Multi-faceted trust and distrust prediction for recommender systems

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ABSTRACT

Many trust-aware recommender systems have explored the value of explicit trust, which is specified by users with binary values and simply treated as a concept with a single aspect. However, in social science, trust is known as a complex term with multiple facets, which has not been well exploited in prior recommender systems. In this paper, we attempt to address this issue by proposing a (dis)trust framework with considerations of both interpersonal and impersonal aspects of trust and distrust. Specifically, four interpersonal aspects (benevolence, competence, integrity and predictability) are computationally modeled based on users' historic ratings, while impersonal aspects are formulated from the perspective of user connections in trust networks. Two logistic regression models are developed and trained by accommodating these factors, and then applied to predict continuous values of users' trust and distrust, respectively. Trust information is further refined by corresponding predicted distrust information. The experimental results on real-world data sets demonstrate the effectiveness of our proposed model in further improving the performance of existing state-of-the-art trust-aware recommendation approaches.

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1. Introduction

Trust has been extensively exploited for improving the predictive accuracy of recommendations by ameliorating the issues such as *data sparsity* and *cold start* that recommender systems inherently suffer from [1,18,16,3,26,9,5]. In essence, trust provides additional information from which user preference can be better modeled, alternative or complementary to rating-based similarity. Both implicit trust [24] and explicit trust [18,3,16,26,9,5] have been investigated in the literature. The former trust is usually inferred from user-item interactions (i.e., ratings) whereas the latter is directly specified by users indicating whom and to what extent they trust. In contrast, although distrust is recognized to play an equivalently important role as trust [22], the investigation of utilizing distrust in recommender systems is still in its infancy [30,31]. To the best of our knowledge, no prior work has attempted to predict distrust for improving recommender systems.

Another issue of existent trust-aware recommender systems is the simplified modeling of trust as a concept with a single aspect, such as the ability to provide accurate ratings (known as *competence*) [24] or the probability of behaving maliciously. However, it is well acknowledged in social science that trust is a concept with multi-faceted properties [19,21,20]. One possible explanation is that only limited information is available in the few and publicly accessible data sets. Although some efforts have been made to capture multiple aspects (e.g. information credibility [12]) of raters (who give ratings) in recommender systems,

they are essentially distinct concepts from trust. A generally agreed proposition states that people trusting each other may not always share similar preferences [10]. This statement leads to the following interesting research question: *which aspects of (dis)trust reflect user preferences more and hence should be more considered for user preference modeling*? The answer would provide a guidance on whom and to what extent one can trust, especially given the fact that most available (i.e. explicit) trust scores are binary, i.e., either 1 (trust) or −1 (distrust) without specific degrees of trust or distrust.

In this paper, we aim to address the research question by proposing a framework of trust and distrust, taking into considerations both interpersonal and impersonal aspects of trust and distrust adapted from social science [20]. Specifically, four interpersonal aspects (i.e., benevolence, competence, integrity and predictability) are computationally modeled based on users' past ratings, while impersonal aspects (e.g., degree centrality) are formulated from the perspective of social links in trust networks. Note that the social links in a trust network consist of both trust and distrust connections among users. Two logistic regression models are developed and trained by accommodating these factors and then applied to predict continuous values of users' trust and distrust, respectively.

We further refine the trust information using the predicted distrust information. These newly generated trust values can then be applied into the existing trust-aware recommender algorithms (i.e. TidalTrust, Merge and SocialMF). The experimental results on real-world data sets demonstrate the effectiveness of our proposed model for improving the performance of three representative trust-aware recommendation algorithms. In addition, the generality of our model is also empirically demonstrated. In all, our work is the first to comprehensively study

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the multiple aspects of trust and distrust in the context of recommender systems. The study results lead to refined trust and distrust predictions, and in consequence notable improvement on recommendation accuracy when the predicted trust and distrust are utilized in recommendation approaches.

The rest of the paper is organized as follows. Section 2 gives an overview of related research in the literature. Section 3 elaborates the proposed (dis)trust framework, and Section 4 introduces the trust and distrust prediction models. The effectiveness of our approach is evaluated and discussed in Sections 5 and 6, respectively. Finally, the conclusion and future work are presented in Section 7.

2. Related work

Both trust and distrust are well-known as heterogenous rather than homogenous concepts in the fields of social science and computational trust, each of which is composed of multiple aspects [19,21]. Specifically, Mayer et al. [19] report that the trust relationship between a trustor (who specifies trust statements) and a trustee (who receives trust statements) is mainly influenced by the trustor's *propensity* to trust others in terms of three interpersonal aspects related with the trustee, namely *ability* (*competence*), *benevolence* and *integrity*. Mcknight and Chervany [21] enrich this model by adding one more aspect of the trustee—*predictability* as well as an impersonal aspect from the view of structural/institutional trust [20,21]. Impersonal aspects are often utilized to predict positive or negative user links [14,13] by virtue of the graph structures of social networks. We defer the formal definitions of these aspects till Section 3. These frameworks have been adopted as the underpinning of the socio-cognitive trust theory in the area of computational trust [2]. Consistently, in this work we employ both interpersonal and impersonal aspects of the trustee along with the trustor's propensity to formulate users' trust and distrust.

