Service selection based on fuzzy TOPSIS method

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Abstract—**With rapid development of service-oriented architecture and cloud computing, web services have been widely adopted for developing various kinds of applications. A set of non-functional requirements such as QoS has become important criteria for service selection. The nature of QoS based service selection can be treated as a multiple criteria group decision making (MCDM) problem. This article presents an evaluation method based on the technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) to help service consumers and providers to analyze available web services with fuzzy opinions. A set of pre-defined linguistic variables parameterized by triangular fuzzy numbers, are used by the group to evaluate the weights of various criteria and the ratings of each alternative web service. As a result, the available alternative web services can be ordered according to group preference. Finally, a numerical example is provided to demonstrate the computational efficiency of the proposed fuzzy TOPSIS method.**

Keywords-QoS; Web Services; multiple criteria decision making (MCDM); fuzzy TOPSIS

I. INTRODUCTION

With rapid advancement of service-oriented architecture (SOA) and cloud computing, web services have made rapid growth. Web services are highly interoperable and loosely coupled software components which can be published, located, and invoked on the web. The growing number of Web services available within an organization and on the Web raises the new challenges which involve the issues relating to service discovery, selection and composition. Service discovery allows service providers to publish the service profiles and descriptions in UDDI repositories that store information about businesses, services and further details. Efforts in this area focus on providing rich and machine-readable representation of service properties, capabilities, and behaviors as well as reasoning mechanisms to support automated discovery [1].

Many research efforts tackling Web service composition problems via workflow planning, AI planning, or rule-based planning. One of the Web service composition techniques is based on workflow. Casati et al [2] used a static workflow generation method in the E-Flow which is a platform for enactment and management of composite service. Casati et al [2] developed a composite service definition language (CSDL) which provides the adaptive and dynamic feature for web services execution. Schuster et al [3] proposed a Polymorphic Process Model (PPM) which combines the static and dynamic settings for service composition. The static setting is supported by reference process-based multi-enterprise process. The dynamic service composition is enabled by a reasoning engine which is based on state machine. Another Web service composition technique is rule-based planning. Narayanan et al [5] presented a technique to generate composite services from high level declarative descriptions. Some other AI planning techniques are proposed for the automatic composition of Web services. Sirin et al [6] presented a semi-automatic method for web service composition.

Most existing discovery techniques, however, do not take into account the preference and expectation from service customers' point of view. Huang et al [7] applied semi-order preference model in content-based service discovery. Their work attempts to assist service providers and consumer in discovering appropriate service with consideration of their expectations and preferences. Wang et al [8] used a fuzzy model for the QoS-aware web service selection. Hence, the customers' preferences are often imprecise and uncertain, so it is intricate to prioritize them.

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, which is initially proposed by Hwang et al [9], is one of the well-known multiple criteria decision making (MCDM) methods. The TOPSIS method introduces the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS) to determine the best alternative. While the PIS is to maximize benefit criteria and minimize cost criteria, the NIS is to maximize cost criteria and minimize benefit criteria.

TOPSIS method has become a popular multiple criteria decision technique due to (1) its theoretical rigorousness [10], (2) a sound logic that represents the human rationale in selection [11], and (3) the fact that it has been proved in [12] as one of the most appropriate methods in solving traversal rank. Recently, some researchers have focused on developing fuzzy TOPSIS methods to deal with imprecise information. Sun et al [13] applied fuzzy TOPSIS to evaluate the competitive advantages of shopping websites. Chamodrakas et al [14] employed fuzzy TOPSIS to help suppliers to evaluate customers within the order acceptance process so that the resource allocation and the priority of orders could be identified. Chu et al [15] designed a fuzzy TOPSIS model based on interval arithmetic of fuzzy numbers. Kahraman et al [16] proposed an interactive group decision making methodology based on fuzzy TOPSIS to select information system providers under multiple criteria. Chen et al [17] extended the TOPSIS method based on interval-valued fuzzy sets in decision analysis. Abo-Sinna et al [18] extended the TOPSIS approach to solve multi-objective large-scale non-linear programming problems with block angular structure. Lin et al [19] applied fuzzy TOPSIS for order selection and pricing for make-to-order products when orders exceed production capacity. Li [20] developed a Compromise Ratio (CR) methodology for fuzzy multi-attribute group decision making (FMAGDM), which is an important part of decision support system. Wang and Chang [21] utilized fuzzy TOPSIS to help the Air Force Academy in Taiwan to select optimal initial training aircraft under fuzzy environment. Wang and Lee [22] generalized TOPSIS to a fuzzy multiple-criteria group decision-making approach by proposing two operators Up and Lo, which satisfy the partial ordering relation on fuzzy numbers to find positive and negative ideal solutions.

