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# A novel multi-objective evolutionary algorithm for recommendation systems

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## HIGHLIGHTS

- A new topic diversity indicator is introduced, which can be used to measure various kinds of items in a recommendation list.
- A new probabilistic multi-objective evolutionary algorithm (PMOEA) is presented, which is suitable for the recommendation systems.
- A new crossover operator is proposed to generate new solution, called the multi-parent probability genetic operator.
- The experimental results show that PMOEA can achieve a good balance between precision and diversity.

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## ABSTRACT

Nowadays, the recommendation algorithm has been used in lots of information systems and Internet applications. The recommendation algorithm can pick out the information that users are interested in. However, most traditional recommendation algorithms only consider the precision as the evaluation metric of the performance. Actually, the metrics of diversity and novelty are also very important for recommendation. Unfortunately, there is a conflict between precision and diversity in most cases. To balance these two metrics, some multi-objective evolutionary algorithms are applied to the recommendation algorithm. In this paper, we firstly put forward a kind of topic diversity metric. Then, we propose a novel multi-objective evolutionary algorithm for recommendation systems, called PMOEA. In PMOEA, we present a new probabilistic genetic operator. Through the extensive experiments, the results demonstrate that the combination of PMOEA and the recommendation algorithm can achieve a good balance between precision and diversity.



## 1. Introduction

With the arrival of the information age, people are faced with a large number of information resources on Internet. This is the problem of information overload, and it causes people cannot quickly find the information that they are interested in. In order to make the user quickly get the interested information, the recommendation system appears in people's eyes. Ricci et al. [24] introduced the basic ideas, concepts and some applications of the recommendation system. The recommendation system can pick out the interested information resources to the user based on the user's history experience. It can achieve the purpose of saving time and cost for people. The recommendation system has been successfully applied in all kinds of network activities [2]. Traditional recommendation algorithm can be roughly divided into content-based recommendation algorithm, collaborative filtering recommendation algorithm and hybrid recommendation algorithm.

The traditional recommendation system evaluates the ratings of items based on the user's experiences, and then the top-$n$ high rating items are selected to recommend. In order to improve the accuracy of the recommendation, the recommendation algorithms have been continuously developed. Some researchers make improvements on the methods of item rating evaluation. Liu et al. [15] analyzed a variety of calculation methods on the similarity, and proposed a new similarity method to improve the traditional collaborative filtering algorithm. Fan et al. [8] integrated content-based recommendation algorithm and user activity level to predict the empty values in user–item matrix when calculating user similarity. Zhou et al. [36] utilized the bipartite network to improve the recommendation system. Koren et al. [11] decomposed user–item

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matrix to evaluate the rating of unknown items to the user. In addition, many researchers consider the trust factor to improve the accuracy of recommendation algorithm. O'Donovan et al. [19] presented two trust models and incorporated them into standard collaborative filtering algorithm. Wanita et al. [31] described the characteristics of social network, trust, and the existing trust models in social networks. The trust of neighbor nodes is used to improve the item rating evaluation for the social recommendation [33,30,10,12]. Wang et al. [29] presented a joint social and content recommendation for user-generated videos in online social network. More and more recommendation systems are deployed on cloud environment. To optimize the resource scheduling in cloud systems, Qiu et al. [21] put forward a genetic-based optimization algorithm and Li et al. [14] presented an online optimization method about scheduling preemptable tasks on cloud for real-time systems. In order to improve the user experience of watching videos on mobile devices and social TV, Niu et al. [18] introduced a wireless interface scheduling algorithm to select proper wireless interfaces and Wang et al. [28] proposed a group recommendation algorithm based on external followee.

