QoS-aware SaaS Services Selection with Interval Numbers for Group User

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***Abstract*—The integration of SaaS service for group user in cloud is challenging, notably because the service's QoS and member's personalization QoS preference in group are uncertain. This is a timely and importance problem with the advent of the SaaS model of service delivery. Therefore, before the SaaS service been utilized, the service alternatives must be ranked for group user based on services' QoS and QoS preference expressed by interval numbers. So, QoS-aware SaaS services selection with interval numbers for group user (QSSSIN_GU) is proposed, in order to identify the pros and cons of alternatives. This approach can obtain the group optimal service when the member's QoS preference in group is personalized and the QoS of service alternatives expressed by interval numbers. Finally, four experiments are given to demonstrate the benefits and effectiveness of QoS-aware SaaS services selection with interval numbers for group user. That is a feasible and supplementary manner in selecting the SaaS services for group user with interval numbers.**

***Index Terms*—software as a service (SaaS), cloud service, service selection, quality of service (QoS), technique for order preference by similarity to an ideal solution (TOPSIS), group user**

I. Introduction

The Software as a Service (SaaS) model - a service model in cloud, where software is delivered on-demand and priced on-use, has been made possible by the widespread adoption of fast Internet access, combined with the widespread acceptance of SOA-based solutions. In order to reduce the cost of ownership and alleviate the burden of software installation and maintenance, enterprises have started to outsource some of their software infrastructure and development projects to SaaS vendors, so the number of SaaS offerings has expanded dramatically [1].

The integration of SaaS is still challenging because the QoS of the external service and user's QoS preference must be considered. Nevertheless, the service QoS depends on the behavior of the provider and QoS preference depends on user's habit, they have a strong uncertainty. Since the behavior of service providers is unknown until the service is rendered, the risk of bad behavior cannot be excluded and can have adverse effects on the project outcomes. Under normal circumstances, the attribute value of service QoS show randomness. It is reasonable that these attributes are expressed by interval numbers. For users, it is difficult to describe imprecisely the QoS preference. But, users usually can describe the range of QoS preference. In addition, the members' QoS preferences in group may be different (named personalized QoS preference). For example, the QoS preference of member A is cost=[150,165], availability=[0.8,0.9], reliability=[0.5,0.6] and reputation=[0.9,0.95] and member B is cost=[100,110], availability=[0.7,0.8], reliability=[0.6,0.7] and reputation=[0.7,0.8].

To solve above difficulties, this paper presents a QoS-aware SaaS services selection with interval numbers for group user (QSSSIN_GU). QSSSIN_GU considered the members' personalized QoS preference in group and the service QoS expressed by interval numbers, which can gain group QoS optimal service. QSSSIN_GU not only enhance user satisfaction but also reduce the risk of service integration.

The remainder of this paper is organized as follows： Section II summarizes the related work． Section III introduces the notion of interval numbers and the method of TOPSIS. Section IV introduces service selection method-QSSSIN_GU. A series of experiments is proposed in Section V to show the effectiveness and benefits of QSSSIN_GU. Finally, Section VI concludes the paper and outlines the future work.

II. Related Work

Service selection and rating is a research topic that emerged recently with the advent of SOA and SaaS. Lots of works in this area have addressed different facets of the topic, such as the model of QoS, service selection algorithms, service framework [27], service discovery [28] etc.

For example, hybrid QoS ontology was proposed in Ref. [3, 4], where Ref. [3, 4] supports real numbers, interval numbers and triangular fuzzy numbers, and Ref. [26] supports real numbers and interval numbers.

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Intuitionistic fuzzy set has been proven to be highly useful to deal with uncertainty and vagueness, which applied to QoS description in Ref. [5]. A new hybrid QoS model supporting real numbers, interval numbers, triangular fuzzy numbers and intuitionistic fuzzy set was proposed by Longchang Zhang in Ref. [6]. A more comprehensive and detailed QoS ontology (WS-QoSOnto) was presented by Tran VX et al. in Ref. [7] which involves QoS role, QoS description, QoS level and QoS group concepts, but did not give specific definition of QoS attributes and aggregation methods. A QoS model based on random numbers was presented in Ref. [8].

