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A New Method Combining QFD with Intuitionistic Fuzzy Sets for Web Services Selection

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Abstract

With the rapidly increasing number of Web services, the consumers have to choose suitable service from a wealth of web services according to the comprehensive factors. QoS is an important criteria to assess whether the consumer's requirements are met by web service. But the QoS attributes offered by many web service suppliers are uncertain, especially the non-functional QoS attributes. In this paper, in view of the uncertain QoS attributes in the process of selecting web services, presents the method of selecting web service on basis of QFD-IFS (Quality Function Deployment- Intuitionistic Fuzzy Sets). Describe the consumer's requirements and QoS attributes with intuitionistic fuzzy sets. Construct the QFD model transforming requirements of consumer into QoS attributes, which gives comprehensive consideration to the relations between requirements of consumer and QoS attributes, and to the impact of the correlation between the QoS attributes on the weights of QoS attributes. After the modified intuitionistic fuzzy entropy is used to obtain the entropy weights of the QoS attributes and alternatives. In the end an example show that the proposed method is feasible and effective.

Keywords: *QFD; Intuitionistic Fuzzy Sets; QoS; web service*

1. Introduction

Following the improvement of web service criteria and the increasing maturity of those software platforms supporting web services, more and more software enterprises package their business functions and modules as criteria web services and release them on the internet, and then offer service with different QoS according to the customer's requirements in payment pattern of utilization. For the single web service fails to meet the customer's requirements, it is necessary to construct service composition: Combine several web services into composition that is of particle size and internal process logic, and then operate the composition to meet the business target.

QoS is one of the key techniques in the selection of web services, also the inevitable requirement of realizing the loose coupling SOA. However, in consideration of the specialty of web services composition and the uncertainty of customer's requirements, the selection of web services based on QoS still faces challenges. Because of the uncertainty in the QoS information offered by suppliers of web services caused by the openness, complexity and dynamic nature of the operating environment, the web service suppliers are difficult to announce the accurate information of their QoS natures. The literature [2] designs a new fuzzy multi-objective optimization model according to the QoS information

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on different levels to solve the problem of selecting web services. The model is able to efficiently choose web services on the condition that the QoS information offered by suppliers is uncertain. the complexity of web services application, the diversity of QoS attributes and the different characteristics of each QoS attributes, customers are difficult to accurately express the importance of various QoS attributes to them, which results in the mismatching between the requirement of customers and the web services. To solve the complexity of web services and the diversity of QoS attributes, the literature [3] provides a new matching method to cope with the fuzziness of customer requirement. The method establishes a new fuzzy classification rule for web services, and extracts the non-functional natures of QoS from the rule in light of the rough set theory, and sorts the candidate web services. The matching method is able to provide more accurate decision for customers to choose web services. The literature [4] uses the grey correlation theory to classify the QoS attributes and does weights ranking over the sorting result. The method can reduce the difficulty of choosing web services and provide basis on which the customer chooses web services. To solve the multi-objective constraint conditions of the QoS attributes, the literature [5] provides a new evolutionary algorithm by mixing the random particle swarm optimization and the simulated annealing algorithm. The algorithm can generate the best web service composition according to the constraint conditions and meanwhile the global convergence of the algorithm is verified. The said literatures, in view of the uncertainty in QoS attributes, present methods to solve the problem concerning the selection and composition of web services on the condition that QoS attributes are uncertain. However, it ignores the following issues: (1) it does not take the impact of the correlation between consumer’s requirements and QoS attributes on the ranking of web services into consideration in the process of analyzing the uncertainty factors in QoS attributes. (2) The researches on the selection and composition of web services are mainly based on the functionality and not suitable for the non-functionality of QoS. On basis of the selection of web services of QoS, it is difficult to fix the non-functional attributes. The main reasons include: ① The web services are complex and the customers’ knowledge concerning web services is insufficient. ② The suppliers of web services are difficult to accurately understand the actual customer’s requirements. There are uncertainty factors in both the assessment of customers on the QoS attributes of web services and the understanding of web service suppliers on the customer’s requirements. Therefore, this paper takes the selection of web services as the issue of fuzzy multi- criteria decision to study, which mainly includes the following aspects:

(1) The uncertainty between the QoS attributes and the customer’s requirements. The information assessment on the QoS non-functional attributes is mainly done by decision-making experts, and the fuzziness in the information assessment by the experts causes the uncertainty in the assessment result. To conduct the efficient research on the selection of web services on the condition that the QoS information is uncertain, the paper applies the intuitionistic fuzzy sets to describe the customer’s requirements and the QoS attributes.

