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A STRATEGY TO ADVOCATE CLOUD MANUFACTURING SERVICE BASED ON THE IMAGINARY CLUSTERING AND IMPROVED SLOPE ONE ALGORITHM

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Abstract: The booming growth of cloud manufacturing services provides users with more choices. However, cloud manufacturing service recommendation remains a challenging issue due to numerous similar candidate services and diverse user preferences. The purpose of this paper is to provide an efficient and accurate cloud manufacturing service recommendation method. A spectral clustering algorithm is first designed to cluster the cloud manufacturing services.

Then the candidate rating service set is constructed based on the service clusters by service function comparison and parameter matching. Finally, an improved Slope one algorithm, which integrates user similarity and service similarity, is proposed to rate the cloud manufacturing services. The top-k services with the highest scores are recommended to the users. Experiments show that the proposed method can provide more accurate service rating with less time consumption. The service recommendation performance of this method is also proved to be superior to other methods in terms of precision, recall, and F-score.

Keywords Cloud manufacturing service, Service similarity, Service rating, Slope one

I. INTRODUCTION

Cloud manufacturing is a typical implementation mode of intelligent manufacturing [1]. In the cloud manufacturing environment, service providers encapsulate their processing equipment resources or manufacturing operations as cloud services. Cloud manufacturing service is a kind of application program interface of manufacturing service. A user can rent cloud manufacturing services from the cloud manufacturing platforms. By integrating different cloud manufacturing services, users can quickly implement manufacturing operations beyond their own business capabilities [2]. There are many cloud manufacturing services with similar functions on the cloud manufacturing platforms. Compared with the common cloud services, cloud manufacturing services have more manufacturing attribute parameters [3]. Moreover, the manufacturing attribute parameters vary greatly between different types of cloudmanufacturing services. The value types of these parameters are also diverse. It is difficult for users to select suitable services from a large number of similar cloud manufacturing services. Therefore, cloud manufacturing service recommendation is greatly concerned by researchers [4]. Service recommendation finds a set of services that fitthe user's needs. In recent years, researchers introduce some methods of recommendation system into the field of service computing. It mainly includes content-based service recommendation, service quality-oriented recommendation, and hybrid service recommendation methods[5]. These methods have improved the accuracy of recommendation. However, cloud manufacturing

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services differ from ordinary commodities and face the following two prominent problems in service recommendation.

One problem is that there are many manufacturing attribute parameters in cloud manufacturing services. The values of these manufacturing attribute parameters have different dimensions and orders of magnitude, so it is much more difficult to determine the similarity between cloud manufacturing services than the common cloud services [6]. Moreover, a large number of cloud manufacturing services are published on the cloud manufacturing service platforms. Cloud manufacturing service recommendation suffers a huge ser- vice search space.

Another problem is that users' historical service preferences greatly influence the recommendation of cloud manufacturing services [7]. Users prefer to choose the cloud manufacturing services published by the service providers with cooperation experience. Alternatively, they are more likely to adopt the cloud manufacturing services from the providers that have cooperated with the users similar to them. The invoking time of historical services, the difference in service scores, and service preferences can also help improve the recommendation accuracy and rationality. These factors need to be considered in the cloud manufacturing service recommendation.

To enhance the quality-of-service recommendation, a cloud manufacturing service recommendation method based on spectral clustering and the improved Slope one algorithm is proposed. The main contributions of this paper are as follows:

(1) A spectral clustering algorithm for cloud manufacturing services is devised. The search space of rating services is reduced by introducing service clustering. It can improve the efficiency of obtaining ser- vices to be rated.

(2) An improved Slope one algorithm, which integrates user similarity and service similarity, is proposed to rate the cloud manufacturing services more reason- ably and accurately.

(3) A cloud manufacturing service data set with user rating is established. Experiments carried out on this data set flow that the proposed method is superior to the current popular methods in service rating and recommendation.

