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An efficient and reliable approach for quality-of-service-aware service composition

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ABSTRACT

With the rapidly increasing number of independently developed Web services that provide similar functionalities with varied quality of service (QoS), service composition is considered as a problem in the selection of component services that are in accordance with users' QoS requirements; a practice known as the QoS-aware service composition problem. However, current solutions are unsuitable for most real-time decision-making service composition applications required to obtain a relatively optimal result within a reasonable amount of time. These services are also unreliable (or even risky) given the open service-oriented environment. In this paper, we address these problems and propose a novel heuristic algorithm for an efficient and reliable selection of trustworthy services in a service composition. The proposed algorithm consists of three steps. First, a trust-based selection method is used to filter untrustworthy component services. Second, convex hulls are constructed to reduce the search space in the process of service composition. Finally, a heuristic global optimization approach is used to obtain the near-optimal solution. The results demonstrate that our approach obtains a close-to-optimal and reliable solution within a reasonable computation time.

1. Introduction

A Web service is a self-describing software system that can be advertised, located, and used across the Web based on a set of XML standards, such as WSDL, UDDI, and SOAP [23]. A large number of Web-based services have been developed for various purposes. Independently developed Web services can be flexibly and dynamically integrated to form more complex and value-added business processes or transactions, known as Web services composition. The dynamic Web service composition usually involves two key steps, namely, composition planning and optimal selection. The planning step seeks to satisfy the functional requirements of the users and ensure the correctness of the composition process, and the optimal selection step attempts to satisfy the non-functional requirements of the users (e.g., price, availability, reliability, and reputation) to maximize the quality of service (QoS) value of a composite service. The second step, known as QoS-aware Web service composition, has recently received a great deal of attention from both the academe and the industry because of the rapid increase in the number of independently developed Web services that provide the same functionality but exhibit different level of QoS [34].

QoS-aware Web service composition is a global optimization problem that is NP-hard [27]. Thus, an optimal solution cannot be found within a reasonable timeframe. Although various approaches to solve this problem have been proposed in the

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past few years [1,7,31,34], high computational complexity remains a major hindrance to large applications that require quicker response to adapt to the different requirements of multiple users. Additionally, current approaches to service composition are not reliable. This is because, in an open and service-oriented environment, services that are published by any service developer may be of poor quality and may be time-consuming, expensive, or even harmful. Hence, an efficient and trustworthy service selection approach is indispensable in supporting the composition process to achieve close-to-optimal results within an acceptable period of time and to distinguish the authenticity of QoS parameters declared by the service providers.

The concept of trust in social relationships is the basis of human interactions and business transactions. Trust solves the problem of interaction, information sharing, and collaboration between two entities without any prior mutually shared experiences [16]. In a service-oriented environment, trust is a key factor in determining the reliability of Web services [22]. A number of efficient trust evaluation models have been proposed recently to solve the service selection problem [13,16,21]. Thus, trust provides us with a promising starting point in the solution of Web service composition. Previous approaches [1,7,34] have only considered trust or reputation as a global QoS requirement proposed by users, but these approaches are incapable of avoiding the selection of malicious services in the process of service composition. That is, most of the selected component services have good reputations, but a few services with poor reputation that may have also been selected, so the aggregated value of the global quality or trust can still satisfy the users' requirements, even though untrustworthy services have been included in the optimal solution.

To address the issues discussed above, we present a novel approach that maximizes the QoS value of a composite service expressed as utility functions over a set of QoS attributes to satisfy the constraints set by the end-users. Our approach guarantees that all the selected services are trustworthy and that the execution time is reasonably short. The main contributions of this paper are listed below.

- A community-based architecture is designed to provide trust management for Web services. Unlike the existing architecture that selects and composes services only by a centralized broker, we combine a set of service communities for trust-based management and selection that can prevent the selection of malicious services and significantly reduce the search space for Web service composition tasks.
- A utility function is defined to manage a compromising value for the three categories of quality attributesgeneric QoS attributes, domain-specific QoS attributes, and user-perceived QoS attributesalong with QoS dependencies.
- A heuristic approach is proposed to maximize the QoS value of the composite service, and the approach is expressed as the utility function over a set of QoS attributes that are required in order to satisfy the constraints set by the users. The heuristic algorithm consists of three steps. First, a trust-based local selection method is designed to filter untrustworthy component services. Second, convex hulls are constructed to reduce the search space for each task in the composition service. Finally, a heuristic global optimization approach based on M-HEU is used to obtain the near-optimal solution. The results of the experiment demonstrate that our approach obtains a close-to-optimal and trustworthy solution within a reasonable time.

The rest of the paper is organized in the following sections. Many reports have discussed research on QoS-based service composition. In Section 2, we will discuss such related reports that address QoS-aware service selection and composition, including the optimal and heuristic algorithm M-HEU, on which our method is based. In Section 3, we use an example to explain the problems and a suggested solution, followed by a general description of the system architecture and algorithm for the implementation of the proposed approach. The approach and algorithm are based on a QoS model, as presented in Section 4 together with the detailed definitions and discussions of the utility function. The algorithm is then further explained in the context of a service composition mechanism in Section 5. In Section 6, we develop a system to test the method by comparing it with other QoS-aware service composition methods to obtain optimal trustworthy results and computation time. In Section 7, we summarize our work by pointing out the key features of the proposed solutions and comparison results and by briefly describing additional inter-QoS attribute dependency and dynamic service scheduling.

2. Related works

Many previous studies have proposed various approaches for QoS aggregation in service composition. Cardoso et al. [6] defined QoS aggregation using four attributes, namely, response time, cost, reliability, and fidelity. According to different workflow patterns, the QoS performance of service processes can be predicted by performing the substitution repeatedly until the whole process is transformed into a composite service node. However, no further solution has been found on QoS-based service discovery and composition in their work. Zeng et al. [34] proposed a QoS-aware middleware for dynamic and quality-driven service composition. They used an integer programming (IP)-based approach to solve the problem of global optimization in Web service selection. However, this method is not suitable for large-size problems because its computational complexity increases exponentially with the growth in size. Alrifai et al. [1] initially used mixed integer programming (MIP) to find the optimal decomposition of global QoS constraints into local constraints. They then used a distributed local selection method to find the best Web services that could satisfy these local constraints. Although this method can dramatically reduce computation complexity (the worst case), the decomposition algorithm is not accurate or reasonable enough when different tasks have different QoS range values; also, the preferences of the users may also differ