A Multi-dimension Qos based Local Service Selection Model for Service Composition

Liurong Hong
Department of Education, Shangqiu Normal University, Shangqiu, China
hongliurong@126.com
Jianqiang Hu
Department of Computer Science & Technology, Tsinghua University, Beijing, China
jqhucn@gmail.com

***Abstract*—There are two service selection strategies in dynamic service composition, i.e., global strategy and local strategy. The existed global service selection algorithms, due to insufficiently show users' partiality and feature of the service, is unfavorable to encourage the service provider to optimize the service quality to some extent. In this paper, an ordinary utility function is used as a numerical scale of ordering local services, and then a multi-dimension Qos based local service selection model is proposed to provide important grounds to choose superior service and sift inferior service. Secondly, subjective weight mode, objective weight mode, and subject-objective weight mode are constructed to not only determine the weight coefficient of each Qos criterion, but also show users' partiality and the objectivity of service quality. At last, this model is proved to be flexibility and effective based on our SEWSCP (Semantic Enable Web Service Composition Platform).**

***Index Terms*—local service selection, service composition, subject-objective weight mode, SEWSCP**

I. Introduction

Service-oriented Architecture and related technologies promise to facilitate efficient execution B2B ecommerce by integrating business applications across networks like the Internet. In particular, service composition is gaining a considerable momentum as an approach for the effective integration of distributed and heterogeneous business application. It is a critical to find and select the appropriate component service to compose services and complete loosely coupled business processes which require dynamic and flexible binding of services. However, with the ever increasing number of services similar in functionality being made available on the Internet, there is a need to be able to distinguish them by using a set of well-defined quality of service (Qos) criteria. Qos-based service selection is vital as it is directly related to the whole quality of Web service composition and adjustment of service binding. In particular, a service composition system that can make use of individual service's Qos information to achieve the optimal Qos of composite services is still ongoing research problem.

Dynamic service composition has two service selection strategies: global strategy and local strategy. Take workflow-based service composition for example, global strategy enables the Qos of composite services which meets the given overall quality of business constraints, while local strategy is to choose component services by using each activity as basic granularity, that is, it respectively investigates the candidate service sets of various activities and chooses a suitable service as component service executed the activity from a set of candidate functional similar in functionality. Currently, a lot of related research has been vigorously expanded as follows.

A. Global Strategy

Global strategy evaluates and determines similar services according to global constraints of composite service. Service selection is formulated as integer programming, multi-choice knapsack algorithm and simulated annealing problem. Reference [2][3] define five-dimension Qos model, and put forward a service selection algorithm to meet global Qos of composite service based on integer programming theory. Considering the system's load and cost, Reference [4] defines utility function to choose their service, which enables end-to-end service composition to maximize the utility in response time. Annealing algorithm [5] considers service selection under global optimum, but solving efficiency will restrict the performance of dynamically binding service. This kind of method achieves the optimal composite service but it fails to sufficiently show users' partiality and features of local service. Furthermore, it is unfavorable to encourage service providers to optimize Qos to some extent.

B. Local Strategy

Local strategy usually grades candidate services based on multi-attribute decision model, and chooses the best local services in accordance with the score sort of candidate services in each activity. How to determine the evaluation criteria and the corresponding weight is the key of local strategy. Reference [6] presents assessment factors customized by domain experts according to domain experiences (including the Qos criteria and service business attributes), and relies on transcendental knowledge and machine learning algorithm to calculate weights. Reference [7] proposed a service selection algorithm based on dynamic preferences, which determine the weight according to maximum request effectiveness of each service configuration, combined with some statement-matching rules to overcome random effects. This kind of method cannot guarantee the balance of features of local service and users' preferences, what's more, it pays more attention to the theoretical study of service selection, whereas, insufficient in practical and popularity.

In view of the above questions, a multi-dimension Qos based local service selection model called MQLSSM is proposed firstly to provide important grounds to choose superior service and sift inferior service on the basis of the introduction of *fidelity* as additional attributes to enhance the reasonableness and fairness of Multi-dimension Qos model. Then, an ordinary utility function is used as a numerical scale of ordering local services, and single weight mode, subjective weight mode, objective weight mode, and subject-objective weight mode are constructed to not only determine the weight coefficient of each Qos properties, but also show users' partiality and the objectivity of service quality. At last, MQLSSM model is proved to be flexibility and effective based on semantic enable Web service composition platform called SEWSCP.

II. Local Service Selection Model

A. Multi-dimension Qos Model

Qos is an important component of non-functional attributes of service, which describes the utility and reliability of service and plays an important role in dynamic scheduling and composing of multi services. With the ever increasing number of functional similar Web services being made available on the Internet, there is a need to be able to distinguish them using a set of well-defined Quality of Service (Qos) criteria.

1) Qos criteria belonged to different domains may be different.

Reference [8] proposes a Qos model including some generic criteria (i.e. execution cost, execution time, reliability and availability). Reference [3] considers Qos model including availability, reliability, cost, throughput, accuracy and reputation, etc. Reference [10] defines five-dimension Qos model including execution time, reliability, availability and reputation. Reference [11] divides Qos criteria into generic criteria (including execution cost, execution time and reputation, etc.) and business-related criteria (including transaction, compensation rate and punitive rate).

