



# On extracting recommendation knowledge for personalized web-based learning based on ant colony optimization with segmented-goal and meta-control strategies

Feng-Hsu Wang\*

Computer Science and Information Engineering, Ming Chuan University, Taiwan

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## ABSTRACT

Personalized web-based learning has become an important learning form in the 21st century. To recommend appropriate online materials for a certain learner, several characteristics of the learner, such as his/her learning style, learning modality, cognitive style and competency, need to be considered. An earlier research result showed that a fuzzy knowledge extraction model can be established to extract personalized recommendation knowledge by discovering effective learning paths from past learning experiences through an ant colony optimization model. Though that results revealed the theoretical potential of the proposed method in discovering effective learning paths for learners, critical limitations arose when considering its applications in real world situations, such as the requirement of a large amount of learners and a long period of training cycles in order to discover good learning paths for learners. These practical issues motivate this research. In this paper, the aim is to resolve the aforementioned issues by devising more efficient algorithms that basically run on the same ant colony model yet requiring only a reasonable number of learners and training cycles to find satisfactory good results. The key approaches to resolving the practical issues include revising the global update policy, an adaptive search policy and a segmented-goal training strategy. Based on simulation results, it is shown that these new ingredients added to the original knowledge extraction algorithm result in more efficient ones that can be applied in practical situations.

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## 1. Introduction

As the explosion of information due to the Internet in modern age, it becomes more important and more difficult to retrieve information adapted to user preferences. Therefore, personalized recommendation systems are in need to provide proper recommendations based on users' requirements and preferences (Riecken, 2000). Besides, recommendation systems also find their applications in the eLearning area, especially as personalized web-based learning has become an important learning paradigm in the 21st century. Since learning resources grow so abundant on the Internet that the problem of how to help learners get appropriate learning materials to fit their learning needs has become a popular research subject in the area of adaptive content delivery.

A challenging work of this research lies in how to discover effective recommendation knowledge efficiently from past access history of a web-based learning platform (Mor & Minguillon, 2005; Tang & Mccalla, 2004). An earlier research (Wang & Lin, 2010)

showed that a fuzzy knowledge extraction model can be established to extract recommendation knowledge for personalized web-based learning by discovering effective learning paths from a past access database through a novel approach that is inspired by the experience sharing mechanism of natural ants. This approach imitates the natural ants, which share the paths they have found leading to food by scattering pheromone along the paths. In this approach, learners play the role of ants, scattering trail marks in a proper way according to their learning performances along the learning paths characterized by specific learning contexts. These trail marks can then be used to discover effective learning paths for learners with specific learning styles and competency.

However, though the research results (Wang & Lin, 2010) revealed the theoretical potential of the proposed method in discovering effective learning paths for learners, critical limitations arose when considering its application in real world situations, such as the requirement of a large amount of learners and a long period of training cycles in order to discover good learning paths for learners. That requirement is impractical for large classes in life and a reasonable time for a course to accumulate good learning experiences should be as short as possible. Therefore, this research is aimed to resolve the aforementioned issues by devising more

\* Address: 5 De-Ming Rd., Gui-Shan Township, Taoyuan County 333, Taiwan. Tel.: +886 3 3507001x3836; fax: +886 3 3593842.

E-mail address: [fhwang@mail.mcu.edu.tw](mailto:fhwang@mail.mcu.edu.tw)

efficient algorithms that basically run on the same ant colony model yet requiring only a reasonable number of learners and training cycles to find satisfactory good results.

## 2. Literature review

In the context of personalized recommendation on the Internet, web usage mining has been used as a potential approach to fulfill the requirement of web personalization (Cooley, Mobasher, & Srivastava, 1997; Eirinaki & Vazirgiannis, 2003; Fu, Budzik, & Hammond, 2000; Gery & Haddad, 2003; Mobasher, Cooley, & Srivastava, 2000; Mulvenna, Anand, & Buchner, 2000). In some commercial applications, the problem is approached by building an anticipation model through analyzing the content of items that a user has purchased in the past or put in the user's personal preference list. In some situations, the items can be those visited in the user's navigation history. However, this content-based approach has several shortcomings and critical issues, such as that only a very shallow analysis of specific kinds of content (text documents, etc.) are available; users can receive only recommendations similar to their earlier experiences; and the sparseness problem of item rating information (Kwak & Cho, 2001; Lee, Kim, & Rhee, 2001).

