A Novel User-based Web Services Evaluation and Selection Model

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***Abstract*—Evaluation of non-functional properties (NFP) of web services is of crucial importance to successful service selection. Current web services evaluation methods have not realized that evaluation of each NFP should be in accordance with its inherent character, nor have they taken the complex requirements of users on multiple NFPs into consideration. Service which can best meet the demands of users could not be chosen based on existing web services evaluation methods. To address this problem, a novel evaluation and selection model for web services based on users is proposed in this paper. The proposed model considers all possible requirements on each NFP, and employs degree of membership, fuzzy judgment theory, probabilistic statistical method as well as the TOPSIS multi-attribute decision making method based on the hosted mathematical property for each NFP. Fuzziness sub-model F and Randomness sub-model R are established, followed with Certainty sub-model C, which finally realizes comprehensive evaluation and selection of services. Simulation results demonstrate that the proposed model can effectively select an appropriate service according to the user's requirements.**

***Index Terms*—web service, evaluation, service selection, non-functional property.**

I. INTRODUCTION

With widespread application of web services, more and more web services have same function prosperities. As a result, in order to select the desired service which best meets the demands of the user, evaluation of non-functional properties (NFPs) for each web service has become more and more important.

Currently, web service selection methods [1-4] mainly include quality of service (QoS)-based selection methods, QoS correction used by trust metrics, which sometimes are called as trust-based selection methods, and QoS prediction based on collaborative filtering selection methods. Some other methods combine these methods together on different occasions. The web service evaluation and selection method is based on QoS in this paper.

In QoS-based web service evaluation methods, Simple Additive Weight (SAW) is the general evaluation method to calculate the evaluation value. For NFPs, some methods treat NFPs as a whole, such as [5], [6]. Some methods divide NFPs into positive properties and negative properties, such as [7], [8]. And some other methods divide NFPs into generic properties and domain properties, such as [9], [10]. Besides, other classification methods are proposed, such as [11]. However, they still have some issues to be resolved.

1) For each NFP of web services, traditional method often uses the same method to deal with all kinds of properties, which ignores the different mathematical properties of each NFPs host.

2) Calculating the evaluation value of a web service is generally used by SAW method, this requires users to provide weighting values of NFPs. However, the process of converting personal preferences into weighting values is abstract.

3) Current evaluation methods consider only overall evaluation values of web services, they ignore that users may still have some special requirements for individual property and multiple NFPs.

4) NFP values of web services are generally taken from Internet Server Providers (ISPs), but they are not real and reliable.

This paper proposes a novel evaluation and selection model for web services based on users. It is a more fine-grained service evaluation method. The proposed service evaluation model classifies NFPs according to the different hosted mathematical properties, then it uses appropriate mathematical tools to calculate NFP values, and it builds evaluation and selection sub-models individually. In order to avoid using weight values, this model replaces the traditional method SAW with the TOPSIS multi-attribute decision making method instead.

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Users need to give a satisfaction interval for each NFP value, and all property values are processed by the User Satisfaction Membership Processing (USMP) proposed in this model. It makes the final selected service satisfies users' requirements not only on the whole, but also on individual NFP and multiple NFPs. Additionally, because some property values provided by ISPs are unreliable, this model will measure and calculate these property values by the client, such as randomness values could be measured and calculated by a client software, fuzziness values could be calculated by the client according to users' feedback. Through this direct way, evaluation values will be more real and reliable. At last, simulation and analysis show the feasibility and effectiveness of the model. Section 2 describes web service NFPs and classification. The proposed model is introduced formally in Section 3. Section 4 shows the simulation results and an analysis. Section 5 draws conclusions and points out the future work.

II. WEB SERVICE NFPS AND CLASSIFICATION

2.1 Web Service NFPs

QoS of web service is clearly pointed out by the World Wide Web Consortium (W3C) [12], which includes 13 aspects. This paper adds other NFPs like service price and reputation into this basis, and takes out six properties which are the most commonly used to describe web services. They are Price (Expressed with Pri), Performance [13,14] (Expressed with Per), Reliability (Expressed with Rel), Availability (Expressed with Ava), Security (Expressed with Sec), Reputation (Expressed with Rep).