2) Overall Qos of component service is focused on credibility, but trustworthiness of individual Qos criterion may not be neglected.

reputation [11,12,13] of a service is a popular criterion to measure total trustworthiness of a service, which mainly depends on users' experiences of using it. However, the reputation criterion, on one hand, is not sufficient because different users may have different opinions on the same Qos criterion, on the other hand, is not in favor of self-adjusting individual Qos criterion of a service. Consequently, we introduce *fidelity* criterion to evaluate trustworthiness of each Qos criterion of a service.

Definition 1 The fidelity $q_{fid}(s)$ of a service *s* is the average marks given by different requesters to the same Qos criterion. It is computed through the expression, $q_{fid}(s)=\{fid_1(s), fid_2(s),..., fid_n(s)\}$, where $fid_i(s)=(\sum_{j=1}^{N}R_{ji})/N$ is users' marks on the i^{th} Qos criterion of a service, R_{ji} is the i^{th} Qos criterion of a service s have been marked by the j^{th} time, *N* is the number of times the i^{th} Qos criterion of a service *s* have been marked, *n* is the number of Qos criteria of a service *s*.

In order to maintain the integration of Multi-dimension Qos model $Qos=\{q_1,q_2,...,q_n\}$, fidelity is used as an additional criterion. For example, a specific Qos model Qos is 4+1 (n=4) dimension vector as follows:

$$Qos=\{q_{cost}(s),q_{time}(s),q_{rel}(s),q_{av}(s)\}\cup\{q_{fid}(s)\} \quad (1)$$

In short, some key features of Multi-dimension Qos model are as follows: (1) It is open and extensible: Multi-dimension Qos model can be customized by users in accordance with their applications. New criteria can be added without fundamentally altering the service selection techniques built on top of it. (2) It is reasonable and fair. Multi-dimension Qos model introduces a *fidelity* criterion to enhance fair characteristics of each Qos criterion.

B. Normalization of Qos Matrix

In order to evaluate services, multi-dimension matrix of Qos criteria $A=[a_{ij}]_{m\times n}$ needs to be normalized. There are two purposes of normalization: one is to allow for a uniform measurement of service qualities independent of units; the other is to put all values a_{ij} in a range from 0 to 1. Two purposes are achieved by normalizing any element in matrix $A=[a_{ij}]_{m\times n}$ into an element of elative membership degree matrix $B=[b_{ij}]_{m\times n}$ using the following formulas:

Definition 2 $A=[a_{ij}]_{m\times n}$ represents the multi-dimension matrix of Qos criteria and their formulas, $a_{ij}=g(q_i,s_j)$ is a numerical value $s_j\in S$ at $q_i\in Qos$, here Qos model $Qos=\{q_1,q_2,...,q_n\}$ represents the set of Qos criteria, and $S=\{s_1,s_2,...,s_m\}$ represents the service set of a service community S providing the information of Qos criteria.

The fidelity $q_{fid}(s)$ of a service *s* is the average marks given by different requesters to the same Qos criterion. It is computed through the expression

(1) Benefit criteria

$$b_{ij} = \begin{cases} \dfrac{a_{ij} - a_j^{\min}}{a_j^{\max} - a_j^{\min}} & a_j^{\max} \neq a_j^{\min} \\ 1 & a_j^{\max} = a_j^{\min} \end{cases} \quad (2)$$

where $a_j^{\max} = \max_i a_{ij}$, $a_j^{\min} = \min_i a_{ij}$, i=1, 2, …, m; j=1, 2, ..,n.

(2) Cost criteria

$$b_{ij} = \begin{cases} \dfrac{a_j^{\max} - a_{ij}}{a_j^{\max} - a_j^{\min}} & a_j^{\max} \neq a_j^{\min} \\ 1 & a_j^{\max} = a_j^{\min} \end{cases} \quad (3)$$

C. Ordinary utility function

Ordinary utility function is defined as weak order between candidate services from the perspective of microeconomics, which is conducive to consuming services.

Definition 3 (Weak order relation) $S = \{s_1, s_2, ..., s_m\}$ is defined as the set of candidate services, S has weak order relation "$\rhd$":

(1) Connectivity: $\forall\ s_i, s_j \in S$, then S has $s_i \rhd s_j$ or $s_j \rhd s_i$.

(2) Transitivity: $\forall\ s_i, s_j, s_k \in S$, then S has $s_i \rhd s_k$ if S has $s_i \rhd s_j$ and $s_i \rhd s_k$.

(3) Chromaticity: $s_i \cong s_k$ if and only if $s_j \rhd s_i$ and $s_j \rhd s_i$.

