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Personalized QoS-Aware Web Service Recommendation via Exploiting Location and Collaborative Filtering

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Abstract— A web service is a software system designed to support interoperable machine-to-machine interaction over a network. Web services have been widely employed for building service-oriented applications in both industry and academia in recent years. The number of publicly available Web services is steadily increasing on the Internet. However, this proliferation makes it hard for a user to select a proper Web service among a large amount of service candidates. An inappropriate service selection may cause many problems (e.g., ill-suited performance) to the resulting applications. This paper, propose a novel collaborative filtering-based Web service recommender system to help users select services with optimal Quality-of-Service (QoS) performance. Recommender system employs the location information and QoS values to cluster users and services, and makes personalized service recommendation for users based on the clustering results. Different from previous work, this approach employs the characteristic of QoS and achieves considerable improvement on the recommendation accuracy.

Keywords— Web service, service recommendation, quality of service (QoS), collaborative filtering, service selection

I. INTRODUCTION

Web services are software components designed to support interoperable machine-to-machine interaction over a network. Web service employs WSDL (Web Service Description Language) for interface description and SOAP (Simple Object Access Protocol) for exchanging structured information. The adoption of web services as a delivery mode in business has fostered a new paradigm shift from the development of monolithic applications to the dynamic setup of business process. In recent years, web services have attracted wide attentions from both industry and academia, and the number of public web services is steadily increasing.

When implementing service-oriented applications, service engineers (also called service users) usually get a list of web services from service brokers or search engines that meet the specific functional requirements. They need to identify the optimal one from the functionally equivalent candidates. However, it is difficult to select the best performing one, since service users usually have limited knowledge of their performance. Effective approaches to service selection and recommendation are urgently needed.

Quality-of-Service (QoS) is widely employed to represent the non-functional performance of web services and has been considered as the key factor in service selection. QoS is defined as a set of user-perceived properties including response time, availability, reputation, etc. Currently, it's not practical for users to acquire QoS information by evaluating all the service candidates, since conducting real-world web service invocations is time-consuming and resource-consuming. Moreover, some QoS properties (e.g., reputation and reliability) are difficult to be evaluated, since long-duration observation and a number of invocations are required. Therefore, different users may observe quite different QoS performance of the same web service, and QoS values evaluated by one user cannot be used directly by another in service selection and recommendation. Moreover, some QoS properties (e.g., reliability) are difficult to be evaluated as long-duration observation is required.

To attack this challenge, this paper investigates personalized QoS value prediction for service users by employing the available past user experiences of Web services from different users. This approach requires no additional Web service invocations. Based on the predicted QoS values of Web services, personalized QoS-aware Web service recommendations can be produced to help users select the optimal service among the functionally equivalent ones.

To enhance the prediction accuracy, this paper propose a location-aware Web service recommender system (named LoRec), which employs both Web service QoS values and user locations for making personalized QoS prediction. Users of LoRec share their past usage experience of Web services, and in return, the system provides personalize service recommendations to them. The main contributions of this work are two-fold:

First, this paper propose a novel location-aware Web service recommendation approach, which significantly improves the recommendation accuracy and time complexity compared with existing service recommendation algorithms.

Second, the use of model-based and memory-based CF algorithms for web service recommendation, which significantly improves the recommendation accuracy and time complexity compared with previous service recommendation algorithms.

II. RELATED WORK

Web service recommendation and selection has been a fundamental research issue since the dawn of Web service technologies. The available Web service search engines such as XMethods largely exploit keyword-based search techniques and are inadequate to match the functionalities of Web services. These search engines do not consider non functional characteristics (QoS) of Web services. Furthermore, users normally have to know how to craft correct queries. The performance of Web service recommendation of these search engines is therefore limited. Over the past few years, service recommendation has been an active research area and many techniques have been proposed. These techniques can be classified into two categories: collaborative filtering (CF), service selection and recommendation approaches.