This paper mainly focuses on generic properties of web services, the same can be applied to this evaluation and selection model for domain properties of web services.

2.2 Classification of Web Service NFPs

According to the classification of numeric quantity and mathematic, this paper divides NFPs into three categories:

1) Fuzziness Property (FP)

Fuzziness property refers to the property values that can not be represented by numeric values accurately, it contains the users' subjectivity, and different subjective judgments will get different results, such as Sec and Rep.

2) Randomness Property (RP)

Randomness property refers to the property values that can be represented by numeric values accurately, but their values are random, such as Per. Besides, since some randomized numeric values can be taken by the periodic probability and statistics method, such as Rel, Ava, they are treated as randomness property, too.

3) Certainty Property (CP)

Certainty property refers to the property values that can be represented by numeric values accurately, and their values are constant, such as Pri.

III. A NOVEL USER-BASED WEB SERVICES EVALUA-TION AND SELECTION MODEL

According to the previous section, Web service NFPs are divided into three classifications: FP, RP and CP. This paper builds three user-based sub-models individually, a novel comprehensive evaluation and selection model is formed at last. Running process of this model is shown in Figure 1.

Concrete steps are: 1) ISPs register services in UDDI. 2) Users give requirements of functional property to UDDI. 3) UDDI inputs a set of services which have this functional property into the novel evaluation and selection model. 4) Users give requirements of non-functional property to the new model. 5) Fuzziness properties and randomness properties of this services set are processed by sub-model F and sub-model R individually, and then processing results are input into sub-model C. 6) All the property values are processed by the User Satisfaction Membership Processing (USMP), and then sub-model C obtains the best service which meets the user's demands through a multi-attribute decision making method. 7) Return the best service to the user. 8) The user uses this service.

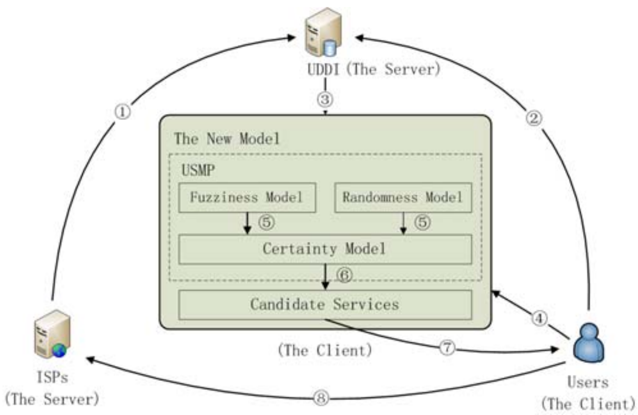

Fig. 1 Running Process of the Evaluation and Selection Model.

3.1 User Satisfaction Membership Processing

In order to make the selected best service satisfy the user's requirements for every NFP, all property values must be processed by the proposed USMP in this new model. Considering the different requirements of users, this paper proposes concepts of satisfaction interval, positive satisfaction, negative satisfaction and membership degree of satisfaction.

Definition 1. Satisfaction Interval. The range of a property value which can satisfy the user. Satisfaction is divided into positive satisfaction and negative satisfaction. Positive satisfaction means the bigger value is, the more satisfied; on the contrary, negative satisfaction means the smaller value is, the more satisfied.

A positive satisfaction interval $[T_1,T_2]$ means the property value which meets the user's demand is T_1 at least, if it could reach T_2 or better, the value is regarded as completely satisfied, if it is less than T_1, the value is regarded as completely unsatisfied. The meaning of a negative satisfaction interval [T_1,T_2] is opposite.

Definition 2. Membership Degree of Satisfaction. For a property value, its degree of belonging to the property satisfaction interval of the user is called the membership degree of satisfaction. The maximum of a membership degree of satisfaction is 1, the minimum is 0. f^+ means a positive satisfaction membership function, f^- means a negative satisfaction membership function.