Theorem 1 Let "$\rhd$" be the weak order relation of $S = \{s_1, s_2, ..., s_m\}$, then there exists an ordinary utility function f, $\forall\ s_i, s_j \in S$, we have

$$f(s_i) \geq f(s_j) \Leftrightarrow s_i \rhd s_j \quad (4)$$

Theorem 2 Let f be an order utility function, t be a strictly increasing function of $S = \{s_1, s_2, ..., s_m\}$, $\forall\ s_i, s_j \in S$, we have

$$t(f(s_i)) \geq t(f(s_j)) \Leftrightarrow s_i \rhd s_j \quad (5)$$

Theorem 3 Let f_1, f_2 be two order utility functions, then $f = f_1 + f_2$ is also an order utility function, $\forall\ s_i, s_j \in S$, we have

$$f(s_i) \geq f(s_j) \Leftrightarrow s_i \rhd s_j \quad (6)$$

Proof. By using Theorem 1, we obtain

$$\forall\ s_i, s_j \in S,\ f_1(s_i) \geq f_1(s_j) \Leftrightarrow s_i \rhd s_j \quad (7)$$

$$f_2(s_i) \geq f_2(s_j) \Leftrightarrow s_i \rhd s_j \quad (8)$$

Use additive principle of inequality, we have

$$f_1(s_i) + f_2(s_i) \geq f_1(s_j) + f_2(s_j) \Leftrightarrow s_i \rhd s_j \quad (9)$$

Therefore

$$f(s_i) \geq f(s_j) \Leftrightarrow s_i \rhd s_j \quad (10)$$

Definition 3 (Ordinary utility function) Let $S = \{s_1, s_2, ..., s_m\}$ be a service candidate set, if $f_1(q_1(s_i))$, $f_2(q_2(s_i))$,…, $f_n(q_n(s_i))$ are the ordinary utility functions of S, then composite function $f(S) = f(f_1(q_1(s_i)), f_2(q_2(s_i)), ..., f_n(q_n(s_i)))$ is an ordinary utility function.

D. Local service selection model

Ordinary utility function is used to grade the candidate services. Combined with multi-dimension Qos model, we can define local service selection model.

Definition 4 (Multi-dimension Qos based Local Service Selection Model) Let $S = \{s_1, s_2, ..., s_m\}$ be a set of candidate services similar functionality, $Qos = \{q_{\text{cost}}(s), q_{time}(s), q_{rel}(s), q_{av}(s)\} \cup \{q_{fid}(s)\}$ be multi-dimension Qos model, if $f_1(q_1(s_i))$, $f_2(q_2(s_i))$,…, $f_n(q_n(s_i))$ are the ordinary utility functions of S, then composite function $f(S)$ = $f(f_1(q_1(s_i)), f_2(q_2(s_i)), ..., f_n(q_n(s_i)))$ is an ordinary utility function and candidate services can be sorted by $f(S)$ value.

For simplicity, let the definition of j^{th} Qos criterion related ordinary function be $f_j(q_j(s_i)) = w_j q_j(s_i)$, we have

Definition 5 (Linear Multi-dimension Qos Based Local Service Model) $A = [a_{ij}]_{m \times n}$ represents the multi-dimension matrix of Qos criteria and their formulas, $a_{ij} = g(q_i, s_j)$ is a numerical value $s_j \in S$ at $q_i \in Qos$, here Qos model $Qos = \{q_1, q_2, ..., q_n\}$ represents the set of Qos criteria, and $S = \{s_1, s_2, ..., s_m\}$ represents the service set of a service community S providing the information of Qos criteria. criteria $A = [a_{ij}]_{m \times n}$ needs to be normalized as $B = [B_1, B_2, ..., B_m]$, if the ordinary function of the set of candidate service is $f(S) = \sum_{j=1}^{n} w_j q_j(s_i) = Bw$, then $s_i \rhd s_j$ if and only if $B_i w^* \geq B_j w^*$, where $B_i = (b_{i1}, b_{i2}, ..., b_{in})$, $w^* = (w_1^*, w_2^*, ..., w_n^*)', s_i, s_j \in sort(S)$, i, j=1, 2, …, m.

III. Decision Mode

According to the approaches to determining weights, the modes for selecting service chain are summarized as four types: (1) *subjective weight mode*, (2) *objective weight model*, (3) *subjective-objective weight mode.* Users can apply one of them to select appropriate service chains from a sorted set (abbreviated as $sort(S)$). In the followings, we will give the definitions of $sort(S)$ according to these four decision modes respectively.

A. Subjective Weight Mode

Suppose the weights are determined according to the relative preferences of users, then service broker selects services with optimal $w_j^* \in w = \{ \sum_{j=1}^{n} w_j = 1,\ w_j \geq 0$, j=1, 2, …, n}, denotes as:

Definition 6 Let w_j be a weight reflecting the relative importance of the values of criterion q_j, where w_j^* is determined by Weighted Least Square Method (Equation (11)) [14]. Let a user give his pairwise comparison matrix $D = [d_{ij}]_{n\times n}$ on the criteria set Qos according to his preference, with elements of matrix D satisfying Equation (13), where d_{kj} denotes the relative weight of the criterion q_k with respect to the criterion q_j, then $sort(s)$ is the sorted set of Web services in a descending ("$\rhd$") order, i.e., $s_i \rhd s_j$ if and only if $B_i w^* \geq B_j w^*$, where $B_i = (b_{i1}, b_{i2}, ..., b_{in})$, $w^* = (w_1^*, w_2^*, ..., w_n^*)'$, $s_i, s_j \in sort(S)$, i, j=1, 2, …, m.

