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Fast track article

Decision support for Web service adaptation

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ABSTRACT

With the Internet of Services, Web services from all areas of life and business will be offered to service consumers. Even though Web service technologies make it easy to consume services on arbitrary devices due to their platform independence, service messaging is heavyweight. This may cause problems if services are invoked using devices with limited resources, e.g., smartphones. To overcome this issue, several adaptation mechanisms to decrease service messaging have been proposed. However, none of these are the best-performing under all possible system contexts.

In this paper, we present a decision support system that aims at helping an operator to apply appropriate adaptation mechanisms based on the system context. We formulate the corresponding decision problem and present two scoring algorithms—one Quality of Service-based and one Quality of Experience-based.

Missing data and, thus, an incomplete system context is a serious challenge for scoring algorithms. Regarding the problem at hand, missing data may lead to errors with respect to the recommended adaptation mechanisms. To address this challenge, we apply the statistical concept of imputation, i.e., substituting missing data. Based on the evaluation of different imputation algorithms used for one of our scoring algorithms, we show which imputation algorithms significantly decrease the error imposed by the missing data and decide whether imputation algorithms tailored to our scenario should be investigated.

1. Introduction

The list of advantages of combining Web service technologies and mobile computing is long and compelling [1]: most notably, the outsourcing of data- and processing-intensive software tasks from mobile devices to more powerful systems is a major reason for the usage of Web service technologies on mobile devices like smartphones. Furthermore, Web services enable quick mobile application development through the reuse of existing software artifacts.

Web service message formats are characterized by a verbose, self-descriptive nature. On the one hand, this leads to platform-independence and high interoperability. On the other hand, it renders service messaging heavyweight due to the high latency and communication overhead in standard SOAP transport protocols like SOAP-over-HTTP and SOAP-over-TCP [2]. Even though mobile devices have evolved into full-fledged computing devices, there is still a gap between their computational power and the available connection bandwidth. Notably, the data volumes that can be processed by mobile devices and the bandwidth available are growing at the same pace [3]. Furthermore, not all mobile devices that may consume

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a Web service are necessarily from the latest smartphone generation, i.e., devices with less computational power than the most recently unveiled smartphones may consume Web services. As a result, the mentioned gap will not vanish in the future, which makes it necessary to research technical solutions that are capable to overcome the limitations resulting from it.

The communication overhead introduced by Web service standards such as the Web Service Description Language (WSDL) or SOAP can lead to unacceptable Quality of Service (QoS) and Quality of Experience (QoE). Thus, standard transport protocols are not always a good match for the resource-constrained nature of mobile, wireless devices.

Since the birth of pervasive computing, the adaptation of the communication in order to enhance the QoS of applications has been one of the biggest concerns in the field [4]. Such adaptations can be performed on different levels, e.g., on the level of the communication channel, such as in the much investigated *Always Best Connected* (ABC) issue, or on a higher level of the OSI model [5], as is done during Web content adaptation. Another possibility appears at the level of software services, where the protocol (or the access method) that is used to communicate with particular services is adjusted to the system context. It is at this level and with such a protocol or access method adaptations that the rest of this paper handles the issue of mobile Web service performance.

Not surprisingly, a number of adaptation mechanisms for Web services have appeared. An *adaptation mechanism* means the re-offering of a Web service with a different protocol or access method, e.g., Wireless SOAP, JAVA RMI, or SOAP-over-UDP [6]. As it has been shown in our former work [6], the beneficial effects of existing Web service adaptation mechanisms depend not only on the Web service, but also on the system context in terms of device capabilities or the network connection. Thus, provided that no single adaptation mechanism is the best-performing under all possible system contexts [6], an algorithm for decision support is needed. This algorithm needs to score how well the possible adaptation mechanisms match the particular context. Different decision support algorithms would have a different perception of what a "good match" is.

Within this paper, we present two *scoring algorithms* for decision support, with the first one being based on QoS, while the second one being based on QoE. These scoring algorithms rely on the use of historical data, i.e., the *system context* of former Web service invocations. Quite often, it is difficult to get a complete system context due to transmission errors, reluctance, or inability of the data source to provide the data. Therefore, missing data, e.g., in the form of incomplete data logs, significantly deteriorates the outcome of a scoring algorithm with respect to the scored adaptation mechanisms. In our previous work [7], we have presented first evaluation results of these algorithms and have identified the need for reducing the serious impact of missing data. In order to overcome this issue, we use the statistical concept of *imputation*, i.e., substituting missing data with other values, and evaluate how using different imputation algorithms for one of our scoring algorithms affects the quality of its scoring results. The goals of this evaluation are, first, to identify which state-of-the-art algorithm achieves the best results and, second, to decide whether new imputation algorithms specifically dedicated to our scenario should be investigated or not.

The remainder of the work at hand is organized as follows: first, we present some background information that is necessary for the understanding of our work, namely the *Internet of Services* (IoS) scenario applied in this paper, the *Mobility Mediation Layer*, and some general information about the usage of proxies for the adaptation of Web services. In Section 3, we formulate the decision problem that is at the core of our work. Afterward, we present the two QoS- and QoE-based scoring algorithms for decision support. In Section 5, we introduce state-of-the-art imputation algorithms that address the challenge of missing data. Afterward, the imputation algorithms are applied to our QoS-based scoring algorithm and evaluated (Section 6). We discuss related work in Section 7 and, finally, conclude this paper in Section 8.

2. Background

2.1. The internet of services scenario

In short, the Internet of Services (IoS) refers to a globalization of service-oriented solutions, where Web services are offered by different providers through global services marketplaces. The IoS should be understood as a future scenario for service-orientation [8,9]. The realization of the IoS is supported and accelerated by certain enabling technologies, such as the *Unified Service Description Language* (USDL) [10], which describes the business and operational aspects of a Web service in addition to the technical details. Thus, Web services are turned into perfectly tradable goods.

In the following compilation, we list features of the IoS that create new challenges and opportunities for performing Web service adaptations with the use of a mediating platform or middleware, as envisioned in the work at hand.

- *Many Web services gathered within a marketplace*: if service marketplaces offer homogeneous, easy access to a large number of Web services, particular adaptation mechanisms can be performed at once for many of them.
- *Less predictable Web service usage characteristics*: traditionally, Web services have been developed for a set of consumers that has been more or less known a priori. In a scenario where Web services are published as tradable goods, it is much more difficult to predict under which system conditions the services will be actually used. For service adaptation mechanisms, this means that they should consider a wide spectrum of different possible systems contexts.
- *Less control or influence over third-party Web services*: another side-effect of the loose relationship between service providers and consumers at a marketplace is the fact that consumers have little influence on the implementations of third-party services. This means that adaptation mechanisms that need any kind of modifications in the code or the hosting system of the services do not come into question in the IoS (cf. Section 7).

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