(2) The fixing of the weight of QoS attributes. The influential factors of the weight of QoS attributes are the customer’s requirements, and the mutual effect between QoS attributes. The thesis introduces the QFD and integrates the requirements of customers, and the mutual effect between QoS attributes to build a QFD model, and then calculate the weight of QoS attributes through the QFD model.

(3) The correction of the weight of QoS attributes. The weight of QoS attributes calculated by the QFD model is an intuitionistic fuzzy number, so the modified intuitionistic fuzzy entropy [9] is used to obtain the entropy weights of the QoS attributes and alternatives.

2. Preliminaries

2.1. Intuitionistic Fuzzy Sets

Atanassov [10], a Bulgarian scholar, expanded the fuzzy sets of Zadeh and presented the intuitionistic fuzzy sets. The scholar made the traditional fuzzy sets only considering degree of membership become the intuitionistic fuzzy sets involved with the membership, the non-membership and the hesitancy degree. Now, the intuitionistic fuzzy sets have been used in many fields: For example, medical diagnosis [11-12], decision problem [13-14], pattern recognition [15-16]. The definition and algorithm of intuitionistic fuzzy sets is as follows:

Let a set X be a finite universal set. An IFS A on X is an object with the from

$$A=\{(x,u_A(x),v_A(x))\,|\,x\in X\} \tag{1}$$

Where $u_A(x),v_A(x):X\to[0,1]$ are membership function and non-membership function, respectively, such that

$$0\le u_A(x)+v_A(x)\le 1 \tag{2}$$

For each intuitionistic fuzzy set in X ,if $\pi_A(x)$ satisfies (3),then $\pi_A(x)$ is the degree of indeterminacy of $x\in X$ as an element of the IFS A. It expresses a hesitation degree to determine whether x belongs to A or not.

$$\pi_A(x)=1-u_A(x)-v_A(x) \tag{3}$$

It is obviously seen that for every $x\in X$: $0\le\pi_A(x)\le 1$ .If the $\pi_A(x)$ is small, knowledge about x is more certain. If $\pi_A(x)$ is great, knowledge about x is more uncertain. Obviously, when $u_A(x)=1-v_A(x)$ for all elements of the universe, the ordinary fuzzy set concept is recovered[17]. For two IFS A and B, the following equations hold true:

$$A\oplus B=\{(x,u_A(x)+u_B(x)-u_A(x)*u_B(x),v_A(x)*v_B(x))\,|\,x\in X\} \tag{4}$$

$$A\otimes B=\{(x,u_A(x)*u_B(x),v_A(x)+v_B(x)-v_A(x)*v_B(x))\,|\,x\in X\} \tag{5}$$

2.2. QFD

QFD is a customer driven product development method. It is a method of quality control in the product design stage. QFD is a comprehensive quality tool specifically aimed at satisfying customers' requirements. The QFD process involves four phases: (1) customer requirement planning. (2) product characteristics deployment. (3) process and quality control, and (4) the operative instruction.

In the study, we focus on the customer requirement planning phase, which transforms the customer's requirements into engineering characteristics [18]. The phase is characterized by the customer requirement planning matrix [19]. The customer requirement planning matrix, also known as house of quality (HOQ), is the first step in investigating customer requirement [20]. The HOQ is composed of six parts, as is shown in Figure1. Part A present customer requirements (CR), which is a guideline for the providers on attributes that the product should possess. Part B represents product technical requirement (EC), are used to determine how well the company meets the customer needs. Part C represents the weight of CR. Part D represents the relationship between CR and EC. Part E represents correlation among the EC, which is how EC affect each other. Part F shows the weight of EC.

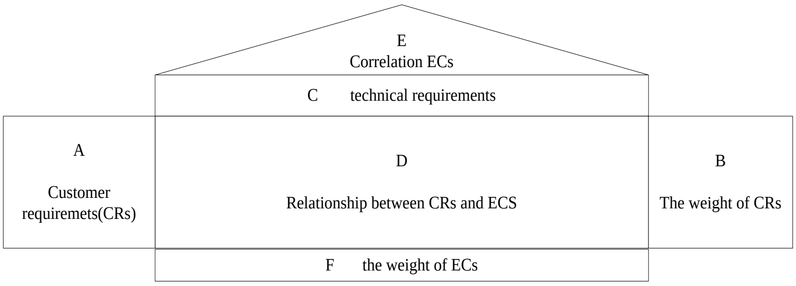

Figure 1. House of Quality

3. The Proposed QFD-IFS Methodology

In this research, the proposed approach includes a new resolution process for determining the linguistic weights of criteria, the importance of the decision makers are considered as linguistic terms expressed in intuitionistic fuzzy numbers and introduces, Introduce the method of intuitionistic fuzzy entropy to correct the weights of QoS attributes, get the ranking of web services through calculation.

