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Recommend products with consideration of multi-category inter-purchase time and price

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HIGHLIGHTS

- A method for deriving the changes of a user's interest for various categories is suggested.
- We put forward an approach to model a user's multi-category inter-purchase interval.
- The price preferences of users are constructed based on fuzzy set theory.
- We propose a recommender system by incorporating purchase interval and price.
- The proposed recommendation algorithm is evaluated with real purchase records.

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ABSTRACT

This study focuses on diversifying recommendations and improving recommendation accuracy by incorporating multi-category purchase interval and price in a novel way. We suggest a method to model the drift of a user's interest for different categories based on sequential pattern mining. Additionally, we propose a new approach to model personalized multi-category inter-purchase interval for the user. By employing fuzzy set theory, we also put forward an approach to model the price preferences for each user. We propose a recommender system that incorporates the methods mentioned above. The experimental results based on real purchase records show that the proposed recommendation algorithm has high stability and superior performance in recommending products with different characteristics. The results also demonstrate the effectiveness of incorporating purchase interval and price factor in recommender systems. This study demonstrates the existence of particular inter-purchase intervals among different categories, and indicates that price is an important factor influencing customers' decision making.

1. Introduction

E-commerce, a new form of shopping, has experienced great development in recent years, and various kinds of shopping websites have appeared filled with millions of different products. Along with the data richness, information overload becomes a problem [1]; however, recommender systems can be effective in tackling this matter [2,3]. Various recommender systems [4] have been proposed that try to generate individual recommendations to satisfy corresponding users' preferences and needs. To summarize, based on how recommendations are made, existing recommender systems can be classified into three main categories: content-based, collaborative filtering and hybrid ones [5]. These methods highly rely on ratings of items, and the scores are taken as representatives of users' preferences. However, people do not always rate products bought previously, and these earlier-purchased products account for only a tiny portion of the product set. This leads to the data sparsity problem, severely affecting the recommendation accuracy [6]. Nevertheless, considerable other information can be used not only to alleviate that problem, but also to improve prediction accuracy [7]. This study aims to raise the recommendation accuracy by considering other unexploited information, including the category attribute, temporal factor and product price. The details of the fundamental principles and application backgrounds regarding these additional factors in recommender system are discussed next.

To begin with, the existing recommender systems emphasize the accurate forecasts of a user's preference for different items [8],

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but seldom consider the relationships among the various product categories [9,10]. However, in the E-commerce domain, people often purchase various kinds of products, but different products of the same category are rarely purchased in a row [11–13]. Thus, given the products a user has purchased before, recommender systems should recommend some items of related categories, namely, cross-category recommendations [14]. Subject to the principle and philosophy behind the existing recommender systems, the homogeneous products are recommended to users.

To resolve this tough issue, at least in part, we consider first the category attributes [15] of products and propose a novel method to model the drift of a user's interest for different categories based on the sequential pattern mining technique. Second, a user often purchases the products of other categories after a particular time interval [16]. Different users may be subject to different purchase intervals for different category pairs, which reflects the change of users' preferences with time lapsing. We propose to employ the multi-category inter-purchase intervals to seek the categories a user is most interested in at a specific time.

Last, considerable research on consumer behavior indicates that price is one of the most dominant factors affecting consumers' marketing activities, and people generally have different preferences for price [17–19]. We put forward an approach to model the price preference of different categories for a user, recommending products where the prices are consistent with the price preference of each user.

Based on the three points mentioned above, we propose a novel recommender system recommending diverse products at different time. More specially, there are four main contributions of this paper:

1. Aiming to diversify the recommendations, we suggest a method to model the changes of a user's interest for different categories. The approach is operated based on sequential pattern mining technique by considering the category attributes.
2. With the temporal factor incorporated additionally, we propose a new approach to model the personalized multi-category inter-purchase interval tendency for every user.
3. We put forward an approach to model the price preference for every user. The approach employs fuzzy set theory to characterize the price level for each product first and then constructs the price preference based on the products in a user's purchase sequence.
4. We propose a novel recommender system incorporating the above-mentioned methods. We also conduct several experiments to test the effectiveness of the additionally considered factors about recommending products with different features.

The rest of this paper is organized as follows. The next section reviews related literature about recommender systems and theoretical foundation. Section 3 details our proposed recommender system. Section 4 reports the experiments. Section 5 concludes the paper.

2. Related work

In this section, we briefly describe several classical approaches widely applied in recommender systems. We also give the theoretical foundations of our model, explaining the effect of product price, cross-category purchase and purchase interval on consumer's purchase decision. Meanwhile, we highlight related work that also considers the factors and show the differences between their methods and ours.

2.1. Content-based and collaborative filtering

The classical methods of recommending items to a user are content-based (CB) and collaborative filtering (CF), and hybrid ones. Various recommender systems based on different recommendation techniques have been implemented [20–22]. The content-based recommender system builds the user profile based on the characteristics of the items a user purchased previously and then recommends the items that have the highest similarities with the user profile [5,23]. The similarity can be measured based on the weighted sum of different features that products possess. Although the concept behind this technique is simple, there are certain limitations. To begin with, various items have different features, and it is not easy and reasonable to unify the common features for all products [24]. Furthermore, the items recommended to users are always similar to those previously bought, namely, homogeneous recommendations [5,23]. The method of collaborative filtering highly relies on the user-item ratings and that can be seen as the representatives of the users' preferences. This approach is usually conducted in such a way that a user's missing rating for an item is predicted by aggregating the scores of users similar with the target user or the scores of items similar with the target item. The commonly employed similarity functions are Pearson correlation coefficient and cosine similarity that are performed with two vectors representing the users' profiles [25]. Since this approach depends highly on the users' ratings for the items, it often experiences the data sparsity problem and cold start matter [26,27]. Besides CB and CF, the hybrid approach combines the content-based method and collaborative filtering, hoping that integration can overcome the limitations of a single method [4,5].

2.2. Price preference

A lot of research has shown that price is one of the most influential factors when people are shopping [17,19]. Some recommender systems have considered price factor. The most common way is that price is considered as an attribute to get the utility of a product for a user in utility-based recommender systems [28]. Other studies apply the price factor in a different way, based mostly on the decreasing marginal utility theory in economics. For instance, Wang and Zhang [29] proposed a marginal net utility function based on the Cobb–Douglas utility function and created a joint probability model. However, the weights of diverse product attributes are various for different consumers and it is difficult to obtain with no interaction. Moreover, in an online shopping environment, the motivation of making compromises between function and price weakens. In traditional offline shopping, subject to location and limited information, prices of similar products, even products with all the same characteristics and quality, are quite disperse. Therefore, people have to make a tradeoff between product price and quality, features and other aspects. However, with the development of virtual environment, the prices become converged and the consumers' price perception is even influenced [30]. Even though a consumer is content with the features of a product, a diversion to other similar products can easily happen if the consumer is not satisfied with the price. Besides, according to mental accounting theory [31], people hold a mental account for every kind of consumption indicating the budget level, and when people are making a purchase decision, the mental accounting works. Accordingly, when a consumer is looking for products of a specific category, the expectancy price is consistent with the budget level. We denote the expectancy price as price preference, indicating the most likely price a user prefers for a certain type of products, and propose a new approach to model each user's price preference for every category based on fuzzy theory.

2.3. Cross-category buying

Different products at different time purchased by a consumer form a purchase sequences. The category attributes and purchase