A. Collaborative Filtering

The basic idea of CF is to predict and recommend potential favourite items for a particular user employing rating data collected from other users. CF is based on processing the user-item matrix. Breese et al. [1] divide the CF algorithms into two broad classes: memory-based algorithms and model-based algorithms. The most analysed examples of memory-based collaborative filtering include user-based approaches, item-based approaches, and their fusion. User-based approaches predict the ratings of users based on the ratings of their similar users, and item-based approaches predict the ratings of users based on the information of item similarity. Memory-based algorithms are easy to implement, require little or no training cost, and can easily take ratings of new users into account. However, memory-based algorithms do not scale well to a large number of users and items due to the high computation complexity.

Model-based CF algorithms, on the other hand, learn a model from the rating data using statistical and machine learning techniques. Examples include clustering models, latent semantic models, latent factor models, and so on. These algorithms can quickly generate recommendations and achieve good online performance. However, these models must be rebuilt when new users or items are added to the system.

B. Web Service Selection and Recommendation

Web service discovery is a hot topic which plays a crucial role in the area of services computing. Some syntactic and semantic-based web service search engines have been proposed in the recent literature. Dong et al. [2] found that the traditional key word-based web service search was insufficient, and they provided a similarity search algorithm for web services underlying the Goggle search engine. Recommendation techniques have been used in recent research projects to enhance web service discovery. Mehta et al. [3] found that semantics and syntax were inadequate to discover a service that meets user requirements. They added two more dimensions of service description: quality and usage pattern. Based on this service description, they propose the service mediation architecture. Blake computed a web service recommendation score by matching strings collected from the user's operational sessions and the description of the web services. Based on this score, they judged whether a user is interested in the service. Maamar et al. [4] proposed a model for the context of web service interactions and highlighted the resource on which the web service performed. Based on the input keywords, users can get a set of recommendations with linkages to the query. Previous work mainly focused on providing a mechanism to formalize users' preference, resource, and the description of web services, and Maintaining the Integrity of the Specifications recommendations are generated based on the predefined semantic models. Different from these methods, our recommendations are generated by mining the QoS records that are automatically collected from interactions between users and services.

Limited work has been done to apply CF to web service recommendation. Zheng et al. [5] combined the user-based and item-based CF algorithm to recommend web services. However, since neither of the two approaches recognized the different characteristic between web service QoS and user ratings, the prediction accuracy of these methods was unsatisfactory.

Different from these existing methods, which suffer from low prediction accuracy, proposed an effective CF algorithm for web service recommendation with consideration of the region factor. Comprehensive experiments conducted with real QoS records show that our method outperforms others consistently.

III. PROPOSED ARCHITECTURE

Web applications such as social networking sites and self-publishing sites encourage users to share their knowledge and learn from others. LoRec employs the idea of user collaboration and provides a platform for users to share observed Web service QoS values and search Web services. This system will generate personalized service recommendations based on user shared QoS values. The more QoS records users contribute, the more accurate the recommendations will be, since more information can be mined from the user-contributed QoS values. In this paper, we assume that users are trustworthy. Fig.1 shows the architecture of LoRec recommender system, which includes the following procedures:

- Web service users log on to LoRec system and share observed Web service QoS records with other users. In this paper, users who have submitted Web service QoS records to LoRec are called training users. If a training user requires Web service recommendation, then the user becomes an active user. QoS values of training users will be employed to make personalized recommendation for the active user.
- LoRec clusters training users into different regions according to their physical locations and past Web service usage experiences.
- LoRec clusters functionally similar Web services based on their QoS similarities.
- LoRec maps the active user to a user region based on historical QoS and user location.

- The recommender system predicts QoS values of candidate Web services for the active user and recommends the best one.
- The active user receives the predicted QoS values of Web services as well as the recommendation results, which can be employed to assist decision making (e.g., service selection, service composition, service ranking, etc.).

