Intelligent Web Services Selection based on AHP and Wiki

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Abstract

Web Service selection is an essential element in Service-Oriented Computing. How to wisely select appropriate Web services for the benefits of service consumers is a key issue in service discovery. In this paper, we approach QoS-based service selection using a decision making model – the Analytic Hierarchy Process (AHP). In our solution, both subjective and objective criteria are supported by the AHP engine in a context-specific manner. We also provide a flexible Wiki platform to collaboratively form the initial QoS model within a service community. The software prototype is evaluated against the system scalability.

1. Introduction

Existing service matchmaking mechanisms (such as UDDI registries, StrikeIron[1], etc.) have provided a clear view of service relevance information. The ranking mechanism does bring the order based on the relevance of service descriptions. However, the static relevance does not necessarily represent run-time appropriateness. For example, a functionally relevant Web service might not be appropriate for some users due to its slow speed or prohibitive cost [1]. Likewise, a Web service with a relatively lower relevance ranking can well suit some service consumers' requirements for data privacy. Therefore, service communities need to provide service selection enabling techniques to help users determine the 'degree of appropriateness' for each service candidate from a user's perspective. Service selection mechanism represents significant value added by service brokers and syndicators.

In this paper, we approach QoS (Quality of Service) -based service selection using a decision making model – the Analytic Hierarchy Process (AHP). In our solution, both subjective and objective criteria are supported by the AHP engine in a context-specific manner. We also provide a flexible Wiki platform to collaboratively form the initial QoS model within a service community.

2. Conceptual Model

For generality, we will use the QoS meta-model defined in [2] as the basis for the QoS and AHP modelling in following sections. In order to apply the AHP model to the QoS meta-model, we have extended the original QoS meta-model [2] in two ways. First, we introduce the concept of *Sub-QA* into the QoS meta-model. The motivation is based on the fact that one QA may be dependent on several key factors at the same time. In other words, the performance of these key factors collectively determines the ultimate score of this QA. These key factors are defined as *Sub-QA* (SQA), and their corresponding QA is termed as *Parent QA* (PQA). It is noted that an SQA automatically becomes a PQA if its measurement hinges on several other SQAs. This way, a tree-like structure of QoS meta-model is formed with unlimited levels of PQA and SQA. The second extension we have made is to place a constraint on the Assessment Criteria: a QA is allowed to have associated AC only if it is not a PQA of any kind. Simply put, only the 'leaf' node in the QoS meta-model tree will have associated AC. This assertion distinguishes the act of measuring QoS and the act of structuring QoS models. Such a decoupling decomposes the complex problem into focused areas. Thus, domain experts can work solely on the QoS modelling, and stakeholders only need to assess AC for the leaf nodes without involving the whole QoS model. The leaf node SQA is termed as LQA in this paper.

The AHP is one of the most widely used multiple criteria decision-making models [3]. The AHP was originally proposed in Saaty [4], allowing decision makers to model a complex problem in a hierarchical structure consisting of Goal, Factors, Sub-factors, and

[1] http://www.strikeiron.com/

0-7695-3026-5/07 $25.00 © 2007 IEEE
DOI 10.1109/WI.2007.15

Alternatives. Since its foundation, the AHP has been successfully applied in a wide range of applications [5] involving multi-criteria decision making. The AHP model is illustrated in Figure 1, where the AHP hierarchy sits in the middle representing the complex problem, i.e. service selection. From the AHP perspective (right), it has four levels of constructs – Goal, Factors, Sub-Factors, and Alternatives – corresponding to four concepts in the QoS meta-model (left) – Context, Quality Aspects, Quality Criteria, and Web Services respectively.

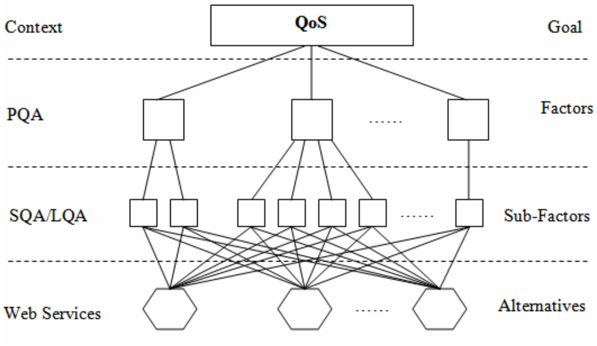


Figure 1 A QoS Meta-model based on AHP model

3. The AHP Approach

The AHP approach has three core processes, each of which includes several steps. During the system *design time*, two processes (two grey arrows) generate the AHP indices, which keep the calculated priority for each web service under each AC. It also stores the original pair-wise comparison matrices. AHP indices are used during the system *run time* (the white arrow) to derive the final QoS score based on consumers' preferences.