The computational formulae of satisfaction membership degree as follows:

1) When positive satisfaction property value is x, the property positive satisfaction interval of the user is [T_1,T_2] ($T_1 < T_2$), then the computational formula of positive satisfaction membership degree is:

$$f^+(x,T_1,T_2)=\begin{cases}0 , & x<T_1\\ \dfrac{x-T_1}{T_2-T_1} , & T_1\le x\le T_2\\ 1 , & x>T_2\end{cases} \tag{1}$$

2) When negative satisfaction property value is x, the property negative satisfaction interval of the user is [T_1,T_2] ($T_1 < T_2$), then the computational formula of negative satisfaction membership degree is:

$$f^-(x,T_1,T_2)=\begin{cases}1 , & x<T_1\\ \dfrac{T_2-x}{T_2-T_1} , & T_1\le x\le T_2\\ 0 , & x>T_2\end{cases} \tag{2}$$

Through this processing, the user's personal requirements are imbedded in NFP values of services. USMP raises the property value, which is completely satisfied with the user, to maximum value namely 1, and lowers the property value, which is completely unsatisfied with the user, to minimum value namely 0. This will largely affect the following service evaluation work; this achieves the purpose that the selected best service satisfies the user’s requirements not only on the whole, but also on individual NFP and multiple NFPs.

3.2 Fuzzy Judgment-Based Fuzziness Evaluation and Selection Sub-Model

The sub-model uses the one level model of fuzzy judgment theory to single judge a service for its Sec and Rep fuzzy properties. Its steps [15] as follows (1) to (3):

1) Determine the judgment object’s factor set $U=\{u_1, u_2,\ldots,u_n\}$.

2) Give the judgment set $V=\{v_1,v_2,\ldots,v_m\}$.

3) Single factor judgment. That is, to establish a fuzzy mapping f from U to V. Fuzzy relationship R_f is induced by f, denoted as a matrix **R**, it is called the single factor evaluation matrix.

4) Convert fuzzy properties’ feedback into certainty values. Firstly, quantify fuzzy comments in the judgment set, then get the single factor certainty values evaluation matrix **T** after computing.

After these steps, it converted users’ feedback of fuzziness properties into certainty values. Then it executes USMP (since Sec and Rep are positive satisfaction properties, Eq.(1) is used) according to satisfaction intervals that the user gave. The following evaluation and selection model will use these results.

3.3 Probability and Statistics-Based Randomness Evaluation and Selection Sub-Model

In this sub-model, Per is a random value determined by environment factors like network and computer system at that time. When the number of requesting service s is N, each Per value is x_i, we take the Per(s)= $\sum_{i=1}^{N} x_i$ /N value as the Per of the service. Rel and Ava are obtained by periodic probability and statistics method. Assuming the number of requesting service s is N in one period, the number of successful results which are returned by the service is n_1, and the number of failed ones is n_2, then Rel(s)=$n_1/(n_1+n_2)$, Ava(s)=$(n_1+n_2)/N$.

Through the above approaches, it converted randomness property values into certainty values. Just like Section 3.2, it also executes USMP (since Rel and Ava are positive satisfaction properties, Eq.(1) is used, yet Per is a negative satisfaction property, Eq.(2) is used) according to the satisfaction intervals that the user gave. The following evaluation and selection model will use these results, too.

3.4 TOPSIS-Based Certainty Evaluation and Selection Sub-Model

The final certainty evaluation and selection sub-model will use TOPSIS [16-18] multi-attribute decision making method to evaluate and select the most ideal service that satisfies the user’s requirements.

Firstly, it executes USMP for values of certainty properties (since Pri is a negative satisfaction property, Eq.(2) is used), then it uses TOPSIS multi-attribute decision making method to select the most ideal service that satisfies the user’s requirements. Its definite steps [16] as follows (1) to (3):

1) According to the design of NFPs and the collected relevant data (certainty values which are output by the above two sub-models, and certainty values of certainty properties, they were all processed by USMP), list the decision matrix **A**.