Let D={D1,D2,..,Dq} be the set of decision makers which are composed of customers and analysts. CR={CR_1,CR_2,..,CR_m}be the set of customer requirement (CR). QC={QC_1,QC_2,..,QC_n}be the set of Qos criteria (QC).WS={WS_1, WS_2,.., WS_z}be the set of Web services.

Suppose $C^k = (\hat{c}_i^k)_{1\times m} = (\mu_i^k, \hat{v}_i^k)_{1\times m}$ be the linguistic decision making matrix of the weight of the customer requirements CR, $CQ^k = (cq_{ij}^k)_{m\times n} = (\mu_{ij}^k, \hat{v}_{ij}^k)_{m\times n}$ be the linguistic decision making matrix of relationship between customer requirements CR_i and Qos criterion QC_j, $QL^k = (ql_{rs}^k)_{n\times n} = (\mu_{rs}^k, v_{rs}^k)_{n\times n}$ be the linguistic decision making matrix of correlation between Qos criterion QL_r and Qos criterion QL_s, $F^k = (wq_{jt}^k)_{n\times z} = (\mu_{jt}^k, \hat{v}_{jt}^k)_{n\times z}$ be the linguistic decision making matrix of relationship between Web services (WS_t)and Qos criterion (QC_j,)which are provided by D_k.

A symbolic linguistic term, $L(\pi)$ is defined to represent a decision maker's rating with the degree of indeterminacy π .Then, the importance of each criterion is evaluated on six scales of intuitionistic fuzzy number(IFN) as shown in Table1 [21].

Table 1. Intuitionistic Fuzzy Number (IFN)

Linguistic terms			IFNs
Very unimportant(VU)	Very low(VL)	Very expensive(VE)	[0.1 0.9-π] $\pi \in$ [0 0.9]
Unimportant(U)	Low(L)	Expensive(E)	[0.3 0.7-π] $\pi \in$ [0 0.7]
Medium(M)	Medium(M)	Medium(M)	[0.5 0.5-π] $\pi \in$ [0 0.7]
Important(I)	High(H)	Price(P)	[0.7 0.3-π] $\pi \in$ [0 0.7]
Very important(VI)	Very high(VH)	Very price(VP)	[0.9 0.1-π] $\pi \in$ [0 0.1]
I do not know(N)	I do not know(N)	I do not know(N)	[0 0]

Step1 Detemining the weights of decision makers.

The importance of the decision makers $D_k (k = 1,..,q)$ are considered as linguistic terms expressed in intuitionistic fuzzy numbers. Let D_k = $L(\pi)$ be an intuitionistic fuzzy number for rating of kth decision maker. Then the weight of kth decision maker can be obtained as:

$$\lambda_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{q}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + v_k}\right)\right)} \left(\sum_{k=1}^{1} \lambda = 1 \in [0,1]\right) \tag{6}$$

Step2 Construct the QFD model of weight of QoS.

HOQ is the core tool to realize the QFD theory. In the process of QoS weights analysis, by constructing the HOQ convert customer requirements into QoS attributes, as is shown in Figure2. In Figure2, Part A is the weights of CR and CR, Part B is the collective correlation between QC and QC, Part C is the collective relationships between CR and QC. Part D is the weights of QC. Part E is the weights of QC with the effects of correlation from other QC.

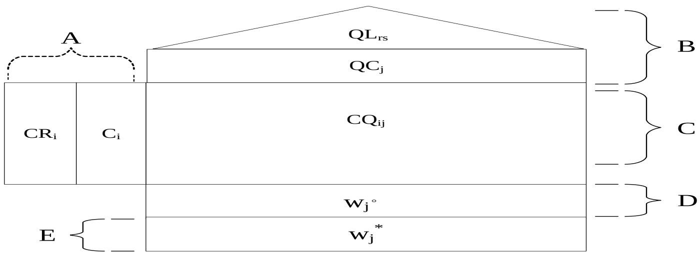

Figure 2. The HoQ of QoS Attributes

Step3 Construct the aggregated intuitionistic fuzzy judgment matrix based on decision maker.

