

Web Service Selection Method Based on Grey Relational Analysis

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Abstract

Based on detailed analysis of computational principles of the grey relational analysis method and a series of the relevant researches, this paper proposes a web service selection method based on Grey Relational Analysis to improve the shortcomings caused by personal assignment, so as to improve the usability of the algorithm and reduce the limitation of service selection. At the same time, this paper gives the detailed description of execution steps and complexity analysis of the algorithm. Then, the validity, applicability and efficiency of the algorithm are verified through some comparison experiments.

Keywords: *Web Service Selection, Grey Relational Analysis, QoS*

1. Introduction

Web service is a kind of distributed application with some standards, such as SOAP, WSDL and UDDI, to realize cross-platform and low coupling's features. It brings a huge revolution to the production mode, operation mode and usage method of software system. There are a large quantity of service units with identical or similar processing function on the service registry because of the openness and autonomy of web service technology itself. How to select the most appropriate service from candidate services for the user has become a research hotspot. So the academic circles conducted a lot of work aimed at web service selection method based on QoS and achieved fruitful results. The most representative research among these acquired results is the web service selection algorithm based on QoS attribute which raised by Zeng LZ, *et al.*, in the document [1]. It weighted QoS service synthesis score through calculating preference values of each dimension non-functional attributes QoS. Then the calculated maximum would be given back to the user.

However, the setting of weighting factor of each attribute in the QoS calculation is lack of objectivity, scientificity and preciseness because of the subjectivity. Therefore, the academic circles have done a lot of work in this field and put forward different methods to decide the weight of QoS attributes. The property weight in the document [2] came from the combination of subjective weight and objective weight determined by entropy weight coefficient method. The document [3] used the effect of synthetic weight with a balance factor synthesis parameter which is jointly used by the subjective weight defined by linguistic values that characterized by triangular fuzzy numbers and the objective weight defined by entropy. Jianqiang Hu, *et al.*, proposed Multi-QoS based Local Optimal Model of Service Selection (MLOMSS) to provide important grounds to choose the best service. Then the subjective weight model, the objective weight model and subject-objective weight model are constructed to determine user preference [4]. The document [5] used rough set theory to select web service driven by QoS. The local variable weight of the candidate service in the decision property comes from similarity between decision

attribute equivalence and condition attribute equivalence. The document [6] made use of the idea of primary component analysis and weighted according to the contribution rate for QoS weight. The document [7] improved the accuracy and the validity of web services selection through the combination of recommendation system and QoS weight method.

The setting of QoS index weight increases the difficulty of using web service selection function for users. Meanwhile, it's to the disadvantage of the expansion of QoS model. For this reason, it's necessary to put forward a web service selection method that can use the original data of QoS metrics to evaluate web service. The document [8] used mainly GM(1,1) model of Gray System Theory to forecast the QoS attribute values of web service through historical data of a small amount of web service samples. When it used the gray relative analysis method to do web service selection, the selection of reference sequence is made by users. Also, the validity and practicability of gray theory on the evaluation of QoS were not proved. To this end, in this paper, we use the grey relational analysis method to solve the problem of selecting the most appropriate web service which based on QoS. We propose a web service selection method based on grey relational analysis. Finally, we prove that its effectiveness of solving the problem of selecting web service based on QoS through contrast tests.

2. Web Services Selection Method based on Gray Correlation Analysis

The grey system theory was first introduced by professor Deng Julong in 1982 [9] and the grey relational analysis is a part of the grey system theory. The so-called web service selection method based on grey relational analysis is a kind of method that takes grey relational analysis as its focus, the QoS attribute values of web service as evaluation metrics, web service as evaluation object and grey relational degree as evaluation criteria to guide users through the web service selection. The algorithm is described in detail below.