The first important task in applying the AHP is to construct the hierarchy, which includes factors and sub-factors that characterize the QoS-based decision making problem. Saaty and Vargas [6] suggest that during the hierarchy construction, one must "include enough relevant detail to represent the problem as thoroughly as possible". Such a user-centered thoroughness requires a collaborative process by which all stakeholders of the decision problem can easily participate in constructing the complete AHP hierarchy. This collaborative process coincides with the concept of "community" defined in [7] , where "a community defines the quality tree for a given class of Web services". We have thus built a Web Wiki platform in order to foster such a collaborative process within the 'community'. It enables service brokers and consumers to collaboratively construct the problem hierarchy in a very efficient manner. The second stage of the AHP approach the pair-wise comparison and the eigenvector method to estimate the overall priorities. This results in the AHP indices that keep all relative priorities for Web services under each Assessment Criteria for different reviewers.

The next step is to estimate the ranking of $WS = \{ws_1, ws_2 ..., ws_n\}, n \geq 2$ based on these ratio values in matrix. In AHP, this is accomplished by deriving a vector of priorities from the raw pair-wise comparison ratios. Saaty [4] proposed an eigenvector method to derive the priorities, where each component in the principal right eigenvector is normalised to between 0 and 1 to represent the relative priority of alternatives. Choo and Wedley [8] has discussed 18 approaches that attempted to achieve this aim. However, [9] has shown that the eigenvector approach is "a theoretically and practically proven" method for estimating the priorities. Thus, the eigenvector approach formally deals with human errors inherent in any decision making processes. The estimate of the overall relative priority for an alternative Web service p_{ws_i} is a component in a vector P . P is derived by solving the eigenvalue problem $SP = \lambda_{\max} P$, where $\lambda_{\max}$ is the largest eigenvalue of matrix S , S is the aggregated comparison matrix, and P is the principal (dominant) right eigenvector corresponding to the eigenvalue $\lambda_{\max}$. In practice, this is accomplished by using the Power Iteration algorithm [10]:

$$\lim_{k \to 0} \frac{S^k e}{\left\| S^k \right\|} \text{ ,where } e = (1,1,...,1)^T \text{ ,and } \left\| S^k \right\| = e^T S^k e \text{ .}$$

The next step is to determine the relative preference for each Quality Aspect (QA). The rationale behind is that the QA should not always be considered equally important during the service selection. Instead, each QA has distinct importance contributing to the ultimate QoS value under certain contexts. Therefore, they should be assessed in a way that their respective significances are measured and integrated. Moreover, these relative preferences are unique from user to user. Thus, user preferences play significant roles in determining the most appropriate services. It reflects the dynamics of the service selection during the system run-time. The raw priorities of each service – the AHP indices – obtained in Sect. 4.3 have to be 'normalised' with user preferences in order to achieve the user-centred service selection.

Given the hierarchical structure of QoS model, the QA comparison starts from the top layer of the AHP hierarchy. It walks through each level of the QoS model by performing pair-wise comparison in that level. To match all these priorities with their corresponding LQA preferences, we can obtain the final QoS result matrix by left multiplying P_{all} with FLP. Thus $FLP \times P_{all}$ yields the final QoS vector:

$$Q = \left[\sum_{i=1}^{m} p^{i}_{ws_1} \times flp_i , \sum_{i=1}^{m} p^{i}_{ws_2} \times flp_i ,..., \sum_{i=1}^{m} p^{i}_{ws_n} \times flp_i \right]$$

where the jth component of Q represents the final QoS score of the jth web services ws_j in a set of functionally-equivalent web services $WS = \{ws_1, ws_2 ..., ws_n\}, n \geq 2$, and $1 \leq j \leq n$.

4. Implementation and Evaluation

The architectural design of intelligent QoS-based service selection contains three types of architectural elements [11] – data, components, and connectors – as its building blocks. We also provide two levels of abstraction for the server-side architectural design. (See Figure 2).