Let $R = (r_{ij})_{M \times N}$ be an intuitionistic fuzzy decision matrix of decision maker. In group decision making process, all the individual decision opinions need to be fused into group opinion to construct an aggregated intuitionistic fuzzy weighted averaging (IFWA) operator proposed by Xu [22]. The aggregation is done using the Equation (7).

$$r_{ij} = IFWA_\lambda(r_{ij}^{(1)}, r_{ij}^{(2)}, .., r_{ij}^{(q)}) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus ... \oplus \lambda_q r_{ij}^{(q)} = \left(\mu_{ij}, v_{ij}, \pi_{ij}\right)$$
$$= \left(1 - \prod_{k=1}^{q}\left(1-\mu_{ij}^k\right)^{\lambda_k}, \prod_{k=1}^{q}((v_{ij}^k)^{\lambda_k}), \prod_{k=1}^{q}\left(1-\mu_{ij}^k\right) - \prod_{k=1}^{q}((v_{ij}^k)^{\lambda_k})\right) i \in M, j \in N \tag{7}$$

Step3.1 Calculate the weights of CR.

Suppose $C = (\hat{c}_i)_{1\times m} = (\mu_i, \hat{v}_i)_{1\times m}$ be the matrix of the weight of the customer requirements CR. We use the method presented by Chen [23]to aggregate the opinions. By Eq.(7), the aggregated result of the weight of CR is derived as follows:

$$\hat{c}_i = \lambda_1 \times \hat{c}_i^1 + \lambda_2 \times \hat{c}_i^2, .., +\lambda_q \times \hat{c}_i^q = \left[1 - \prod_{k=1}^{q}\left(1-\mu_i^k\right)^{\lambda_k}, \prod_{k=1}^{q}(\hat{v}_i^k)^{\lambda_k}\right](i = 1..m) \tag{8}$$

Step3.2 Calculate the collective relationships between CR and QC.

Suppose $CQ = (cq_{ij})_{m\times n} = (\mu_{ij}, \hat{v}_{ij})_{m\times n}$ be the matrix of relationship between customer requirements CRi and Qos criterion QCj. similar to step2.1, the aggregated result of the relationship between CRi and QCj is derived by

$$cq_{ij} = \lambda_1 \times cq_{ij}^{1} + \lambda_2 \times cq_{ij}^{2}, .., \lambda_q \times cq_{ij}^{q}$$
$$= \left[1 - \prod_{k=1}^{q} \left(1 - \mu_{ij}^{k} \right)^{\lambda_k}, \prod_{k=1}^{q} (\hat{v}_{ij}^{k})^{\lambda_k} \right] (i = 1..m,\ j = 1..n) \tag{9}$$

Step3.3 Calculate the collective correlation between QC.

Suppose $QL = (ql_{rs})_{n \times n} = (\mu_{rs}, v_{rs})_{n \times n}$ be the matrix of correlation between Qos criterion QLr and Qos criterion QLs. similar to step2.1, the aggregated result of the relationship between QLr and QLs is derived by

$$ql_{rs} = \lambda_1 \times ql_{rs}^{1} + \lambda_2 \times ql_{rs}^{2}, .., \lambda_q \times ql_{rs}^{q}$$
$$= \left[1 - \prod_{k=1}^{q} \left(1 - \mu_{rs}^{k} \right)^{\lambda_k}, \prod_{k=1}^{q} (\hat{v}_{rs}^{k})^{\lambda_k} \right] (r, s = 1..n) \tag{10}$$

Step3.4 Calculate the collective relationships between WS and QC.

Suppose $F = (wq_{jt})_{n \times z} = (\mu_{jt}, \hat{v}_{jt})_{n \times z}$ be the matrix of relationship between Web services WSt and Qos criterion QCj. similar to step2.1, the aggregated result of the relationship between WSt and QCj is derived by

$$F = (wq_{jt})_{n \times z} = (\lambda_1 \times wq_{jt}^{1} + \lambda_2 \times wq_{jt}^{2}, .., \lambda_q \times wq_{jt}^{q})_{n \times z}$$
$$= \left(\left[1 - \prod_{k=1}^{q} \left(1 - \mu_{jt}^{k} \right)^{\lambda_k}, \prod_{k=1}^{q} (\hat{v}_{jt}^{k})^{\lambda_k} \right] \right)_{n \times z} \quad (j = 1..n, t = 1..z) \tag{11}$$

Step4 Calculate the weight of QC.

