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A Method for Determining Importance Degree of Customer Requirements in Software Quality Function Deployment

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Abstract
A method based on Fuzzy Analytic Hierarchy Process was provided to determine customer requirements in this study, and the importance degree was analyzed by using trapezoid fuzzy function. The method overcame the impact on subjective judgments & preference, and caused decision-making more reasonable. Finally, the effectiveness and practicality of the method was verified by the example of fetching customer requirement in the process of software project development.
Keywords Analytic Hierarchical Process, Customer requirements, Quality function deployment, House of Quality

1 Introduction

Software is a product that integrating knowledge and procedure. Software engineers must focus on how to consider the maximum requirements of users in programming. Therefore, the software must be designed to collect and analyze customer requirements, and be oriented to maximize the value of customers in the whole software development. However, what are customer requirements for a complex problem must be investigated and analyzed. Data existing software programming showed that more than 50% unsuccessful projects of software development occurred in the wrong requirement analysis.

Quality function deployment (QFD) is a widely used customer-driven quality, design and manufacturing management tool. It is becoming a methodology of modern design theory applied for new products design and old products improvement[1-3]. Customer requirements were mapped to the corresponding technical characteristics of products design that will be around customer requirements by the House of Quality (HOQ) in QFD[4]. But the success rate of traditional QFD is subject to restrictions because of various shortcomings, such as: fussy process, too large matrix, complicated manual calculation, unreasonable score mechanism. For the determination of the house of quality problems, the non-linear programming method that determined customer demands and technical requirements of the relationship was provided by large number of experimental data in quotation[5], and the method of multi-feature map based on Taguchi theory was used to obtain the above-mentioned relationship in quotation[6]. However, these methods must rely on a large number of relevant experimental data. Consequently, the experimental time and cost will be fundamental obstacles.

With the development of decision-making and information science, Fuzzy Analytic Hierarchy Process (FAHP) is more and more widely applied in various fields[7-8]. It decreased subjective judgmental errors account of the fuzzy factor, so the final set of index weight are more realistic. Based on this, the algorithm model based on FAHP was provided to determine the importance degree in this study, and applied to get customer requirements in software programming.

2 Structure of Software Quality Function Deployment Methodology

2.1 House of Quality

The core of QFD is the demand for conversion, the house of quality, that is QFD matrix, is a quality function deployment plans that associate with customer requirements and technical characteristics of products. Software QFD run through the whole process of software development, which is derived from manufacture QFD and originated in Japan[9]. The house of quality of Software QFD is similar to the traditional QFD, as is shown in Fig.1:

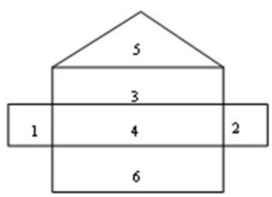

Fig.1 Structure of HOQ

The house of quality can converted customer requirements to the quality characteristics. It is composed of six matrices, as is shown in Fig.1: (1) WHATS matrix, said customer demand; (2) Plan matrix, said the evaluation of WHATS matrix. (3) HOWS matrix, the demands for what to do; (4) the relationship matrix, the relationship between WHATS and the HOWS; (5) the matrix of HOWS inner relationship; (6) Technology matrix, said that the evaluation of the technical cost: comparison of competitiveness or feasibility. The conversion of “what needs” to “how to do” was completed after building house of quality.

2.2 Process of QFD Implementation

In general, the implementation of software QFD consists of two basic processes: the extraction of customer requirements and waterfall decomposition of customer requirements. Information of customer requirements through face-to-face, telephone, e-mail, network, on-site investigation, after-sales service, were collected, classified, organized and analyzed to form well-organized user requirements and weighted importance degree. Then, Software engineers disassembled customer requirements and constructed HOQ according to technical feasibility, practicability, economy and other aspects. The importance degree of QFD indexes were determined after completed above process.

3 Model of Determining Importance Degree of Customer Requirements in Software QFD Based on FAHP

3.1 Algorithm of FAHP

It is reasonable decision-making for FAHP because of overcoming shortcomings of human subjective judgments, choices and preferences. This study was used trapezoidal fuzzy number to score the weight because it is more accordant with actual states and more extensive application, although trigonometric number, logarithmic trigonometric number, normal distribution function can be used while scoring. FAHP algorithm steps are as follows:

Step 1: Hierarchical structure construction.

Put the goal of the desired problem on the top layer of the hierarchical structure, and then put the evaluation criteria on the second layer of the hierarchical structure. Further, the third layer is the sub-indexes of evaluation criteria. Finally, the candidate alternatives lay in the bottom layer. Hierarchical structure is shown in Fig.2.