Within our knowledge, the existing service selection algorithms can be divided into three categories. Firstly, QoS computation. The computation of QoS during dynamic selection of services (based on the simple weighted average) was considered in Ref. [9], and an open, fair, dynamic QoS computation framework was tried to build to evaluate the OoS of a vast number of web service. Secondly, linear Programming. The sevice selection algorithm was proposed based on multiple attributes decision making for supporting heterogeneous QoS model in Ref. [3, 4]. A QoS-driven middleware platform and a service selection algorithm based on simple additive weighting method was proposed for the purpose of service composition in Ref. [10]. A new decision model under vague information and extended Max-Min-Max composition of intuitionistic fuzzy sets (IFS) for selection of web services was proposed by Ping Wang in Ref. [5]. Based on TOPSIS, a service selection method to supporting triangular fuzzy numbers was proposed by Ping Wang in Ref. [2]. Dynamic Web service selection methods supporting hybrid QoS were proposed by Longchang Zhang in Ref. [6, 19, 23, 24, and 25]. Tran VX et al. [7] applied AHP algorithm for getting the optimal composition plan. Yi Sun et al. [11] applied AHP and BG methods to get the optimal composition plan. One reliable Web service composition algorithm was designed based on markov decision process in Ref. [8]. Anselmi et al. [12] provided a Mixed Integer Linear Programming (MILP)-based on formulation of the selection problem and consider a greedy heuristic to find near-optimal solutions. Service selection problem was formalized as a mixed integer linear programming problem, loops peeling was adopted in the optimization, and constraints posed by stateful Web services were considered in Ref.[13]. Thirdly, heuristics. Considering the complexity of Integer Linear Programming optimization, Yu et al. [14] proposed heuristics to find near-optimal solutions in polynomial time. The genetic algorithm was applied in the Web service composition in Ref. [15, 16]. The particle swarm optimization was applied in the Web service composition in Ref. [17]. Li F et al. [18] proposed a distributed service composition algorithms that can support multiple QoS registry centers.

However, the above methods were all based on single-user or multi-users with the same QoS reference. Obviously, they ignored the service selection for multi-users (group user) with personalized QoS reference and the expression habits of users. Compared with above methods, our method has the following advantages: 1) QSSSIN_GU can obtain group optimal service; 2) QSSSIN_GU can support the QoS and users QoS preferences expressed by interval numbers; 3) QSSSIN_GU is a general algorithm for single-user and group user.

III. PRELIMINARIES

A. Interval Numbers (INs)

In this section, we review some arithmetic operations on interval numbers for the purpose of representing the proposed algorithm in Section IV [22].

Definition 1 Given the intervals $X=[x^l,x^u]$ and $Y=[y^l,y^u]$, the application of the basic operators upon x and y as follows.

Addition: $X+Y=\left(x^l+y^l,x^u+y^u\right)$

Subtraction: $X-Y=\left[x^l-y^u,x^u-y^l\right]$

Multiplication: $X*Y=[\min\{x^l y^l,x^l y^u,x^u y^l,x^u y^u\}$ $\max\{x^l y^l,x^l y^u,x^u y^l,x^u y^u\}]$

Division: $X\div Y=X*\frac{1}{Y}$, where $\frac{1}{Y}=\left[\frac{1}{y^u},\frac{1}{y^l}\right]$, if $y^l\succ 0$ or $y^u\prec 0$.

B. TOPSIS Method

TOPSIS (technique for order preference by similarity to an ideal solution) method is presented in Ref. [20, 21], which is a multiple attributes method to identify solutions from a finite set of alternatives. The basic principle is that the chosen alternative should have the shortest distance from the positive ideal solution and the farthest distance from the negative ideal solution. The procedure of TOPSIS can be expressed in a series of steps (let $\left[x_{ij}\right]_{m\times n}$ be matrix of alternatives):

(1)Calculate the normalized decision matrix. The normalized value n_{ij} is calculated as

$$n_{ij}=x_{ij}\Big/\sum_{i=1}^{m}x_{ij}^2 \text{ for } i=1,\cdots,m \text{ and } j=1,\cdots,n \quad (1)$$

(2)Calculate the weighted normalized decision matrix. The weighted normalized value v_{ij} is calculated as $v_{ij}=\omega_i n_{ij}$ for $i=1,\cdots,m$ and $j=1,\cdots,n$ where ω_i is the weight of the ith attribute or criterion, and $\sum_{i=1}^{n}\omega_i=1$.

