Temporal-Aware QoS-Based Service Recommendation using Tensor Decomposition

Zhi Li, Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, China
Jian Cao, Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, China
Qi Gu, Department of Computer Science and Engineering, Shanghai Jiao Tong University, Shanghai, China

ABSTRACT
The number of services on the Internet is growing rapidly. Thus, the problem of selecting proper services for most users becomes serious and service recommendation is widely needed. Besides functions, QoS information is also an important factor to be considered when making recommendations to users. However, QoS changes with time. To address and solve these challenges, this paper proposes a temporal-aware QoS-based service recommendation framework, and also comes up with a prediction algorithm based on Tucker decomposition. Moreover, the authors use real-world datasets to verify our method with results better than traditional methods.

Keywords: Algorithm, QoS-Based, Service Recommendation, Temporal-Aware, Tucker Decomposition

1. INTRODUCTION
In recent years, with the development of Service-Oriented Architecture (SOA), Cloud Computing and open platform technologies, providing and using services via the Internet is becoming more and more popular. Therefore, the Internet is evolving into a services-sharing platform from the original information-sharing platform.

As service technologies are developing rapidly, its forms are increasingly diversifying, which include SOAP-based Web Service, RESTful style Web Service, Web Service agreement based on JSON to name a few. Cloud computing also offers several variations of the service-computing model, including Infrastructure as a Service (IaaS), Platform as a Service (PaaS) or Software as a Service (SaaS). Traditional software components, such...
as RMI and DCOM, can also be regarded as services. Recently, the concept of service is further extended to capabilities shared through the Internet, e.g. Communication as a Service, Security as a Service, and Test as a Service. Some companies even raise the concept of People as a Service, and provide relevant technical support. As a result, Google proposes the concept of Everything as a Service (XaaS). It is not surprising that the quantity of services on the Internet is growing rapidly. For example, the famous open API and Mashup sharing website ProgrammableWeb offers the information of more than 10000 APIs and 7000 Mashups.

Matching or recommending the proper services to users in need becomes a key problem within the process of large-scale service technology application and popularization. It is not surprising that recommender systems and recommendation technologies have been introduced to solve this problem (Zhang, 2007).

Quality-of-Service (QoS) is usually employed for describing nonfunctional characteristics of services (Zeng, 2004). QoS is a combination of several qualities or properties of a service, such as availability, security properties, response time, throughput, etc. The QoS measure is observed by services’ users (Menasce, 2002) or collected by systems automatically. QoS is believed to be the key factor in service selection and composition (Moser, 2008).

Intuitively, QoS evaluation is highly correlated to users’ invocation time, since the service status and the network environment change over time (Zhang & Zheng, 2011), for example the network congestion may occur over a specific time period.

Considering QoS values, existing service recommendation approaches usually use Collaborative Filtering methods. However, most of these methods don’t consider the influence of temporal information on QoS evaluation. A few approaches have been proposed on a temporal-aware Web Service recommendation. One such proposal from Zhang, Zheng and Lyu was a Tensor Decomposition algorithm to predict QoS values (Zhang & Zheng, 2011). However, this method doesn’t perform well on prediction accuracy.

In this paper, we propose a temporal-aware scalable Tensor Decomposition approach to predict QoS values to facilitate service recommendation. We realize the importance of temporal information on QoS prediction, and establish a new collaborative framework. We generate the QoS third order tensor from real-world datasets and use a scalable Tucker Tensor Decomposition method to make full use of temporal and other information from real-world datasets. We can perform the recommendation from the predicted QoS tensor. Experiment in Section IV shows the improvement on recommendation accuracy.

The rest of the paper is organized as follows. Section 2 introduces related background such as Collaborative Filtering, Matrix Factorization and Tensor Decomposition. Section 3 describes the new collaborative framework we raised and gives the TUCKALS3 Tensor Decomposition algorithm. Section 4 gives the experiments and results. Finally, Section V summarizes the whole paper and discusses future work.

2. RELATED WORK

Some work has been done on the field of service recommendation based on QoS information. Most of them use Collaborative Filtering (CF) methods. CF is divided into two categories: memory-based and model-based, while memory-based methods are further divided into user-based and item-based methods (Zanker, 2011). For memory-based methods, the rating information is saved in the memory and recommendation result is generated directly. On the other hand, model-based methods process the raw rating data offline and then generate corresponding models for use during the recommendation process. Mostly widely used model-based CF algorithm is Matrix Factorization (MF) (Koren, 2009).

Many methods have been raised using memory-based CF methods. Shao, Zhang and Wei (2007) proposed a user-based Collaborative Filtering method to predict QoS values...