

Multi-attribute group decision making algorithm for web services selection based on QoS

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Abstract: To address the problem of web services selection based on quality, an approach of multi-attribute group decision making algorithm is proposed. Based on the Borda social choice function, the group decision making algorithm aggregates the results of multiple methods with different principles which are used to obtain constantly changing quality of service, thus increasing the confidence to select the most appropriate web service for a special task. The experimental results indicate that the proposed approach has better scalability and can be applied to large-scale distributed service computing environments. It is also shown that the proposed group decision making approach can effectively optimize the services selection and outperforms the random and robin policies. By using this approach, it can extend a method to obtain constantly changing quality of service and construct a synthetic information entity with multi-level knowledge, which guarantees the accuracy of services selection.

Key words: web services; quality of service; group decision making; Borda function

A web service is a self-describing, self-contained, modular application accessible over the web^[1]. The software system can interact with the web service using SOAP messages^[2]. In order to take advantage of the potential web services, service requesters search the web services in common service repositories and select the most appropriate one based on QoS. QoS is an important aspect of web services^[3-5], and some related web services selection based on the hypothesis that QoS can be obtained before invocation has been conducted^[6-9]. However, in an open Internet environment, QoS is constantly changing and it is impossible to obtain the actual quality of service that a given service instance will deliver until the instance is invoked. In order to accurately obtain the QoS before invocation, some methods are introduced. One is to obtain QoS by the description of web service. Another regards the average quality of past invocations as the “actual” QoS. Meanwhile, some other methods were proposed to predict possible status of certain web service^[10]. Different methods reflect different aspects of QoS, and any single method cannot reflect the overall characteristics of QoS. Aggregating the results of different methods will increase the confidence to select the most appropriate one for a special task. The above process is, in nature, a multi-attribute group decision making problem. By

using this approach, it can not only extend a method to obtain QoS but also construct a synthetic information entity with multi-level knowledge, which guarantees the accuracy of services selection.

1 Social Choice Function

A social choice function is a function that takes lists of preferences ranked by people and outputs a single alternative. In this paper the weighted Borda function is applied.

Suppose that the number of alternatives and decision makers is m and l , respectively. Each decision maker ranks the alternatives and assigns $m-1, m-2, \dots$, and zero to the first, second, ..., and the last alternative respectively. The value of the Borda function is defined as follows:

$$f_B(x) = \sum_{k=1}^l N(x \succ_k y)$$

where N is the number of votes of satisfying priority relationship $x \succ_k y$ according to the preference of the k -th decision maker. Based on the above discussion, the weighted Borda function is defined as follows:

$$f_{WB}(x) = \sum_{k=1}^l v_k N(x \succ_k y)$$

where v_k is the voting power of the k -th decision maker. The winner is the alternative with the highest value of the weighted Borda function.

2 Web Service Quality Model

In the scope of web services, QoS concerns the

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non-functional aspects of the service. In this paper, five quality criteria are discussed.

Cost This quality criterion measures the money that a service consumer has to pay for the service provider.

Time It is defined as the total time needed for a web service instance to transform a set of inputs into outputs.

Reliability It refers to the ability of a service to function correctly and consistently and provides the same service quality despite system or network failures.

Accessibility It represents the degree with which a web service request is served.

Reputation The reputation of a service is a measure of its trustworthiness.

3 Group Decision Making

3.1 Presentation of decision data

Let a multi-attribute group decision be of l decision makers, m alternatives and n criteria, and let $D_1, D_2, \dots, D_l; A_1, A_2, \dots, A_m; C_1, C_2, \dots, C_n$ represent the decision makers, alternatives and criteria, respectively. The group decision data can be shown as follows:

$$T_k = \begin{bmatrix} a_{11}^k & a_{12}^k & \dots & a_{1n}^k \\ a_{21}^k & a_{22}^k & \dots & a_{2n}^k \\ \vdots & \vdots & & \vdots \\ a_{m1}^k & a_{m2}^k & \dots & a_{mn}^k \end{bmatrix} \quad 1 \leq k \leq l$$