(3)Determine the positive ideal and negative ideal solution.

$$\begin{aligned}A^+&=\left\{\left(v_1^+,v_2^+,\cdots,v_n^+\right)\right\}=\left\{\left(\max v_{ij}\,\middle|\,i\in O\right),\left(\min v_{ij}\,\middle|\,i\in I\right)\right\}\\A^-&=\left\{\left(v_1^-,v_2^-,\cdots,v_n^-\right)\right\}=\left\{\left(\min v_{ij}\,\middle|\,i\in O\right),\left(\max v_{ij}\,\middle|\,i\in I\right)\right\}\end{aligned} \quad (2)$$

where O is associated with benefit attributes, and I is associated with cost attributes.

(4)Calculate the separation measures, using the n-dimensional Euclidean distance. The separation of each alternative from the ideal solution is given as

$$d_j^+ = \left\{ \sum_{i=1}^{n} \left(v_{ij} - v_i^+ \right)^2 \right\}^{\frac{1}{2}}, j = 1, \cdots, m \tag{3}$$

Similarly, the separation from the negative-ideal solution is given as

$$d_j^- = \left\{ \sum_{i=1}^{n} \left(v_{ij} - v_i^- \right)^2 \right\}^{\frac{1}{2}}, j = 1, \cdots, m \tag{4}$$

(5)Calculate the relative closeness to the ideal solution. The relative closeness of the alternative A_j with respect to A^+ is defined as $R_j = d_j^- \Big/ \left(d_j^+ + d_j^- \right), j = 1, \cdots, m$ .Since $d_j^- \geq 0$ and $d_j^+ \geq 0$, then clearly $R_j \in [0,1]$.

For ranking alternatives using the relative closeness, we can rank them in decreasing order. The first one is the best, which has the “shortest distance”' from the ideal solution and the “farthest distance” from the negative-ideal solution.

C. Quality of Service for SaaS

Here are the definitions of five QoS attributes and metrical methods. Attributes can be dynamically added without changing the service selection algorithm.

Cost is the client has to pay when invoking a service operation, which may be changed. So it is expressed by interval numbers.

Availability is the probability for a service to be available from user feedback, was a ratio of the accessible times and the total times of requests within a unit of time. Availability will fluctuate within a certain range due to various complexities and uncertainties. It is expressed by interval numbers.

Reliability is the percentage of successfully completed requests of a service within a unit of time, which may be changed and expressed by interval numbers.

Reputation measures the trust of a service, which may be changed and expressed by interval numbers.

In above 4 QoS attributes, cost is cost criteria and others are benefit criteria. In addition, upper and lower limits of interval numbers are non-negative real numbers.

IV. The Proposed Method for Ranking SaaS Services (QSSSIN_GU)

A. Problem Formulation

Consider the problem of ranking service alternatives $a_i \left(i = 1, \cdots, m \right)$, there are n QoS attributes in a_i, say $p_j \left(j = 1, \cdots, n \right)$ expressed by interval numbers. There are q members ($c_k \left(k = 1, \cdots, q \right)$) in group; they share the same service. Member has to give his QoS preference ω_{kj} expressed by interval numbers, which represents the importance of service a_i with respect to attributes p_j for member c_k. The leader of group gives $w_k \left(k = 1, \cdots, q \right)$ expressed by interval numbers, which represents the importance of member c_k in group. The performance rating matrix $\tilde{X}$ for service alternatives is shown as Eq. (5), where $\tilde{x}_{ij}$ represents the rating of service a_i with respect to attribute p_j.

$$\tilde{X} = \left[\tilde{x}_{ij} \right]_{m \times n} = \begin{array}{c|cccc} & p_1 & p_2 & \cdots & p_n \\ \hline a_1 & \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ a_2 & \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_3 & \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{array} \tag{5}$$

B. Evaluating Synthetic Performances

Step 1: Normalize the decision matrix.