(1) Define the reference sequence and compare sequence of web service

Defining the reference sequence (evaluation criterion) and compare sequence (evaluation object) based on qualitative analysis of studied problem. Assume there are m services in the candidate service set, which is as evaluation object. Choose n QoS attributes as evaluation criterion. Then there are m compare data columns.

$$\begin{bmatrix} X_1(1) & X_1(2) & \dots & X_1(n) \\ X_2(1) & X_2(2) & \dots & X_2(n) \\ \vdots & \vdots & & \vdots \\ X_m(1) & X_m(2) & \dots & X_m(n) \end{bmatrix}$$

$x_i(n)$ represents the quantitative and qualitative descriptions of the n th QoS attribute of the i th web service.

The so-called reference data column is to setup a benchmark data columns. The usual practice is to choose the maximum value (or minimum value) to constitute the optimal (or worst) reference data columns, that is recorded as:

$$X_0 = (X_0(1) \quad X_0(2) \quad \dots \quad X_0(n))$$

where,

$$X_0(j) = \max(X_1(j) \quad X_2(j) \quad \dots \quad X_m(j)) \quad (j=1, 2, \dots, n)$$

(2) the non-dimensional of variables sequence

(3) Generally, original data sequence has different dimensions and orders of magnitude. It's necessary to make the variables dimensionless in order to ensure the reliability of analysis results. The standardized calculation formula of QoS attribute metrics is as shown in (1).

$$q_s = (Max(q_i) - q_i) / (Max(q_i) - Min(q_i)) \quad (1)$$

Evaluation of sequences of difference, the maximum difference formula and the minimum difference formula are as shown in (2).

$$\Delta_{oi}(k) = |X_0(k) - X_i(k)| \quad (2)$$

where, $i=1,2,\dots,m, k=1,2,\dots,n$

The maximum and the minimum in the absolute difference array is the maximum difference and the minimum difference.

(4)The calculation formula of grey relational coefficient is as shown in (3).

$$\delta_{oi}(k) = \frac{\Delta(\min) + \rho\Delta(\max)}{\Delta_{oi}(k) + \rho\Delta(\max)} \quad (3)$$

where, $\Delta(\min) = \min_i \min_k \Delta_{oi}(k)$; $\Delta(\max) = \max_i \max_k \Delta_{oi}(k)$; ρ is the resolution ratio, among the range of 0 and 1. The grey relational coefficient matrix is as the following.

$$\begin{bmatrix} \delta_{o1}(1) & \delta_{o1}(2) & \dots & \delta_{o1}(n) \\ \delta_{o2}(1) & \delta_{o2}(2) & \dots & \delta_{o2}(n) \\ \vdots & \vdots & & \vdots \\ \delta_{om}(1) & \delta_{om}(2) & \dots & \delta_{om}(n) \end{bmatrix}$$

(5)The calculation formula of grey relational degree of web service is as shown in (4).

$$\gamma_{oi} = \frac{1}{n} \sum_{k=1}^n \delta_{oi}(k) \quad (4)$$

Where, i is the i th service object, n is the number of QoS attributes.

(6)Evaluation and analysis

According to the grey weighted relational degree, we can sort the evaluation objects, and establish relational order of evaluation objects. The bigger of the grey weighted relation degree, the better of the evaluation results.