$$\begin{cases} \min\ f_1 = \sum_{k=1}^{n} \sum_{j=1}^{n} (d_{kj} w_j - w_k)^2 \\ subject\quad to\quad \sum_{j=1}^{n} w_j = 1 \\ w_j \geq 0 \quad j = 1, 2, ..., n \end{cases} \tag{11}$$

$$d_{kj} > 0,\ d_{jk} = 1/d_{kj},\ d_{kk} = 1\ i, k=1, 2, ..., n \tag{12}$$

It is a special case of subjective weight model. Suppose the most criterion q_k ($w_k^* = 1$) is given by a user, then the service broker selects Web services from $sort(s)$, which is sorted in a descending ("$\rhd$") order, i.e., $s_i \rhd s_j$ if and only if $b_{ik} \geq b_{jk}$, $s_i, s_j \in sort(S)$, i, j =1, 2, …, m .

B. Objective Weight Mode

Suppose the weights are determined by solving mathematical models automatically without any users' preference, including the entropy method [15], and multiple objective programming, etc., then service broker selects services with optimal $w_j^* \in w = \{ \sum_{j=1}^{n} w_j = 1$, $w_j \geq 0$, j=1,2,…,n}, denotes as:

Definition 7 Let w_j be a weight reflecting the relative importance of the values of criterion q_j, where w_j^* can be obtained by solving model (13), where $b_j^* = \max\{b_{1j}, b_{2j}, …, b_{mj}\}$ is the 'ideal' value of the criterion q_j in decision matrix B, the objective function f_2 can be interpreted as minimization of the deviation between the 'ideal' value of alternatives and the ranking value of each alternative, then $sort(s)$ is the sorted set of Web services in a descending ("$\rhd$") order, i.e., $s_i \rhd s_j$ if and only if $B_i w^* \geq B_j w^*$, where $B_i = (b_{i1}, b_{i2}, ..., b_{in})$, $w^* = (w_1^*, w_2^*, ..., w_n^*)'$, $s_i, s_j \in sort(S)$, i, j=1, 2, …, m.

$$\begin{cases} \min\ f_2 = \sum_{i=1}^{m} \sum_{j=1}^{n} (b_j^* - b_{ij})^2 w_j^2 \\ subject\quad to\quad \sum_{j=1}^{n} w_j = 1 \\ w_j \geq 0 \quad j = 1, 2, ..., n \end{cases} \tag{13}$$

Either subjective weight mode or objective weight mode has its advantages and disadvantages. The weights determined by subjective weight mode reflect the subjective judgment of users, which makes the marks of alternatives of the MADM problem have more arbitrary factors. The objective weight mode determines weights through mathematical calculation, which neglects subjective judgment information of users. Since neither of two approaches is perfect, an integrated mode may be more desirable for the determination of criterion weights.

C. Subjective-objective Weight Mode

Let the weights be determined by both subjective consideration and objective impact, then service broker selects Web services with optimal $w_j^* \in w = \{ \sum_{j=1}^{n} w_j = 1,\ w_j \geq 0$, j=1, 2, …, n}, denotes as:

Definition 8 Let w_j be a weight reflecting the relative importance of the values of criterion q_j, where w_j^* can be obtained by solving Equation (14), then $sort(s)$ is the sorted set of Web services in a descending ("$\rhd$") order, i.e., $s_i \rhd s_j$ if and only if $B_i w^* \geq B_j w^*$, where

$B_i = (b_{i1}, b_{i2}, ..., b_{in})$, $w^* = (w_1^*, w_2^*, ..., w_n^*)'$, $s_i, s_j \in sort(S)$, *i*, *j*=1, 2, …, *m*.

$$\begin{cases} \min\ f_1 = \sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj}w_j - w_k)^2 \\ \min\ f_2 = \sum_{i=1}^{m}\sum_{j=1}^{n}(b_j^* - b_{ij})^2 w_j^2 \\ subject\ \ to\ \ \sum_{j=1}^{n} w_j = 1 \\ w_j \ge 0 \quad j = 1,2,...,n \end{cases} \tag{14}$$

In order to obtain $w_j^* \in w$ in Equation (14), a linear weighted summation method in multiple objective programming analyses is used to derive a solution to Equation (15)

$$\begin{cases} \min f_3 = \alpha\sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj}w_j - w_k)^2 + \beta\sum_{i=1}^{m}\sum_{j=1}^{n}(b_j^* - b_{ij})^2 w_j^2 \\ subject\ \ to\ \ \sum_{j=1}^{n} w_j = 1 \\ w_j \ge 0 \quad j = 1,2,...,n \end{cases} \tag{15}$$

where α , β denotes the relative importance of the *subjective weight* mode and the *objective weight* mode respectively, α , β has

$$\alpha + \beta = 1,\ 0 < \alpha, \beta < 1 \tag{16}$$

To solve Equation (15), ignore the nonnegative constraint ($w_j \ge 0$, *j*=1, 2,…, *n*) and set up the following function

$$L = \alpha\sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj}w_j - w_k)^2 + \beta\sum_{i=1}^{m}\sum_{j=1}^{n}(b_j^* - b_{ij})^2 w_j^2 + 2\lambda(\sum_{j=1}^{n} w_j - 1) \tag{17}$$

where λ is the Lagrange multiplier. Let $\frac{\partial L}{\partial w_h}$, *h*=1, 2, …, *n*., then

$$\alpha[\sum_{k=1}^{n}(d_{kh}w_h - w_k)d_{kh} - \sum_{j=1}^{n}(d_{hj}w_j - w_h)] \tag{18}$$