The raw data are normalized to eliminate anomalies with different measurement units and scales in several MADM problems. However, the purpose of linear scales transform normalization function used in this study is to preserve the property that the ranges of normalized interval numbers to be included in [0, 1]. If $\tilde{R}$ denotes the normalized decision matrix from $\tilde{X}$, then $\tilde{R} = \left[\tilde{r}_{ij} \right]_{m \times n}$, where the normalized values are calculated as follows:

$$\begin{cases} \tilde{r}_{ij}^l = \tilde{x}_{ij}^l \Big/ \sqrt{\sum_{i=1}^{m} \left[\left(\tilde{x}_{ij}^l \right)^2 + \left(\tilde{x}_{ij}^u \right)^2 \right]} \\ \tilde{r}_{ij}^u = \tilde{x}_{ij}^u \Big/ \sqrt{\sum_{i=1}^{m} \left[\left(\tilde{x}_{ij}^l \right)^2 + \left(\tilde{x}_{ij}^u \right)^2 \right]} \end{cases} \tag{6}$$

Step 2: Calculate weighted normalized decision matrix.

The normalization method above is to preserve the attribute that the ranges of normalized interval numbers belong to [0, 1].

If the QoS preferences of any two members in group are not completely consistent, then the performance rating matrix $\bar{R}\left(c_k \right) = \left[\bar{r}_{ij}\left(c_k \right) \right]_{m \times n}$ is calculated for member c_k is shown as Eq. (7).

$$\bar{R}\left(c_k \right) = \begin{array}{c|cccc} & p_1 & p_2 & \cdots & p_n \\ \hline a_1 & \omega_{k1} * \tilde{r}_{11} & \omega_{k2} * \tilde{r}_{12} & \cdots & \omega_{kn} * \tilde{r}_{1n} \\ a_2 & \omega_{k1} * \tilde{r}_{21} & \omega_{k2} * \tilde{r}_{22} & \cdots & \omega_{kn} * \tilde{r}_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_m & \omega_{k1} * \tilde{r}_{m1} & \omega_{k2} * \tilde{r}_{m2} & \cdots & \omega_{kn} * \tilde{r}_{mn} \end{array} \tag{7}$$

The performance rating matrix $\bar{R}\left(c_k \right)$ considered the importance of member in group is calculated as Eq. (8).

$$\bar{R}\left(c_k \right) = \begin{array}{c|cccc} & p_1 & p_2 & \cdots & p_n \\ \hline a_1 & w_k * \left(\omega_{k1} * \tilde{r}_{11} \right) & w_k * \left(\omega_{k2} * \tilde{r}_{12} \right) & \cdots & w_k * \left(\omega_{kn} * \tilde{r}_{1n} \right) \\ a_2 & w_k * \left(\omega_{k1} * \tilde{r}_{21} \right) & w_k * \left(\omega_{k2} * \tilde{r}_{22} \right) & \cdots & w_k * \left(\omega_{kn} * \tilde{r}_{2n} \right) \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ a_m & w_k * \left(\omega_{k1} * \tilde{r}_{m1} \right) & w_k * \left(\omega_{k2} * \tilde{r}_{m2} \right) & \cdots & w_k * \left(\omega_{kn} * \tilde{r}_{mn} \right) \end{array} \tag{8}$$

Step 3: Aggregate the decision matrix of members.

The aggregated decision matrix $\overline{R}=\left[\overline{r}_{ij}\right]_{m\times n}$ of members is calculated as Eq. (9).

$$\overline{R}=\begin{array}{c|ccc} & p_1 & \cdots & p_n \\ \hline a_1 & \overline{r}_{11}(c_1)+\cdots+\overline{r}_{11}(c_n) & \cdots & \overline{r}_{1n}(c_1)+\cdots+\overline{r}_{1n}(c_n) \\ a_2 & \overline{r}_{21}(c_1)+\cdots+\overline{r}_{21}(c_n) & \cdots & \overline{r}_{2n}(c_1)+\cdots+\overline{r}_{2n}(c_n) \\ \vdots & \vdots & \vdots & \vdots \\ a_m & \overline{r}_{m1}(c_1)+\cdots+\overline{r}_{m1}(c_n) & \cdots & \overline{r}_{mn}(c_1)+\cdots+\overline{r}_{mn}(c_n) \end{array} \quad (9)$$

Step 4: Determine the positive ideal solution and the negative ideal solution.