Trust is also applied in real applications, such as Epinions.com where users can explicitly specify other users as trustworthy or untrustworthy. The value of trust has been explored by many trust-aware recommender systems, given the strong and positive correlation between trust and preference [28]. For example, Donovan and Smyth [24] treat trust as a single aspect and equivalent with the expertise or competence of users. Massa and Anesani [18] replace user similarity with explicitly specified trust relationships, and also allow trust relationships to propagate through the trust networks. They show that more robust recommendations can be produced without significant loss in accuracy. Golbeck [4] introduces a trust-flow-based method (called *TidalTrust*) to compute rating predictions for target items. She finds out that better accuracy can be achieved. Later works [3,26] claim that better performance can be obtained by integrating both trust and similarity for recommendations. Jamali and Ester [8] design the *TrustWalker* approach to randomly select neighbors in the trust network formed by users and their trusted neighbors. TrustWalker combines trust information of the selected neighbors with an item-based technique, where both the ratings of the target item and similar items are considered. The recent work conducted by Guo et al. [5] focuses on the problems of data sparsity and cold start from which traditional recommender systems suffer. They empirically contend that by merging the ratings of trusted neighbors, the preferences of active users can be better modeled and hence the performance is improved.

Other than these neighborhood-based approaches, trust is also adopted in model-based approaches. For example, Ma et al. [17] design a latent factor model called *SoRec* based on probabilistic matrix factorization [23]. They fuse the user-item rating matrix with user–user trust matrix by sharing a common latent low dimensional user feature matrix. The two matrices are factorized by three sets of latent features: user vector and feature vector (for each user), and item vector. Experimental results demonstrate that SoRec outperforms the basic matrix factorization model and other trust related neighborhood models. However, although the trust information is considered, the real world

recommendation processes are not reflected, where the two sets of latent features for each user cause the low interpretability of the model. To overcome this problem and model trust-aware recommender systems more realistically, they further propose *RSTE* [16], a linear combination of a basic matrix factorization technique and a trust-based approach. Jamali and Ester [9] later enhance this model by enabling trust propagation in their *SocialMF* model. On the other hand, only very few works have been conducted to study the utility of distrust in recommender systems, although Victor et al. [31,30] have shown that distrust is indeed helpful in trust-aware recommender systems.

All the approaches mentioned above simply treat trust as a single-aspect term and adopt the explicit trust or distrust values without further adjustments. This simplification may work well when trust values can correctly refer to the trustworthiness of users. However, the exact fine-grained values of trust and distrust are often unavailable due to various concerns such as privacy issues. The most common form is simply the social links among users. In this case, the utility of trust and distrust may not be well exploited. Inaccurate or incomplete trust networks may further decline the performance of trust-aware recommender systems [29]. Therefore, we claim that it is important to infer and hence refine trust and distrust links for better recommendation performance.

Very few approaches for recommender systems have been proposed to capture the heterogenous property of (dis)trust. For example, Kwon et al. [12] adopt the source credibility theory to select credible neighbors by investigating multiple credibility attributes. The concept of "credibility" is essentially distinct from that of "trust" defined in our paper. Specifically, the former concept refers to the reliability of users' ratings for a given item, i.e. the reliability of the recommender. The attributes considered for selecting credible recommenders are mainly expertise, trustworthiness, similarity and attraction. However, the latter focuses on a better trust network which is most suitable for recommender systems. We only consider choosing trustworthy recommenders based on a set of (dis)trust antecedents. We intend to empirically reveal the correlations of each aspect with the trust relationship, and target better predictions of trust and distrust for recommender systems.

3. The (Dis)trust framework

In this section, we introduce the formal definitions of the interpersonal and impersonal aspects of trust and distrust from which they will be computationally modeled according to users' historic ratings and trust networks.

Trust in social science has been well recognized as a multi-faceted concept that consists of three major parts, namely dispositional trust, institutional/structural-based trust, and interpersonal trust [21]. Dispositional trust, also known as a trustor's trust propensity, refers to the trustor's inherent propensity to trust other users. Mathematically, it could be treated as a continuous constant (in the range of [0,1]) subject to each trustor. An Institutional/structural-based trust refers to a belief held by a trustor about impersonal things of a trustee such as environments and situation. Hence, in our framework, as all users are in the same environments, we differentiate this part of the trustee by regarding it as trustor's public view of the trustee's trustworthiness. This is mainly determined by impersonal aspects of the trustee such as her reputation and position in a trust network. The impersonal aspects also have an impact on trustor's perception and hence the trust evaluation [20]. Interpersonal trust mainly involves *benevolence*, *integrity*, *competence*, and *predictability*.

With respect to the original trust model in [19,21], we make minor modification towards the connections between the aspects and trust as shown in Fig. 1. Specifically, we regard the combination of each aspect of a trustee and the propensity of a trustor as *an aspect of the trustee perceived by the trustor*, or a *trusting belief* of the trustor that the trustee has the corresponding characteristic in her favor. Therefore,