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Preference recommendation for personalized search

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ABSTRACT

Conditional Preference Networks (CP-nets) are widely used to express qualitative preferences. As users are sometimes reluctant or unable to specify complete CP-nets, it prohibits personalized search from being effectively conducted. In this article, we present an approach to perform personalized search using incomplete CP-nets. We propose a preference recommendation scheme for complementing a user's CP-nets, so as to improve the accuracy of personalized search. We have conducted extensive simulation and user study to demonstrate the effectiveness of our approach.

1. Introduction

With the enrichment of products and services on the Internet, service consumers are faced with an increasing spectrum of choices. Decision making in face of a large number of choices is always a challenge, especially when decision makers have diverse tastes or criteria. Personalized search [1–5] is a technology aiming to help users identify desirable products or services based on their personal preferences. It elicits a user's preferences, expresses them in standard models, and let computer systems automatically identify products interested by the user.

In recent years, a number of models, with varying expressiveness and complexity, have been proposed to describe user preferences for personalized search. For instance, Matthijs et al. [6] presented a personalization approach that builds user profiles using users' complete browsing behavior. Kim et al. [7] proposed a tag-based personalized search model to enhance the accuracy and coverage of information retrieval. Among these models, Conditional Preference Networks (CP-nets) [8–10] is a widely used one. It is not only able to concisely express users' qualitative preferences, but also able to specify the scopes of user preferences. This makes CP-nets a suitable model for personalized search systems.

Most of the existing search systems based on CP-nets [11,12] assume that users should completely specify their preferences prior to search. This assumption may not hold in many real word circumstances. As preference elicitation and description are usually tedious and error-prone processes [13], it is not always realistic to acquire complete CP-nets expressions of users' preferences. To make personalized search work, it is essential that a system could cope with incomplete CP-nets expressions and make the best of the available information to retrieve user desired products or services.

Some relevant technologies were introduced in our previous work [14,15], which attempts to utilize incomplete CP-nets to select Web services [14]. Furthermore, we have introduced a framework based on collaborative filtering [15] to perform preference complementation. In this paper, we extend our previous work and propose a complete system for conducting personalized search using incomplete CP-nets. Firstly, we broaden the application of our approach from service selection to object search. Secondly, we propose a new and complete framework to manage the process of this method. Thirdly, based on the principle of collaborative filtering [16], we propose a preference recommendation scheme for users to incrementally complement incomplete CP-nets and resolve conflicting CP-nets during the course of personalized search. Three new algorithms are proposed and applied in different steps of personalized search. Finally, new sets of simulation and user study were conducted, to compare our approach against other approaches.

The remainder of the paper is organized as follows. Section 2 reviews some background on CP-nets and collaborative filtering.

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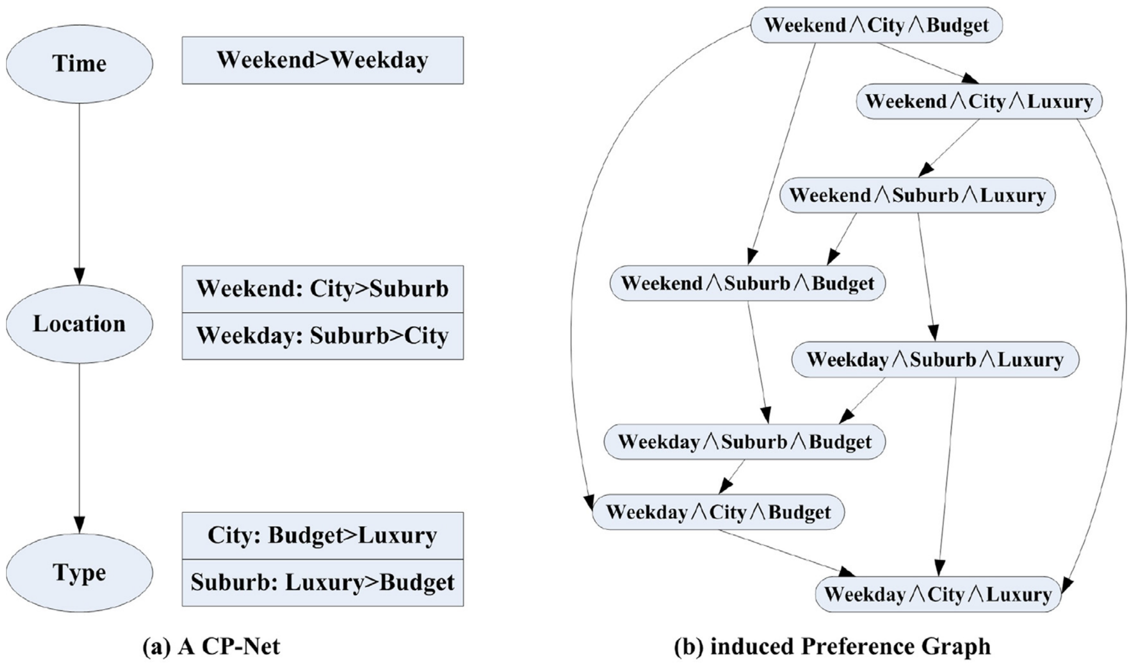

