Supporting Collaborative Recommendation Services in the Pervasive Computing Era

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1 Recommendation Services in Pervasive Computing Era

With the wide deployment of wireless network infrastructure and the success of many popular mobile devices, the era of pervasive computing has emerged as part of our daily life. Via those devices, mobile users nowadays are able to get connected with friends, find useful information for various needs, conduct business/tasks/shopping conveniently, and participate in activities from anywhere, any time. To embrace the growing population of mobile users, many websites and services have enhanced their mobile web support and created new service features. For example, conventional e-commerce sites such as Amazon and Netflix facilitate mobile shopping and video watching. Additionally, powered by the ever-growing capability of smart mobile devices and the advances of Web 2.0 technology, Frickr and Bikely allow mobile users to easily acquire information about happenings in their surroundings or about themselves (e.g., photographs and biking trajectories) for sharing with their friends or even the public.

Personalization has long been a buzzword on the Web. As users become more proficient in their use of the Web, the one-size-fits-all approach for web service provisioning no longer satisfies users' expectation on web experience. To improve their customer satisfactory and boost potential sales, a growing number of websites and web services, e.g., Amazon and Netflix, have incorporated personalized recommendation techniques to enhance the on-line experience of their users. For example., when a user is searching for product information regarding an item of interests, the service provider may promote a number of relevant items as recommendation to the user, e.g., an extra battery or tripod are recommended to a user who buys a camera. The arrival of pervasive computing era brings great opportunities for provisioning of recommendation services to mobile users. For example, mobile advertisement/coupons, which can be seen as a variant of recommendation, from nearby stores may be offered when a user enters a shopping mall. Meanwhile, these opportunities also brings new technical challenges since simply sending all the ads and offers from nearby stores to perspective customers is not going to be effective. Even worse, mistargeted advertisement may annoy mobile users and result in customer complains.

2 Mobile and Social Computing for Recommendation as a Cloud Service

The rapid technological development of cloud computing and data centers in the past few years has provided a much needed service infrastructure for various pervasive computing applications. Due to a wide spectrum of applications, we envisage recommendation as an important cloud service (like the intelligent personal assistant Siri on iphone) for supporting various activities of mobile users.

Recommender systems have attracted a lot of attention from the industry and academic research communities in the past decade and become a core technology for many e-commerce sites. The basic idea behind most recommender systems is to exploit the best matches between user preference and product profile in order make the most effective recommendation to targeted users. Capturing *user preference* accurately is essential for recommender systems as people participate in events or select items (e.g., books, places, etc) mainly based on their interests/preferences for the items. Thus, recommender systems explore user preferences in various ways to recommend matched objects. For example, content-based filtering techniques recommend items to a user by matching item content (including item description, tags or other attributes) with the user's explicitly maintained personal interests/preferences, while collaborative filtering techniques recommend items to a user by exploiting the preferences of *like-minded users* over items. While collaborative filtering and content-based recommendation techniques both have their own strengths and weakness, e.g., the content-based techniques are constrained in the scope of recommendations while the collaborative filtering techniques require a large amount of information on a user in order to make accurate recommendations, we see great research potential in the collaborative filtering approach due to the growth of mobile and social computing technology in supporting collaborative recommendations. Notice that collaborative recommendations are enabled by collecting and analyzing a large amount of information on users behaviors, activities or preferences for predicting what users will like based on their behavior/preference similarity to other users. Without even understanding the item content, recommendation of various complex items can be made accurately based on preference/behavior (i.e., previous selections) of "similar" users. Social and mobile computing technologies are envisaged to support the social crowd wisdom of similarly behaved users.

- Taking into account more preference and behavior information of users in the recommendation process can intuitively enhance the effectiveness of recommendation services. The smart mobile devices, carried and used by their owners, can be used to collect valuable data in order to dictate the preference and behavior information of users. Note that the information is useful for understanding the on-going activities/context in decision making process of users and thus valuable for making effective recommendation. This information, if voluntarily shared by users, can also be aggregated to identify users with similar behavior (i.e., like-minded users) for collaborative recommendation.
- In addition to personal behavior information, the social relationship among users can be exploited to alleviate the *cold start* problem faced by collaborative recommendation. Specifically, the problem concerns the issue that the system cannot draw an effective recommendation for those users whom it has not yet gathered sufficient information. Based on the observed *homophily* and *social influence* phenomena exhibited among friends, not only the behavior similarity but also the social influences from friends can be incorporated to explore the social wisdom in the recommendation process.

3 Technical Challenges

Enabling collaborative recommendation services is a very challenging task due to the dynamic nature of user behaviors and social relationship as well as various issues such as accuracy, data sparsity, scalability, privacy, etc. Efficient collection of personal behavior data from a large mobile user population and transform them into useful social wisdom for collaborative recommendation is very challenging. The following are a number of technical areas that require research effort:

- Data Collection – collaborative filtering techniques rely on a large amount of information on user preference and behavior to make effective recommendations. Thus, collecting user preference and behavior data is essential. In addition to explicitly ask for rating information of items from users, mobile devices can be used to implicitly keep track of the times, places, duration, and responses when users are accessing/examining some items. Moreover, other factors such as the emotion perception of users may be considered for making recommendations. How to explore the various sensors equipped in mobile devices and various types of applications/information accessed via mobile devices to collect useful information is an important task.
- Crowd Sourcing – due to the data sparsity and cold start problems inherently faced in collaborative filtering techniques, creating the much needed "crowd wisdom" is very important to get the service started. In addition to provide incentives or devise some interesting applications (e.g., games) to attract users, tools to facilitate crowd sourcing to the mobile users, e.g., CrowdDB, are useful.
- Preference Mining – to explore the crowd wisdom of mobile users, it is important to develop data mining techniques for efficient processing of large-scale data collected from mobile users to capture their preference. Probabilistic latent classes modeling techniques can be employed to mine and capture user preferences to support collaborative recommendation.
- Social Behavior Modeling and Mining – to better understand the behavior similarity and social influence of friends, data mining techniques that consider both social friendship information along with collected user behavior data need to be developed. Quantitative measure of the behavior similarity and social influence among friends may provide theoretical basis for capturing the social behaviors in decision making process and thus are very useful for collaborative recommendations.
- Scalability – developing efficient algorithms under the cloud framework to provide effective realtime recommendation services for the large population of mobile users is a very challenging yet important task. Algorithms that can exploit the rich resources in the cloud infrastructure and incrementally adapt the mining result to the dynamic changes in user behavior and social data are desirable.
- Privacy Issue – as collaborative recommendation is enabled by collecting preferences and behavior information from many users, privacy preservation of collected user data is a major concern. Thus, it is desirable develop effective techniques for the above-discussed technical areas without directly using sensitive private user data.

In summary, collaborative recommendation is envisaged as an important cloud service for supporting various activities of mobile users. Mobile and social computing techniques for enabling collaborative recommendation services on the cloud may provide technological advances and great benefits to applications in the pervasive computing era.