However, in the above recommendation algorithms, accuracy is regarded as a single evaluation metric. As shown in [9], we know that the traditional recommendation algorithms are faced with four challenges: the data sparse problem, the cold start problem, the single evaluation metric, and the problem of false data. The first two challenges have been slowed down in the existing recommendation algorithms. For the issue of the single evaluation metric, a good recommendation algorithm not only relies on the accuracy to measure the performance, but also takes some other metrics into account. McNee et al. [17] indicated that accuracy metrics have hurt recommendation systems. When a person likes to eat bread for breakfast, we not only recommend the bread to the user, but also need to recommend other types of breakfast. Some non-accuracy indicators of the recommendation system are proposed [2,34,13,3,16,1,37,20]. Bobadilla et al. [2] made a summary about the accuracy indicators and non-accuracy indicators. Accuracy indicators contain precision, recall and F1-measure. Non-accuracy indicators contain novelty, diversity, stability, and reliability. Zhang et al. [34] defined diversity according to the differences between items. Lathia et al. [13] showed that temporal diversity is an important facet of the recommendation systems. Castells et al. [3] demonstrated that novelty is the difference between present and past experience, and diversity is the internal differences within parts of an experience. Ma et al. [16] proposed an algorithm to solve the dilemma between accuracy, diversity and novelty based on bidirectional transfer. They defined diversity as the mean value of Hamming distance. Belem et al. [1] took a tag diversity into account for the topic diversity. Ziegler et al. [37] used dissimilarity rank to calculate the diversity. Panniello et al. [20] used the Simpson's diversity index, the Shannon's entropy and the Tidemann & Hall's index to represent recommendation diversity. In our reality life, the diversity should be used to describe various types of items. But sometimes, an item belongs to several types. In this situation, all above diversity indicators cannot effectively describe the diversity of items in a recommendation list. In this paper, we introduce a new indicator for the topic diversity.

Most traditional recommendation algorithms concentrate on item rating evaluation, which means the items are sorted by item rating, and the top-$n$ items are selected to recommend for the user. These algorithms can try to ensure the accuracy since the high rating items are recommended. However, they could not guarantee the non-accuracy indicators of the recommendation list. In order to solve the conflict between the accuracy indicator and non-accuracy indicator, some multi-objective algorithms are introduced into the recommendation system [9,39,26,22,23,27]. Geng et al. [9] proposed a recommendation algorithm, which utilizes non-dominated Neighbor Immune Algorithm. Zuo et al. [39] presented a MOEA-based recommendation method to solve conflicting between accuracy and diversity. Wang et al. [26] designed a multi-objective framework for long tail items recommendation. Ribeiro et al. [22] proposed a hybrid recommendation approach and utilized multi-objective approach to find several hybridization parameters of different algorithms. Ribeiro et al. [23] introduced the Pareto efficiency concept and presented a way to combine several recommendation algorithms that the multi-objective can be maximized simultaneously. Wang et al. [27] proposed a multi-objective evolutionary algorithm based on the decomposition to optimize the rating and the popularity of items simultaneously.

Although the multi-objective evolutionary algorithms can improve the performance of the recommendation algorithms, they are not satisfying enough. In this paper, we will try to carry on the improvement based on the application features of the recommendation system. Actually, in the recommendation system, the more times an item is recommended, the more likely it is to be accepted. In other words, when many friends recommend the same item to a user, this user would pay more attention to this item. According to this fact, we present a new multi-objective evolutionary algorithm (called PMOEA) for the recommendation systems. Our proposed multi-objective evolution algorithm is based on NSGA-II. The main contributions of this paper are as follows:

(1) We propose a new topic diversity indicator, which can be used to measure various kinds of items in a recommendation list.
(2) We propose a probabilistic multi-objective evolutionary algorithm, called PMOEA, which is suitable for the recommendation systems. PMOEA utilizes the probability to estimate whether the gene is inherited to the offspring solution. In PMOEA, we also design a new solution generation method, called the multi-parent probability genetic operator.
(3) Compared with some known recommendation algorithms, the experimental results show that the combination of PMOEA and the recommendation algorithm can improve the metrics of diversity and novelty, sacrificing a certain degree of precision.

The remainder of this paper is organized as follows. Section 2 introduces the research background and related works. In Section 3, we present the multi-objective recommendation framework and propose a novel multi-objective optimization for recommendation algorithms. The experimental results are discussed in Section 4. Finally, Section 5 concludes this paper.

## 2. Background

In this section, we will introduce the background of item rating evaluation, the typical multi-objective evolutionary algorithm and a classical multi-objective evolutionary recommendation algorithm.

### 2.1. Item rating evaluation

The traditional recommendation algorithm is based on the evaluation about the ratings of unknown items. And then, it selects the top-$n$ items to recommend. The item rating evaluation is the basic step for a recommendation algorithm. We briefly introduce User-based Collaborative Filtering algorithm, Item-based Collaborative Filtering algorithm [25] and ProbS method [36]. Collaborative Filtering algorithm utilizes the similarity between users or items to make item rating evaluation. ProbS method uses the concept of bipartite network and the allocating resource to make item rating evaluation. We will briefly introduce these three methods as follows.