In this research, we employ the fuzzy TOPSIS method proposed by Yong [23] to evaluate web services for selection. TOPSIS uses triangular fuzzy numbers representing linguistic variables as the weights of criteria and as the ratings of web services which can be transformed into crisp numbers. The transformation is performed by the graded mean integration representation method proposed by Chou [24]. The canonical representation of the addition and the multiplication operations on triangular fuzzy numbers is then used to obtain the PIS and the NIS. To avoid the problem with doubling weightings on each alternative, the distance of each alternative web service from the PIS and the NIS is measured by Minkowski distance function. As a result, the preference order of available alternative web services can be identified accordingly. Based on the graded mean integration representation of triangular fuzzy numbers and the canonical representation of addition and multiplication on triangular fuzzy numbers, the procedure of fuzzy TOPSIS method can be performed in an efficient way. This property can reduce the computational complexity in the decision making process.

The remainder of this article is organized as follows. Section 2 reviews a number of definitions of fuzzy sets theory which are utilized in this study. Section 3 presents the fuzzy TOPSIS method. Section 4 provides an illustrative example to clarify the application of the fuzzy TOPSIS method in the problem of selecting QoS-aware web services. Finally, concluding remarks are given in Section 5.

II. FUZZY NUMBERS

In this section, some basic and related definitions of fuzzy sets will be briefly reviewed.

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Definition 1. *Triangular fuzzy number*. Let $\tilde{A}$ as a fuzzy set and its values will be located between 0 and 1. It is a triangular fuzzy number $\tilde{A}$ can be defined by a triplet(a, b, c), as shown in Fig. 1. Its membership function is defined as

$$\mu_{\tilde{A}} = \begin{cases} 0, & \text{if } x < a, \\ \dfrac{x-a}{b-a}, & \text{if } a \le x \le b, \\ \dfrac{c-x}{c-b}, & \text{if } b \le x \le c, \\ 0, & \text{if } x > c. \end{cases}$$

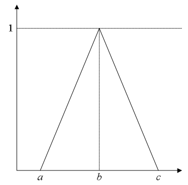

Figure 1. The membership function.

Definition 2. *The graded mean integration representation on triangular fuzzy numbers*. Let $\tilde{A}$=(a, b, c) be a triangular fuzzy number. The graded mean integration representation of $\tilde{A}$ is defined as

Definition 3. *The canonical representation of addition and multiplication operations on triangular fuzzy numbers*. Let $\tilde{A}$=(a_1, b_1, c_1) and $\tilde{B} = (a_2, b_2, c_2)$ be two triangular fuzzy numbers. Then the canonical representation of addition and multiplication operations on triangular fuzzy numbers can be defined as follows.

Addition operation ⊕:

$$P(\tilde{A} \oplus \tilde{B}) = P(\tilde{A}) + P(\tilde{B})$$
$$= \frac{1}{6}(a_1 + 4b_1 + c_1 + a_2 + 4b_2 + c_2)$$

Multiplication operation ⊗:

$$P(\tilde{A} \otimes \tilde{B}) = P(\tilde{A}) \times P(\tilde{B})$$
$$= \frac{1}{6}(a_1 + 4b_1 + c_1) \times \frac{1}{6}(a_2 + 4b_2 + c_2)$$

Two important operators, the addition and the multiplication operations on triangular fuzzy numbers, can be used to obtain the PIS and the NIS. The use of graded mean integration representation method is to transform a triangular fuzzy number into a crisp number which can reduce the required computation under fuzzy environment. For more detailed information, it can be found in [24].

In evaluation processes, human temps to use natural languages to express their opinions rather than exact numbers. Linguistic variables can be defined to represent evaluations. Then each linguistic variable can be parameterized into a fuzzy set. For example, the importance weights of various criteria and the ratings of the criteria can be expressed as linguistic variables which can be modeled as triangular fuzzy numbers as shown in Table1 and Table 2, respectively.