Together with the constraint $\sum_{j=1}^{n} w_j = 1$ in the model 11, the *n*+1 equations can written in a compact form

$$\begin{bmatrix} Z & e \\ e^T & 0 \end{bmatrix}\begin{bmatrix} w \\ \lambda \end{bmatrix} = \begin{bmatrix} O \\ 1 \end{bmatrix} \tag{19}$$

where $w = (w_1, w_2, ..., w_n)'$, $Z = [z_{ij}]_{n\times n}$, $e = (1, 1, ..., 1)'$, $O = (0, 0, ..., 0)'$. The elements in matrix Z are

$$z_{ij} = -\alpha(d_{ij} + d_{ji})\ i \ne j; i, j = 1,2,...,n$$

$$z_{ii} = \alpha(\sum_{k=1}^{n} d_{ki}^2 + n - 2) + \beta\sum_{k=1}^{m}(b_i^* - b_{ki})^2\ i = 1,2,...,n$$

$$\lambda = -\frac{1}{e'Z^{-1}e}$$

where $w*$ is the weight vector determined by the subjective-objective weight mode.

The theoretically obtained weights have practical meanings only if they have $w_j^* \in w = \{ \sum_{j=1}^{n} w_j = 1$, $w_j \ge 0$, j=1,2,…,*n*}. The problem is to prove w_j^* must satisfy the nonnegative constraints in Equation (14), i.e., $w_j \ge 0$, j=1, 2,…, *n*.

Theorem 4 Let $D = [d_{kj}]_{n\times n}$ be a pairwise comparison matrix. If for any *i* and *j*, there is at least one $b_j^* \ne b_{ij}$, then Z^{-1} exists and matrix Z is positive definite.

Proof. By the definition of objective function in Equation (15), we have

$$\begin{aligned} f_3 &= \alpha\sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj}w_j - w_k)^2 + \beta\sum_{i=1}^{m}\sum_{j=1}^{n}(b_j^* - b_{ij})^2 w_j^2 \\ &= \alpha\sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj}^2 w_j^2 - 2d_{kj}w_k w_j + w_k^2) + \beta\sum_{i=1}^{m}\sum_{j=1}^{n}(b_j^* - b_{ij})^2 w_j^2 \\ &= \alpha\sum_{j=1}^{n}(\sum_{k=1}^{n} d_{kj}^2 + n)w_j^2 + \beta\sum_{j=1}^{n}\sum_{i=1}^{m}(b_j^* - b_{ij})^2 w_j^2 - 2\alpha\sum_{k=1}^{n}\sum_{j=1}^{n} d_{kj}w_k w_j \\ &= \sum_{j=1}^{n}[\alpha(\sum_{k=1}^{n} d_{kj}^2 + n) + \beta\sum_{i=1}^{m}(b_j^* - b_{ij})^2]w_j^2 - \alpha\sum_{k=1}^{n}\sum_{j=1}^{n}(d_{kj} + d_{jk})w_k w_j \\ &= \sum_{j=1}^{n}[\alpha(\sum_{k=1}^{n} d_{kj}^2 + n - 2) + \beta\sum_{i=1}^{m}(b_j^* - b_{ij})^2]w_j^2 - \alpha\sum_{k=1}^{n}\sum_{j=1, j\ne k}^{n}(d_{kj} + d_{jk})w_k w_j \\ &= w'Zw \end{aligned}$$

Since any *i* and *j*, there exists at least one $b_j^{\max} \neq b_{ij}$, such that f_3 holds. The symmetry of matrix Z and the definition of positive define quadratic form indicate that Z is a positive definite matrix. By the property of positive definite matrix, Z is inversive.

IV. Validation of Local Service Selection Model

In this section, we present the simulation experiments to evaluate the proposed MQLSSM. We will give the experiment scenario and then some tests are done.

SEWSCP provides an environment for rapid composition of Web services. SELF-SERV [16] has a similar architecture to it. The processes of integrating multiple component services are: (1) Service Editor allows a composer to define composite services based on process model, and (2) Service Composer has to search Service Broker and select an appropriate Web service based on service functionalities and MQLSSM model from service communities, then (3) Service Composer achieves the goal of composite services based on selected services. Here, one scenario involves several Web services including: travel path selecting (WS_1), domestic flight booking (WS_2), international flight booking (WS_3), attractions search (WS_4), and car rental (WS_5). The travel scenario works as follows: (1) a traveler selects the travel path; (2) a domestic flight and an international flight are booked; (3) a search for attractions is performed in parallel with the flight, and (4) when the search and the bookings are done, a car rental is performed if the major attraction is far from the booked accommodation. A composite service is defined by drawing a DAG structure diagram (Figure 1), and Service Broker needs to find an appropriate component service in each service state along the execution path (Figure 2). We choose WS_4 as a sample to do the simulation experiments.