$$W = \begin{bmatrix} w_1^1 & w_1^2 & \dots & w_1^l \\ w_2^1 & w_2^2 & \dots & w_2^l \\ \vdots & \vdots & & \vdots \\ w_n^1 & w_n^2 & \dots & w_n^l \end{bmatrix}, V = \{v_1, v_2, \dots, v_l\}$$

where T_k is the evaluation matrix of decision maker D_k for all alternatives; W is the weight matrix; V is the voting power vector; a_{ij}^k represents the evaluation of decision maker D_k for alternative A_i on the criterion C_j ; w_j^k represents the individual preference of decision makers D_k on the criterion C_j ; and v_k represents the voting power assigned to decision maker D_k .

3.2 Group decision making process

The multi-attribute group decision making process consists of the following eight steps.

Step 1 For negative criteria such as cost and time, values are scaled according to Eq. (1). On the other hand, for positive criteria, Eq. (2) is used.

$$r_{ij}^k = 1 - \frac{a_{ij}^k}{\max_i \{a_{ij}^k\} + \min_i \{a_{ij}^k\}} \quad (1)$$

$$r_{ij}^k = \frac{a_{ij}^k}{\max_i \{a_{ij}^k\} + \min_i \{a_{ij}^k\}} \quad (2)$$

In Eqs. (1) and (2), $\max_i \{a_{ij}^k\}$ and $\min_i \{a_{ij}^k\}$ are the maximum element and minimal element of the j -th column vector in matrix T_k , respectively. After the above operation is done, the following matrix T'_k can be obtained.

$$T'_k = \begin{bmatrix} r_{11}^k & r_{12}^k & \dots & r_{1n}^k \\ r_{21}^k & r_{22}^k & \dots & r_{2n}^k \\ \vdots & \vdots & & \vdots \\ r_{m1}^k & r_{m2}^k & \dots & r_{mn}^k \end{bmatrix} \quad (3)$$

Step 2 For each decision maker D_k , the positive ideal solution M^{k+} and the negative ideal solution M^{k-} according to matrix T'_k are obtained.

$$M^{k+} = \{M_1^{k+}, M_2^{k+}, \dots, M_n^{k+}\}$$

$$M^{k-} = \{M_1^{k-}, M_2^{k-}, \dots, M_n^{k-}\}$$

where M_j^{k+} and M_j^{k-} are the maximum element and the minimum element of the j -th column vector in matrix T'_k , respectively.

Step 3 For each decision maker D_k , compute the weighted Euclidean distance d_i^{k+} ($1 \leq i \leq m$) between A_i and the positive ideal solution M^{k+} .

$$d_i^{k+} = \sqrt{\sum_{j=1}^n [w_j^k (M_j^{k+} - r_{ij}^k)]^2} \quad (4)$$

Step 4 For each decision maker D_k , compute the weighted Euclidean distance d_i^{k-} ($1 \leq i \leq m$) between A_i and the negative ideal solution M^{k-} .

$$d_i^{k-} = \sqrt{\sum_{j=1}^n [w_j^k (r_{ij}^k - M_j^{k-})]^2} \quad (5)$$

Step 5 For each decision maker D_k , calculate membership degree of each alternative belonging to the positive ideal solution. Define a membership function $\mu^k(A_i)$ which gives the membership degree of the alternative A_i ($1 \leq i \leq m$) belonging to the positive ideal solution M^{k+} based on the preference of decision maker D_k .

$$\mu^k(A_i) = \frac{1}{1 + (d_i^{k+}/d_i^{k-})^2} \quad (6)$$

Step 6 For each decision maker D_k , rank the alternatives according to the result of step 5. The result is expressed as follows when the indices are ranked:

$$A_{i_1} >_k A_{i_2} >_k \dots >_k A_{i_m}$$

Assign $m-1, m-2, \dots, 0$ to alternative $A_{i_1}, A_{i_2}, \dots, A_{i_m}$, respectively.

Step 7 According to the definition of the weighted Borda function, compute the value of the weighted Borda function for all alternatives.

