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A learner oriented learning recommendation approach based on mixed concept mapping and immune algorithm

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ABSTRACT

Personalized recommendation in e-learning has attracted the interest of many researchers. How to select the proper learning objects (LOs) and provide a suitable learning path for learners is a complex task. The effectiveness of personalized recommender systems are mostly decided by the reasonable models of learners and learning resources. However, the modeling method needs further research for the learners' special natures in e-learning. Heuristic methods have achieved significant successes on personalized recommendation, but the operators of some heuristic algorithms are often fixed, which diminishes the algorithms' extendibility. In this paper, we propose a learner oriented recommendation approach based on mixed concept mapping and immune algorithm (IA). First, we build universal models for learners and LOs respectively, then apply mixed concept mapping to assimilate their attributes. Second, we model the learner oriented recommendation as a constraint satisfaction problem (CSP) which aims to minimize the penalty function of unsatisfied indexes. Last, we propose an advanced IA which takes the inherent characteristics of personalized recommendation into consideration, and we design the monomer vaccine and block vaccine to optimize the IA. Our approach is compared with other heuristic algorithms and traditional teaching method. From the experimental results, it can be concluded that the proposed approach shows high adaptability and efficiency in e-learning recommendation.

1. Introduction

Ubiquitous learning resources on the Internet foster the growth of e-learning. In particular, the extensive application of Massive Open Online Courses (MOOCs) triggers a revolution in e-learning and many learners have benefited from it. However, along with the popularity of e-learning, many ill-structured and informal learning materials arise, and this usually brings about a confusing and boring learning process. How to ensure learners conveniently and effectively access e-learning resources, and how to enhance learners' learning experience and satisfaction are critical challenges [1]. Personalized recommendation can provide the appropriate LOs and learning paths according to learners' individual preferences.

Currently, some technologies have been applied on personalized recommendations. Salehi and Kamalabadi [2] categorized recommendation methods into four groups, that is, data mining, content-based recommendation, collaborative filtering and hybrid approach. Data mining is more suitable for learning path recommendations. Content-based recommendation sometimes faces with the problem of information overload because of the excessive recommendation for some specific demands. Collaborative filtering is limited to cold start and sparsity problems [3]. Hybrid approach is a more reliable method for personalized recommendation [4,5], and this approach is widely applied, especially on the recommendations of e-commerce [6–9]. However, it is obvious that content-based recommendation is the fundamental approach and it is important for personalized recommendation. Well-designed content-based recommendation can accurately reflect learners' intrinsic attributes and learning styles, and it also provides valuable information for other recommendation approaches.

In e-learning, there are a lot of researches in the field of content-based recommendation. Adaptive educational hypermedia system (AEHS) was proposed to generate possible learning paths to match learners' learning goals, and then adaptively recommend the LOs under the guide of a decision model [10]. However, this method is often accompanied by high complexity. Georgiadis et al. [11] attempted to obtain the ordered partitions of personalized curricula based on course priority constraints and learners' cognitive level. De-Marcos et al. [12] focused on competency-based

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learning resources sequencing. It turns the personalization recommendation into a CSP by matching learners' competency with learning object (LO) metadata. Durand et al. [13] put forward a graph theory model which organized LOs with a competency-based clique, and computed the local optimal learning path using greedy algorithm. Based on item response theory (IRT), Chen [14] devoted to match LOs' difficulty level with learners' ability. It obtained learners' weaknesses and implemented the personalized learning by improving the weaknesses. Limongelli et al. [15] gave an initial LO sequence based on a learner's present cognitive state and learning style, and then applied the linear temporal logic adaptation algorithm to output a new LO sequence responding to the learner's changes. Katuk and Ryu [16] focused on learners' feelings and emotions and aimed to provide fluent learning processes. The above researches put emphasis on learners' some special preferences or demands. In fact, the learner's learning effect is determined by many factors, such as emotions. Especially in e-learning, the learner's learning experience cannot be timely accessed and processed because of the lack of face to face communication; learners often feel tired and lower incentives if there is no immediate feedback on their emotions. In our study, to improve the efficiency of personalized recommendation, we considered some critical factors which influence learners' learning effects in e-learning and proposed a more comprehensive modeling method for learners.