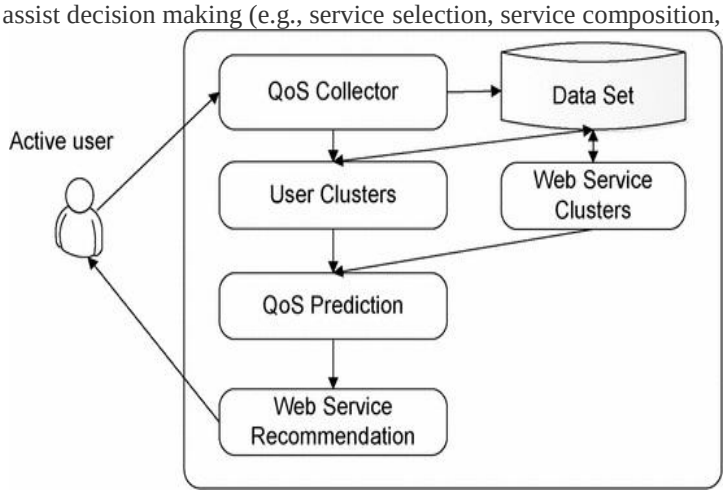

Fig.1 System Overview of LoRec

IV. THE RECOMMENDATION APPROACH

A. Motivating Scenario

In this section, an online service searching scenario to show the research problem of this paper. The basic idea of this approach is that users closely located with each other are more likely to have similar service experience than those who live far away from each other. Inspired by the success of Web 2.0 websites that emphasize information sharing, collaboration, and interaction, we employ the idea of user-collaboration in our web service recommender system. The more QoS information the user contributes, the more accurate service recommendations the user can obtain, since more user characteristics can be analysed from the user contributed information. Based on the collected QoS records, our recommendation approach is designed as a two-phase process. In the first phase, we divide the users into different regions based on their physical locations and historical QoS experience on web services. In the second phase, we find similar users for the current user and make QoS prediction for the unused services. Services with the best predicted QoS will be recommended to the current user.

B. Phase 1: Region Creation

In web service recommender system, users usually provide QoS values on a small number of web services. Traditional memory-based CF algorithms suffer from the sparse user contributed data set, since it's hard to find similar users without enough knowledge of their service experience. Different from existing methods, we employ the correlation between users' physical locations and QoS properties to solve this problem. In this paper, we focus on the QoS properties that are prone to change and can be easily obtained and objectively measured by individual users, such as response time and availability.

C. Phase 2: QoS Value Prediction

After the phase of region aggregation, thousands of users are clustered into a certain number of regions based on their physical locations and historical QoS similarities. The service experience of users in a region is represented by the region center. With the compressed QoS data, searching neighbours and making predictions for an active user can be computed quickly. Traditionally, the QoS prediction methods need to search the entire data set, which is rather inefficient. In this approach, similarity between the active user and users of a region is computed by the similarity between the active user and the region center. Moreover, it is more reasonable to predict the QoS value for active users based on their regions, for users in the same region are more likely to have similar QoS experience on the same web service, especially on those region-sensitive ones.

V. RECOMMENDATION VISUALIZATION

Conventionally, CF-based web service recommender systems employ the predicted QoS mainly in two ways. 1) When users query a service with specific functionality, the one with the best predicted QoS is recommended to them. 2) Top-k best-performing services are recommended to help users discover potential services. While this kind of recommendation is useful, it is not obvious to users why certain services are recommended. More than a service list ranked by predicted QoS as recommendation, we need to develop an exploratory recommendation tool that provides valuable insight into the QoS space and enables an improved understanding of the overall performance of web services. The QoS space visualization of all web services on a map will reveal the rationale behind QoS-based service recommendations. QoS space visualization is more than a picture or method of computing. It transforms the information of high dimensional QoS data into a visual form enabling service users to observe, browse, and understand the information.

VI. CONCLUSION

This paper presents an innovative QoS-aware Web service recommendation approach .The basic idea is to predict Web services QoS values and recommend the best one for active users based on historical Web service QoS records. In order to better recommend Web services to users from amount of services with identical functions, this paper proposed a Web service recommendation approach based on collaborative filtering.

In this paper, recommendation approach considered the correlation between QoS records and users' physical locations by using IP addresses, which has achieved good prediction performance and makes the QoS prediction more confident for Web service recommendation.

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