Because $\overline{r}_{ij}$ is included in the interval [0, 1], the positive ideal reference point (PIRP) denoted by A^{+} and negative ideal reference point (NIRP) denoted by A^{-} can be defined as Eq.(10).

$$\begin{cases} A^{+}=\left(\tilde{v}_1^{+},\tilde{v}_2^{+},\ldots,\tilde{v}_j^{+}\right) \\ A^{-}=\left(\tilde{v}_1^{-},\tilde{v}_2^{-},\ldots,\tilde{v}_j^{-}\right) \end{cases}, j=1,2,\ldots,n \quad (10),$$

where $\begin{cases} v_j^{+}=[1,1],\ j\in B \\ v_j^{+}=[0,0],\ j\in C \end{cases}$ and $\begin{cases} v_j^{-}=[0,0],\ j\in B \\ v_j^{-}=[1,1],\ j\in C \end{cases}$.

Step 5: Calculate the distances of each initial alternative to PIRP and NIRP.

The distance of alternative from positive ideal reference point and negative ideal reference point are defined by square distance using the normalized Euclidean distance:

$$\begin{cases} d_i^{+}=\sqrt{\sum_{j=1}^{n}\left(\left(\overline{r}_{ij}^{L}-v_j^{+L}\right)^2+\left(\overline{r}_{ij}^{U}-v_j^{+U}\right)^2\right)\Big/2n} \\ d_i^{-}=\sqrt{\sum_{j=1}^{n}\left(\left(\overline{r}_{ij}^{L}-v_j^{-L}\right)^2+\left(\overline{r}_{ij}^{U}-v_j^{-U}\right)^2\right)\Big/2n} \end{cases} \quad (11),$$

where d_i^{+} represents the distance of alternative a_i from PIRP and d_i^{-} is the distance of alternative a_i from NIRP.

Step 6: Obtain the closeness coefficient of the alternatives.

Calculate the closeness coefficient (CC_i) of each alternative as follow:

$$CC_i=\frac{d_i^{-}}{d_i^{+}+d_i^{-}}, i=1,2,\ldots,m \quad (12)$$

Since $d_i^{-}\geq 0$ and $d_i^{+}\geq 0$, then clearly $CC_i\in[0,1]$. An alternative with CC_i approaching 1 indicates that the alternative is close to the positive ideal reference point and far from the negative ideal reference point. The alternative in closeness coefficient matrix with the highest CC_i value will be the best choice.

V. Experimential Evaluation

A. An Illustrative Example

There are four service alternatives for travel agents $a_i(i=1,2,3,4)$, where alternatives will be evaluated across four QoS attributes with regard to: (1) cost (p_1); (2) availability (p_2); (3) reliability (p_3); (4) reputation (p_4), where p_1 is a cost attribute and p_2 , p_3 and p_4 are benefit attributes. The QoS values of four alternatives collected by QoS monitor module (shown in **Table 1**). There are three members $c_k(k=1,2,3)$ in group, the QoS preferences $\omega=(\omega_1,\omega_2,\omega_3)$ are shown in **Table 2**. The group weight is ([0.15, 0.20], [0.3, 0.35], [0.45, 0.55]) for (c_1,c_2,c_3).

TABLE 1
THE QOS VALUE OF SERVICE ALTERNATIVES

	p_1	p_2	p_3	p_4
a_1	[30,35]	[0.93,0.95]	[0.97,0.99]	[0.97,1.0]
a_2	[35,40]	[0.96,0.98]	[0.98,1.0]	[0.98,1.0]
a_3	[50,55]	[0.92,0.95]	[0.95,0.97]	[0.99,1.0]
a_4	[45,50]	[0.91,0.93]	[0.94,0.96]	[0.95,0.97]

TABLE 2
THE QOS PREFERENCES OF MEMBERS

	p_1	p_2	p_3	p_4
ω_1	[0.35,0.45]	[0.25,0.35]	[0.15,0.25]	[0.05,0.15]
ω_2	[0.15,0.25]	[0.05,0.15]	[0.25,0.35]	[0.35,0.45]
ω_3	[0.05,0.15]	[0.15,0.25]	[0.35,0.45]	[0.25,0.35]

The proposed method is applied to solve this problem according to the following six steps:

Step 1: Normalize the decision matrix using Eq. (6) shown in **Table3**.