TABLE I. LINGUISTIC VARIABLES FOR THE IMPORTANCE WEIGHT OF EACH CRITERION

Linguistic variables	Importance weight of each criterion
Very low (VL)	(0, 0.1, 0.3)
Low (L)	(0.1, 0.3, 0.5)
Medium (M)	(0.3, 0.5, 0.7)

Linguistic variables	Importance weight of each criterion
High (H)	(0.5, 0.7, 0.9)
Very high (VH)	(0.7, 0.9, 1.0)

TABLE II. LINGUISTIC VARIABLES FOR THE RATING OF EACH ALTERNATIVE

Linguistic variables	Importance weight of each criterion
Very poor (VP)	(1, 1, 3)
Poor (P)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Good (G)	(5, 7, 9)
Very good (VG)	(7, 9, 9)

Once the users express their opinions based on the above tables, Eq. (2, 3) can be applied to obtain the graded mean integration representation of the importance weight of each criterion and ratings shown in Table 3 and Table 4 to form the importance weight of each criterion and each alternative rating.

TABLE III. GRADED MEAN INTEGRATION REPRESENTATION FOR THE IMPORTANCE WEIGHT OF EACH CRITERION

Linguistic variables	Importance weight of each criterion
Very low (VL)	0.1167
Low (L)	0.3000
Medium (M)	0.5000
High (H)	0.7000
Very high (VH)	0.8833

TABLE IV. LINGUISTIC VARIABLES FOR THE RATING OF EACH ALTERNATIVE

Linguistic variables	Importance weight of each criterion
Very poor (VP)	1.3333
Poor (P)	3.0000
Fair (F)	5.0000
Good (G)	7.0000
Very good (VG)	8.6667

III. A FUZZY TOPSIS METHOD FOR WEB SERVICE SELECTION

Assume that a group of k users (D_1, D_2,…, D_k) is formed for ranking m alternatives of web service (A_1, A_2,…, A_m) with respect to n criteria (C_1, C_2,…, C_k). Then the decision matrix, R_t, given by decision maker, d_t, t=1,2,…k, is as follows.

$$R_t = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} r_{11t} & r_{12t} & \cdots & r_{1nt} \\ r_{21t} & r_{22t} & \cdots & r_{2nt} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1t} & r_{m2t} & \cdots & r_{mnt} \end{bmatrix} \end{array} \tag{1}$$

We use $r_{ijt}=(o_{ijt}, p_{ijt}, q_{ijt})$, $r_{ijt} \in \Re^+$, i=1,2,…m, j=1,2,…n, t=1,2,…k, to denote the rating of alternative a_i with respect to criterion c_j given by the user d_t.

The procedure of the fuzzy TOPSIS method is stated as follows.

Step 1. aggregate the importance weights. Let $w_{jt}=(a_{jt}, b_{jt}, c_{jt})$, j=1,2,…n, t=1,2,…k, be the importance weight of criterion C_j given by the user d_t. Then we can calculate the aggregated crisp weight W_j of criterion C_j by the following formula:

$$W_j = \frac{\sum_{t=1}^{k} w'_{jt}}{k}, \tag{2}$$

where w'_{jt} is the weight derived from the graded mean integration representation of fuzzy numbers, as illustrated in Equation (2).

Step 2. aggregate rating of alternatives. The following formula is used to obtain the aggregated crisp rating of alternatives R_{ij}.

$$R_{ij} = \frac{\sum_{t=1}^{k} r'_{ijt}}{k}, \tag{3}$$

where r'_{ijt} is obtained by the graded mean integration representation of fuzzy numbers, as illustrated in Equation (2).

Step 3. construct the normalized and weighted decision matrix. Let $S=[s_{ij}]_{m\times n}$ be the normalized decision matrix. We can calculate the normalized value s_{ij} via the following formula.

$$s_{ij} = \frac{R_{ij}}{\sqrt{\sum_{i=1}^{m} \left(R_{ij}\right)^2}}. \tag{4}$$

Let $V=[v_{ij}]_{m\times n}$ be the weighted decision matrix. The weighted value v_{ij} is derived from the product of elements in the normalized decision matrix and crisp weights.

$$v_{ij} = W_j s_{ij}. \tag{5}$$

Step 4. determine the Positive Ideal Solution (PIS) and the Negative Ideal Solution (NIS). Let I and J be the index sets associated with the alternative set and the criterion set, respectively. We can gain the PIS, A^+, and the NIS, A^-, from the following methods.

