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A cognitive approach for agent-based personalized recommendation

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Abstract

There is an increasing need for various e-service, e-commerce and e-business sites to provide personalized recommendations to on-line customers. This paper proposes a new type of personalized recommendation agents called fuzzy cognitive agents. Fuzzy cognitive agents are designed to give personalized suggestions based on the user's current personal preferences, other user's common preferences, and expert's domain knowledge. Fuzzy cognitive agents are able to represent knowledge via extended fuzzy cognitive maps, to learn users' preferences from most recent cases and to help customers make inferences and decisions through numeric computation instead of symbolic and logic deduction. A case study is included to illustrate how personalized recommendations are made by fuzzy cognitive agents in e-commerce sites. The case study demonstrates that the fuzzy cognitive agent is both flexible and effective in supporting e-commerce applications.
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1. Introduction

In recent years, people have seen a huge increase of e-service, e-commerce and e-business applications operating over the Internet [1]. Recommendation systems are increasingly being used by application providers for making suggestions to their customers [2]. However, most of the traditional recommendation systems mainly focus on extracting and recommending the common preferences based on user's historical data [3,4]. Although general users' common preference may be of relevant consideration, an individual user also has his/her own personal preferences. He/she may also reply on the domain expert's knowledge to some extent to make decisions. Moreover, very often, while using traditional recommendation systems, it is not easy for the users to distinguish whether the items contained in a page are actual recommendations or simply the contents of the page which are displayed indiscriminately to all users. Hence, traditional recommendation systems do not give the customers the impression of being treated individually. Jeff Bezos, CEO of Amazon.com drew a conclusion that "If I have 3 million customers on the Web, I should have 3 million stores on the web" [3]. Personalized recommendation agents are emerging to overcome the impersonal nature of integrated recommendations by using technology to assist customers to do decision-makings in treating each customer individually [5].

Agent technology is one of the most promising technologies for facilitating personalized recommendations. Software agents are being used in an increasingly wide variety of software applications – ranging from comparatively small systems such as personalized e-mail filters to large complex mission critical systems such as air-traffic control [6]. The notable characters associated with software agents such as autonomous, pro-active, goal-oriented, intelligent, social, etc. make software agents well suited for playing the role of personalized recommenders to individual users of various e-service, e-commerce and e-business sites.

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The key characteristic of e-commerce/business applications is that they will inevitably move more and more into a customer-centric paradigm in order to increase competitiveness [7]. Therefore, nowadays, there are increasing demands for applying the capabilities of agents to e-commerce/business applications [8]. However the potential of agent's usage in customer-centric paradigm such as personalized recommendations is highly unrealized in the current e-commerce/business applications [9]. An analysis by the Gartner Group reveals that a large proportion of users find difficulty in determining what they really want while visiting electronic commerce sites [10]. This is because the constraints of physical space no longer dictate the organization of information in electronic shopping environments [11]. Online vendors are able to offer a very large number of products to consumers. On one hand, easy access to large amounts of product information allows consumers to select products that better match their personal preferences. On the other hand, human beings have limited cognitive capacity of information-processing. A solution to the above information-overload problem is that users tend to rely heavily upon an electronic agent's product recommendation in order to reduce the amount of effort required to make a purchase decision [5]. However, although a number of electronic commerce sites have already provided shopping agents to assistant users, the help that they offer is very limited [8,9]. What customers expect and require are more knowledgeable shopping agents who are able to understand their exact concerns, represent both their knowledge and domain expert's knowledge, and help them to recommend satisfactory products, similar to what happen in real life shops.

In order to meet the customer's expectation, software agents must have the ability to represent knowledge, learn and reason which remain as research challenges in the area of agent world [12]. First, software agents have to represent user's desires or intentions that are usually imprecisely or vaguely expressed using human language. For instance, a user may give a vague goal such as: "*Locate a flight to Hong Kong on a carrier with a high safely record, is not expensive price and has quality services.* Secondly, the environment that the agent acts in may contain a lot of uncertain and fuzzy information as a large number of the features that characterize the real world objects are described by imprecise linguistic expressions. Finally, besides the capability of understanding the users and perception of environment, agent must also be able to learn from previous experiences and to infer based on its knowledge.

In this paper, we propose a new type of personalized recommendation agents called fuzzy cognitive agents. Fuzzy cognitive agents are designed to give personalized suggestions to the on-line customers based on the current user's personal preferences, other user's common preferences, and the expert's knowledge. Our focus is on integrating the two types of preferences, which represents our novel contribution to recommendation systems.

The paper is organized into 5 sections. Following this introduction, Section 2 describes the proposed fuzzy cognitive agents. A case study and some experimental results are included in Section 3 to illustrate how personalized recommendations are made by fuzzy cognitive agents in e-commerce sites. Section 4 reviews some related research work. Finally the conclusion and the future work are given in Section 5.

2. Fuzzy cognitive agent

A personalized recommendation agent is conceptualized as a software agent that (a) attempts to understand and represent a human decision maker's preferences with respect to a particular domain or product category, (b) makes recommendations by its learning and inference ability in the form of a sorted list of alternative provided to the human in a decision task based on its understanding of that individual's preferences [5]. In this section, we present a particular type of personalized recommendation agents called fuzzy cognitive agent to meet the requirements and challenges we discussed in Section 1. Fuzzy cognitive agents are able to present the following behaviors:

- Communicate with users.
- Perceive the environment.
- Represent knowledge including current user's personal preferences, other users' common preferences and expert's knowledge, etc.
- Learn from general users' most recent behavior records.
- Make inference based on its represented knowledge.
- Make personalized recommendations to individual users based on current user's personal preferences, general users' common preferences and expert's knowledge.

To enable fuzzy cognitive agents to represent (express) both the user's preferences and the experts' knowledge with learning and inference capabilities, following, we propose an agent knowledge model based on the FCM theory and its extension [13,14].

2.1. The agent's knowledge model

The knowledge model of a fuzzy cognitive agent can be viewed as an extended fuzzy cognitive map. The model comprises two types of objects: *concept* and *weight*. The factors that fuzzy cognitive agents need to perceive within a given environment are represented by concepts. These concepts are connected by weights which indicate there are causal–effect relationships between the concepts. Therefore, the concepts existing in an agent environment can be organized into signed and weighted directed maps.

An example directed graph of the agent knowledge model is shown in Fig. 1. Concepts are indicated by nodes, and weights are presented by directed, signed and weighted edges. The weight edge points from the "cause concept" to the "effect concept". The value of the weight describes the