On the other hand, in the approach of collaborative filtering (Riecken, 2000), items are recommended to a particular user when other similar users also prefer them. The definition of 'similarity' between users depends on applications. For example, it may be defined as users having similar ratings of items or users showing similar navigation behavior. However, a pure collaborative filtering system also has several shortcomings and critical issues, including that the coverage of item ratings could be very sparse, hence yielding poor recommendation efficiency; the difficulty of providing recommendations for users who have unusual tastes; and the user clustering and classification problems for users with changing and/or evolving preferences (Konstan et al., 1997).

As far as learning on the web is concerned, the experiences that learners have gone through need to be further distinguished into good and bad ones in terms of learning effectiveness. Therefore, the aforementioned approaches to personalized recommendation have to be extended in some way so that they can distinguish good experiences from the bad ones in terms of some performance measurement. Another fact that distinguishes recommendation systems for web-based learning from other fields is that intrinsic characteristics of a learner, such as learning style, learning modality, cognitive style and competency, need to be considered to deliver appropriate contents to his/her characteristics (Jegade, Taylor, & Okebukola, 1991; Liu & Ginther, 1999). For example, to match the type of content with Kolb's abstract-concrete style (Kolb learning styles, 2005), convergers should access abstract information, and divergers should access concrete information in the learning process. Furthermore, convergers should access examples in physical science, while divergers should access examples in liberal arts and humanities; assimilators should access examples in research and planning work, while accommodators should access examples in marketing and sales work (Dick & Carey, 1996). From this point of view, we need a new approach that can deal with the recommendation problem for personalized web-based learning by considering all the aforementioned demands in a seamless way.

Finally, a research area that relates to this research is the development of a new paradigm for computational optimization algorithms, called ACO (Ant Colony Optimization) in computer science. The ant algorithm proposed in (Gambardella & Dorigo, 1996) generated an artificial wisdom (heuristic) which was developed based on the behavior of nature ants to control the direction of finding good solutions to optimization problems. Computational threads, called artificial ants, are executed separately to find solu-

tions based on their individual states. At each move of an artificial ant, the choice is made in a certain probabilistic distribution, which is determined by a proper combination of a priori information of the structure of good solutions and a posteriori information of the structure of previously found solutions. A posteriori information of the structure of previously found solutions is accumulated by the amount of "pheromone" spread over the moves of the solutions previously found. The better quality of a found solution is of, the more pheromone it will spread over its moves. Besides, in order to avoid the phenomena of "local optimization", evaporation of pheromone in a proper rate is allowed.

An earlier research (Wang & Lin, 2010) showed that a fuzzy knowledge extraction model can be established to extract recommendation knowledge for personalized web-based learning based on the ACO model. Compared with the problem dealt with in this research, the problems solved by ACO algorithms are simpler in the sense that there is only one goal to be solved for all artificial ants, and the goal to be solved is independent of the internal states of the artificial ants during the search of solutions. In contrast, the problem addressed in this research considers different goals pursued by individuals with different and changing internal states. For example, a learner who is a beginner should pursue a more achievable learning goal than the one pursued when she/he becomes an advanced learner. Nevertheless, though the research results (Wang & Lin, 2010) revealed the theoretical potential of the proposed method in discovering effective learning paths for learners, critical limitations arose when considering its application in real world situations, such as the requirement of a large amount of learners and a long period of training cycles in order to discover good learning paths for learners. That makes the work of (Wang & Lin, 2010) impractical for large classes in life, and the time to accumulate good learning experiences should be as short as possible.

## 3. The revised ant colony model

In the following, to facilitate a better understanding of the problem dealt with in this research, a brief explanation about the term "learning experience" is given first. Learning experience is defined as the sequence of learning resource accesses, where resources refer to those in a web-based learning platform that are helpful for student learning, such as online materials, assessments, learning activities and so on. Another term for learning experience used interchangeably here is "learning path". Furthermore, "good" learning experiences refer to those that can help certain types of students (with specific learning styles and competency) to achieve significant improvement in learning performance. It should be noted that good learning experiences mean different for different types of learners. Finally, learning performance is assumed to be measurable by assessment tools such as those developed in Wang (2010). Therefore, the "value" of a learning experience is defined as the degree to which it can help students to improve their learning performances. Next, we present the main idea of our approach in the following subsections.

In the context of web-based learning, learners learn through accessing online materials and doing self-assessments to evaluate their performance, hence producing a large amount of learning experiences. Learners with different characteristics need different types of materials to meet their specific learning styles and competency. The problem here is how to provide appropriate recommendations for learners matching their individual characteristics so that they can learn in a more efficient way tailored to their learning characteristics. In this research, individual characteristics are described in terms of competency and personal innate characters like learning styles, modalities, and/or cognitive styles. For examples, for learning styles, categories developed by researchers can be a

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