$$A^+ = \left\{v_1^+, v_2^+, \cdots, v_n^+\right\} = \left\{\max_{i\in I} v_{ij} \mid j \in J\right\} \tag{6}$$

$$A^- = \left\{v_1^-, v_2^-, \cdots, v_n^-\right\} = \left\{\min_{i\in I} v_{ij} \mid j \in J\right\} \tag{7}$$

Step 5. measure the distance of each alternative from the PIS and the NIS respectively. Traditionally, the Euclidean distance is used to measure the distance of each alternative from A^+ and A^- as follows.

$$d_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2}, i = 1, 2, \ldots, m, \tag{8}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, i = 1, 2, \ldots, m. \tag{9}$$

However, the use of the Euclidean distance may have the problem associated with weight having been calculated twice. This problem can be resolved by introducing Eq. (10) or Eq. (11) as follows.

From Eq. (14), we can easily observe that the decision results overly controlled by weighting.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij}-v_j^+\right)^2} = \sqrt{\sum_{j=1}^{n}\left(W_j s_{ij}-W_j s_j^+\right)^2} = \sqrt{\sum_{j=1}^{n}W_j^2\left(s_{ij}-s_j^+\right)^2}. \quad (10)$$

Therefore, this problem can be overcome by means of Minkowski distance [27][28], L_p^w, as follows.

$$L_p^w(x,y) = \left[\sum_{j=1}^{n} w_j \left|x_j - y_j\right|^p\right]^{1/p} \quad (11)$$

where w_j is the weight of importance with respect to the jth criterion and $p \geq 1$. Note that L_p^w with p=2 is known as the weighted Euclidean distance.

Based on the weighted Euclidean distance, A^+ and A^- can be redefined as follows. Recall that $S=[s_{ij}]$ is the normalized decision matrix. Define

$$A^+ = \left\{s_1^+, s_2^+, \ldots, s_n^+\right\} = \left\{\left(\max_{i\in I} s_{ij} \mid j \in J\right)\right\} \quad (12)$$

$$A^- = \left\{s_1^-, s_2^-, \ldots, s_n^-\right\} = \left\{\left(\min_{i\in I} s_{ij} \mid j \in J\right)\right\} \quad (13)$$

and then the distance of each alternative from A^+ and A^- based on the weighted Euclidean distance is computed as

$$d_i^+ = \sqrt{\sum_{j=1}^{n} W_j \left|s_{ij} - s_j^+\right|^2}, i = 1, 2, \ldots, m, \quad (14)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} W_j \left|s_{ij} - s_j^-\right|^2}, i = 1, 2, \ldots, m \quad (15)$$

Step 6. Calculate the relative closeness coefficient and rank the preference order. The relative closeness coefficient of the ith alternative, RCC_i, can be computed by

$$RCC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (16)$$

Consequently, the alternatives can be ranked according to RCC_i.

IV. ILLUSTRATIVE EXAMPLE

In this section, we will use an example to demonstrate the how the TOPSIS method can resolve conflicting opinions in evaluating services. More detailed information about the following example can be found in [29]. Assume that three alternatives of web services, A_i, i=1,…,3, are chosen for evaluation. A group of four users, D_k, k=1,…,4, has been formed to conduct the assessment based on five categories and 17 QoS criteria, denoted by C_l, l=1,…,5, which are extracted from W3C research report in [30]. The hierarchical structure of these criteria is shown in Fig. 2.

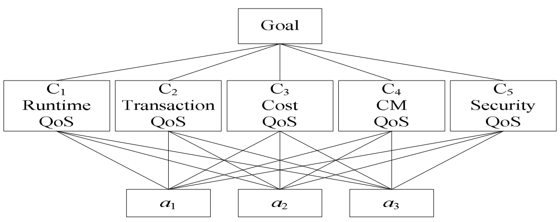

Figure 2. A hierarchical structure for the web service selection problem

The details for these criteria are listed as follows: (1) Runtime Related QoS (C_1)-contains 5 performance criteria: Scalability (c_{11}), Capability (c_{12}), Performance (c_{13}), Reliability (c_{14}), and Availability (c_{15}). (2) Transaction Support Related QoS (C_2)-consists of only one criterion: Data Integrity (c_{21}). (3) Cost Related QoS (C_3)-focus on Acceptable Price (c_{31}), It is charged by US dollars ($) /month. (4) Configuration Management (CM) Related QoS (C_4)-this category is judged by Regulatory (c_{41}), Supported Standard (c_{42}), Stability/Change Cycle (c_{43}), and Completeness (c_{44}). (5) Security Related QoS (C_5)-this category emphases Identity Authentication (c_{51}), Confidentiality (c_{52}), accountability (c_{53}), Traceability and Auditability (c_{54}), Data Encryption (c_{55}) and Non-Repudiation (c_{56}).

