Guest Editorial: Recommendation Techniques for Services Computing and Cloud Computing

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Abstract—As the number of Web services surges rapidly, recommending the right service for various users on demand has become one of the most challenging research issues in the fields of services computing and cloud computing. This special issue focuses on the recommendation techniques for services computing and cloud computing including classic recommendation algorithms for services computing and cloud computing, emerging recommendation techniques for service selection and composition, and applications of recommendation techniques in composition of complex service mashups, ad-hoc social networks, and green cloud environment. The papers introduced in this special issue illustrate the efficiency and effectiveness of services computing and cloud computing, while demonstrating a variety of challenges that arise. It is expected that this special issue, as a whole, will provide integrated and synthesized view of the current state of the art, identify key challenges, possible research directions and opportunities for investigation, and promote community-building efforts among researchers and practitioners in the related fields.

Index Terms—Recommendation technique, services computing, cloud computing, Quality-of-Service

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1   INTRODUCTION

WITH the prevalence of services computing and cloud computing, a large number of services are supplied by different service providers. By composing these services, service-oriented systems can be efficiently built [1]. Nowadays, service-oriented systems are becoming large-scale and very complex. An enormous amount of data are generated by various service-oriented systems and cloud applications day by day. It is challenging for users to find the right information they want from such large volume of data. For example, determining the optimal Web service from a large number of service candidates when making service selection, detecting vulnerable components in complex service-oriented applications and cloud applications, identifying suitable servers for deploying cloud applications, and so on. In the field of services computing and cloud computing, efficient and effective recommendation techniques are critical in helping designers and developers analyze the available information intelligently for better application design and development.

Recommendation techniques aim to support users in their decision-making while the users interact with large information spaces [2]. Recommendation has been a hot research topic with the rapid growth of information. In recent years, recommendation techniques are widely employed in services computing and cloud computing, such as Web service recommendation [3], [4], reliability prediction [5], service selection and composition [6], social recommendation [7], case studies [8], etc. Recommendation techniques can draw from a wide variety of input data, and

benefit from different types of analysis. Nowadays, recommendation techniques are one of the most important and fast-growing research topics in services computing and cloud computing. The amount of service and cloud related information is rapidly accumulating, including a large number of application services, service descriptions, quality of service (QoS), service invocation graphs, and huge volumes of runtime data and traces generated by various service-oriented applications and cloud applications. The information explosion in the area of services computing and cloud computing makes it a formidable task for users to find the appropriate information that they need timely. So efficient and effective service customized recommendation techniques are urgently required.

This special issue focuses on recommendation techniques for services computing and cloud computing. We expect that this special issue will provide integrated and synthesized view of the state of the art as well as best current practices. In addition, a number of key challenges, together with possible research directions and opportunities, are identified in this issue. The research and development outcomes are therefore expected to promote community-building among researchers and practitioners in the fields related to services computing. Papers submitted to this issue underwent a thorough selection process where every submission was reviewed by at least three reviewers for several rounds of reviews. We eventually selected eight high quality papers to be included in this special issue. The acceptance rate is 20 percent (among totally 40 submissions).

2   SPECIAL ISSUE PAPERS

The eight papers of this special issue mainly address three specific challenges: recommendation algorithm design, recommendation techniques for service selection, and applications of recommendation techniques in real-world environments. The first three papers propose various new

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recommendation algorithms, including QoS-aware recommendation approach, reputation-based recommendation approach, and semantic content based service recommendation. In the next two papers, service selection with probabilistic QoS and runtime aspects are respectively investigated. The last three papers focus on applications of recommendation techniques in different settings, including complex service mashups, ad-hoc social networks, and green cloud environment. A brief overview of the eight accepted papers of this special issue is presented below.

In the first paper entitled "Prediction of Atomic Web Services Reliability for QoS-aware Recommendation," Marin Silic, Goran Delac, and Sinisa Srbljic present a model named CLUS for reliability prediction of atomic Web services, which estimates the reliability for an ongoing service invocation based on the data merged from previous invocations. On one hand, this article focuses on the impact of specific parameters of the invocation context regarding the accuracy of the prediction models. The work extends existing specific parameters by introducing environment- specific parameters in prediction models, hence improving the accuracy of the prediction by incorporating user-, service- and environment- specific parameters. On the other hand, this paper aggregates the past invocation data using K-means clustering algorithm to achieve better scalability comparing with other current approaches. In addition, the paper proposes a model-based collaborative filtering approach LinReg based on supervised learning technique and linear regression to estimate the missing reliability values. When running CLUS on services deployed in different regions of the Amazon cloud, the authors confirm that CLUS achieves more scalable and accurate predictions.