The rest of this paper is organized as follows. Related work section introduces the related works on service recommendation. Spectral clustering for cloud manufacturing services section presents a spectral clustering method for cloud manufacturing services. The improved Slope one algorithm is elaborated in The improved Slope one method integrating user and service similarity section. Recommendation of cloud manufacturing services section provides our proposed service recommendation method. Experiment and comparison section verifies the performance of the proposed method. Conclusions section concludes this paper and throws light on future work.

II. RELATED WORK

Service recommendation has been concerned by researchers for more than a decade. Early service recommendation focused on Web services described by WSDL [8, 9]. Currently, the research objects of ser- vice recommendation mainly include Web services described by natural language text [10], various cloud services (for example, cloud manufacturing services [11], e-health cloud services [12]), and Internet of things services [13, 14].

Researchers have proposed many types of service recommendation methods. Among these methods, collaborative filtering and its variants are the most widely used. For example, Xiao et al. proposes a hybrid collaborative filtering algorithm to recommend the manufacturing ser- vice based on the multidimensional information in cloud manufacturing resource, the information entropy and rough set theory [15]. Zhou et

al. presents a hybrid collaborative filtering model for consumer service recommendation based on mobile cloud by introducing user preferences. It can effectively reduce the data sparsity and increase the accuracy of the prediction. To improve the accuracy and scalability, Wang et al. integrates the score, social trust information and review into a comprehensive model through collaborative filtering and pro- pose a multi-source information fusion recommendation method. The existing collaborative filtering service recommendation methods usually assist recommendation from one dimension of users or services. Although they can improve the quality of recommendation, it lacks comprehensive consideration of the similarity between users and services, which may affect the improvement of service recommendation accuracy. Service quality is an important factor in evaluating recommended services. QoS-aware service recommendation has always attracted much attention. Chang et al. designs an integrated-graph to consolidate multi-source information from user-aware context and service-aware context. A Gaussian Mixture Model of QoS value is built to combine local and global information on the integrated-graph and to perform QoS-based Web service prediction. Cao et al. proposes a QoS-aware service recommendation based on relational topic model and factorization machines. It exploits factorization machines to train the latent topics for predicting the link relationship among Mashup and services to recommend adequate relevant top-k Web APIs . Service trust and location information are frequently used to improve QoS-aware ser- vice recommendation. For example, Liu et al. presents a trust-aware collaborative filtering approach to build the trust network of clustered users. A more personalized QoS prediction and reliable cloud service can be recommended for a user by the proposed method . Khavee et al. proposes a probabilistic matrix factorization-based recommendation approach, which considers geographic location information in the derivation ofthe preference degree underlying a mashup-API inter- action. The geographical location information increases the precision of API recommendation for mashup services. Although service quality can improve the recommendation quality, the recommendation effect is affected by the constituent services in the candidate service set. If there is no high-quality candidate recommendation service set, the effectiveness of such methods is very limited.

Service social relationships are also a key concern in the service recommendation. A series of service recommendation methods based on social network are proposed. For example, a Social-powered Graph Hierarchical Attention Network (SGHAN) is designed to capture users' social connections by Wei . By mining users' dynamic preferences through social connections, SGHAN outperforms the state-of-the-art methods in terms of service prediction accuracy for mashup creation. Cao et al. proposes a Web service recommendation method via combining bilinear graph attention representation and xDeepFM (eXtreme Deep Factorization Machine) quality prediction. It adopts the content and structure-oriented service function classification and predicts service invocation based on multi-dimensional quality attributes . Service social relationships can effectively improve the quality of recommendation. However, how to obtain the social relationships between services is a very challenging problem in the cloud manufacturing service environment.