The fuzzy TOPSIS method is then applied to solve this problem according to the following procedures:

Step 1. The DMs use the linguistic variables to evaluate the importance of each criterion. Without using the linguistic variables, the example illustrated in [29] applied the entropy method to obtain fuzzy weights of criteria as follows.

w1=(0.090,0.200,0.208); w2=(0.129,0.206,0.216)

w3=(0.041,0.141,0.477); w4=(0.107,0.131,0.167)

w5=(0.197,0.322,0.369);

In this step, we use the above fuzzy weights of criteria and apply Eq. (2) to calculate the weights of criteria as follows.

w1=0.183; w2=0.1948; w3=0.1803; w4=0.133; w5=0.309

Step 2. For each web service, the DMs use the linguistic variables, as shown in Table 2, to produce fuzzy or crisp performance ratings against each criterion as follows.

TABLE V. RATINGS BY DMS WITH RESPECT TO CRITERIA

Criteria	Candidates	DMs			
		D_1	D_2	D_3	D_4
C_1	A_1	F	VG	G	G
	A_2	G	F	VG	VG
	A_3	F	G	F	G
C_2	A_1	G	F	G	F
	A_2	G	F	G	F
	A_3	G	G	F	G
C_3	A_1	5.0	5.5	7.0	6.0
	A_2	8.5	7.5	6.5	6.5
	A_3	4.5	4.0	7.5	3.5
C_4	A_1	G	F	G	F
	A_2	G	G	P	F
	A_3	P	G	F	F
C_5	A_1	F	G	G	P
	A_2	F	G	G	VG
	A_3	P	F	G	G

The graded mean integration representation of each linguistic variable is listed in Table 4.

Step 3. By applying Eq. (4), the aggregated ratings of web services with respect to the five criteria can be computed and shown as follows.

TABLE VI. THE AGGREGATED DECISION MATRIX

	Criteria				
Candidates	C_1	C_2	C_3	C_4	C_5
A_1	*6.9167*	*6.0000*	*5.8750*	*6.0000*	*5.5000*
A_2	*7.3333*	*7.4167*	*7.2500*	*5.5000*	*6.9167*
A_3	*6.0000*	*6.5000*	*4.8750*	*5.0000*	*5.5000*

Step 4. Construct the normalized decision matrix. The normalized decision matrix can be calculated by applying Eq. (5) as follows.

TABLE VII. THE NORMALIZED DECISION MATRIX

	Criteria				
Candidates	C_1	C_2	C_3	C_4	C_5
A_1	*0.5896*	*0.5198*	*0.5580*	*0.6281*	*0.5284*
A_2	*0.6251*	*0.6425*	*0.6886*	*0.5758*	*0.6645*
A_3	*0.5115*	*0.5631*	*0.4630*	*0.5234*	*0.5284*

Step 5. Determine the positive ideal solution, A^+, and the negative ideal solution, A^- as follows.

A^+=(0.6251, 0.6425, 0.6886, 0.6281, 0.6645)

A^-=(0.5115, 0.5198, 0.4630, 0.5234, 0.5284)

Step 6. Calculate the weighted Euclidean distance of each web service from A^+ and A^- as follows.

TABLE VIII. THE DISTANCE MEASURE

Candidates	The distance measure	
	d^+	d^-
A_1	*0.1094*	*0.0648*
A_2	*0.0191*	*0.1434*
A_3	*0.1412*	*0.0191*

a. Sample of a Table footnote. (Table footnote)

Step 7. Obtain the relative closeness coefficient and rank the order of web services.

RCC_1=0.3721, RCC_2=0.8825, RCC_3=0.1192

According to the above relative closeness coefficient, the ranking order of the three alternative web services is A_2, A_1, and A_3. The result of the fuzzy TOPSIS method is the same as the result determined in [29]. From Eq. (12) and Eq. (13), our method is capable of revealing the positive and negative preference degree associated with DMs' alternative and assisting the DMs in making a decision based on group consensus.

