An Approach for Measuring Quality of Web Service

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Abstract

Quality of Web Service (QoWS) measure is crucial for selecting web services to take part in seamless and dynamic integration of business applications on the web. However, since QoWS are often influenced by several factors, traditional approaches are not very efficient and effective in measuring QoWS. The authors introduce in this study a novel QoWS measure approach to efficiently measure QoWS for web service recommendation and selection. The core of this approach is to take the five factors, that is, price, latency, accessibility, accuracy, and reputation into QoWS measure. The experimental results demonstrate that the proposed approach is efficient and effective in measuring QoWS.

Keywords: Web Service; Quality of Web Service (QoWS)

1. Introduction

With the rapid development of the service-oriented software architecture, the web service technology based on XML has been widely applied as a good implementation technique for Service-Oriented Architecture (SOA). However, when the number of web services that are delivered on-demand and priced on-use, has expanded dramatically, it becomes a challenge to select appropriate services for service requesters among many functionally equivalent services. Hence, measuring the quality of web service (QoWS) [1-3] plays an important role in service recommendation and selection. The concept of QoWS is considered as a key feature in distinguishing between competing web services [4]. QoWS encompasses different quality parameters that characterize the behavior of a web service in delivering its functionalities. According to the W3C’s definition, QoWS refers to a kind of ability that can respond to the expected request and complete the related tasks with a certain quality of service that meets the expectations of both the service provider and the customer.

The acquisition of service quality indicator data consists of three channels: firstly, information given by service providers when issuing the services, such as the price of services. Secondly, feedback gained by monitoring the service execution process. Finally, the tests conducted by the third-party on the issued services. Web services quality data are not static, especially for indicators related to performance (such as latency) which will be affected by a variety of factors such as server load and network environment. Thus frequent updates should be conducted to reflect the latest changes.

This paper is based on our previous work on a framework for monitoring the QoWS [5-6]. Our approach presented in this paper is to define a model of web service, taking price, latency, accessibility, accuracy, and reputation factors into account for quality evaluation. We have used the model to measure QoWS.
The remainder of this paper is organized as follows. Section 2 briefly surveys the current literature on the subject. The model is given in Section 3. Section 4 describes the algorithm for each factor. In Section 5 we give some results with measuring QoWS of the proposed model. Finally we give certain conclusions in Section 6.

2. Related Work

At present QoWS evaluation has gained much attention in recent years due to the growth of online transactions and e-business activities in service-oriented environment. The authors of [7] proposed a computing-oriented description of QoWS and an approach to QoWS-based service evaluation based on hierarchical constraint logic programming (HCLP). This approach allows web service designer to describe the real values such that the non-functional properties (NFPs) will expose at runtime by means of proper mathematical functions, and allows users to specify their preferences on NFPs by exploiting HCLP and introducing tendency functions. The authors of [8] stressed that the quality of service issues should be considered while accessing web services and they proposed the concept of Service Level Agreement (SLA). The authors of [9] proposed the concepts such as web services reputation and gave a quantitative method of calculating based on SLA. The authors of [10] clearly defined QoWS, which has won recognition from the academia and industries as a metric to assess the performance of web services. The authors of [11] established the description ontology for web service to describe its quality. The authors of [12] proposed an adaptive evaluation model of web service based on artificial immune network. Evaluation tree is established, which is adaptive for different services.

References [13-15] instructively gave the factors that should be included in the service quality model, such as price and latency. These models are for QoWS in the monitoring, forecasting and analysis process instead of service evaluation. The relevant studies mentioned above considered the QoWS from a single perspective and failed to make the overall assessment of the web service quality.

In the grid environment, researchers proposed some effective approaches [16-17] which can be used for reference in QoWS measure.

3. Modeling QoWS

The purpose of our model is to be able to design quantifiable metrics for quality evaluations by measuring the QoWS of a given web service.

3.1. The Summary of Pentagram

QoWS is presented in Table 1. It shows key attribute indicator and most important measures of the QoWS. Each web service has unique Key Attribute Indicators (KAIs) that need to be identified. Various studies have been conducted on this subject and different standardization bodies have defined these KAIs in their own ways as general guidelines. These guidelines can be used as a basis to find KAIs for each web service.

As shown in Figure 1, QoWS is measured and presented using a pentagram diagram based on the measurement of its five factors in the proposed QoWS model. Each factor is measured based on the results of their refined factors during QoWS measure process.

