



Collaborative filtering based on workflow space

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ABSTRACT

The traditional recommender systems are usually oriented to general situations in daily lives (e.g. recommend movies, books, music, news and etc.), but seldom cover the recommendation scenarios for the collaborative team environments. We have done an explorative study on collaborative filtering mechanism for collaborative team environments, which is some kind of multi-dimensional recommender systems problem with consideration of workflow context. This paper proposed 3-dimensional workflow space model, and investigated the new similarities measure between members in workflow space. Then, the new similarities measure is utilized into collaborative filtering for recommender systems in collaborative team environments. At last, the efficiency and usability of the proposed method are validated by experiments referring to a real-world collaborative team of a manufacturing enterprise.

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1. Introduction

With the advancement of electronic commerce, recommender systems (RSs) have become an important research area, since the appearance of the first paper on collaborative filtering in mid-1990s (Hill, Stead, Rosenstein, & Furnas, 1995; Resnick, Iakovou, Sushak, Bergstrom, & Riedl, 1994; Shardanand & Maes, 1995). There have been numerous ways of recommendation methods that utilize various types of data and analysis tools (Adomavicius & Tuzhilin, 2005; Burke, 2002). One of the most famous methods is collaborative filtering (CF), which recommend the user with the items that people with similar tastes and preferences liked in the past (Herlocker, Konstan, Terveen, & Riedl, 2004). The collaborative filtering has been validated to be successful and efficient by a large number of researches in academia area, and also has been implemented by many real-world businesses in industrial area.

Those traditional CF-based recommender systems are usually oriented to general situations in daily lives (e.g. recommend movies, books, music, news and etc.). Few existing researches have been covered specific situations, such as collaborative environments. Team members among a collaborative team usually come from diverse disciplines, each with particular expertise and contribution from their relevant areas. So their demands for knowledge are also different from each other (Zhen & Jiang, 2008). Collaborative team also requires a mechanism to efficiently recommend proper knowledge to proper members.

The CF mechanism in collaborative team environments will be different from traditional CF-based recommender systems in daily

lives. The CF mechanism is essentially heuristics that make rating predictions based on similar members, so the most important step for the collaborative filtering mechanism is finding similarities between users effectively. The traditional CF so far has relied on vector similarity measures (e.g. Pearson's correlation or Cosine) of existing user-item rating records. As to the collaborative team environments with a specific domain, the traditional CF is not most suitable and efficient, especially when the existing user-item rating records are not sufficient. Moreover, the inner relationships involved in collaborative team environments are ignored by traditional CF in calculating the similarities between users, which refers to the serious degradation of recommendation quality.

This paper has been done an explorative study on CF mechanism in collaborative team environments by taking some domain-specific context information into account for CF. More specifically; we view CF as an organizational process and investigate process-oriented solution for it. As the premise of CF, the recommendation entities are also set with the orientation for organizational process, such as workflow. Workflow model consists of three key concepts: members, roles and tasks. Therefore, the CF problem in this paper is involved in a multi-dimensional space: (members \times roles \times tasks \times items) rather than ordinary 2-dimension problem: (members \times items). A workflow space model is proposed in this paper, and is utilized to solve the multi-dimensional CF problem for collaborative team environment. This paper mainly studied the similarities measure between members based on the proposed workflow space model, and also utilized the similarities measure into CF in experiments, which refer to a real-world collaborative team of a manufacturing company.

The rest of this paper is organized as follows. Some related works done by other scholars are briefly introduced in the next

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section. In Section 3, we introduce multi-dimensional recommender systems within workflow context. The workflow space model is proposed and introduced in Section 4. As to the applications of workflow space in collaborative filtering, Section 5 gives detail illustrations. Section 6 is the experimental evaluation for the proposed approaches. Closing remarks and summary are then outlined in the last section.

2. Related works

The roots of recommender systems can be traced back to the extensive work in cognitive work (Rich, 1979), approximation theory (Powell, 1981), information retrieval (Salton, 1989), forecasting theories (Armstrong, 2001), and also have relationships with consumer choice modeling in marketing (Lilien, Kotler, & Moorthy, 1992). The recommender systems emerged as an independent research area in the mid-1990s when scholars researched the problems of estimating ratings for the items that have not been seen by a user. The recommendation technology has become a promising and hot area in both academia and industry; various recommendation systems have been developed. Tapestry is one of the earliest recommendation systems (Goldberg, Nichols, Oki, & Terry, 1992). Based on this work, several automated recommendation systems have been developed. A recommendation system for news and movie recommendations was developed by Konstan et al. (1997). As to book recommendation, Mooney and Roy (2000) proposed a content-based recommendation system. McNee et al. (2002) proposed a recommendation system to help research paper citation. For improving e-commerce sites sales, a taxonomy recommendation system is developed by Schafer, Konstan, and Riedl (1999). Based on analyzing customer behaviors (navigational patterns), Yong, Yum, Song, and Su (2005) proposed a CF-based recommendation system for e-commerce sites. Yeong, Yoon, and Soung (2005) proposed a new methodology in which customer purchase sequences are used to improve the quality of CF-based recommendations. Chen and Cheng (2008a) brought interactions among group members into consideration for RS. As to the users' preference not expressed in numbers, Chen and Cheng (2008b) also proposed a novel CF for recommending ranked items. In order to adapt to large-scale P2P environment, Han, Xie, Yang, and Shen (2004) suggested a distributed CF algorithm to construct a scalable distributed recommendation system. Kim, Kim, and Cho (2008) have been brought out one CF-based method for recommendation in the P2P environment.

