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A reliability-based recommendation method to improve trust-aware recommender systems

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ABSTRACT

Recommender systems (RSs) are programs that apply knowledge discovery techniques to make personalized recommendations for user's information on the web. In online sharing communities or e-commerce sites, trust is an important mechanism to improve relationship among users. Trust-aware recommender systems are techniques to make use of trust statements and user personal data in social networks. The accuracy of ratings prediction in RSs is one of the most important problems. In this paper, a Reliability-based Trust-aware Collaborative Filtering (RTCF) method is proposed to improve the accuracy of the trust-aware recommender systems. In the proposed method first of all, the initial trust network of the active user is constructed by using combination of the similarity values and the trust statements. Then, an initial rate is predicted for an unrated item of the user. In the next step, a novel trust based reliability measure is proposed to evaluate the quality of the predicted rate. Then, a new mechanism is performed to reconstruct the trust network for those of the users with lower reliability value than a predefined threshold. Finally, the final rate of the unrated item is predicted based on the new trust network of the user. In other words, the proposed method provides a dynamic mechanism to construct trust network of the users based on the proposed reliability measure. Therefore, the proposed method leads to improve the reliability and also the accuracy of the predictions. Experimental results performed on two real-world datasets including; Epinions and Flixster, demonstrated that the proposed method achieved higher accuracy and also obtained reasonable user and rate coverage compared to several state-of-the-art recommender system methods.

1. Introduction

With the rapid development of the World Wide Web, the search process for relevant information spends a lot of times. Recently, e-commerce sites, where people can easily share their opinions on various products and services, are becoming increasingly popular (Kim & Phalak, 2012). In the presence of existing thousands of products in these sites, making recommendations for users about their interested items is an important problem. Accurate recommendations enable the users to quickly locate desirable items without being overwhelmed by irrelevant information. Recommender systems are widely used in the e-commerce applications to provide high quality personalized recommendations and also help the users to find those of the interested items among available choices.

Collaborative filtering (CF) is one of the most important and successful approaches in the recommender systems (Javari & Jalili, 2014a; Bojnordi & Moradi, 2013; Adomavicius & Tuzhilin, 2005; Gharibshah & Jalili, 2014; Herlocker, Konstan, Terveen, & Riedl, 2004; Ramezani, Moradi, & Akhlaghian, 2014; Yu, Schwaighofer, Tresp, Xu, & Kriegel, 2004; Su & Khoshgoftaar, 2009). The CF approach is based on the assumption that similar users share similar interests. Therefore, to provide suitable recommendations for an active user, the opinions of the other users with similar tastes are used in this approach. The CF-based methods use those of rate values given by the active user to different products in the system to find its neighbors and also make a list of recommendations on unseen items based on opinions of the neighbors. In other words, these methods generally use a similarity measure to determine the distance between each pair of the users to identify the active user neighbors. The basic idea of the CF-based methods is that two users with similar ratings are more appropriate to make recommendations, and also it is most likely that they will prefer similar items (Javari & Jalili, 2014b; Jeong, Lee, & Cho, 2009a; Kiasat & Moradi, 2012; Kim, Kim, & Cho, 2008; Kim, Kim, & Ryu,

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2009; Balabanovic & Shoham, 1998; Lee, Park, & Park, 2008; Park & Chang, 2009). Therefore, these approaches can be able to use those of the items that are rated by the neighbors as preferred items to the active user.

The CF-based algorithms can be classified into two well-known categories including: memory-based and model-based methods. The memory-based methods use a given similarity measure to act directly on user-item rating matrix which contains the rate values of all users who have expressed their opinions on the collaborative service. The similarity metric is used to compute the distance between a pair of the users or items based on their respective ratings. Moreover, the memory-based methods attempt to find a group of the users with similar interests and use the entire user-item rating matrix to produce a prediction for the active user. On the other hand, the model-based methods employ machine learning algorithms to fit a statistical model, and also estimate rates values for those of unseen items using the generated model (Hofmann, 2004). Several model-based methods have been proposed in the literature including: Bayesian belief nets (Miyahara & Pazzani, 2000; Su & Khoshgoftaar, 2009), dimensionality reduction techniques (Goldberg, Roeder, Gupta, & Perkins, 2001), clustering models (Javari & Jalili, 2014a; Birtolo & Ronca, 2013; Guo, Zhang, & Smith, 2015a; Moradi, Ahmadian, & Akhlaghian, 2015; Kim & Phalak, 2012), matrix factorization methods (Navgaran, Moradi, & Akhlaghian, 2013; Guo, Zhang, & Smith, 2015b; Deng, Huang, & Xu, 2014; Jamali & Ester, 2010; Ocepek, Rugelj, & Bosnić, 2015; Pirasteh, Hwang, & Jung, 2015), latent semantic models (Hofmann, 2004), and Markov decision process-based CF systems (Shani, Heckerman, & Brafman, 2005). A review of the research indicates that the memory-based techniques are more widely used than the model-based techniques (Breese, Heckerman, & Kadie, 1998; Huete, Fernández-Luna, de Campos, & Rueda-Morales, 2012; Resnick, Iacovou, Suchak, Bergstrom, & Riedl, 1994; Soboroff & Nicholas, 2000).