We applied concept mapping to deal with the learner and LO models. As a graphical tool for organizing and representing knowledge, concept mapping has been successfully applied on education, especially to increase meaningful learning [17]. Chen et al. [18] proposed a scaffold concept mapping strategy, which considers students' prior knowledge and provides a more flexible (scaffolding and fading) strategy with various levels of support. Chen and Sue [19] proposed a method for automatically constructing concept maps by analyzing answer-consistence. There are still many researches applied concept mapping on accessing learners' achievement changes and just-in-time feedback during the learning process [20,21]. The existing work only focuses on the organization and representation of objective knowledge without considering the relationship between learners' and LOs. We take learner as a concept for the first time and design mixed concept mapping. The multidimensional attributes and hierarchical learning goals of a learner are combined into LOs' concept map. This knowledge representation effectively enhances the effect and efficiency of the personalized recommendation.

Once the learner model is built up, we can sequence LOs and present them to specific learner. In this paper we mainly discuss formal setting environment in e-learning, that is, the learning offers from educational institutions (e.g., universities, schools) within a curriculum or syllabus framework [2]. Personalized recommendation is considered as a nondeterministic polynomial-time problem, heuristics and meta-heuristics are usually used to find the approximate optimal solution. Al-Muhaideb and Menai [22] overviewed recent developments of evolutionary algorithms. For instance, Seki et al. [23] presented a distributed genetic algorithm (GA) to provide an optimal learning path considering learners' cumulative cognitive complexity. Chen [24] studied the novel genetic-based curriculum sequencing scheme based on ontology-based concept map, which can be automatically constructed by the pretest results of numerous learners, to plan appropriate learning paths for individual learners. Romero et al. [25] combined GA with the learner-LO association. GA is easy to be implemented and it is effective to solve LO sequencing. However, GA faces the problems of parameter setting and operator selection. For example, the inappropriate parameter designs of crossover, mutation and recombination often make the evolutionary process uncertain and even out of control [26]. Particle swarm optimization (PSO) implements LO sequencing using swarm intelligence mechanism, especially owing to the guidance of velocity and direction from gbest and pbest [27–29]. PSO has fewer parameters and it has been applied on CS with more complexity levels of resources. Yet, compared with GA, PSO is easier to fall into local optimum and it lacks effective convergent analysis approach. As a typical swarm intelligence algorithm, ant colony optimization (ACO) algorithm performs better in learning path regulation [30–32]. Pheromone accumulation and evaporation mechanism influence the movement of ant colony. LO is taken as search node and the weighted edge between LOs indicates the selection probability of LOs. But it is hard to organize the large quantity of LOs into a foraging graph, and pheromone is not convenient to represent the large number of constraints.

Nevertheless, in terms of the implementation of the above algorithms, their operators have fixed forms, therefore, they are difficult to reflect the inherent informations in the unsolved problems. As for immune system, it is a highly evolved and complicated functional system of organisms. It can self-adaptively identify and eliminate the foreign antigens which intrude into antibodies. In addition, the immune system is capable of learning, memorizing and self-adaptive controlling. IA uses the clonal selection principle to guarantee the diversity and availability of antibodies. The immune strategy accelerates the search speed and also ensures the global search capacity [33,34]. Many derived algorithms refer to the immune mechanism, such as artificial immune algorithm and immune genetic algorithm, and they work well in many fields, especially in multi-objective optimization and layout problems [35–37]. For e-learning, Lee et al. [38] applied IA to improve the efficiency of composing near optimal test sheet from item banks to meet multiple assessment criteria. However, the inherent characteristics of unsolved problems are rarely studied for the algorithm's improvement. How to design immune strategies according to the characteristics of recommendation problems is a key issue. In this paper the characteristics of learners' preference constraints are combined into immune mechanisms and vaccine inoculation, such as the sequence preferences on LOs' media and content, the prior relationships among resources.

Our paper is innovative since it is the first to propose a resources and emotions related model for learners in e-learning, and it is the first to apply mixed concept mapping on the representation of both learners and resources. The immune strategies of vaccine extraction are also innovative. This paper makes contributions to the key technologies in e-learning. The flexible modeling and knowledge representation approaches of learners and resources are developed, and an advanced immune algorithm is proposed to solve personalized e-learning recommendation. Experiments show the proposed approach can improve the success of personalized recommendation and enhance learners' learning experience.

The rest of this paper is structured as follows: Section 2 describes the related methods in our approach. It includes the modeling methods, the advanced strategies of IA and the experiment design. Section 3 is about experiment results. Section 4 discusses the results. Section 5 presents conclusion and our future work.

2. Methods

2.1. Material preliminaries

2.1.1. Learner modeling

In learner oriented recommendations, learners' attributes affect the selection and sequence of learning resources. So learner modeling is the basic and vital step for recommendation. But the fact has been acknowledged that learning style is a fuzzy concept [39]. There are many categorizations of learning style. David Kolb put forward four kinds of individual learning styles which are

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