Since the relationships derived in Step2.2 represents the relationship between CRs and QCs. By eq. (4) and (5), the weight wj of Qos criterion QCj determined by the relationships between CR and QC(cqij) and the weight of customer requirements(ci), which is got as follows:

$$\overset{\circ}{w}_j = (\mu_j, \hat{v}_j) = \sum_{i=1}^{m} \left(\hat{c}_i \times cq_{ij} \right) = \sum_{i=1}^{m} \left(\mu_i \times \mu_{ij}, \hat{v}_i + \hat{v}_{ij} - \hat{v}_i \times \hat{v}_{ij} \right) (j = 1..n) \tag{12}$$

Step5 Calculate the weights of QC with the effects of correlation from other QC.

After the weight of QC are determined, we must take into consideration the effects of correlation from other QC. Accordingly, the weight of QC, the collective correlation between QC, eq.(4) and (5), which is got as follows:

$$\overset{*}{w}_s = (\mu_s, \hat{v}_s) = \sum_{j=1}^{n} (\overset{\circ}{w}_j \times ql_{js}) = \sum_{j=1}^{n} (\mu_j \times \mu_{js}, \hat{v}_j + \hat{v}_{js} - \hat{v}_j \times \hat{v}_{js}) (s = 1..n) \tag{13}$$

Step6 Calculate average normalized weights aggregated matrix of F and $\overset{*}{w}_s$.

We modified intuitionistic fuzzy entropy introduced by Valachos [24]. The summation in [24]is removed to obtain aggregated value of each IFS matrix row. The intuitionistic fuzzy entropy of each aggregated of F is defined as (19).

$$\overline{\overline{wq_{jt}}} = -\frac{1}{z \ln 2} \left[\mu_{jt} \ln \mu_{jt} + \hat{v}_{jt} \ln \hat{v}_{jt} - \left(1 - \pi_{jt}\right) \ln \left(1 - \pi_{jt}\right) - \pi_{jt} \ln 2 \right] (j = 1..n, t = 1..z) \tag{14}$$

Thus the collective relationships matrix of WS and QC define $F = (wq_{jt})_{n*z}$ and wq_{jt} is defined as (15)

$$wq_{jt} = \frac{1-\overline{\overline{wq_{jt}}}}{1-\sum_{f=1}^{z}\overline{\overline{wq_{jf}}}}(j=1,2,..,n) \tag{15}$$

The intuitionistic fuzzy entropy of each aggregated of $\overset{*}{w_s}$ is defined as (16).

$$\overline{\overline{\omega_s}} = -\frac{1}{n\ln 2}\left[\mu_s \ln \mu_s + \hat{v}_s \ln \hat{v}_s - (1-\pi_s)\ln(1-\pi_s) - \pi_s \ln 2\right] \tag{16}$$

Thus the final weight of QCs is redefined as(17).

$$\omega_s = \frac{1-\overline{\overline{\omega_s}}}{n-\sum_{f=1}^{n}\overline{\overline{\omega_f}}} \quad where \sum_{s=1}^{n}\omega_s = 1 \tag{17}$$

Step7 Rank all the web services.

Compute the relative weight of web services and finally rank the alternatives using Eq. (18).

$$W_t = \sum \omega_j F_{jt} \tag{18}$$

4. An Example

An example of selecting web services is used to illustrate the application of the proposed method. Dk(k=1,..,3) be the set of decision makers which are composed of customers and analysts. CRm(m=1,..,4) be the set of customer requirements (CR), the details for CRm are listed as follows: performance(CR1), reliability(CR2), cost(CR3), security(CR4), QCn(n=1,..,6)be the set of Qos criteria (QC), the details for QCn are listed as follows: response time(QC1), throughput(QC2), success rate(QC3), stability(QC4), cost of buying(QC5) , confidentiality(QC6). WSz(z=1,..,3)be the set of Web services. In Table2, the importance of the Dk are given by the linguistic variables in Table1.

Table 2. The Importance of the D_k

	D_1	D_2	D_3
the linguistic variables	VI(0)	I(0.1)	M(0.2)

The decision makers use the linguistic variables in Table1 to express their preferences. The weight of CR are given in Table3. The relationships between CR and QC are given in Table4. The correlation between QC are given in Table5. The relationships between WS and QC are given in Table6.