Let’s assume the measurement result of each factor is a value from 0 to 1. The value “1” indicates the maximum value for each factor, and “0” indicates the minimum value. The area of the pentagram is used as the measurement of QoWS. Clearly, the smallest value of this
The pentagram area is 0, and the maximum value is approximately 2.4. Since the pentagram consists of five triangles. The area of each triangle can be computed \( \frac{0.5 \times l_1 \times l_2 \times \sin \lambda}{2} \) as:

where \( l_1, l_2 \), represent the sides of the triangle, and \( \lambda \) represents the 72-degree angle between the two sides. The letters \( a, b, c, d, \) and \( e \) in Figure 1 are used to represent the five factors of QoWS respectively. When each factor is measured, then, QoWS can be computed below:

\[
QoWS = \frac{1}{2} \sin 72^\circ (ab + bc + cd + de + ea)
\]

\[
\approx \frac{1}{2} \times 0.9511 \times (ab + bc + cd + de + ea)
\]

\[
\approx 0.48 \times (ab + bc + cd + de + ea)
\]

Table 1. Factors that influence QoWS and most important Measures

<table>
<thead>
<tr>
<th>Key Attribute Indicator</th>
<th>Most Important Measures</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>Price represents the amount of money paid for each web service using</td>
<td>( a )</td>
</tr>
<tr>
<td>Latency</td>
<td>Latency time between starting the request for a service and addressing the requirement</td>
<td>( b )</td>
</tr>
<tr>
<td>Accessibility</td>
<td>Accessibility represents the frequency of the service provider answering the request when the client asks for web service</td>
<td>( c )</td>
</tr>
<tr>
<td>Accuracy</td>
<td>Accuracy represents the probability of the request being responded correctly while providers answering the client’s requests</td>
<td>( d )</td>
</tr>
<tr>
<td>Reputation</td>
<td>Reputation is the credibility of the web service</td>
<td>( e )</td>
</tr>
</tbody>
</table>

Figure 1. Quality of Web Service Pentagram Model

3.2. The Advantages of the Area Calculation

There are three advantages of the area calculation: firstly, in the pentagram model, every estimate is equal and independent, because the weight leaning to any side will weaken the effect of the omni directional estimation. The sum account adopts the same weight in order to
show the coequal recognition on the every estimation index. Secondly, it adopts subjectively and objectively integrative estimation. Finally, it’s easy to show the difference of the sum. If one dimension has a lesser change, and the other four have no change, the area calculation method with the influence on total scores is more than weighted average computing (as the light shadow is shown in Figure 1). For example, if each edge score equals to 0.8, and weight equals to 0.2, when $d$ change to 1.0, $\Delta QoWS=1.67-1.52=0.15$, $\Delta QoWS'=0.84-0.8=0.04$. The change of scores is obviously, and $\Delta QoWS$ is more than $\Delta QoWS'$. Therefore, the method impels service providers to improve their total qualities of service, giving more attentions to the accuracy but not just to the price.

4. Algorithm

4.1. Price

While providing operation $O$ for service $S$, the price of its service $q_{pri}(s,o)$ is the expenses that must be paid while accessing the service. And it is generally given directly by the service provider.

4.2. Latency

While providing operation $O$ for service $S$, its service lag time $q_{lat}(s,o)$ includes the time from clients turning in service request to receiving respond. To describe it specifically in formula:

$$q_{lat}(s,o) = T_{process}(s,o) + T_{trans}(s,o)$$  \hspace{1cm} (2)

In this formula, $T_{process}(s,o)$ represents the service processing time, usually given directly by the service provider; $T_{trans}(s,o)$ represents the required transmission time, which can be calculated with the following formula based on the statistical data of the past service operation.

$$T_{trans}(s,o) = \frac{\sum_{i=1}^{n} T_i(s,o)}{n}$$  \hspace{1cm} (3)

In it, $T_i(s,o)$ is the transmission time obtained through measuring the past experience of providing the service; $n$ is the number of times of measuring the operations.

4.3. Accessibility

As The accessibility of the service $S$ refers to the probability of the service that can be accessed, and its quantitative formula is:

$$q_{accr}(s) = \frac{T(s)}{n}$$  \hspace{1cm} (4)

In this formula, $T(s)$ stands for the total time that $S$ can be accessed in recent consecutive time $T$ (usually calculated in seconds). The selection of the $T$’s value is associated with the particular environment. For instance, for a service that has frequent visits, its $T$ should be of a
relatively small value. For services that are not frequently accessed, T’s value can be bigger. The web services we assumed here can send message to the system to inform their status (accessible and inaccessible).