TABLE 3
THE NORMALIZED DECISION MATRIX

	p_1	p_2	p_3	p_4
a_1	[0.2449, 0.2858]	[0.3492, 0.3567]	[0.3535, 0.3608]	[0.349, 0.3598]
a_2	[0.2858, 0.3266]	[0.3605, 0.368]	[0.3571, 0.3644]	[0.3526, 0.3598]
a_3	[0.4082, 0.4491]	[0.3455, 0.3567]	[0.3462, 0.3535]	[0.3562, 0.3598]
a_4	[0.3674, 0.4082]	[0.3417, 0.3492]	[0.3426, 0.3498]	[0.3418, 0.349]

Step 2: Calculate weighted normalized decision matrix using Eq. (7) and Eq. (8) shown in **Table4**.

TABLE 4
THE DECISION MATRIX FOR MEMBERS

	p_1	p_2	p_3	p_4
member c_1				
a_1	[0.0129, 0.0257]	[0.0131, 0.025]	[0.0080, 0.018]	[0.0026, 0.0108]
a_2	[0.015, 0.0294]	[0.0135, 0.0258]	[0.0080, 0.0182]	[0.0026, 0.0108]
a_3	[0.0214, 0.0404]	[0.013, 0.025]	[0.0078, 0.0177]	[0.0027, 0.0108]
a_4	[0.0193, 0.0367]	[0.0128, 0.0244]	[0.0077, 0.0175]	[0.0026, 0.0105]
member c_2				

a_1	[0.011, 0.025]	[0.0052, 0.0187]	[0.0265, 0.0442]	[0.0366, 0.0567]
a_2	[0.0129, 0.0286]	[0.0054, 0.0193]	[0.0268, 0.0446]	[0.037, 0.0567]
a_3	[0.0184, 0.0393]	[0.0052, 0.0187]	[0.026, 0.0433]	[0.0374, 0.0567]
a_4	[0.0165, 0.0357]	[0.0051, 0.0183]	[0.0257, 0.0429]	[0.0359, 0.055]
member c_3				
a_1	[0.0055, 0.0236]	[0.0236, 0.049]	[0.0557, 0.0893]	[0.0393, 0.0693]
a_2	[0.0064, 0.0269]	[0.0243, 0.0506]	[0.0562, 0.0902]	[0.0397, 0.0693]
a_3	[0.0092, 0.0371]	[0.0233, 0.049]	[0.0545, 0.0875]	[0.0401, 0.0693]
a_4	[0.0083, 0.0337]	[0.0231, 0.048]	[0.054, 0.0866]	[0.0385, 0.0672]

Step 3: Aggregate the decision matrix of service consumers using Eq. (9) shown in **Table5**.

TABLE 5
THE AGGREGATED DECISION MATRIX FOR MEMBERS

	p_1	p_2	p_3	p_4
a_1	[0.0294, 0.0743]	[0.0419, 0.0927]	[0.0902, 0.1515]	[0.0785, 0.1368]
a_2	[0.0343, 0.0849]	[0.0432, 0.0957]	[0.091, 0.153]	[0.0793, 0.1368]
a_3	[0.049, 0.1168]	[0.0415, 0.0927]	[0.0883, 0.1485]	[0.0802, 0.1368]
a_4	[0.0441, 0.1061]	[0.041, 0.0907]	[0.0874, 0.147]	[0.077, 0.1327]

Step 4: Determine the positive ideal solution and the negative ideal solution, A^+ and A^- are calculated using Eq. (10) shown in **Table 6**.

TABLE 6
IDEAL SOLUTIONS

	p_1	p_2	p_3	p_4
PIRP	[0.0,0.0]	[1.0,1.0]	[1.0,1.0]	[1.0,1.0]
NIRP	[1.0,1.0]	[0.0,0.0]	[0.0,0.0]	[0.0,0.0]

Step 5: Calculate the distances of each initial alternative to PIRP and NIRP using Eq. (11), respectively.