Although CF-based recommender systems are the most commonly used methods to personalized recommendations, these approaches often suffer from several shortcomings. These methods use a similarity metric to calculate the similarity value between a pair of the users based on the given ratings to the items by these users (Herlocker, Konstan, Borchers, & Riedl, 1999a; Herlocker, Konstan, & Riedl, 2002; Ciaccia & Patella, 2011). Although, to make good recommendations it is need to extensive data which contains exclusively the ratings made by the users over most of the items, the e-commerce users typically rate only a few number of the items. Therefore, the CF-based methods have problem to identify similar neighbors. This problem is called data sparsity problem. It should be noted that, based on the existing similarity metrics, the CF-based methods could be able to suggest those of the users that at least rated sufficient number of the items. Therefore, these methods are weak to deal with cold start users who have rated a few number of the items (Lee, Yang, & Park, 2004). Moreover, the CF approach is not able to provide suitable recommendations for the cold start users and also this approach is weak on sparse user-item rating matrixes. Furthermore, recommending the new items that have just been added into the system is also challenging because there are not available sufficient feedbacks on these items. Another problem of the CF approach is malicious attacks on the system (Mahony & Hurley, 2005). The recommender systems can be easily attacked by coping user profiles and shifting the predicted ratings of a particular item in order to influence the recommendations for genuine users (Massa & Avesani, 2007).

Several approaches have been proposed in the literature to overcome the mentioned problems of the CF-based methods. One of the most important approaches to improve the CF shortcomings is incorporating trust statements into the online recommender systems (Golbeck, 2006; O'Donovan and Smyth, 2005; Massa & Avesani, 2007). The main idea behind the trust statements is that there is high correlation between the trust and the user similarity. Therefore, the trust statements can be used as the same way of the similarity values to predict unknown rates in the recommender systems (Rahman & Hailes, 2000). On the other hand, the central roles of a trust network in the CF approach are to resolve the neighbor selection problem. Combining a user's trust network with the user-item rating matrix can resolve the data sparsity problem through the capture of information that is stored outside of each user's local similarity neighborhood (O'Donovan and Smyth, 2005; Jamali & Ester, 2009, 2010; Lathia, Hailes, & Capra, 2008; Bedi & Vashisth, 2014; Massa & Avesani, 2004, 2007; Moradi et al., 2015; Yan, Zheng, Chen, & Wang, 2013; Kim & Phalak, 2012). On the other hand, the trust networks can resist shilling attacks to a certain extent. Thus, using the trust statements in the CF approach can prevent the malicious attacks.

Recently, a measurement has been introduced to show the reliability of a prediction in the recommender systems, where it is shown that the measure has a high correlation with the accuracy of the predicted ratings (Hernando, Bobadilla, Ortega, & Tejedor, 2013). This measure just uses the similarity values between the users and does not consider the trust statements. In this paper, we attempt to propose a novel method to improve the performance of the recommender systems by means of incorporating reliability measures and the trust statements in these systems. The main insufficient of the current reliability measures is their lower performance while dealing with sparse data. To deal with this problem, in this research we consider both similarity and trust statements to calculate a novel reliability measure in the CF approach. Furthermore, a novel mechanism is proposed to reconstruct the trust networks of the users to improve the accuracy of the rating prediction by using the proposed trust based reliability measure. In the proposed reconstruction mechanism, first of all a trust network is generated for each user and then this network is used to predict the initial rate for a given unseen item. Then, the proposed trust based reliability measure is used to evaluate the predicted rate. If the corresponding reliability value is lower than a predefined threshold value, then a new trust network with higher quality than the previous one is constructed based on two positive and negative factors. These factors are used to identify the lower reliable users and remove them from the trust networks. Finally, the final rate of the unseen item is predicted based on the new trust network. In order to evaluate the performance of the proposed method, several experiments were performed on the Epinions and Flixster datasets. The results show that the proposed method could significantly improve the accuracy of the trust-aware recommender systems while preserving a good coverage compared to the well-known state-of-the-art methods.

The remainder of this paper is organized as follows: Trust-aware recommender systems are reviewed in Section 2; Section 3 introduces the proposed approach for trust-aware recommender systems; In Section 4, we validate the effectiveness of the proposed method by experimental evaluation on two real-world datasets; and Section 5 outlines conclusions.

2. Trust-aware recommender systems

Online social networks are growing across the web and joining more users to these systems leads to increasing distribution of through social network services (Oufi, Kim, & Saddik, 2012; Jiang, Wanga, & Wub, 2014). Social networks increasingly provide users with the ability to engage in social interaction with other users, such as online friending, making social comments, social tags, etc. These networks allow different users to build trust relationships similar to those in the real world, thus trust relationship is

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