3. The Analysis of the Algorithm Complexity

In order to analyze the algorithm complexity of “web service selection method based on grey relational analysis”, we will give the pseudo code description of the algorithm. The description is as shown in 1. From the implementation of pseudo code, we can draw conclusions that the computing capability of “web service selection method based on the grey relational analysis” studied in the paper is related to the number(m) of candidate web service in the candidate service set and the number of (n) of QoS attribute index. Its asymptotic time complexity is $O(mn)$. Therefore in terms of asymptotic time complexity, the algorithm studied in the paper is identical to the linear weighted service selection algorithm introduced by Zeng LZ group. That means the computing capability of both algorithms belongs to the same level. We will prove this point in the following experiment.

```
// The standardization of QoS attribute index
For i = 1 to m do //m indicates the number of candidate Web services
For j = 1 to n do //n indicates the number of QoS attribute index
//Standardizing the QoS attribute  $q_{ij}$ 
End For
End For
//Constructing the optimal reference data column
 $X_0 = (X_0(1), X_0(2), \dots, X_0(n))$ ;
For i = 1 to m do
For j = 1 to n do
Calculating the correlation coefficient for standard value  $q_{ij}$  of each QoS attribute
index according to formula (3-1)
End For
End For
//Calculating the grey relational degree between each candidate Web service and the
optimal service
For i = 1 to m do
For j = 1 to n do
Sum the correlation coefficient  $\xi_{ij}$  for the QoS attribute index of every candidate Web
service
End For
 $r_i = \text{Sum} \xi_{ij} / n$ ; //Calculating the correlativity for each candidate Web service
End For
Sorting the correlativity;
Printout ( $r_i$ ); //Printing the sort correlativity
```

4. Experiments and Results

a) Test Platform

(1) Hardware Environment

CPU: Intel(R) Core(TM)i3 2.53GHz;

Internal Storage: DDR3 1066MHz 2G;

(2) Software Environment

Operation System: Windows 7

Analysis Software: Excel 2007; Matlab R2009a;

(3) Test Data Set

This paper used the instance dataset of QWS_Dataset Version2. Please see the official website: <http://www.uoguelph.ca/~qmahmoud/qws/> for other more information.

(4) Comparison Algorithm

This paper chooses the linear weighting web service selection algorithm which was introduced by Zeng Lz in the document [1] as comparison algorithm. The algorithm is a common decision-making method in the multi-attribute decision-making and its core idea is to set the weight of evaluation parameters and make weighted summation for all of attribute index and make the sum as evaluation basis of evaluation object, which is introduced in detail in document [1].

b) Validation

Firstly, we need to verify the validity of the algorithm. We chose 2, 5, 10 web services from QWS_Dataset respectively that have the same function but different QoS attributes as the testing dataset. And then we use the grey relational analysis and the linear weighting web service selection algorithm which introduced by Zeng Lz separately to calculate the QoS attribute values of choosing web services. Finally, we verify whether or not the algorithm introduced in the paper is valid through comparing the two results. For illustration purposes, we use Algorithm One to refer to the linear weighting web service selection algorithm which introduced by Zeng Lz and Algorithm Two to refer to the grey relational analysis based on web service selection algorithm.

For brevity, the result of the third experiment is listed here. The grey relational analysis and comparison result of 10 web services is shown in Table 1.

Table 1. Calculating Result Comparison about 10 Web Services

WS	RT(ms)	AV(%)	Success Rate(%)	QoS (algorithm 1)	QoS(algorithm 2)
S1	47.27	61	62	1	1
S2	63.83	19	20	0.493303	0.527399
S3	68.91	19	20	0.484277	0.518067
S4	64.96	18	18	0.475386	0.520036
S5	71.54	18	18	0.463695	0.508226
S6	68.88	17	18	0.461603	0.511175
S7	70.23	17	18	0.459204	0.508792
S8	143.65	19	19	0.346931	0.425227
S9	221	18	18	0.198129	0.373090
S10	328.67	21	21	0.040909	0.345793

From the experiment result in Table 1, we can conclude that the Algorithm One result we presented are identical to the result of the linear weighting web service selection algorithm generally. However, there are differences among several service selections. We can see the differences are reflected in the similarity of three QoS attributes of web service. According to the previous experiment, we know that the weighting ratios about QoS attributes when calculating web service are 5:3:2. That means users focused on the response time among three indicators. Also, S6 is more preferable than S5. So you can see that the comprehensive evaluation result given by the algorithm introduced in the paper has better objectivity and realistic guiding significance.

