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Shu-Yen Lee

Tsung-Yen Lee

Yeh-Jui Fey

Huey-Ming Lee

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Shu-Yen Lee [a], Tsung-Yen Lee [b], Yeh-Jui Fey [c], Huey-Ming Lee [d]

[a] BOT Project, China Engineering Consultants, INC. Taipei, Taiwan
[b] Department of Agricultural Economics, National Taiwan University, Taipei, Taiwan
[c] Department of Banking and Insurance, Ling Tung College, Taichung, Taiwan
[d] Department of Information Management, Chinese Culture University, Taipei, Taiwan
hmlee@faculty.pccu.edu.tw

Abstract

Information techniques have brought us tremendous benefit, whereas people are increasingly depended on lots of information systems. Therefore, how to establish an assessment model to choose a better software quality suitable for end-users is an important issue. This study is to present an algorithm of the group decision makers with crisp or fuzzy weights to tackle the integrated software quality for evaluating user satisfaction using fuzzy set theory, where the grades of quality and the grade of importance of quality items are assessed by linguistic values represented by triangular fuzzy numbers. The proposed algorithm is more flexible and useful than the ones that have presented before, since the weights against decision makers are considered.

1. Introduction

During the past decades, information industries have been flourishing in Taiwan. Compared to hardware information technologies, software engineering needs to improve more because more efforts are put into the development process than the control of software quality. Software products are powerful but hard to revise, modify, expand or transfer. Therefore, how to promote the quality of software is important.

Software quality was assessed with software attributes but its complexity and unpredictable nature cannot be easily processed. Therefore, how to build an effective software quality measure model becomes an important issue. In the early 1990s, the software engineering community attempted to consolidate the many views of quantity into one model that could act as a worldwide standard for measuring software quantity. The result was ISO 9126, a hierarchical model with six major attributes contributing to quality [7]. Since ISO 9000 is already widely used in industry and also corresponds with Satty's Analytical Hierarchy Process (AHP) [8], as shown in Table 1, we denote the attribute to be X_i and the items as X_{ij} [4-5, 7, 9].

Based on the algorithm developed in [4], Wang and Chiang [9] presented a software quality assessment model to evaluate user satisfaction. In [2], Fey et al. presented the simplified algorithm to tackle the user satisfaction. In [2, 9], they assumed the relative important weights of each evaluator to be the same. But, in general, the relative importance of each decision maker or expert probably may be widely different. Sometimes there are important experts in the group decision making, the final decision is influenced by the different importance of each expert. Therefore, the best method of aggregating experts' assessing data must consider the degree of importance of each expert in the aggregation procedure.

We reviewed the Wang and Chiang method [9], Fey et al. method [2] in Section 2, 3, respectively. In Section 4, we proposed the fuzzy group decision making for evaluating the user satisfaction.

2. A review of Wang and Chiang's method [9]

Based on Lee [4], when evaluating each item of software quality, we assign its grade of quality, and grade of importance [4, 9]. Then we range both of them into 11 ranks, as shown in Table 2 [4, 9].

We made the linguistic values 1, 2, …, 11 into corresponding reasonable fuzzy numbers with triangular membership functions as listed in Table 3 [4, 9].

By the multiplication of fuzzy number of grade of quality and fuzzy number of grade of importance, and the defuzzification g(a, i) by the centroid method, Lee derived the values of g(a,i) as shown in [4]. Based on [4], Wang and Chiang [9] constructed the ISO 9126 model into the structure model as shown in Table 4. The weight of quality attribute X_i is represented as W_i, while W_{ij} denotes the weight of item X_{ij}.

The criteria ratings are linguistic variables with values $V_1, V_2, V_3, V_4, V_5, V_6, V_7$ (as shown the figure in [4]), where V_1 = extra low, V_2 = very low, V_3 = low, V_4 = middle, V_5 = high, V_6 = very high, V_7 = extra high. These linguistic values are treated as fuzzy numbers with triangular membership functions [4]. Let

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V={ $V_1, V_2, V_3, V_4, V_5, V_6, V_7$ } be the set of the criteria rating of quality for each item. By fuzzy relation on X_ixV, we can form a fuzzy assessment matrix M(X_i) for X_ixV. Thus, fuzzy assessment matrix $M(X_2)$ for X_2 is formed as the following [4]:

$$M(X_2)=\begin{bmatrix} V(a_{21}, i_{21}, 1) & V(a_{21}, i_{21}, 2)... & V(a_{21}, i_{21}, 7) \\ V(a_{22}, i_{22}, 1) & V(a_{22}, i_{22}, 2)... & V(a_{22}, i_{22}, 7) \\ V(a_{23}, i_{23}, 1) & V(a_{23}, i_{23}, 2)... & V(a_{23}, i_{23}, 7) \end{bmatrix}$$

By using the same way, fuzzy assessment matrices $M(X_1), M(X_3) \ldots M(X_6)$ can be formed respectively. Then the first-stage aggregated assessment quality $R_2 = (W_{21}, W_{22}, W_{23}) \times M(X_2)$ for attribute X_2 . $R_1, R_3, \ldots R_6$ can be derived respectively.