Step 6: Obtain the closeness coefficient of the alternatives using Eq. (12).

The distances, closeness coefficient and ranking order of four alternatives are tabulated in **Table 7**. We can see that the ranking order is "$a_1 \succ a_2 \succ a_4 \succ a_3$", where "$\succ$" indicates the relation "preferred to".

TABLE 7
DISTANCES, CLOSENESS COEFFICIENT AND RANKING ORDER OF FOUR ALTERNATIVES

	d_x^+	d_x^-	CC_i	Rank
a_1	0.5528	0.3414	0.3818	1
a_2	0.5522	0.3389	0.3803	2
a_3	0.5537	0.3307	0.3739	4
a_4	0.5548	0.3331	0.3752	3

B. Comparison Analysis

To illustrate our approach can get the alternative with group optimal QoS, we introduce a scoring method to get the optimal alternative. While the group weight is not considered, the ranking orders for members (c_1, c_2, c_3) are "$a_1 \succ a_2 \succ a_4 \succ a_3$", "$a_1 \succ a_2 \succ a_4 \succ a_3$", "$a_1 \succ a_2 \succ a_4 \succ a_3$", respectively. The best alternative is scored 4 point; the second alternative is scored 3 and so on. So, the scorings of alternatives (a_1, a_2, a_3, a_4) for three members (c_1, c_2, c_3) are "(4, 3, 1, 2)", "(4, 3, 1, 2)", "(4, 3, 1, 2)", respectively. The most important member is scored 3 in group; the second member is scored 2 and so on. So, the scorings of members (c_1, c_2, c_3) in group is "(3, 2, 1)". The synthetic scorings of alternatives (a_1, a_2, a_3, a_4) for three members (c_1, c_2, c_3) are "(12, 9, 3, 6)", "(8, 6, 2, 4)", "(4, 3, 1, 2)", respectively. The total scorings of alternatives (a_1, a_2, a_3, a_4) is "(24, 18, 6, 12)", the ranking order is $a_1 \succ a_2 \succ a_4 \succ a_3$. The result is same with the proposed approach in this paper, so our approach is feasible.

C. Sensitivity Analysis

To investigate the impact of member' QoS preferences (denoted by ω_i for criteria p_i where $i = 1, 2, \cdots, n$) on the selection of alternative with best service quality, we conducted the sensitivity analysis (A consumer need only be considered in this analysis). Some experiments were conducted, and the goal of experiments is to see which attribute the most important is in influencing the decision making process. The details of the experiments are presented in **Table 8** below, let $X = \left[(1-0.1*\alpha)/3, (1-0.1*\alpha)/3\right]$, $Y = \left[0.1*\alpha, 0.1*\alpha\right]$ and $\alpha = 0, 1, 2, \cdots, 10$.

TABLE 8
EXPERIMENTS FOR SENSITIVITY ANALYSIS (QOS PREFERENCES CHANGING)

No.	a_1	a_2	a_3	a_4
1	Y	X	X	X
2	X	Y	X	X
3	X	X	Y	X
4	X	X	X	Y
5	$\omega_1 = \omega_2 = \omega_3 = \omega_4 = [0.25, 0.25]$			

The results of the sensitivity analysis are presented in **Fig.1**. It can be seen from **Table 8** and **Fig.1** that out of 45 experiments, alternative a_1 has the highest score in 38 experiments. In this 5 experiments, the alternative a_2 has emerged as the winner. a_3 and a_4 are the winner in 0 experiment. Therefore, we can say that the decision making process is relatively sensitive to the criteria weight with alternative a_1 emerging as the winner (84.4% votes).