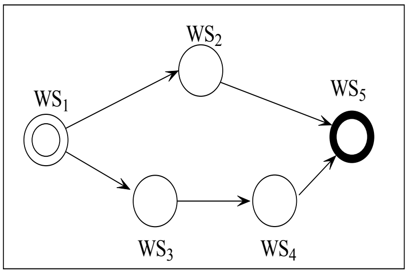

Figure 1. DAG Structure

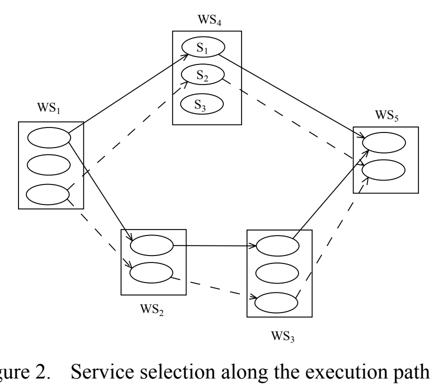

Figure 2. Service selection along the execution path

Suppose there are 10 Web services similar in functionality to WS_4, and service providers have provided Qos information namely execution cost ($q_{\cos t}(s_i)$), execution time ($q_{time}(s_i)$), reliability ($q_{rel}(s_i)$), availability ($q_{av}(s_i)$), and an additional criterion fidelity ($q_{fid}(s_i)$) which is given by monitor broker. Suppose the 10 Web services all satisfy the threshold points based on the users' requirements. Information of decision criteria is shown in Table 1.

B. Testing and Analyzing

Suppose 10 similar Web services in Table 1 are all satisfying the constraints on decision criteria (i.e. the threshold points) on decision criteria. The $q_{\cos t}(s_i)$, $q_{time}(s_i)$, $q_{rel}(s_i)$ and $q_{av}(s_i)$ in Table 2 respectively represent the result of single weight model that execution cost emphasizes, execution time emphasizes, reliability emphasizes, and availability emphasizes. The weight of the emphasized criterion is assigned to 1, and other weights are 0. If execution cost is emphasized, then the elements of $sort(S)$ have $s_3 \rhd s_1 \rhd s_7 \rhd s_{10} \rhd s_4 \rhd s_8 \rhd s_9 \rhd s_5 \rhd s_2 \rhd s_6$.

Suppose that a user gives his the pairwise comparison matrix D_1 , D_2 on the criteria (Equation (20)) respectively, the cases of Web services selected by three decision modes in MQLSSM are addressed as follows:

(1) In subjective weight mode (SWM), we can obtain the weights $w^* = (0.08, 0.48, 0.24, 0.2)'$ according to matrix D_1 and model 12, then Web services ordered by $s_2 \rhd s_9 \rhd s_{10} \rhd s_5 \rhd s_3 \rhd s_8 \rhd s_4 \rhd s_1 \rhd s_7 \rhd s_6$ are shaped in Table 2. If the pairwise comparison matrix D_2 is assigned, the weights w^* are changed as (0.13, 0.15, 0.33, 0.39) and Web services are sorted, i.e., $s_2 \rhd s_5 \rhd s_3 \rhd s_8 \rhd s_9 \rhd s_7 \rhd s_1 \rhd s_4 \rhd s_{10} \rhd s_6$. We can learn that weights obtained by different comparison matrixes result in different marks.

(2) In objective weight mode (OWM), weights $w^* = (0.15, 0.35, 0.31, 0.19)'$ are assigned according to model 14 and Web services are sorted, i.e., $s_2 \rhd s_3 \rhd s_5 \rhd s_{10} \rhd s_9 \rhd s_8 \rhd s_4 \rhd s_1 \rhd s_7 \rhd s_6$. The result is independent of comparison matrixes.

(3) In subjective-objective weight mode (SOWM), $\alpha = 0.3$, $\beta = 0.7$ is adopted to reflect the relative importance of the subjective weight mode and objective weight mode, respectively. We can obtain the weights $w^* = (0.10, 0.42, 0.27, 0.21)'$, and Web services are sorted, i.e., $s_2 \rhd s_9 \rhd s_5 \rhd s_{10} \rhd s_8 \rhd s_3 \rhd s_4 \rhd s_1 \rhd s_7 \rhd s_6$. When comparison matrix is changed as D_2 , we can

obtain the weights $w^* = (0.13, 0.24, 0.34, 0.29)'$ and

$s_2 \rhd s_5 \rhd s_9 \rhd s_8 \rhd s_3 \rhd s_{10} \rhd s_7 \rhd s_4 \rhd s_1 \rhd s_6$.

$$D_1 = \begin{bmatrix} 1 & 1/3 & 1/4 & 1/4 \\ 3 & 1 & 2 & 3 \\ 4 & 1/2 & 1 & 4/5 \\ 4 & 1/3 & 5/4 & 1 \end{bmatrix}, D_2 = \begin{bmatrix} 1 & 2 & 1/3 & 1/3 \\ 2 & 1 & 1/2 & 1/2 \\ 3 & 2 & 1 & 3/4 \\ 3 & 2 & 4/3 & 1 \end{bmatrix} \quad (20)$$