Table 3. The Weights of CR

	D_1	D_2	D_3
CR_1	VI(0)	I(0.1)	I(0)
CR_2	I(0.2)	I(0)	VI(0)
CR_3	M(0.3)	M(0.2)	U(0.6)
CR_4	I(0)	I(0)	M(0.3)

Table 4. The Relationships between CR and QC

	$QC_1(D_1\ D_2\ D_3)$	$QC_2(D_1\ D_2\ D_3)$	$QC_3(D_1\ D_2\ D_3)$
CR_1	VI(0) VI(0) I(0.1)	VI(0.1) I(0.1) I(0.1)	M(0.2) M(0.1) M(0)
CR_2	I(0.1) I(0.2) I(0)	M(0.3) M(0.1) M(0.2)	VI(0) I(0.1) VI(0.1)
CR_3	M(0.1) U(0.4) M(0.3)	U(0.2) M(0.2) M(0.3)	U(0.1) U(0.3) U(0.2)
CR_4			
	$QC_4(D_1\ D_2\ D_3)$	$QC_5(D_1\ D_2\ D_3)$	$QC_6(D_1\ D_2\ D_3)$
CR_1	U(0.2) U(0.3) U(0.1)	M(0.4) M(0.1) U(0.2)	
CR_2	VI(0) VI(0) VI(0.1)	U(0.3) U(0.2) U(0.1)	
CR_3	U(0.3) M(0.2) U(0.1)	VI(0) VI(0) VI(0)	
CR_4			VI(0) VI(0.1) VI(0.1)

Table 5. The Correlation between QC

	$QC_1(D_1\ D_2\ D_3)$	$QC_2(D_1\ D_2\ D_3)$	$QC_3(D_1\ D_2\ D_3)$
QC_1	VH(0) VH(0)VH(0)	L(0.1)L(0.2)VH(0.1)	H(0)M(0.1)M(0.2)
QC_2		VH(0) VH(0)VH(0)	L(0.2)VL(0.4) VL(0.5)
QC_3			VH(0) VH(0)VH(0)
QC_4			
QC_5			
QC_6			
	$QC_4(D_1\ D_2\ D_3)$	$QC_5(D_1\ D_2\ D_3)$	$QC_6(D_1\ D_2\ D_3)$
QC_1	M(0.4)L(0.2)L(0.3)	L(0.2)L(0.1)VL(0.2)	
QC_2	M(0.2)M(0.4)M(0.1)	L(0.3)M(0.4)L(0.2)	
QC_3	H(0.1)H(0)M(0.1)	M(0.1)L(0.2)L(0.1)	
QC_4	VH(0) VH(0)VH(0)	M(0.2)M(0.1)L(0.2)	
QC_5		VH(0) VH(0)VH(0)	
QC_6			VH(0)VH(0)VH(0)

Table 6. The Relationships between WS and QC

	$WS_1(D_1\ D_2\ D_3)$	$WS_2(D_1\ D_2\ D_3)$	$WS_3(D_1\ D_2\ D_3)$
QC_1	I(0.1) I(0.2) M(0.3)	I(0.3) M(0.1) VI(0.1)	M(0.3) U(0.2) M(0.1)
QC_2	VI(0.1) I(0.1) I(0.2)	M(0.2) I(0.1) I(0.1)	I(0.1) M(0.2) M(0.1)
QC_3	M(0.2) M(0.3) I(0.1)	I(0.1) VI(0.1) I(0.2)	M(0.2) M(0.1) I(0.1)
QC_4	U(0.4) M(0.2) M(0.3)	M(0.4) M(0.1) I(0.2)	I(0.1) I(0.2) M(0.3)
QC_5	E(0.2) E(0.1) M(0.1)	E (0.1) P(0.2) M(0.3)	M(0.1) P(0.2) M(0.3)
QC_6	I(0.1) I(0.1) VI(0)	M(0.1) I(0.2) M(0.1)	I(0.1) I(0.2) M(0.3)

Step1 Determining the weights of decision makers

The importance of the decision makers is shown in Table2. In order to obtain the weights of the decision makers, Equation(6) is used, $\lambda1= VI(0)=(\mu,v,\pi)=(0.9,0.1,0)$, at the same time $\lambda2=(0.7,0.2,0.1)$, $\lambda3=(0.5,0.3,0.2)$.

$$\lambda_1 = \frac{(0.9+0)}{0.9+\left(0.7+0.1\times\left(\frac{0.7}{0.7+0.2}\right)\right)+\left(0.5+0.2\times\left(\frac{0.5}{0.5+0.3}\right)\right)} = 0.391$$

By applying the same equation, the weight of $\lambda2=0.338$, $\lambda3=0.271$.

Step2 Construct the aggregated intuitionistic fuzzy judgment matrix based on decision maker

After the transformation of the data in Table3-6 into intuitionistic fuzzy numbers. the Equation(8)-(11) are used to aggregate the decision makers' opinions, the collective weights of CR., the collective relationships between CR and QC, the collective correlation between QC, the collective relationships between WS and QC are shown in Table7-10.