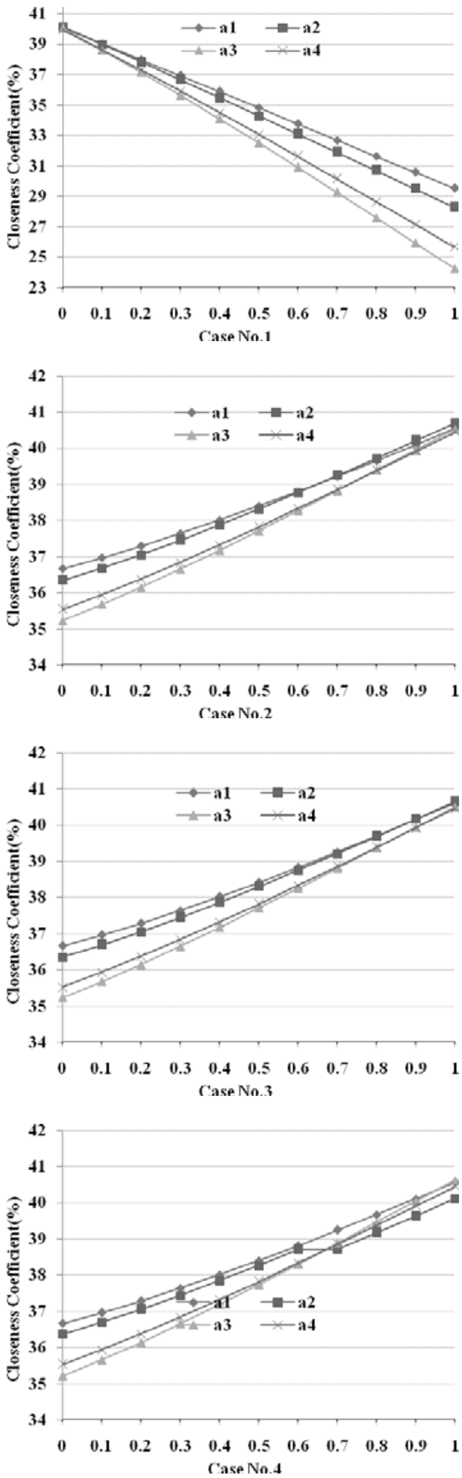

Fig.1 Results of sensitivity analysis (QoS preferences changing)

D. *Time Complexity Analysis*

We analyze the time complexity of our approach on one PC with Intel Core 2 2.0 GHz CPU, 2 GB memory. There are two experiments in this section. 1), the number of alternatives is 100, the number of members changes from 200 to 100. We get the average time of 100 times execution time. 2), the number of members is 100, the number of service alternatives changes from 200 to 1000. The result of experiment demonstrates our approach has linear or polynomial time complexity, so it is an effective and fast approach.

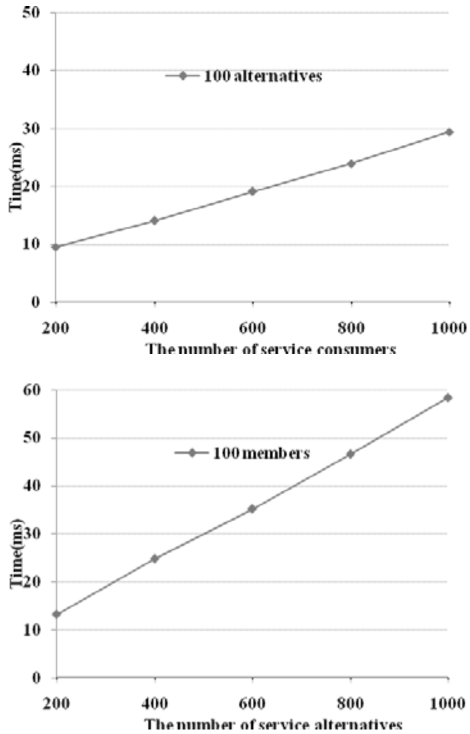

Fig.2 Time complexity

VI. CONCLUTION AND FUTURE WORK

Group activities exist in everywhere of social life, according to user personalized QoS reference to provide information service is the trend. In this perspective, QSSSIN_GU based on QoS and user's personalized QoS preference expressed by interval numbers is presented supporting the group user. QSSSIN_GU is a general service selection method for single user and group user, which can gain the optimal service for single user and gain group optimal service for group.

In the future, our on-going researches on service selection for group are planned as follows. First, we plan to improve QSSSIN_GU performance because lots of service alternatives and more members in group will affect the performance of QSSSIN_GU. Further, it is reasonable that some QoS attributes of service expressed by triangular fuzzy numbers, we will propose the service selection method to solve problem above.

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