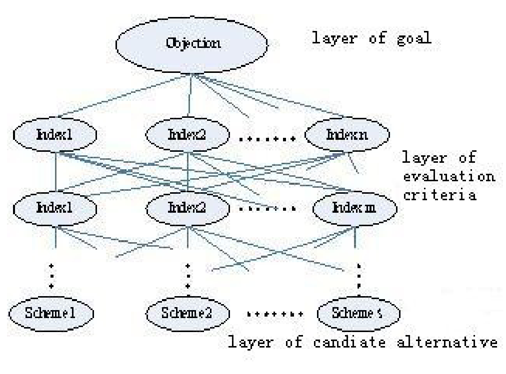

Fig.2 Hierarchical structure

Step 2: Constructing the fuzzy judgment matrix

In this study, the fuzzy judgment matrix X is the matrix of the combination of each candidate alternative and evaluation criteria, and the fuzzy judgment matrix X is represented by trapezoid fuzzy numbers such as 1, 3, 5, 7 and 9; the values are shown in Tab.1. The judgment matrix is as follows:

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \vdots & \vdots & \dots & \vdots \\ x_{n1} & x_{n2} & \dots & x_{nn} \end{bmatrix}$$

Where $x_{ij} = (a_{ij}, b_{ij}, c_{ij}, d_{ij},)$, and $a_{ij}, b_{ij}, c_{ij}, d_{ij}$ denote four values of trapezoid fuzzy numbers respectively.

Table 1 Membership of trapezoid fuzzy numbers

Meaning of relative importance	Scale of relative importance	Value of fuzzy numbers
Equal importance	1	(1, 1, 1, 1)
Weak importance	3	(2, 2.5, 3.5, 4)
Strong importance	5	(4, 4.5, 5.5, 6)
Demonstrated importance	7	(6, 6.5, 7.5, 8)
Absolute importance	9	(9, 9, 9, 9)

Step 3: Testing the consistency of the matrix and calculating fuzzy weights

Testing the consistency of fuzzy matrix after clarifying above fuzzy matrix, algorithm of testing the consistency of AHP is described in quotation[10]. Return to Step 2 to re-structure trapezoidal fuzzy judgment matrix and calculate it until the consistency is passed, and then, calculating fuzzy weights, fuzzy weighting formula is defined as follows:

$$D_{\bar{X}} = \sum_{j=1}^{n} x_{ij} \otimes \left(\sum_{i=1}^{n} \sum_{j=1}^{n} x_{ij} \right)^{-1} \tag{1}$$

Where $\bar{X}$ is judgment matrix, x_{ij} is the element of judgment matrix.

Step 4: Single sorting weight of same hierarchy

For any of two trapezoidal fuzzy numbers M and N, the possibility of $M \geq N$ is following results.

Theorem:

Suppose $M = (r_1, r_2, r_3, r_4)$, $N = (s_1, s_2, s_3, s_4)$ are two trapezoidal fuzzy numbers, then the possibility degree is

$$V(M \geq N) = \begin{cases} 1 & r_3 \geq s_2 \\ \frac{r_4 - s_1}{(r_4 - r_3) + (s_2 - s_1)} & r_3 \leq s_2, r_4 \geq s_1 \\ 0 & r_4 \leq s_1 \end{cases} \tag{2}$$

Where
$r_1 > 0, r_2 > 0, r_3 > 0, r_4 > 0, s_1 > 0, s_2 > 0, s_3 > 0, s_4 > 0$

Approach to sorting the weights of hierarchical indexes is as follows:

(1) Calculating possibility degree of $D_{\bar{X}_1} \geq D_{\bar{X}_2}, \ldots, D_{\bar{X}_1} \geq D_{\bar{X}_n}$ .Calculating possibility degree of $D_{\bar{X}_1} \geq D_{\bar{X}_2}, \ldots, D_{\bar{X}_1} \geq D_{\bar{X}_n}$ according to formula (2), that is

$$V\left(D_{\bar{X}_1} \geq D_{\bar{X}_2}\right), V\left(D_{\bar{X}_1} \geq D_{\bar{X}_3}\right), \ldots, V\left(D_{\bar{X}_1} \geq D_{\bar{X}_n}\right).$$

(2) Calculating the possibility value that $\bar{X}_1$ is greater than other matrices.

$$d\left(\bar{X}_1 = minV\left(D_{\bar{X}_1} \geq D_{\bar{X}_2}, D_{\bar{X}_3}, \ldots, D_{\bar{X}_n}\right)\right)$$

And analog,$d\left(\bar{X}_2\right)$,$d\left(\bar{X}_3\right)$,$\ldots d\left(\bar{X}_n\right)$ can also be calculated.