2) Data preprocessing. In order to unify comparison, we must clear the inconsistency of data dimension and range, range transformation is used in this paper. Because of USMP, now all property values are effective data (namely positive satisfaction data), so we use the range transformation formula of effective data.

3) Evaluation and selection of services. Given the ideal service point and the negative ideal service point, then according to Euclidean distance, calculate distances between a service point and the ideal service point, a service point and the negative ideal service point. Next, calculate the relative closeness C_i between each service point and the ideal service point respectively. At last, sort C_i by the value, a service which has the greater C_i value, it is more ideal for the user, so the service which has the greatest C_i value can be the final selected service.

IV. Simulation and Analysis

4.1 Simulation Background

The experiment simulates a process of a user selects the best ideal service in 30 music sites which provide the service of listening to high quality music online. The data of services NFPs includes the data provided by ISPs and the data measured and calculated by the client. The data is all simulated data. When generating the data randomly, in order to avoid unreasonable cases that the service property values are excessively low, the program limits random numbers within a certain range, this could ensure that the simulation is more realistic. The experiment simulates the SAW evaluation method based on users' experience, the evaluation method based on the machine learning algorithm from [10], and the novel model evaluation method proposed in this paper, to compare and analyze each property of the three selected final services respectively.

4.2 Simulation Results and Analysis

At last, we compare the difference of each property of the three selected best services respectively, which are selected by the three methods, using the histograms. The abscissa axis NEW represents the evaluation method in this paper, C1 represents the SAW method, C2 represents the method from [10]. The horizontal solid lines in each property figure represent the user's satisfaction intervals. When they are in positive satisfaction property figures, it means the parts which are over horizontal lines are satisfied by the user, the parts which are below horizontal lines are not satisfied by the user. When they are in negative satisfaction property figures, the meaning is opposite.

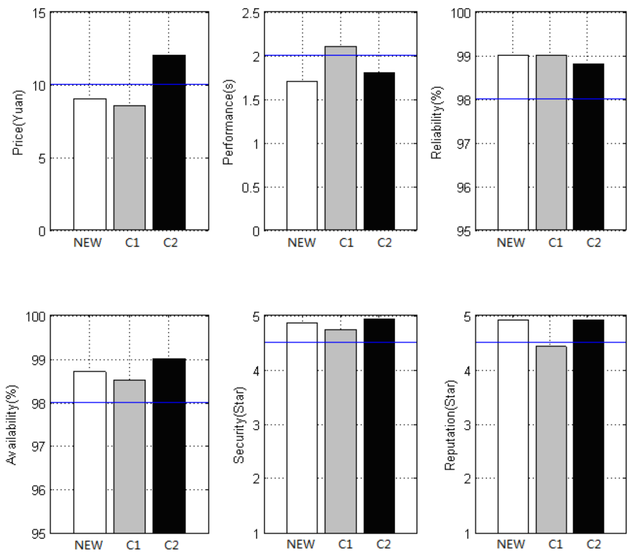

Fig. 2 Simulation Results.

Through the comparison in Figure 2, we could see each property of the best service selected by the new method satisfied the user's requirements. However, the best services selected by C1 and C2 methods do not satisfy the user's requirements on some NFPs. Such as C1 method does not satisfy the user on performance and reputation, C2 method does not satisfy the user on price. In conclusion, compared with other methods, the best service selected by the new method satisfies the user's requirements both on the whole and on multiple NFPs, it is superior to other methods especially on multiple NFPs. The simulation shows the feasibility and effectiveness.

V. Conclusions and Future Work

This paper proposed a novel evaluation and selection model for web services based on users, this model can select the best ideal web service which satisfies the user's requirements. The simulation and results analysis show that this model improves the effectiveness of evaluation and selection for web services, and it can better meet the demands of the user.

Future work will study further on the effectiveness and optimality of web services selection, considering how to reduce the cost of service evaluation, focusing on the research of web services evaluation methods and models, and evaluation and selection models of combination services.

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