Hybrid service recommendation methods have gradually become the mainstream way of service recommendation. The proposes a method to enablethe context-sensitive service recommendation system with great analysis and learning capabilities based on a knowledge graph. The recommendation algorithm is defined to deliver top-rated services according to the target user's context . Jiang et al. proposes a two-stage

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model for cloud service recommendation. He first uses Hierarchical Dirichlet Processes model to cluster cloud services and then accurately rank and recommend cloud services in each cluster based on the personalized PageRank algorithm .Ma et al. employs the interval neutrosophic numbers to meas ure the fuzzy trustworthiness of cloud services by client contexts. A non-compensatory multi-criteria decision-making procedure is used to rank candidate services. It can effectively recommend the trustworthy service for small and medium-sized enterprises . Chao et al. explores the relationship between the content and location information to enhance the accuracy of service recommendation. It alleviates the data scarcity problem in cloud services by introducing similar domain knowledge based on transfer learning. Currently, hybrid recommendation is a popular service recommendation method. Liu et al. proposes a similarity-enhanced hybrid group recommendation approach for cloud manufacturing. A weighted rank ing aggregation model is established to generate a recommendation list according to the representative user of each subgroup. Zhang et al. proposes service hyper-network to recommend the raw material sup- pliers, semi-finished product processors and finished product manufacturers that realize on-demand customization. Further, he proposed an architecture of C3DP (cloud 3D printing) order task methods for complex networks based on the dynamic coupling of nodes. The C3DP model can identify the work break- down structure of coupling task sets with high accuracy. However, most hybrid recommendation methods have high complexity in practical application or require more service implicit information to assist in improving the recommendation accuracy.Although the introduction of collaborative filtering, quality of service, and service collaboration into service recommendation can improve the quality of recommen dation. However, the single use of the above methods has limited improvement in recommendation accuracy. In this paper, we synthesize the recommendation idea of the above methods and construct a new cloud manufacturingservice recommendation method with low complexity and high accuracy.

Spectral clustering for cloud manufacturingservices

To facilitate the elaboration of the proposed methods, we provide Table 1 to describe the symbols in this study.

Normally, cloud manufacturing services need to be rated in the service recommendation. To improve recommendation efficiency, we do not rate all cloud manufacturing services. A set of candidate rating services is constructed to store the cloud manufacturing services to be rated. The services in the candidate rating service setcan meet the recommendation requirements in terms of functions and manufacturing attribute parameters. It is costly to find the suitable services for the candidate rating service set from a large number of cloud manufacturing services. Spectral clustering is adopted to reduce the search space in discovering the target services. In spectral clustering, it is necessary to construct the similarity matrix between the objects participating in the clustering. The existing methods are unsuitable for computing the similarity of cloud manufacturing ser- vices because of the many types of attribute parameters and the large difference of their values. Similarity evalu ation of cloud manufacturing services section provides a method for computing the similarity of cloud manufacturing services and constructs the similarity matrix. After the similarity matrix of cloud manufacturing ser- vices is obtained, the spectral clustering algorithm can be employed for clustering.

Similarity evaluation of cloud manufacturing services

It is a popular way to convert service description into service function vector and determine service similarity by calculating the Cosine angle value or Euclidean

distance of service function vectors. Unlike the common cloud services, there are not only service function descriptions but also multi-dimensional manufacturing attribute parameters in the cloud manufacturing services. The values of these manufacturing attribute parameters have different dimensions and orders of magnitude, so the cloud manufacturing services with similar functions may be grouped into different service clusters due to their difference in manufacturing attribute parameters. Therefore, both service descriptions and manufacturing attribute parameters should be involved in computing the cloud manufacturing service similarity.

III. CONCLUSIONS

This paper proposes a method to recommend cloud manufacturing service based on spectral clustering and an improved Slope one algorithm. We design a similarity matrix for cloud manufacturing services containing many textual and numerical attributes, and apply it to spectral clustering to achieve cloud manufacturing services clustering. The introduction of service clustering reduces the service rating space in service recommendation. Additionally, we integrate service similarity anduser similarity into Slope one algorithm to improve the accuracy of service rating and top-*k* service recommendation. The experimental results demonstrate that the proposed method outperforms the comparison method in terms of service rating and recommendation. Moreover, the time consumption of our method is significantly lower than that of other methods. Future work includes exploring a more reasonable method to supplement the missing values of service scores, so as to better cope with the problem of sparse service score data and cold start.

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