context-aware u-learning environment.

Most of the previous studies on personalized learning path generation schemes have mainly focused on guiding the students to learn in the digital world; that is, each learning path represents a set of digitalized learning objects that are linked together based on some rules or constraints (Liu, Wu, Chang, & Heh, 2008). While determining such digitalized learning paths, the learning achievements, online behaviors or personalized features (such as learning styles) of individual students are usually taken into consideration (Chen, 2008a, 2008b, 2009; Chen, Lee, & Chen, 2004; Schiaffino, Garcia, & Amandi, 2008).

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While conducting learning activities in a real-world situation, the factors to be taken into account are quite different. For example, several studies have found that the number of students is an important factor that significantly affects the learning achievements of students due to the physical constraints of real-world positions (Westerlund, 2008; Zahorik, 1999). Din (2009) also indicated that, in the real-world learning environment, better learning performance will be achieved if the number of students is well controlled.

Thus, this study proposes a learning guidance strategy for a personalized context-aware u-learning system by taking the relevance of the real-world objects to be learned and the number of students who visit the same objects into consideration. The learning system incorporates RFID (Radio Frequency Identification) technology, an automatic identification method which stores and remotely retrieves data using devices called RFID tags, to detect the learning behaviors of students in the real-world so that it is able to guide them to interact with real-world learning objects. In this innovative approach, the repertory grid-oriented technique (Chu & Hwang, 2008) is applied to help the teachers describe the relevance between learning objects; accordingly, a Heuristic Algorithm is proposed to plan u-learning paths for individual students based on the relevance between each pair of learning objects and some practical considerations for conducting learning activities in the real-world. In addition, the experimental results from the learning activities conducted in an elementary school are presented to show the effectiveness of the innovative approach.

2. Objectives and problem definition

In a conventional authentic learning activity, the students are guided by a learning-mission sheet prepared by the teacher, and write down their findings on the sheet after visiting each of the learning objects. Such a learning activity allows the students to observe the real-world objects without personalized guidance or support; consequently, some students might fail to pay attention to the key features to be observed, or fail to complete the mission owing to a lack of sufficient information or guidance.

Consequently, in this study, a context-aware u-learning activity is considered, in which students are guided to observe several learning objects and complete their mission with support from the learning system via mobile devices (i.e. PDAs), wireless communication and sensor technology. That is, personalized support can be given to individual students to assist them in completing their learning-mission in an authentic learning environment. It should be noted that wherever in the conventional authentic learning environment or the context-aware u-learning environment the learner may be, to more effectively control the time of the learning activity, the learning procedure is usually divided into several stages with identical expected learning times; that is, the teachers will carefully design the missions in each stage, so that most of the students can complete their missions in the specified time. When the expected learning time is approached, all of the students are guided to start the next stage of their new mission. Such an arrangement aims to prevent the students from fooling around in one stage; moreover, it enables the teachers to more clearly observe the learning behaviors of students.

Although context-aware u-learning has been reported to be effective in several studies (Chu, Hwang, Huang, & Wu, 2008; Hwang et al., 2008; Hwang, Yang, Tsai, & Yang, 2009; Liu, Chu, Tan, & Chang, 2007; Ogata & Yano, 2004; Rogers et al., 2005; Wu, Yang, Hwang, & Chu, 2008), there are some problems to be coped with as follows:

(1) In the u-learning environment, there are many target objects for students to observe and learn about. As each target object represents different concepts or features to be learned, it is difficult for the students to determine the learning path for visiting the target objects without any guidance. If the learning path is not well arranged, they might fail to understand the relationships among those target objects. That is, they are likely to be disorientated in the learning process. Novak (1998) indicated that learning is a continuous process which adds new information to the existing information repository. If a learner can be guided to connect new information with their existing knowledge, the learning process is called meaningful learning. In the past decades, researchers have addressed the importance of guiding students to learn in a meaningful way; that is, to assist the students to learn new concepts based on the relevant concepts they already know (Araujo, Veit, & Moreira, 2008; Cardellini, 2004; Grabe & Grabe, 2007; Mass & Leauby, 2005).

(2) In conducting learning activities in real-world environments such as museums, ecology gardens or classrooms, researchers have found that the learning quality might be significantly affected if too many people attempt to visit or learn about the same target object simultaneously (Chang, Chang & Heh, 2007; Din, 2009; Jonassen, 1995; Limongelli, Sciarrone, Vaste, & Temperini, 2008). Thus, it is necessary to adequately guide them to visit a target object at the proper time, such that the learning quality for each target object can be better.

Assume that the degrees of relevance among these target objects are known. In a learning path, it is more meaningful to arrange the students to successively visit two greatly relevant learning objects. Moreover, in designing the learning activities conducted in an authentic environment, the time for visiting the learning object is usually the same, so that the students who are observing different learning objects can start to learn about the next learning object at the same time. Under these assumptions and criteria, we propose the following equation to evaluate the fitness for designing personalized learning paths in a context-aware ubiquitous learning environment:

$$\text{Minimize } \alpha\left(\sum_{t=1}^{m}\sum_{i\neq j}\frac{|Num(A_i,t)-Num(A_j,t)|}{m^2(m-1)n/2}\right)+\beta\left(\sum_{k=1}^{n}\sum_{t=1}^{m-1}\frac{[1-\text{Relevance }(\text{Location}(S_k,t+1),\text{Location }(S_k,t))]}{(m-1)n}\right) \quad (1)$$

The meanings of the symbols in Eq. (1) are described as follows:

- n indicates the number of students attending this context aware u-learning course
- m denotes the number of learning objects. Identical learning time is reserved for each student to observe each learning object
- t denotes the phase number in the learning activity, $1 \leqslant t \leqslant m$
- S_k represents the k th student, $1 \leqslant k \leqslant n$
- A_i means the i th learning object, $1 \leqslant i \leqslant m$
- $Num(A_i,t)$ means the number of students located at the i th learning object in the t th phase
- Relevance (Ai, Aj) indicates the degree of relevance between object i and object j, $0 \leqslant$ Relevance $(A_i, A_j) \leqslant 1.0$
- Location (S_k, t) denotes that the location of the learning object for the k th student in the t th phase, Location $(S_k, t) = A_i$ and $1 \leqslant i \leqslant m$