Table 7. The Collective Weights of CR

$CR_1(\mu,v)$	$CR_2(\mu,v)$	$CR_3(\mu,v)$	$CR_4(\mu,v)$
(0.805 0.170)	(0.777 0.145)	(0.452 0.190)	(0.655 0.269)

Table 8. The Collective Relationships between CR and QC

	$QC_1(\mu,v)$	$QC_2(\mu,v)$	$QC_3(\mu,v)$
CR_1	(0.865,0.121)	(0.805,0)	(0.500,0.380)
CR_2	(0.700,0.177)	(0.500,0.282)	(0.855,0.126)
CR_3	(0.440,0.301)	(0.430,0.328)	(0.300,0.498)
CR_4			
	$QC_4(\mu,v)$	$QC_5(\mu,v)$	$QC_6(\mu,v)$
CR_1	(0.300,0.487)	(0.452,0.247)	
CR_2	(0.900,0)	(0.300,0.481)	
CR_3	(0.375,0.405)	(0.900,0)	
CR_4			(0.900,0)

Table 9. The Collective Correlation between QC

	$QC_1(\mu,v)$	$QC_2(\mu,v)$	$QC_3(\mu,v)$
QC_1	(0.900,0.100)	(0.251,0.610)	(0.591,0.331)
QC_2		(0.900,0.100)	(0.184,0.471)
QC_3			(0.900,0.100)
QC_4			
QC_5			
QC_6			
	$QC_4(\mu,v)$	$QC_5(\mu,v)$	$QC_6(\mu,v)$
QC_1	(0.386,0.251)	(0.251,0.583)	
QC_2	(0.500,0.224)	(0.375,0.425)	
QC_3	(0.541,0.277)	(0.386,0.482)	
QC_4	(0.900,0.100)	(0.452,0.380)	
QC_5		(0.900,0.100)	
QC_6			(0.900,0.100)

Table 10. The Collective Relationships between WS and QC

	$WS_1(\mu,v)$	$WS_2(\mu,v)$	$WS_3(\mu,v)$
QC_1	(0.656,0.158)	(0.735,0)	(0.440,0.329)
QC_2	(0.805,0)	(0.634,0.234)	(0.591,0.277)
QC_3	(0.565,0.234)	(0.793,0)	(0.565,0.296)
QC_4	(0.430,0.269)	(0.565,0.160)	(0.656,0.158)
QC_5	(0.361,0.501)	(0.520,0.243)	(0.579,0.207)
QC_6	(0.777,0.166)	(0.579,0.250)	(0.655,0.158)

Step3 Calculate the weights of QC.

The weight w_i of Qos criterion QC_i determined by the relationships between CR and $QC(cq_{ij})$ and the weight of customer requirements(c_i). Equation(12) is used to get as follows:

$$\overset{\circ}{w}_1 = (\mu_1, \hat{v}_1) = \sum_{i=1}^{4}\left(\hat{c}_i \times cq_{i1}\right) = \left(\hat{c}_1 \times cq_{11}\right) + \left(\hat{c}_2 \times cq_{21}\right) + \left(\hat{c}_3 \times cq_{31}\right) + \left(\hat{c}_4 \times cq_{41}\right)$$

$$= (0.889, 0.009)$$

By applying the same equation, the weight of $\overset{\circ}{w}_2$=(0.827,0.008), $\overset{\circ}{w}_3$=(0.827,0.020),

$\overset{\circ}{w}_4$=(0.811,0.012), $\overset{\circ}{w}_5$=(0.711,0.015), $\overset{\circ}{w}_6$=(0.589,0.001).

Step4 Calculate the weights of QC with the effects of correlation from other QC.

After the weight of QC are determined, we must take into consideration the effects of correlation from other QC. Accordingly, the weight of collective correlation between QC. Equation(13) is used to get as follows:

$$\overset{*}{w}_1 = (\mu_1, \hat{v}_1) = \sum_{j=1}^{6}\left(\overset{\circ}{w}_j \times ql_{j1}\right) = \left(\overset{\circ}{w}_1 \times ql_{11}\right) + \left(\overset{\circ}{w}_2 \times ql_{21}\right) + \left(\overset{\circ}{w}_3 \times ql_{31}\right) + \left(\overset{\circ}{w}_4 \times ql_{41}\right) +$$

$$\left(\overset{\circ}{w}_5 \times ql_{51}\right) + \left(\overset{\circ}{w}_6 \times ql_{61}\right) = (0.956, 0.003)$$

By applying the same equation, the weight of $\overset{*}{w}_2$=(0.926,0.003), $\overset{*}{w}_3$=(0.958,0.003), $\overset{*}{w}_4$=(0.961,0.001), $\overset{*}{w}_5$ =(0.843,0.005), $\overset{*}{w}_6$=(0.530,0.469).