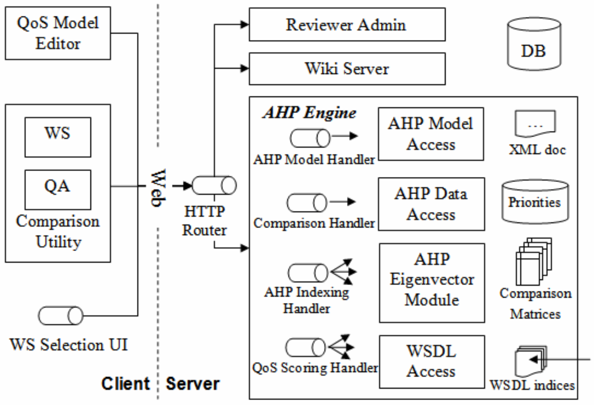
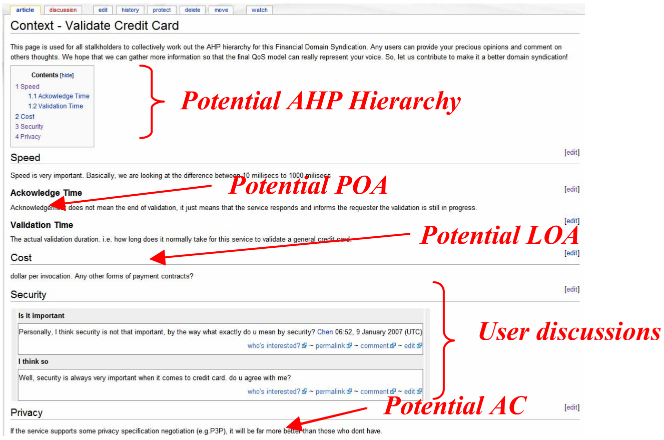


Figure 2 Overall architecture

We have implemented the architectural design and produced a proof-of-concept prototype for QoS-based service selection. Firstly, in order to collect more users opinions for the QoS mode (i.e. the AHP hierarchy), the Wiki UI provides a convenient collaborative editing environment, where any interested uses can have their own thoughts posted. As shown in Figure 3, users can quickly establish potential PQA and LQA of the QoS model by clicking the 'edit' link for each item. The AHP hierarchy is automatically generated as a 'Table of Content' for normal Wiki headings.



Context - Validate Credit Card

This page is used for all stalkholders to collectively work out the AHP hierarchy for this Financial Domain Syndication. Any users can provide your precious opinions and comment on others thoughts. We hope that we can gather more information so that the final QoS model can really represent your voice. So, let us contribute to make it a better domain syndication!

Contents [hide]
1 Speed
1.1 Ackowledge Time
1.2 Validation Time
2 Cost
3 Security
4 Privacy

Speed

Speed is very important. Basically, we are looking at the difference between 10 millisecs to 1000 milisecs

Ackowledge Time

Acknowledgement does not mean the end of validation, it just means that the service responds and informs the requester the validation is still in progress.

Validation Time

The actual validation duration. i.e. how long does it normally take for this service to validate a general credit card.

Cost

dollar per invocation. Any other forms of payment contracts?

Security

Is it important

Personally, I think security is not that important, by the way what exactly do u mean by security? Chen 06:52, 9 January 2007 (UTC)
who's interested? ~ permalink ~ comment ~ edit

I think so

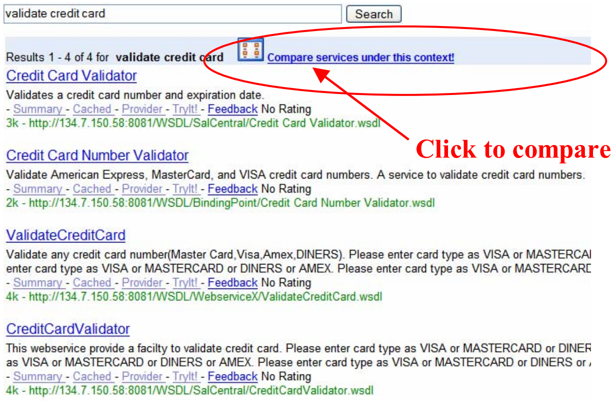
Well, security is always very important when it comes to credit card. do u agree with me?
who's interested? ~ permalink ~ comment ~ edit

Privacy

If the service supports some privacy specification negotiation (e.g.P3P), it will be far more better than those who dont have.

Figure 3 Wiki platform UI

In order to conduct the pair-wise comparison in the AHP approach, a reviewer is first provided with all functionally-equivalent Web services based on a certain *Context*. An example is illustrated in Figure 4, where the reviewer has run a service search using the context name – validate credit card – as keywords. Four functionally-equivalent Web services are listed in the search result as all of them appear to have the similar capability to validate credit cards from their service descriptions. The search is based on WSDL indices crawled and indexed by the service search engine described in our previous work [12]. The reviewer can then follow the link to start to the review job – pairwise comparisons amongst these four Web services. This brings the reviewer to the Comparison Utility GUI.



validate credit card

Results 1 - 4 of 4 for **validate credit card** Compare services under this context!