4.4. Accuracy

The accuracy \( q_{\text{acc}}(s) \) of the service \( S \) refers to the probability of provider correctly providing service \( S \) to the service requestor after being requested. The quantization formula is as follows:

\[
q_{\text{acc}}(s) = \frac{C(s)}{n}
\]  

In this formula, \( C(s) \) represents the number of times that service \( S \) is correctly executed and \( n \) represents the total number of executions of the service \( S \).

4.5. Reputation

The service \( S \)'s credibility \( q_{\text{rep}}(s) \) is the measure the service requestors use to measure the reliability of the services. Mainly influenced by the user experience, different service requestors might be inconsistent with their views on the same web service. It is can be calculated by the following formula:

\[
q_{\text{rep}}(s) = \frac{\sum_{i=1}^{n} R_i(s)}{n}
\]  

In it, \( R_i(s) \) is the service requestor’s comment on the credibility of the service. \( n \) is the number of times that \( S \) is being commented. Under normal circumstances, the service provider will set up an evaluation range to let the service requestors choose.

4.6. Combinational Web Service

The service quality indicators above for basic web service can also be used to describe combinational web service, but their definition and quantitative formula will be slightly different.

<table>
<thead>
<tr>
<th>Service Quality Indicator</th>
<th>Quantitative Formulas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price</td>
<td>( q_{\text{pri}}(p) = \sum_{i=1}^{n} q_{\text{pri}}(s_i, o(t_i)) )</td>
</tr>
<tr>
<td>Latency</td>
<td>( q_{\text{lat}}(p) = \text{CPA}(p, q_{\text{lat}}) )</td>
</tr>
<tr>
<td>Accessibility</td>
<td>( q_{\text{acc}}(p) = \prod_{i=1}^{n} (q_{\text{acc}}(s_i)^{y_i}) )</td>
</tr>
<tr>
<td>Accuracy</td>
<td>( q_{\text{acc}}(p) = \prod_{i=1}^{n} (q_{\text{acc}}(s_i)^{y_i}) )</td>
</tr>
<tr>
<td>Reputation</td>
<td>( q_{\text{rep}}(p) = \frac{1}{n} \sum_{i=1}^{n} q_{\text{rep}}(s_i) )</td>
</tr>
</tbody>
</table>
The formulas in Table 2 are analyzed one by one as following:

**Price:** The service price of the combinational web service equals to the sum of the prices of the basic web services that are used in execution path $P$.

**Latency:** We can use Critical Path Algorithm (CPA [18]) to calculate the response time of the entire combinational web service, which is decided by the most time-consuming path in the execution path $P$. The total response time of all the web services in the most time-consuming execution path is the response time of the combinational web service. The mission critical of the critical path is called key services.

**Accessibility:** The accessibility of the combinational web service is the product of all the basic service divisor $q_{acces}(s_i)$. The value of $e$, here is either 0, or 1. When the service $S_i$ is the key task of the critical path $P$, it is 1. Otherwise, it is 0. When $e = 0$, $q_{acces}(s_i) = 1$. In this situation, when we assume a certain non-critical web service fails on its execution, it can be re-run without affecting the availability of the entire combinational web service.

**Accuracy:** The accuracy of the combinational web service is the product of all the basic web services’ correct implementation rate factor $q_{accurate}(s_i)$. Similarly, the value of $e$, here is either 0, or 1. When the service $S_i$ is the key task of the critical path $P$, it is 1. Otherwise, it is 0. When $e = 0$, $q_{accurate}(s_i) = 1$. For non-critical web service, if it is not available, we assume we can re-select it without affecting the availability of the entire combinational web service.

**Reputation:** Credibility of the combinational web service is the average credibility of all the basic web services.

4.7. Normalization

Each QoWS attribute of web services has different units of measure and value range. In order to ensure the comparability of QoWS calculation, the QoWS evaluation attribute should be normalized and all the QoWS evaluation attributes can be reflected in the same value range. The QoWS attribute’s measurement factors is:

$$G = (\text{name}, \text{direction}, \text{valueRange}, \text{unit}, \text{location})$$

In it, name is the title of the measurement factor, and direction is its value reading direction. In this direction, the target object will get better and better evaluation results by the measurement factor. Value reading direction is divided into two kinds—the positive and the negative. For instance, as the smaller the price the better, the value reading direction of the price should be negative. And for reputation which is bigger the better, its direction should be positive. ValueRange is the value reading range of the measurement factor, and valueRange = (min, max). The measurement index data outside the valueRange can be regarded as min or max according to its location. In the model, all the value readings are numerical form. Unit represents a unit of data used when reading the measurement factor in order to avoid the ambiguous explanation and different measure index value range caused by different units. Location represents whether the measure data given by living example is from the client side or service side.