V. DISCUSSION

Without any comparison of the proposed method with other well-established methods, the resulting decision may be questionable. The major computation mentioned in the previous section is the similarity measure computation. The opinion data collected from the users is crisp number. In traditional method for getting the similarity proposed by Hsu [31], it would calculate the maximum and minimum intersection area of two membership functions which derived from two different users. For example, the triangle membership function includes four piecewise linear segments. The first segment function which belongs to User 1 will be calculated with respect to the four piecewise linear segments specified by User 2 to determine the intersection point. After that, the rest of segment functions would be checked sequentially until all the four segments have been calculated. Computing the similarity measures and constructing the agreement matrix would be done in time $O(m^n)$. The crisp values can be obtained from the graded mean integration representation method. So, the required computation on the crisp number significantly decreases the complexity compared with fuzzy values. It can be complete in time $O(m \cdot n)$.

According to the complexity of computing users' evaluation, we also used the TOPSIS method to eliminate the problem associated with the duplicated calculation on weightings by introducing the Minkowski distance function. This can increase the accuracy in measurement. Fig. 3 shows the system performance of our proposed TOPSIS method against Huang's work-SAM. Overall, the TOPSIS is very efficient in places where the large number of users involves. Hence, the approach is suitable for on-line applications which often involve large amount of data.

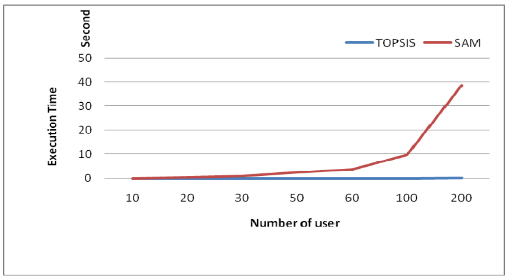

Figure 3. Performance Analysis

In the related works, Huang's work was the first one that applies fuzzy logic for ranking services based on user preference. The issue associated with web selection based on user consensus was not only a group decision making problem but also a solution ranking problem. We summarized the comparison of the related works and the related methods in Table IX.

TABLE IX. COMPARISION OF OUR METHOD AND RELATED WORKS

	Methods		
Subject	Fuzzy Logic	TOPSIS	FUZZY+TOPSIS
Order selection	[19]	[10]	[13]
Group Decision Making	[20],[31]	[11]	[22]
Customer evaluation	[7]	X	[14]
WS Slection based on user consensus	[29]	X	**Our study**

From the illustrative example via the proposed approach, we can conclude the order of the three alternative web services that is A_2, A_1, and A_3 based on the information provided by four decision makers. In the case of the large number of decision makers being involved, the proposed approach can obtain the ranking faster than the work in [29]. In other words, new user's preferences and evaluations can be included in the decision matrix, R_t and the system can efficiently recalculate them to determine the new order.

VI. CONCLUSION

In this paper, the fuzzy TOPSIS method proposed by [23] is employed to solve the web service selection problem when a group of users have different opinions on evaluation. The linguistic terms represented by triangular fuzzy numbers are used for evaluating the weights of criteria and the ratings of each alternative web services with respect to various criteria. These linguistic assessments are transformed into crisp numbers by the graded mean integration representation method. The canonical representation of addition and multiplication operations on triangular fuzzy numbers is then used to obtain the positive ideal solution (PIS) and the negative ideal solution (NIS). Due to the use of crisp number rather than triangular fuzzy number for canonical representation, the complicated calculations involving triangular fuzzy numbers can be avoided in the reasoning procedure of fuzzy TOPSIS. Minkowski distance function is applied to measure the distance of each alternative web service from the PIS and the NIS to overcome the drawback of duplication calculation on weighting. Consequently, the preference order of available alternative web services can be identified according to the relative closeness coefficients.

The existing fuzzy TOPSIS methods involve considerable number of arithmetical operations on fuzzy numbers. Its fuzzy ranking approach, however, to obtain the fuzzy PIS and NIS provides an effective and efficiency solution on analyzing fuzzy numbers. An approach to rank fuzzy numbers for all cases and situations and to produce satisfactory results does not exist yet. However, the canonical representation of addition and multiplication operations on triangular fuzzy numbers can enormously decrease the computational complexity to improve efficiency in conflict resolution. This property can be of great use in real-time applications.

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