TABLE I. VALUTES OF 10 SIMILAR WEB SERVICES

	$q_{cost}(s_i)$	$q_{time}(s_i)$	$q_{rel}(s_i)$	$q_{av}(s_i)$	q_{fid}
s1	0.14	175	0.90	0.92	(0.99,0.94,0.90,0.95)
s2	0.20	150	0.95	0.98	(0.95,0.89,0.93,0.92)
s3	0.10	158	0.92	0.91	(0.95,0.85,0.90,0.91)
s4	0.15	152	0.85	0.95	(0.88,0.90,0.90,0.88)
s5	0.18	165	0.92	0.98	(0.85,0.90,0.95,0.95)
s6	0.20	175	0.90	0.88	(0.99,0.94,0.92,0.90)
s7	0.15	190	0.94	0.92	(0.95,0.95,0.92,0.95)
s8	0.16	155	0.88	0.96	(0.95,0.88,0.95,0.90)
s9	0.18	150	0.92	0.92	(0.92,0.92,0.90,0.95)
s10	0.15	145	0.92	0.88	(0.92,0.90,0.92,0.90)

TABLE II. MARKS FOR 10 SIMILAR WEB SERVICES

	$q_{cost}(s_i)$	$q_{time}(s_i)$	$q_{rel}(s_i)$	$q_{av}(s_i)$	***SWM***	***OWM***	***SOWM***
s1	0.59	0.31	0.45	0.38	0.3819	0.4105	0.3388
s2	0	0.79	0.93	0.92	0.7869	0.7400	0.7766
s3	0.95	0.60	0.63	0.27	0.5719	0.6012	0.4908
s4	0.44	0.76	0	0.62	0.5232	0.4490	0.4530
s5	0.17	0.50	0.67	0.95	0.6032	0.5872	0.5908
s6	0	0.31	0.46	0	0.2608	0.2523	0.2558
s7	0.48	0	0.83	0.38	0.3127	0.4001	0.3081
s8	0.38	0.68	0.29	0.72	0.5713	0.5217	0.5194
s9	0.18	0.82	0.63	0.38	0.6345	0.5813	0.5952
s10	0.46	0.90	0.64	0	0.6234	0.5836	0.5565

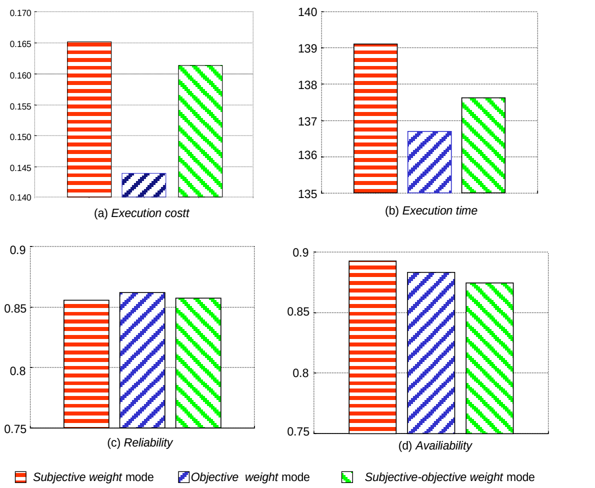

Figure 3. Criteria Comparisons among Web services selected by using different decision modes

Based on the information above, we compare different decision modes in different criteria by using the former 4 candidate services, which is shown in Figure 3. (1) Subjective weight mode achieves maximal value in execution cost, execution time and availability, while its reliability value is minimum. (2) Objective weight mode is generally optimal in execution cost, execution time and reliability criteria. (3) Subjective-objective weight mode exhibits robust characteristic. All values of different criteria are medial with reflecting subjective judgment and objective impact.

V. RELATED WORK

The Qos-based selection of Web services is an active research topic in the dynamic composition of Web services.

Al-Ali et al. [17] introduce the concept of application Qos (AQos) and describe a framework for adding Qos considerations in Grid Services for selection and management of individual services within the Grid. They differ primarily from our approach in that our aim is to select services in open environment.

Sravanthi et al. [18] propose a new Qos metric to help select Web services. They introduce the notion of Verity, which measures the consistency of compliance over time. Yutu et al. [4] propose an extensible and fair Qos model including common and business related criteria, such as execution price, execution duration, and transaction etc. The major differences with our work are that we introduce fidelity evaluate trustworthiness of each Qos criterion of a service.

Liangzhao Zeng et al. [17] discuss a global planning approach for selecting composed services. They propose a simple Qos model using the examples of price, availability, reliability, and reputation. They apply linear programming for solving the optimization Qos matrix formed by all of the possible execution plans that result in the plan with the maximum Qos values. Tao Yu et al. [4]

design the service selection algorithms to meet the end-to-end Qos constraints. Their works are not focused on the trustworthiness of Qos criteria of a service. Although the global quality constraints can be satisfied, service selection may not be locally optimized. Therefore, good component service often fails to exert its potential and embody its personality. Our method can raise the efficiency and utility of Web services reservation by sorting them. In addition, it can help to improve both the total Qos of composite service and that of single Web service based on users' preference and objective impact.

VI. CONCLUSION

Dynamic selection of component services is an important issue in Web services composition. In this paper, we have presented a local service selection model MQLSSM model for evaluating Web Services. It can help to select component services based on users' preference and objective impact. It lays down a sound theoretical basis for our further research of dynamic Web service composition. We have also conducted experiments to validate the availability of MQLSSM model.