The rate of aggregated quality of software quality for user satisfaction is calculated by using the second-stage assessment as the following formula:

$$(fW_1, fW_2, fW_3, fW_4, fW_5, fW_6, fW_7)$$

$$= (W_1, W_2, W_3, W_4, W_5, W_6) \times \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \\ R_5 \\ R_6 \end{bmatrix}$$

The final rate of aggregated quality of software quality for user satisfaction is then defuzzyfied by centroid method and becomes:

$$FW = \frac{\sum_{i=1}^{7} VG(i) \times fW_i}{\sum_{k=1}^{7} fW_k} = \sum_{i=1}^{7} VG(i) \times fW_i$$

where $\sum_{k=1}^{7} fW = 1$, $VG(i), i = 1 \ldots 7$, which are the centroids of $V_1, V_2 \ldots V_7$ [4] and VG (1)=0.0556, VG (2)=0.1667, VG (3)=0.3333, VG (4)=0.5, VG (5)=0.6667, VG (6)=0.8333, VG (7)=0.9444.

3. A review of Fey et al. method [2]

Step 1. Let

$$R2(k) = \frac{\sum_{j=1}^{n(k)} W_{(k,j)} * g(r_{kj}, i_{kj})}{\sum_{j=1}^{n(k)} W_{(k,j)}}$$

$$= \sum_{j=1}^{n(k)} W_{(k,j)} * g(r_{kj}, i_{kj})$$

$(\text{since} \sum_{j=1}^{n(k)} W_{(k,j)} = 1)$, k=1, 2, …, 6, where n(k) is the number of quality item for attribute X_k, then we have $n(1)$=4, n(2)=3, n(3)=3, n(4)=4, n(5)=4, n(6)=2; $g(r_{kj}, i_{kj})$ is the rate of quality item X_{kj} appeared in [4]; $W_{(k,j)}$ is the weight of quality item X_{kj}.

Step 2. The final rate of aggregative quality of the software quality for the user satisfaction is by the centroid method as follows:

$$\text{Let } R1 = \frac{\sum_{k=1}^{6} W_{(k)} * R2(k)}{\sum_{k=1}^{6} W_{(k)}}$$

$$= \sum_{k=1}^{6} W_{(k)} * R2(k)$$

$(\text{since} \sum_{k=1}^{6} W_{(k)} = 1)$, where $W_{(k)}$ is the weight of attribute of X_k, for k=1, 2, …, 6. Then, the value of R1 is the rate of aggregative quality of the software system for the user satisfaction.

4. A fuzzy group decision makers with crisp or fuzzy weights to evaluate the user satisfaction

In [5], Lee proposed an algorithm of the group decision makers with crisp or fuzzy weights to tackle the rate of aggregative risk in software development in fuzzy circumstances by fuzzy set theory during any phase of the life cycle. We applied this algorithm to this Section as follows:

Step 1: Let SAT(k) be the rate of aggregative quality of the software system for the user satisfaction for the evaluator D_k's assessing data, i.e., let SAT(k) be *FW(k)* in Section 2, or R1(k) in Section 3.

Step 2:

(A) Corresponding to the crisp relative importance of each decision maker or evaluator:

We assign $d_1, d_2, \ldots, d_n$ to be the relative weight of each evaluator $D_1, D_2, \ldots, D_n$. Then, we define

$$w(j) = \frac{d_j}{\sum_{k=1}^{n} d_k}, \text{ for } j=1, 2, \ldots, n$$

to be the normalization of $d_1, d_2, \ldots, d_n$.

(B) Corresponding to the fuzzy relative importance of each decision maker or evaluator:

We assign the relative fuzzy weight $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ to be the triangular fuzzy number in [0, 1] for the evaluator D_j for j=1, 2,. …, n. Defuzzzified $\tilde{w}_j = (w_{j1}, w_{j2}, w_{j3})$ by the classical centroid method, we obtain $w_j = \frac{1}{3}(w_{j1} + w_{j2}, + w_{j3})$

Normalize w_j, we obtain the degree of importance w(j) for the evaluator D_j as follows:

$$w(j) = \frac{w_j}{\sum_{k=1}^{n} w_k}, \text{ for } j=1, 2, \ldots, n.$$

Step 3: By Step 1 and Step 2, we have that the rate of aggregative quality of the software system for the user satisfaction for the evaluators with weights w(1), w(2), …, w(n) is

$$SAT\_User = \sum_{j=1}^{n} SAT(j) \cdot w(j)$$

The value of SAT_User is the rate of aggregative quality of the software system for the user satisfaction for the evaluators' assessing data. If there is only one evaluator to evaluate then we have the same formula as in [2] and [9].

5. Conclusion

The proposed algorithm of the group decision makers or evaluators with crisp or fuzzy weights for evaluating rate of aggregative quality of the software system for the user satisfaction is more useful and flexible than Wang and Chiang in [9] and Fey et al. in [2], since the weights against evaluators /decision makers are considered.

