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The dynamical modeling and simulation analysis of the recommendation on the user–movie network

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HIGHLIGHTS

- The dynamical models are established to describe the evolution of a user–movie network with time.
- The personal search and different recommendation methods are studied and compared.
- The search time is considered in our work for the first time.
- The effects of the different recommendation methods depend on the initial degree of the movie.

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ABSTRACT

At present, most research about the recommender system is based on graph theory and algebraic methods, but these methods cannot predict the evolution of the system with time under the recommendation method, and cannot dynamically analyze the long-term utility of the recommendation method. However, these two aspects can be studied by the dynamical method, which essentially investigates the intrinsic evolution mechanism of things, and is widely used to study a variety of actual problems. So, in this paper, network dynamics is used to study the recommendation on the user–movie network, which consists of users and movies, and the movies are watched either by the personal search or through the recommendation. Firstly, dynamical models are established to characterize the personal search and the system recommendation mechanism: the personal search model, the random recommendation model, the preference recommendation model, the degree recommendation model and the hybrid recommendation model. The rationality of the models established is verified by comparing the stochastic simulation with the numerical simulation. Moreover, the validity of the recommendation methods is evaluated by studying the movie degree, which is defined as the number of the movie that has been watched. Finally, we combine the personal search and the recommendation to establish a more general model. The change of the average degree of all the movies is given with the strength of the recommendation. Results show that for each recommendation method, the change of the movie degree is different, and is related to the initial degree of movies, the adjacency matrix A representing the relation between users and movies, the time t. Additionally, we find that in a long time, the degree recommendation is not as good as that in a short time, which fully demonstrates the advantage of the dynamical method. For the whole user–movie system, the preference recommendation is the best.

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1. Introduction

In recent years, with the development of science and technology and the advent of the internet, people face various information on the internet every day, which brings about not only great convenience for our daily life, but also much trouble. It is a new problem that we face to how to get what we really want from a large amount of information. To address this problem, recommender systems have emerged as a tool, which help users find the information they are interested in on the basis of the items' contents and personal historical activities [1–3]. For example, Fab is a recommender system for the Web, and it can recommend pages to users on the basis of their interests [4]. Amazon.com can recommend books and other items according to the users' purchased items, which indicate their preferences [5]. Cinematch is a movie recommender system, and it can predict whether the user will be fond of the movie that has not been watched according to the genres of the movies that have been watched, and make recommendation in the light of each user's interest [6].

Based on the different research methods, there has been a large quantity of research on the recommender system recently. Here, we divide them into two types, one of which is based on the algorithms [7–16], and the other is based on the graph models [17–22]. Sarwar et al. [7] explored item-based recommendation algorithms, and investigated the different ways of computing the similarity between items and the different techniques for obtaining the recommendations. Moradi et al. [8] presented a model-based collaborative filtering method by applying a novel graph clustering algorithm and considering trust statements. Liu et al. [9] proposed a hybrid collaborative filtering algorithm, which considered the user-based and the item attribute-based mechanisms. Zhang et al. [10] utilized the keywords correlated with corresponding websites to model users features, and proposed the tag-aware k-nearest neighbor collaborative filtering. Furthermore, in order to improve accuracy, diversity and novelty of the recommendation, and solve the cold-start problem, the related research has been done [11–16]. The above researches are based on the recommendation algorithms, and what most of them have in common is that they are based on the similarity, including the user similarity and the object similarity. Next, we review the research based on graph models. Huang et al. [17] developed a two-layer graph model in the context of digital libraries by representing books and users, and it incorporated book-to-book correlation, user-to-user correlation and book-to-user correlation. Xiang et al. [18] proposed a graph-based model to capture the users' long-term and short-term preferences over time by using the different node types and treating edges with different weights. Leskovec et al. [19] considered information cascades in the context of recommendation, and studied the patterns of cascading recommendations. Additionally, people are concerned about a particular class of the networks, called bipartite network, which has two types of vertices, and each edge connects the different types of vertices. If one type of vertex represents users, the other type denotes items, and the edges denote interactions between the users and the items in the bipartite network, such a bipartite network shows the basic structure of recommender system [20]. Zhou et al. [21] proposed a personal recommendation based on the weighting method, with asymmetrical weights in the bipartite network. Liu et al. [22] presented a personal recommendation on the basis of the resource-allocation on the bipartite networks, whose nodes were assigned an attraction that was proportional to the power of their degree. During the resource-allocation process, each item distributed its resource to its neighbors depending on their attractions. The above methods have been used to investigate movie recommendation by many researchers. Roy et al. [6] developed a movie recommender system by means of collaborative filtering, and could recommend movies to new users. Choi et al. [23] considered a movie recommender system and improved the previous algorithms based on genre correlations. Wei et al. [24] proposed a hybrid movie recommendation approach using tags and ratings. Grujić [25] studied the two types of movie recommendation networks. One was based on the Internet Movie Database recommendation, the other was based on the collaborative filtering through the users' habits, and the properties of the networks were investigated as well. In addition, many effective recommendation methods have been proposed based on the aforementioned methods. However, they cannot predict the evolution of the system with time under the recommendation method, and cannot dynamically analyze the long-term utility of the recommendation method. But these two aspects can be studied by the dynamical method, which essentially investigates the intrinsic evolution mechanism of things. So, we use the dynamical method of complex network to investigate the evolution of the system with time under the recommendation mode and the long-term utility of the different recommendation methods.

A large number of complex systems in nature can be described through complex networks, such as social networks [26,27], citation networks [28], World Wide Web [29,30], power networks [31], etc., where the node denotes the entity, and the edge stands for the relation between the nodes [32,33]. By studying the dynamical behavior on complex networks, we can deeply understand many phenomena in nature and human society, such as the propagation of public opinion [34], the spread of epidemics [35–37], the collaboration and mutual influence between scientists [38–40], and so on. And it can help to predict the future trend of the system. Now, to the best of our knowledge, the dynamics of complex networks is almost not been used to study the recommendation methods.

Considering movies and users as the research objects, this paper establishes dynamical models to describe the user–movie network, in which users can actively search for movies, or the system can automatically recommend movies to users. Firstly, the dynamical model without the recommendation mechanism is established, in which the user personally searches for the favorite movie to watch in terms of his own taste. For convenience, we call it personal search (PS). In order to provide users with convenience, and reduce the user's search operation, the recommendation method is proposed, then the user can watch by referring to recommended movies. Here, the four recommendation methods, including random recommendation (RR), preference recommendation (PR), degree recommendation (DR) and hybrid recommendation (HR), are given. In this paper, the effectiveness of the recommendation method is evaluated by the movie degree, i.e., the number