ACKNOWLEDGMENT

This research project was supported by Natural Science Foundation of He'nan Educational Committee under the grant No. 2009B520024.

REFERENCES

[1] J. Cardoso, and A. Sheth, "Quality of Service and Semantic Composition Workflows," *Ph.D. Dissertation*, Department of Computer Science, University of Georgia, 2002.

[2] T. Yu, Y. Zhang and K.J. Lin, "Efficient Algorithms for Web Services Selection with End-to-End QoS Constraints," *ACM Transaction on Web*, May 2007.

[3] L. Zeng, B. Benatallah, M. Dumas, J. Kalagnanam, and Q. Z. Sheng, "Quality Driven Web Services Composition," In *Proc. of 12th International Conference on World Wide Web (WWW-03)*, Budapest, Hungary, 2003.

[4] T. Yu, K.J. Lin, "Service Selection Algorithms for Web Services with End-to-end Qos Constraints," *Journal of Information Systems and e-business management*, volume 3, Number 2, July 2005.

[5] H. Jin, H. Chen, Z. Lu, and X. Ning, "Q-SAC: Towards Qos Optimized Service Automatic Composition," In *5th IEEE/ACM International Symposium on Cluster, Computer and the Grid (CCGRID)*, 2005.

[6] W. Yang, "Research On Web Service Composition Technology," *Ph.D. Dissertation*, Department of Computer Science, Tsinghua University, 2005.

[7] S. Lamparter, A. Ankolekar, R. Studer, S. Grimm, "Preference-based Selection of Highly Configurable Web Services," In *Proc. of the 16th Int. World Wide Web Conference (WWW'07)*, Banff, Canada, May 2007.

[8] B. Benatallah and F. Casati, editors, "Distributed and Parallel Database," *Special issue on Web services*, 2002.

[9] L. Zeng, B. Benatallah, M. Dumas, J. Kalagnanam, and Q. Z. Sheng, "Quality Driven Web Services Composition," In *Proc. of 12th International Conference on World Wide Web (WWW-03)*, Budapest, Hungary, 2003.

[10] A. Sheth, J. Cardoso, J. Miller, and K. Kochut, "Qos for Service-oriented Middleware," In *Proc. of the 6th World Multiconference on Systemics, Cybernetics and Informations (SCI02)*, Orlndo, FL, 2002.

[11] Y. Liu, A. H.H. Ngu, L. Zeng, "Qos Computation and Policing in Dynamic Web Service Selection," In *Proc. of 13th International Conference on World Wide Web (WWW-04)*, New York, USA, 2004.

[12] E. Michael Maximillien, M. P. Singh, "Reputation and endorsement for Web Services," *ACM SIGecom Exchenges*, 3(1), 24-31, 2002.

[13] E. Michael Maximillien, M. P. Singh, "Toward Autonomic Web Services Trust and Selection," In *Proc. of 2nd International Conference on Service Oriented Computing (ICSOC2004)*, New York, Nov. 2004.

[14] A.T.W. Chu, R.E. Kalaba, and K. Spingarn, "A Comparison of Two Methods for Determining the Weights of Belonging to Fuzzy Sets," *Journal of Optimization Theory and Application*, 27, 531-538, 1979.

[15] C. L. Hwang, and K. Yoon, "Multiple Attribute Decision Making: Methods and Applications," Springer-Verlag, Berlin Heidelberg, New York, 1981.

[16] Q. Z. Sheng, B. Benatallah, M. Dumas, and EO-Y. Mak, "SELF-SERV: A Platform for Rapid Composition of Web Services in a Peer-to-Peer Environment," In *Proc. of the 28th VLDB Conference*, Hong Kong, China 2002.

[17] R. J. Al-Ali, O. F. Rana, D. W. Walker, S. Jha, and S. Sohail, "G-QoSM: Grid Service Discovery Using Qos Properties," *Computing and Informatics Journal*, 21(4), 363-382, 2002.

[18] S. Kalepu, S. Krishnaswamy, S. W. Loke, "Verity: A Qos Metric for Selecting Web Services and Providers," In *Proc. of the First Web Services Quality Workshop*, Rome, Italy, 2003.

Liurong Hong was born in Anhui, China, in 1969. He received his Ph.D. in China University of Mining & technology, Xuzhuo, in 2005, and the bachelor degree in Department of Engineering Survey from Wuhan University of Geodesy and Geomatics, Wuhan, in 1991 and the master degree in China University of Mining & technology, Beijing, in 1999. His research area is artificial intelligence, distributed systems integration, and image processing.

Jianqiang Hu was born in Jinhua, China, in 1971. He received his Ph.D. degree in computer software and theory from National University of Defense Technology, China, in 2005, and his M.Sc. and B.Sc. degrees in computational mathematics from Fuzhou University and Zhejiang Normal University, China, in 1998 and 1995, respectively. He is currently a post-doc research fellow in Knowledge Engineering Group at the Department of Computer Science and Technology, Tsinghua University, China. His current research interests include distributed systems integration, service composition, semantic-based requirements engineering.