As the evaluation effect and valueRange of most QoWS evaluation attributes have a linear relationship, this paper also adopted the linear normalization method to standardize the QoWS attribute data. Make linear transformation from the original measure data of its former
range $\text{valueRange} = (\text{min}, \text{max})$ into the interval $[0, 1]$ and unify the value reading direction of each measurement factor at the same time.

We assume that $G$’s value range is $\text{valueRange} = (\text{min}, \text{max})$ and the original measure date of a certain QoWS’ evaluation attribute is $v_i$. If the value reading direction of the measurement factor is positive, then the bigger value suggests better QoWS. It can be normalized as following:

\[
v'_i = \begin{cases} 
\frac{v - \text{min}}{\text{max} - \text{min}} & \text{min} \leq v \leq \text{max} \\
1 & v \geq \text{min} \\
0 & v \leq \text{max}
\end{cases} \quad (7)
\]

If the value reading direction is negative, then smaller the value, better the QoWS. It can be normalized as following:

\[
v'_i = \begin{cases} 
\frac{\text{max} - v}{\text{max} - \text{min}} & \text{min} \leq v \leq \text{max} \\
1 & v \leq \text{min} \\
0 & v \geq \text{max}
\end{cases} \quad (8)
\]

After the preprocessing of normalization, all the measure data will fall in the interval $[0, 1]$ and their value reading directions are all positive. This paper introduced the five-star model to calculate the overall level of QoWS of the target object.

### 5. Experiment and Analysis

The experimental subjects are two types of professional weather services provided by the China Meteorological Administration. The collected results are listed in the following table.

<table>
<thead>
<tr>
<th></th>
<th>$D_a$</th>
<th>$D_b$</th>
<th>$D_c$</th>
<th>$D_d$</th>
<th>$D_e$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.74</td>
<td>0.48</td>
<td>0.69</td>
<td>0.45</td>
<td>1.0</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>0.94</td>
<td>0.76</td>
<td>0.88</td>
<td>1.0</td>
</tr>
</tbody>
</table>

$D_a, D_b, D_c, D_d,$ and $D_e$ respectively represents the price, latency, accessibility, accuracy, and reputation metric of its requirements measurement. Applying QoWS pentagram model for the five factors, we have the followings results:

\[
\text{QoWS}(S_1) = 0.48 \times [(0.74 \times 0.48) + (0.48 \times 0.69) + (0.69 \times 0.45) + (0.45 \times 1.0) + (1.0 \times 0.74)] = 1.04
\]

\[
\text{QoWS}(S_2) = 0.48 \times [(1.0 \times 0.94) + (0.94 \times 0.76) + (0.76 \times 0.88) + (0.88 \times 1.0) + (1.0 \times 1.0)] = 2.02
\]

Based on the QoWS verification, the measurement results of QoWS for both tests are shown in Figure 2. It is clear that the QoWS of Figure 2(b) is higher than the QoWS of Figure 2(a).

We give indication that the marking scheme compares to subjective testing. **Satisfaction Rate** is an indicator of the consumer’s perception in complying with the agreed QoWS. The
corresponding model-based approach values are shown in Figure 3. It shows that users are basically satisfied when the model-based approach is > 1.9 and for values below this level we can expect significant user dissatisfaction with the level of service that is being provided.

![Figure 3. Satisfaction Rate](image)

### Figure 3. Satisfaction Rate

<table>
<thead>
<tr>
<th>Model-based</th>
<th>Satisfaction Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.4</td>
<td>Very satisfied</td>
</tr>
<tr>
<td>2.2</td>
<td>Satisfied</td>
</tr>
<tr>
<td>1.9</td>
<td>Some users dissatisfied</td>
</tr>
<tr>
<td>1.5</td>
<td>Many users dissatisfied</td>
</tr>
<tr>
<td>1.3</td>
<td>Nearly all users dissatisfied</td>
</tr>
<tr>
<td>1.1</td>
<td>Not recommended</td>
</tr>
<tr>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

**6. Conclusion**

In this paper, we proposed a novel approach to measure the QoWS, discussed the concept and the quantitative methods of web service quality parameters and conduct comprehensive evaluation towards the selected web service based on the evaluation model. The efficiency of our proposed approach is evaluated and validated by our experiment. The experimental results show that our proposed approach can efficiently and effectively provide truthful QoWS measure. From these results, there may be some practical implications. Furthermore, our results suggest that taking price, latency, accessibility, accuracy, and reputation into QoWS measure should be a very suitable approach, while several factors influence the truthfulness of QoWS measure. We will further research on how to effectively improve the QoWS from perspective of the quality assessment algorithm in practical applications.

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References


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