Step 8 Select the final decision alternative with the highest value of the weighted Borda function.

4 Experiment

The response time of group decision making is shown in Fig. 1. As the number of the alternatives increases, the time taken for decision making naturally increases. However, there is no significant wave while the number of alternatives is increasing, which indicates that this approach has better scalability.

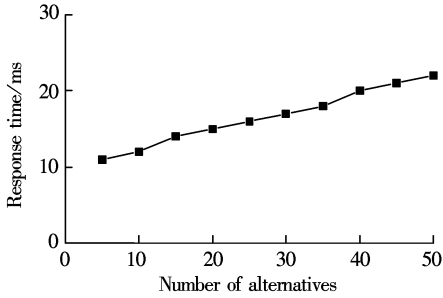


Fig. 1 Response time of decision making

Another group of simulation experiments are conducted to compare our approach with random and round robin selection policy. When concurrent requesters submit their service requirements for a special task, the random policy, round robin policy and ours are applied for services selection and the average actual quality of all services assigned to concurrent requesters by different approaches serves as the performance of that decision making algorithm. The principle of services selection for concurrent requesters is that each alternative service can only be assigned to one requester. Due to space limitation, only the comparison results of the cost and time criteria are illustrated in Figs. 2 and 3, respectively, and the other criteria have similar results to the cost criterion.

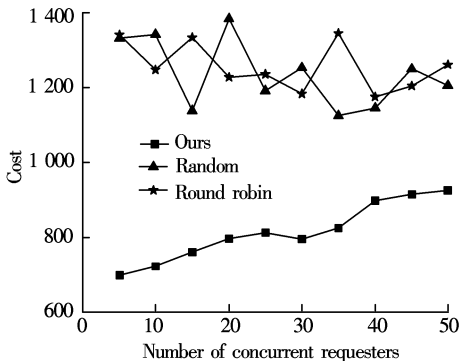


Fig. 2 Comparison of cost

Fig. 2 indicates that the approach in this paper selects cheaper services for service requesters. Fig. 3 shows that the three approaches have similar performance as far as the time criterion is concerned. There are

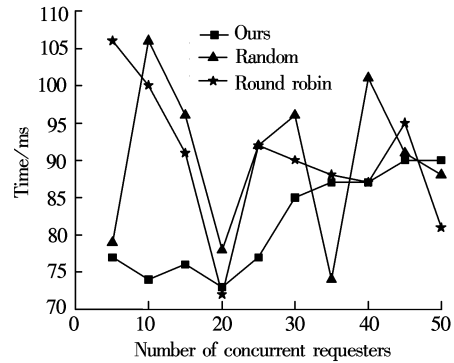


Fig. 3 Comparison of time

two reasons for this phenomenon: one is that the time in our approach includes group decision time; the other is that the weight value for the time criterion is lower. According to the above discussion, it is easy to see that the group decision making approach applied in this paper has ideal performance.

5 Conclusion

A multi-attribute group decision making is applied to services selection in this paper, which aggregates group preference from different methods used to obtain quality of service and guarantees better services selection.

It should be pointed out that the decision making approach in this paper is built on the compensability between the decision attributes. But in some cases, the compensability between the decision attributes is conditional, and even non-compensable. Therefore, other comprehensive decision making approaches are needed and those problems should be studied further in the future.

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基于服务质量的多属性群决策服务选择算法

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摘要:为解决基于服务质量的服务选择,提出了一个多属性群决策算法. 该算法通过使用 Borda 社会选择函数集成了多种具有不同原理用于计算不断变化的服务质量方法的结果,从而增强了服务选择的可靠性. 实验结果表明该方法具有较好的可扩展性,从而能适用于大规模的分布式服务计算环境;同时相比于随机和轮转服务选择策略,所提出的基于群决策的服务选择策略具有更优的性能,它能够有效地优化服务选择. 该算法不仅仅是增加了一种用于获取不断变化的 web 服务质量的方法,而是建立一个具有多层知识的综合信息体,从而保障了服务选择的正确性.

关键词:web 服务;服务质量;群决策;Borda 函数

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