From the experiment results above, we can conclude that the web service selection algorithm based on grey relational analysis is effective and it reflects the high prediction accuracy of the grey relational analysis method.

c) Applicability

We know that the evaluation index of QoS models about web service is divided into two kinds: qualitative index and quantitative index. The QoS attributes selected in the previous experiment are quantitative index. That means we just prove that the algorithm is valid with quantitative index. Therefore, in order to fully verify the validity of algorithm introduced in the paper, it's necessary to validate how well the algorithm reflects with qualitative index. Because the QoS attributes about web service in QWS_Dataset are quantitative indexes, we define the "credibility" as a qualitative index. There are five levels: "very good", "good", "general", "poor" and "very poor", rated according to national standard and related psychology experiment results.

The previous experiment for validity provides reference of this experiment and we add the evaluation description about credibility to the selected 5 web services. The results after expansion are as shown in Table 2.

Table 2. The QoS Index Values of Five Web Services after Introducing the "Credibility"

WS	RT(ms)	AV(%)	Success rate (%)	credibility
S1	47.27	61	62	very good
S2	63.83	19	20	good
S3	71.54	18	18	general
S4	143.65	19	19	poor
S5	221	18	18	verypoor

After introducing qualitative index, the five levels of credibility{"very good", "good", "general", "poor", "very poor"} are one to one correspondence {5,4,3,2,1}. Then we use

the Partial daxingcauchy division subordinate function to process the credibility in quantity.

$$f(x) = \begin{cases} [1 + \alpha(X - \beta)^{-2}]^{-1} & 1 \leq x \leq 3 \\ \alpha \ln X + b & 3 < x \leq 5 \end{cases} \quad (5)$$

At the same time, we assume that when the credibility is fine, the membership is 1, namely $f(5) = 1$;

when the credibility is good, the member-ship is 0.8, namely $f(3) = 0.8$

when the credibility is poor, the membership is 0.01, namely $f(1) = 0.01$

Then, from the assumption above, we can see that $\alpha = 1.1086, \beta = 0.8942, a = 0.3915, b = 0.3699$. Then the four coefficients are plugged into formula (7) and the calculated quantitative standard value of credibility is {"1", "0.912634", "0.8", "0.52449", "0.01"}.

After the corresponding quantitative value, the grey relevancy of each service and optimal service based on grey relational analysis method is as shown in Table3.

Table 3. The Correlativity of Five Web Services after Expanding QoS Index Values

WS	RT(ms)	AV(%)	Success rate(%)	credibility	correlativity
S1	47.27	61	62	very good	1
S2	63.83	19	20	good	0.593051
S3	71.54	18	18	general	0.540130
S4	143.65	19	19	poor	0.415281
S5	221	18	18	very poor	0.333333

From Table 3 we can see that the final evaluation result of each web service based on grey relational analysis method is still $S1 > S2 > S3 > S4 > S5$ after we introduce the credibility as a kind of qualitative index. So the web service selection method based on grey relational analysis studied in the paper remains consistency of the algorithm after introducing qualitative index. The generalizability of the algorithm is verified preliminarily.

d) Validation Verification of the Algorithm's Computing Capability

After the validity and applicability of the web service selection method based on grey relational analysis are proved primarily, what we need to do is to inspect the effectiveness of the algorithm's computing capability. That is, the comparison of execution time between the algorithm and traditional web service selection algorithm is within acceptable limits. In this part, we still choose the linear weight service selection algorithm introduced by Zeng LZ as the contrast experiment. Consider the linear weight service selection algorithm is a typical example of web service selection method based on comprehension weighted evaluation with subjective weight. Therefore, it has more persuasion with the linear weight service selection algorithm as contrast experiment.

To this end, we choose 50 and 100 web services that have same function from QWS_dataset and respectively choose 3, 4 and 5 QoS attribute qualitative indexes. Then we do the contrast experiment for time with the linear weight service selection algorithm introduced by Zeng LZ on the previous platform.