Credit Card Validator
Validates a credit card number and expiration date.
- Summary - Cached - Provider - TryIt! - Feedback No Rating
3k - http://134.7.150.58:8081/WSDL/SalCentral/Credit Card Validator.wsdl

Credit Card Number Validator
Validate American Express, MasterCard, and VISA credit card numbers. A service to validate credit card numbers.
- Summary - Cached - Provider - TryIt! - Feedback No Rating
2k - http://134.7.150.58:8081/WSDL/BindingPoint/Credit Card Number Validator.wsdl

ValidateCreditCard
Validate any credit card number(Master Card,Visa,Amex,DINERS). Please enter card type as VISA or MASTERCAI
enter card type as VISA or MASTERCARD or DINERS or AMEX. Please enter card type as VISA or MASTERCARD
- Summary - Cached - Provider - TryIt! - Feedback No Rating
4k - http://134.7.150.58:8081/WSDL/WebserviceX/ValidateCreditCard.wsdl

CreditCardValidator
This webservice provide a facilty to validate credit card. Please enter card type as VISA or MASTERCARD or DINER
as VISA or MASTERCARD or DINERS or AMEX. Please enter card type as VISA or MASTERCARD or DINERS or
- Summary - Cached - Provider - TryIt! - Feedback No Rating
4k - http://134.7.150.58:8081/WSDL/SalCentral/CreditCardValidator.wsdl

Figure 4 A list of functionally-equivalent Web services ready to be compared under the context "*validate credit card*"

In order to evaluate the scalability of the AHP solution, we have designed an experiment, where the response time is measured given the increased number of reviewers during the AHP comparison phases. It examines the sensitivity of the AHP eigenvector response time when the system load (i.e. the number of the users – reviewers) increases in at least one order of magnitude. Thus, four test runs have been conducted based on four different matrix orders (4 – 7). This yields four curves in Figure 5. Within each test run, a certain number (20 – 200) of reviewers concurrently submit their comparison matrices to the AHP engine. The engine calculates the derived principal eigenvector and its associated Consistence Rate (CR). The reviewer aggregation processes is omitted so that we can focus solely on the eigenvector test result. The eigenvector and the CR are sent back to reviewers via HTTP response afterwards. When all reviewers receive the result, the TestRun manager then collects time duration of each reviewer and calculates the average response time (in milliseconds) shown as the Y-axis in Figure 5.

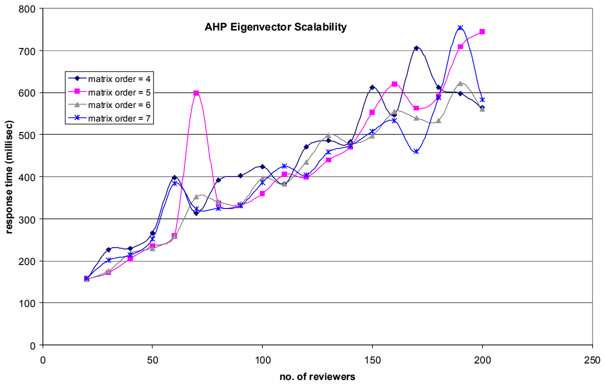


Figure 5 AHP eigenvector scalability test result

The results suggest that when the system loads increase, the response time does increase but at a rather lower rate (roughly 1/3 of the rate of loads increase). For example, when 200 reviewers simultaneously submit their comparison matrices of order of 7, the average response time for each reviewer is about 580 milliseconds (around more than half second). When 20 reviewers submit at the same time, the result is 160 milliseconds. Hence the difference is 420 milliseconds (less than half second), which is hardly noticed by most users. However, the number of users has increased 10 times.

5. Conclusions

Selecting the most appropriate one amongst these functionally-equivalent Web services becomes an important issue to solve. In most cases, Quality of Services (QoS) plays a crucial role since the major concerns have been shifted from the 'function' to the 'quality' of a Web service in service selection. In this paper, we have provided an intelligent QoS-based service selection solution. We apply the Analytic Hierarchy Processes (AHP) as the underlying model to characterize the QoS problem and its associated decision making approach. We have defined four steps of the AHP-based service selection approach including detailed mathematical model, algorithms and their applications in service selection amongst the service community. To validate the conceptual mode and approach, the architectural design and the software prototype are provided as a complete solution by which users can easily conduct the service selection through Web user interfaces. The solution is evaluated against the scalability.

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