(3) Normalizing the matrix and getting the weight vectors$\left(W_{\bar{X}_1}, W_{\bar{X}_2} \ldots W_{\bar{X}_N}\right)$.

Step 5: Sorting the general hierarchy

The sorting general hierarchy means that weights of all schemes are ordered in the layer of candidate alternative. The general sorting value is the weight of the scheme multiply the value of single sorting of the same hierarchy.

3.2 Application

In accordance with steps of FAHP, calculated as follows:

Step 1: Constructing trapezoidal fuzzy judgment matrix, testing consistency and completing the single-sort in the same hierarchy.

(1) Constructing trapezoidal fuzzy judgment matrix $\bar{C}$ in C layer and calculating weight.

The trapezoidal fuzzy judgment matrix $\bar{C}$ is as follows:

$$\bar{C} = \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} = \begin{bmatrix} (1,1,1,1) & (1,1.5,2.5,3) \\ (0.333,0.4,0.6667,1) & (1,1,1,1) \end{bmatrix}$$

(2) Calculating synthetically fuzzy values.

$$D_{C_1} = \sum_{j=1}^{2} x_{1j} \otimes \left\{ \sum_{i=1}^{2} \sum_{j}^{2} x_{ij} \right\}^{-1} = (0.3334, 0.4838, 0.8974, 1.2)$$

$$D_{C_2} = (0.2223, 0.2709, 0.4237, 0.6)$$

(3) Single sorting in C layer.

Single sorting in C layer using step 4 of section 3.1, then

$$d(C_1) = minV\left(D_{C_1} \geq (D_{C_2}\right) = 1 \quad d(C_2) = minV\left(D_{C_2} \geq (D_{C_1}\right) = 0.8251.$$

The weight can be concluded while normalizing the matrix, it is shown as follows:

$$\left(W_{C_1}, W_{C_2}\right) = (0.5479, 0.5421), \text{and then}$$

$$(W_{R_1}, W_{R_2}, W_{R_3}) = (0.5270, 0.4730, 0.0007)\,,$$
$$(W_{S_1}, W_{S_2}) = (0.5479, 0.4521)\,.$$

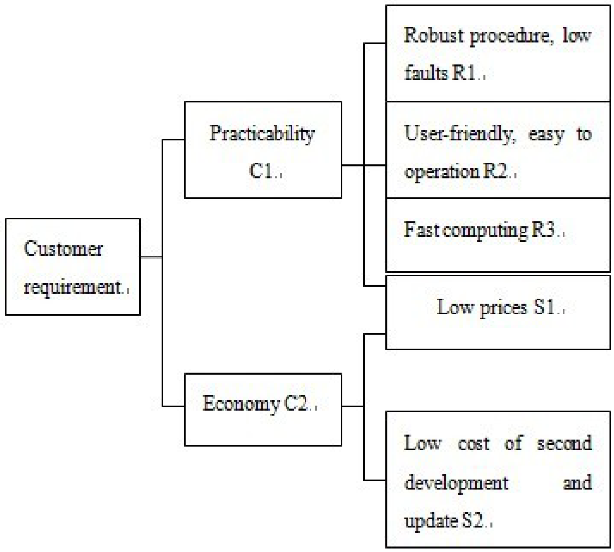

Fig.3 Hierarchical structure of software QFD development

Step 2: Sorting the general hierarchy.

$$V_{R_1} = W_{R_1} \times W_{C_1} = 0.5479 \times 0.5270 = 0.2883,$$
$$V_{R_2} = 0.2592, V_{R_3} = 0.0004,$$
$$V_{S_1} = 0.2477, V_{S_2} = 0.2044.$$

Therefore, the general sorting and respective weight is as follows:
$R_1(0.2883), R_2(0.2592), S_1(0.2477), S_2(0.2044), R_3(0.0004)$.

As can be seen from the result the most important customer requirements are robust procedure & low faults, user-friendly & easy to operation and low prices.

4 Conclusion

It is very important to determine the importance degree, relationship degree and competitive forces in HOQ. In this study, FAHP method is used to determine the importance degree of customer requirements of the effective factors in the model of software QFD. Humans are often uncertain in assigning the evaluation scores in conventional AHP. FAHP can capture the vagueness of human thinking style and effectively solve multi-criteria decision making problems. By using FAHP and appropriate calculations, there are extremely accurate for fetching customer requirements and the quality characteristics. The application shows that FAH-P can access to design new products, software development and evaluation of customer satisfaction that provide a new thinking for exactly getting customer requirements.

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