Both content-based filtering and collaborative filtering are two main categories for the RSs. The latter one (CF) has been very popular for both researchers and practitioners evidenced by the abundance of publications and actual implementations. The CF has a lot of variations, but the basic essential idea is to calculate similarity among users using some measure to recommend items. There is some famous similarity measures often used for CF. (1) Pearson's correlation (COR) measures the linear correlation between two vectors of ratings (Resnick et al., 1994). (2) The cosine (COS) measure looks at the angle between two vectors of ratings where a smaller angle is regarded as implying greater similarity (Breese, Heckerman, & Kadie, 1998). (3) The constrained Pearson's correlation (CPC) allows only the pairs of rating on the same side, e.g. both being positive or negative (Shardanand & Maes, 1995). (4) Adjusted cosine (ACOS) is usually used in item-based CF for similarity among items (Sarwar, Karypis, Konstan, & Riedl, 2001). (5) The Spearman's rank correlation (SRC) measures the similarity between two vectors based on ranks of values in the vectors (Herlocker et al., 2004). Those traditional similarity measures among users are usually oriented to general situations in daily lives (e.g. recommend movies, books, music, news and etc.). While, as to

the collaborative team environments, more context information should be brought in calculating similarities among users, so as to improve the accuracy and efficiency of CF.

3. Multi-dimensional RS based on workflow space

3.1. Multi-dimensional RS within workflow context

Traditionally, recommender systems (RSs) deal with applications that have two types of entities: users and items. The recommendation problem is reduced to the problem of estimating ratings for the items that have not been seen by a user. The estimation process is usually based on some existing ratings given by this user to other items, or other similar users to items. More formally, the recommender system tries to estimate the rating function R : users \times items \rightarrow ratings, for (users, items) pairs that are unknown. Once gained the above rating tables, which has 2-dimensions: users and items, we can recommend to users the items with highest estimated ratings.

Distinctive with traditional recommender systems researches on items in humans' daily lives (e.g. movies, books, music, news and etc.), our approach is oriented to support knowledge recommendation and sharing among a collaborative team or organization. We view knowledge recommendation as an organizational process and investigate process-oriented solution for it. As the premise of recommender systems, the recommendation entities are also set with the orientation for organizational process, such as workflow. Workflow model consists of three key concepts: members, roles and tasks. Therefore, the RS problem in this paper is involved in a 4-dimensional space: (members \times roles \times tasks \times items) rather than ordinary 2-dimension problem (members \times items). Based on the above 4-dimensional RS, the proper knowledge could be supplied to the proper members, roles, and tasks, respectively.

Fig. 1 illustrates the above 4-dimensional problem for RS in workflow context, and the comparison with the ordinary 2-dimensional RS problem. Shown in the right part of Fig. 1, the 4-dimensional problem space is reduced to 2-dimension problems by 'reduction-based approach' (Adomavicius, Sankaranarayanan, Sen, & Tuzhilin, 2005). Then, all previous researches on 2-dimensional RS are directly applicable. With the rating tables, items could be recommended to members, roles, and tasks, respectively. With the mappings between roles-to-members, tasks-to-members, those items are actually delivered to members ultimately. It should be mentioned that those above mappings are involved in workflow's definitions.

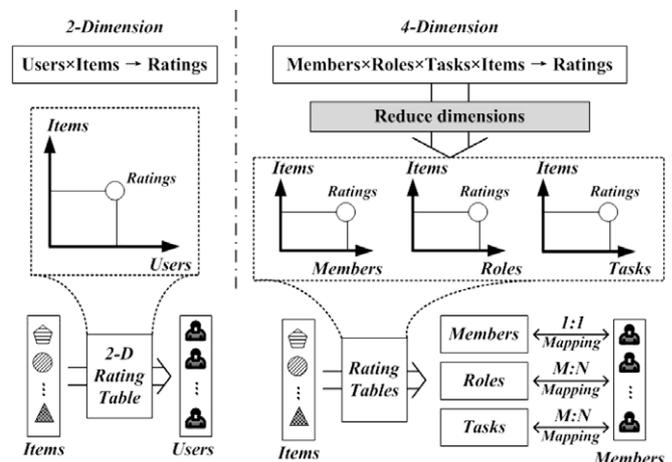


Fig. 1. 4-Dimensional problem for RS with workflow context.

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