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Table 1: The ISO 9126 Sample Quality Model [6]

	Attribute (X_i)	Item (X_{ij})
Software quality	X_1 Functionality	X_{11} Suitability
		X_{12} Accuracy
		X_{13} Interoperability
		X_{14} Security
	X_2 Reliability	X_{21} Maturity
		X_{22} Fault tolerance
		X_{23} Recoverability
	X_3 Usability	X_{31} Understandability
		X_{32} Learnability
		X_{33} Operability
	X_4 Maintainability	X_{41} analyzability
		X_{42} Changeability
		X_{43} Stability
		X_{44} Testability
	X_5 Portability	X_{51} Adaptability
		X_{52} Installability
		X_{53} Conformance
		X_{54} Replaceability
	X_6 Efficiency	X_{61} Time behavior
		X_{62} Resource behavior

Table 2: Linguistic values of grades of quality and grades of importance

Eleven ranks of grade of quality	Eleven ranks of grade of importance
1: Definitely low	1: Definitely important
2: Extra low	2: Extra unimportant
3: Very low	3: Very unimportant
4: Low	4: Unimportant
5: Slightly low	5: Slightly unimportant
6: Middle	6: Middle
7: Slightly high	7: Slightly important
8: High	8: Important
9: Very high	9: Very important
10: Extra high	10: Extra important
11: Definitely high	11: Definitely important

Table 3: Fuzzy numbers of grade of quality and grade of importance

Grade of quality	Fuzzy number	Grade of importance	Fuzzy number
1	N_1=(0.0,0.0,0.1)	1	N_1=(0.0,0.0,0.1)
2	N_2=(0.0,0.1,0.2)	2	N_2=(0.0,0.1,0.2)
3	N_3=(0.1,0.2,0.3)	3	N_3=(0.1,0.2,0.3)
4	N_4=(0.2,0.3,0.4)	4	N_4=(0.2,0.3,0.4)
5	N_5=(0.3,0.4,0.5)	5	N_5=(0.3,0.4,0.5)
6	N_6=(0.4,0.5,0.6)	6	N_6=(0.4,0.5,0.6)
7	N_7=(0.5,0.6,0.7)	7	N_7=(0.5,0.6,0.7)
8	N_8=(0.6,0.7,0.8)	8	N_8=(0.6,0.7,0.8)
9	N_9=(0.7,0.8,0.9)	9	N_9=(0.7,0.8,0.9)
10	N_{10}=(0.8,0.9,1.0)	10	N_{10}=(0.8,0.9,1.0)
11	N_{11}=(0.9,1.0,0.0)	11	N_{11}=(0.9,1.0,0.0)

Table 4: The contents of structure model [2, 4, 9]

Attribute	Weight (w_i)	Item	Weight (w_{ij})	Grade of quality (a)	Grade of importance (i)	Defuzzication g (a, i)
X_1	W_1	X_{11}	W_{11}	a_{11}	i_{11}	g (a_{11}, i_{11})
		X_{12}	W_{12}	a_{12}	i_{12}	g (a_{12}, i_{12})
		X_{13}	W_{13}	a_{13}	i_{13}	g (a_{13}, i_{13})
		X_{14}	W_{14}	a_{14}	i_{14}	g (a_{14}, i_{14})
X_2	W_2	X_{21}	W_{21}	a_{21}	i_{21}	g (a_{21}, i_{21})
		X_{22}	W_{22}	a_{22}	i_{22}	g (a_{22}, i_{22})
		X_{23}	W_{23}	a_{23}	i_{23}	g (a_{23}, i_{23})
X_3	W_3	X_{31}	W_{31}	a_{31}	i_{31}	g (a_{31}, i_{31})
		X_{32}	W_{32}	a_{32}	i_{32}	g (a_{32}, i_{32})
		X_{33}	W_{33}	a_{33}	i_{33}	g (a_{33}, i_{33})
X_4	W_4	X_{41}	W_{41}	a_{41}	i_{41}	g (a_{41}, i_{41})
		X_{42}	W_{42}	a_{42}	i_{42}	g (a_{42}, i_{42})
		X_{43}	W_{43}	a_{43}	i_{43}	g (a_{43}, i_{43})
		X_{44}	W_{44}	a_{44}	i_{44}	g (a_{44}, i_{44})
X_5	W_5	X_{51}	W_{51}	a_{51}	i_{51}	g (a_{51}, i_{51})
		X_{52}	W_{52}	a_{52}	i_{52}	g (a_{52}, i_{52})
		X_{53}	W_{53}	a_{53}	i_{53}	g (a_{53}, i_{53})
		X_{54}	W_{54}	a_{54}	i_{54}	g (a_{54}, i_{54})
X_6	W_6	W_{61}	W_{61}	a_{61}	i_{61}	g (a_{61}, i_{61})
		W_{62}	W_{62}	a_{62}	i_{62}	g (a_{62}, i_{62})