Step5 Calculate average normalized weights aggregated matrix of F and $\overset{*}{w}$.

Equation(14) is used to modify matrix of the collective relationships between WS and QC, the weights of QC with the effects of correlation from other QC. The intuitionistic fuzzy entropy of each aggregated of F is calculated.

$$\overline{\overline{wq_{11}}} = -\frac{1}{3\ln 2}\left[\mu_{11}\ln\mu_{11} + \hat{v}_{11}\ln\hat{v}_{11} - \left(1-\pi_{11}\right)\ln\left(1-\pi_{11}\right) - \pi_{11}\ln 2\right]$$

$$= -\frac{1}{3\ln 2}\left[0.656\ln 0.656 + 0.158\ln 0.158 - (1-0.186)\ln(1-0.186) - 0.186\ln 2\right] = 0.115$$

By applying the same equation, $\overline{\overline{wq_{12}}}$ =0.088, $\overline{\overline{wq_{13}}}$ =0.187. Equation(15) is used to calculate wq_{11}, wq_{12}, wq_{13}.

$$wq_{11} = \frac{1-\overline{\overline{wq_{11}}}}{1-\left(\overline{\overline{wq_{11}}}+\overline{\overline{wq_{12}}}+\overline{\overline{wq_{13}}}\right)} = \frac{1-0.115}{1-(0.115+0.008+0.187)} = 0.339$$

wq_{12}=0.349, wq_{13}=0.312.

Finally, through the final calculated of $F = \begin{bmatrix} 0.339 & 0.349 & 0.312 \\ 0.349 & 0.328 & 0.323 \\ 0.324 & 0.352 & 0.324 \\ 0.318 & 0.335 & 0.347 \\ 0.316 & 0.338 & 0.346 \\ 0.347 & 0.322 & 0.331 \end{bmatrix}$.

Similarly, the use of formula (16),(17) to get $\overset{*}{w} = \begin{bmatrix} 0.1693 & 0.1684 & 0.1693 & 0.1695 & 0.1661 & 0.1572 \end{bmatrix}$.

Step6 Rank all the web services.

Compute the relative weight of web services and finally rank the alternatives using Eq(18).

$$W_t = \sum \overset{*}{w}_j F_{jt}$$

Table 11. The Resulting Weight of Web Services

$W_1(WS_1)$	$W_2(WS_2)$	$W_3(WS_3)$
0.332	0.338	0.330

Based on the weight of the web services are ranked in a descending order: WS_2> WS_1> WS_3.

5. Discussions

The main difference between the model proposed in this paper and those models proposed in previous studies is the application of QFD in web service selection. In previous research, QoS attributes are directly used to establish multi-objective optimization mode and to carry on web services selection. It didn't consider the actual requirements of consumers. This can lead to the dissatisfaction of consumers on the web service selection. On the other hand, it is difficult for the consumers to assess reasonably on QoS attributes because of professional restriction. Therefore, connecting the QoS attributes and the requirements of consumer through QFD in the proposed method resolves the problem. The other difference is to describe the requirements of consumer and QoS attributes with intuitionistic fuzzy sets and the modified intuitionistic fuzzy entropy is used to obtain the entropy weights of the QoS attributes and alternatives. The utilization of the proposed model is demonstrated with an example. The results show that the proposed model fit the web service selection.

6. Conclusions

In light of the uncertainty factors of non-functional attributes in the selection of web services based on QoS, the paper comes up with the decision method on the strength of the intuitionistic fuzzy sets to solve the problem in selecting web services. The method boasts the following features:

(1) The QFD model based on the intuitionistic fuzzy sets is built. The model establishes the correlation matrix of the requirements of customers and the QoS standards, and then fully thinks over the mutual relation between QoS attributes to set up a correlation matrix between QoS attributes and obtain the weight of QoS attributes.

(2) The weight of QoS attributes and the assessment on web services is an intuitionistic fuzzy number, so it is impossible to accurately calculate the ranking weight of web services. The modified intuitionistic fuzzy entropy is used to obtain the weights of QoS attributes, finally get the sequence of final web services through calculation.

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