For brevity, the experiment with 50 web services that have the same function is not listed here. In the second experiment, 100 web services are combined with 3, 4, and 5 QoS attribute qualitative indexes to compose 3 test datasets respectively. Then we count up the time of solving candidate service sorted result for the algorithm presented in the paper and the linear weight service selection algorithm introduced by Zeng LZ. In order to eliminate the impact of the real-time change of experiment platform hardware system on the statistic result of algorithm's execution time, we do the two experiments 100 times respectively with 3 datasets and recorded the corresponding results and displayed them in

a graphical way. The comparison chart of two algorithm's execution time with 100 web services and 5 QoS attributes is as shown in Figure 1. And the final comprehension experimental data comparison is shown as Table 4 and 5.

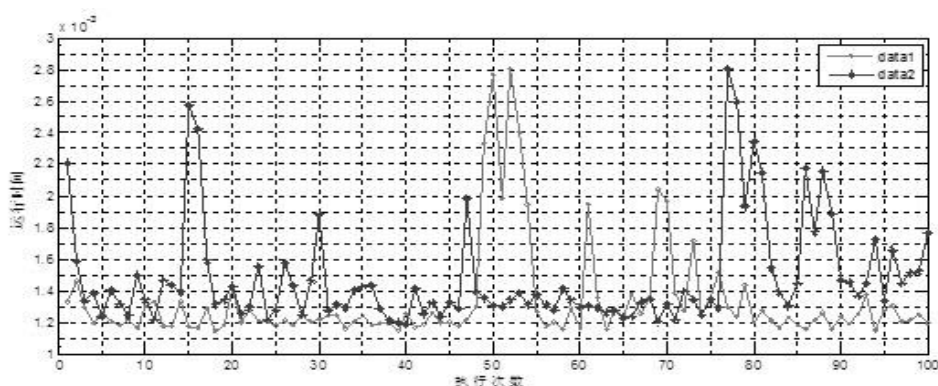


Figure 1. The Comparison Diagram of the Two Algorithms

(100 candidate services and 5 QoS attributes)

Note: The “data 1” represents the execution time curve of the linear weight service selection algorithm introduced by Zeng LZ and the “data 2” represents the execution time curve of the web service selection method based on grey relational analysis studied in the paper. From the comprehension execution of the algorithm above, we can see that the algorithm remains thereliability in general and there is no obvious difference between the execution time of both algorithms.

Table 4. Computing Time of the Two Algorithms with 50 Web Services (Unit:µS)

Algorithm	3 QoS criteria	4QoS criteria	5QoS criteria
Linear weighted service selection	741	1023	1255
grey relevancyservice selection	810	1113	1324

Table 5. Computing Time of the Two Algorithms with 100 Web Services (Unit:µS)

Algorithm	3 QoS criteria	4 QoS criteria	5 QoS criteria
Linear weighted service selection	870	1133	1337
grey relevancyservice selection	981	1208	1483

Comprehensively, the calculation shown in Table 5 doublesprevious50 candidate web services. However, the performance comparison and the algorithm's stability have no obvious change based on the final experiment result. It proves that the algorithm presented in the paper has identical computation complexity on computing capability in comparison with other traditional web service selection methods based on QoS again and they belong to the same level. Therefore, the algorithm can be acceptable.

5. Conclusion and Discussion

This paper comes up a problem about solving the web service selection based on QoS attribute through the grey relational analysis, which is aimed at the weakness of subjective weight of weighting comprehensively evaluation in practical application. The detailed calculating process and pseudo-code are described after doing research into the calculation principle and researches about the grey relational analysis method. Finally, the

paper proves the viability, applicability and validity in practical computing of solving the problem about the QoS attribute weighted by humans for web service.

The research is investigated on condition that the QoS attribute information is complete. However, under the dynamic web services composition environments, all sorts of unpredictable factors could lead to the missing of QoS information. We will focus on whether the web service selection method based on the grey relational analysis is valid or not on condition that the QoS information is incomplete in the near future.

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