Fig. 1. CP-nets example.

Section 3 presents the personalized search system based on preference recommendation. Section 4 introduces a set of novel personalized search methods. Section 5 presents the results of the experimental evaluation and user study. Finally, Section 6 concludes the paper and provides direction for future work.

2. Background and related work

In this section, we give a brief introduction of CP-nets and collaborative filtering.

2.1. CP-nets

Conditional Preference Networks (CP-nets) [8,17] were designed for representing qualitative user preferences. The model can be defined as follows.

Definition 1 (CP-nets)**.** Let $V = \{X_1, \ldots, X_n\}$ be the set of attributes of a type of objects. The CP-nets over V is a directed graph G over $X_1,\ldots, X_n$ (which is called *dependency graph*), whose nodes are annotated with conditional preference tables, denoted by $CPT(X_i)$ for each $X_i \in V$. Each conditional preference table $CPT(X_i)$ associates a total order of X_is values with each instantiation of X_is parents.

We illustrate the semantics of CP-nets using an example in Fig. 1. Suppose Alice plans to visit Sydney and need to book a hotel on the Internet. She is then faced with a number of choices, such as *time* (i.e., on a weekend or weekday), *location* of hotel (i.e., in the city or a suburb), and *type* of hotel (i.e., a budget hotel or a luxury one). As shown in Fig. 1(a), Alice has an unconditional preference on time. Indicated by the corresponding CPT, she prefers to spend weekend in Sydney rather than weekday. Alice's preference on location, however, depends on the when she visits Sydney. If it is a weekend, she would like to stay in the city, as a lot of activities take place in the city on weekend. If it is a weekday, she prefers to stay in a suburb. Moreover, Alice's preference on the type of hotel depends on the area she is staying. If she lives in the city, she would like to book a budget hotel, as she will spend most of her time in the shopping malls rather in the hotel. If she lives in a suburb, she prefers a luxury hotel with quality service. Based on the CP-nets presentation of Alice's references, we can induce the detailed preference graph of her, which is shown in Fig. 1(b). A budget hotel in the city booked for a weekend will be Alice's first choice.

In real-world settings, a user may not be able to provide a complete CP-nets presentation of his/her preferences, especially when there are a large number attributes describing the products or services. As a result, Alice's preferences for hotels may be incomplete. As shown in Fig. 2(a), some fields in the CPT are missing. In this situation, *Weekend*∧*City*∧*budget, Weekend*∧*City*∧*Luxury* and *Weekday*∧*Suburb*∧*Luxury* become incomparable (see Fig. 2(b)). When preference specifications in a CP-nets are incomplete, personalized search will be less effective, as there can be too many candidates appearing optimal to the user.

The model of CP-nets was first introduced in [8,17], in which the authors present a number of core properties of this model as well as the algorithms for personalized search, such as the algorithms for optimal outcome generation and rankings.

In recent years, the model of CP-nets has been further expanded in some follow-up work [18]. Various techniques have been proposed to apply CP-nets to personalized search and decision making. They include the procedures to conduct CP-nets elicitation [19] and the methods to integrate CP-nets with other decision making supporting tools [20]. Recently, a CP-nets-based model for consumer-centric information service composition has been proposed [21]. However, existing techniques of personalized search rarely deal with the cases of incomplete CP-nets. In this paper, we provide solutions to personalized search with incomplete CP-nets.

2.2. Recommender system and collaborative filtering

Recommender system is a technology aiming to find products or services that can be interested by specific users. It analyzes a user's profile and predicts the user's interests through statistical methods. Then, users interests can be used to identify products. The approaches of recommender system can also be applied to preference elicitation. The most typical technique used in recommender system is collaborative filtering [16,22]. It assumes that like-minded users tend to have similar interests, and utilizes the