The second paper, entitled "ReputationNet: Reputation-based Service Recommendation for e-Science," by Jinhui Yao, Wei Tan, Surya Nepal, Shiping Chen, Jia Zhang, David D. Roure and Carole Goble, proposes the ReputationNet framework as an enhancement of the existing ServiceMap framework to employ trust and reputation mechanisms for service recommendations in building scientific workflows. In particular, the authors design heuristic algorithms to recommend reputable services, service associations and compositions. The key contribution of the paper is the proof of a strong positive correlation (with Pearson correlation coefficient of 0.82) between the proposed reputation score and the usage frequency, which would enhance end-user usage and re-use of the system. Experiments using the workflows on myExperiment social website demonstrate the positive correlation which shows the effectiveness of ReputationNet.

In the third paper titled "Unified Collaborative and Content-Based Web Service Recommendation," Lina Yao, Quan Z. Sheng, Anne H. H. Ngu, Jian Yu, and Aviv Segev propose a hybrid approach which combines collaborative filtering and semantic content-based methods to advance the current Web services recommendation. Furthermore, three main requirements, including high recommendation accuracy, recommendation serendipity, and recommending newly deployed services, are also considered for designing and developing effective Web service recommender systems. The proposed approach is applied to a dataset of real-world Web services to show that the proposed approach indeed achieves better recommendation performance.

As illustrated in "Service Selection for Web Services with Probabilistic QoS," San-Yih Hwang, Chien-Ching Hsu and Chien-Hsiang Lee believe that the difficulties in the service selection remain an important challenge, although Web service selection has been a common research topic. Consequently, a novel approach by representing services QoS values as discrete random variables with probability mass functions is proposed to address the service selection problem. The authors aim to select a set of atomic services for constructing a composite service, so as to satisfy the constraints imposed on the composite service with high probability and to achieve reasonable execution time. In addition, the article provides numerical results that demonstrate effectiveness and efficiency of the proposed method, where QoS values are modeled as probability distributions and an initial service assignment finding algorithm is executed.

In "Service Selection with Runtime Aspects: A Hierarchical Approach," Rene Ramacher and Lars Mönch present a hierarchical service selection by integrating a tactical service selection with a service reconfiguration to satisfy the cost minimization objective and to maintain a successful execution of requests. It is a novel idea to systematically integrate both tactical and operational service selection, which can achieve both runtime-related goals and tactical objectives. Experiments are conducted to assess the hierarchical service selection and to confirm the advantages of the proposed method.

"Assisting Navigation and Complementary Composition of Complex Service Mashups" by Gang Huang, Yun Ma, Xuanzhe Liu, Yuchong Luo, Xuan Lu and M. Brian Blake proposes an approach for recommending developers in terms of navigation and completion of mashup components with a large-scale component repository. Given a partial mashup and component repository, it exploits data dependency, similarity and usage to suggest ranking recommendations. The novel contributions of this paper are as follows: 1) A real problem, that users may not understand how to connect the partial components with an explicit goal, is solved. 2) A component model is proposed to employ data dependency in different classes and data inheritance in the same class. 3) The experiments illustrate that the proposed approach can generate meaningful and potentially relevant recommendations with fast response to user requests in a real component repository.

In their paper entitled "Environment-aware Virtual Slice Provisioning in Green Cloud Environment," Kim Khoa Nguyen and Mohamed Cheriet present an environment-aware virtual slices provision solution in green cloud environment to address the problem of optimal flow assignment for virtual slice based on software-defined paradigms, which aim to provide environment-aware recommendation services for cloud operators. The basic advantage of the proposed solution is two-fold: 1) An algorithm to resolve the problem of virtual slice assignment achieves better performance than the existing network embedding algorithm with respect to network footprint reductions. 2) A good intra data center network topology, which is considered in an optimization model, can reduce network carbon footprint. Simulations are carried out on the GreenStar Network, which demonstrates satisfactory performance of the proposed solution.

Finally, the paper by Fei Hao, Shuai Li, Geyong Min, Hee-Cheol Kim, Stephen S. Yau, and Laurence T. Yang, entitled "An Efficient Approach to Generating Location-Sensitive Recommendations in Ad-hoc Social Network Environments," advocates the importance of the spatial factor in recommendation mechanisms. In the paper, the authors present an approach of similarity measurement between two users that integrates the interconnection among users, items and locations, which is named *Spatial Social Union* (SSU). In addition, the SSU-aware location-sensitive recommendation algorithm is consequently proposed to generate location-sensitive recommendations in ad-hoc social networks. Experimental results show that the proposed SSU algorithm achieves more effective results in predicting rating of items and recommending items in location-based ad-hoc social networks.

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