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Weight Analysis based on ANP and QFD in Software Quality Evaluation

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Abstract: Over the past two decades, considerable efforts focused on improving software quality to satisfy the customers needs in software industry, but it is hard to deal with the customers needs for its vague and inexact characteristic. In order to evaluate software quality accurately and comprehensively, the weights of customers needs and the weights of technical attributes of the software are determined by ANP and QFD in the paper. An illustrated example is presented to show the application of the proposed model, and the results show that the weights of product characteristics and the customers needs in HoQ (House of Quality) analyzed by ANP can make software quality more accurate and comprehensive in software quality evaluation.

Keywords: software quality, quality function deployment, analytic network process

1 Introduction

With the development of economy, a large number of software products widely used in all aspects of life have been produced. However, the satisfaction of customers to these software products could not be guaranteed very well so far, which easily lead to poor quality of these software products. It is important to study the method of software quality evaluation to make sure that the products better meet the customers needs.

Software products are very different from other products. One important difference we can not ignore is that software products are often based on a user's specific needs. Each software is produced by different demands put forward by customers. For example, military applications have more requirements for security, but software for the aerospace, real-time should belong to high reliability. It is important to make clear the customers needs and the relative importance of each demand before programming. The weight of each customers needs should be calculated quantitatively if you want to satisfy the customer. The so-called weight, is a relative concept, the weight of an indicator is the relative importance in the overall evaluation. In this paper, we mainly study the weight of the customers needs and the weight of technical attributes of the software.

Many scholars have made a lot of researches for the determination of the weight. In China, some early researchers usually used the expert scoring method to determine the target weight, which mainly made use of expert experience to estimate the relative importance of indicators. However, the expert scoring method has many disadvantages which easily lead to large errors because of its strong subjectivity. Many scholars have applied other methods to determining the weight of indicators, and a lot of theories and methods have been studied in this field. For example, some scholars have applied principal component analysis to analyzing the weights which adopts the theory of dimensionality reduction to cut the original interrelated indicators integrated into fewer new indicators, which contain the main information of original indicators[1]. It could reduce the computational complexity of the problem by the principal component analysis method to analyze the weights of indicators when it comes to a small problem, but the calculation becomes much complicated when the scale of the problem gets larger. Many scholars analyzed the indicators weight with the rough set theory which focuses on the situation whose information is not complete[2]. At present, one of the most popular methods is AHP, which decomposes elements into three layers: objectives, guidelines, and properties and take qualitative analysis on this basis. Some researches combined AHP with the

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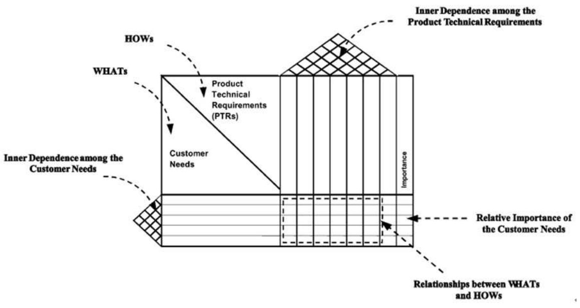

Fig. 1: House of quality

quality of house to determine the weight of the indicators. However, AHP decision-making is only emphasized one-way relationship between the levels, which focuses on the impact between two levels, but in a lot of complex problems, the elements in the same layer also could interact each other[3,9]. For example, the interaction between the properties of software product can not be ignored in software quality evaluation. In this paper, we propose the use of the analytic network process (ANP) to incorporate the inner dependence into customer needs and properties in HoQ(Quality of House). ANP enables us to take the degree of interdependences between customers needs and properties by means of AHP into consideration, which better express the ”voice of the user”[4,5,12].

2 Quality Function Deployment (QFD) and literature review

Quality Function Deployment (QFD) is a key tool for application of concurrent engineering and implementing total quality management, which emphasizes providing a coherent response to customers needs in the process of product planning, product design, process planning, and production planning. In other words, QFD can be seen as a set of planning tools, which help introducing new or improved products faster to market by focusing on the customers satisfaction.

The basic concept of QFD is to translate the needs of customers (CNs), in other words, voice of customer, into product technical requirements (PTRs) or engineering characteristics, and subsequently into parts characteristics, process plans, and production requirements related to its manufacture. Each translation uses a chart, called House of Quality(HoQ)[3]. The components of HoQ are displayed in Fig. 1.

(1) Customers needs (WHATs). This part is called the voice of the customer or customers requirements. It is the initial input for the HoQ and points at to the product characteristics which should be paid attention to. Customer needs, usually collected by focus groups or individual interviews, should be expressed in customers own phrases. Preserving customers own words usually causes problems during the phase of translation and interpretation since they are usually too general and/or detailed to be directly used as customer needs. A number of approaches are used in order to overcome this problem. Initially the words are collected, and then they are organized to form a tree-like hierarchy usually with three or four levels. Those at the appropriate level are chosen as the final customer needs. Affinity diagram, which is a method used to gather large amounts of qualitative data and to organize them into subgroups based on the similarities between them, can be used for this purpose. Cluster analysis can also be used to form and structure customer needs.

(2) PTRs (HOWs). PTRs are also known as product features or product attributes. They can also be developed using the affinity diagram and tree diagram. They describe the product in the language of the engineer. Therefore, they are sometimes referred to as the voice of the company. The PTRs are used to determine how well the company satisfies the customer needs. Customer needs tell the company what to do while the PTRs tell how to do it.

(3) Relative importance of the customer needs. Because the collected and organized data from the customer usually contain too many needs to deal with simultaneously, the company have to trade off one benefit against another, and work on the most important needs while disregarding relatively unimportant ones. In this manner, customers are surveyed using 5-, 7- or 9-point scales.

(4) Relationships between WHATs and HOWs. The relationship matrix indicates how much each PTR affects each customer need. The relations can either be presented in numbers or symbols. In this paper, we will use numbers to denote the relationship between WHATs and HOWs.

(5) Inner dependence among the customer needs. In general, customer needs have inner dependence among them. Some of them will support each other whereas others will adversely affect the achievement of others. These supporting and conflicting needs can be identified by a correlation matrix emphasizing necessary trade-offs.

(6) Inner dependence among the PTRs. The HoQs roof matrix is used to specify the various PTRs that have to be improved collaterally, and provide a basis to calculate to what extent a change in one feature will affect other features. A desirable change in one feature may result in a negative effect on another feature. This correlation facilitates the necessary engineering impacts and trade-offs. The HoQ is usually built by using the seven elements mentioned above. With its design-oriented nature, the HoQ serves not only as a valuable resource for designers but also as a way to summarize and convert feedback from customers into information for engineers. In addition, marketing can benefit from it since it is based on the voice of customer, and upper management can use it to develop strategic opportunities. Hence, the HoQ strengthens vertical and horizontal communications. Once

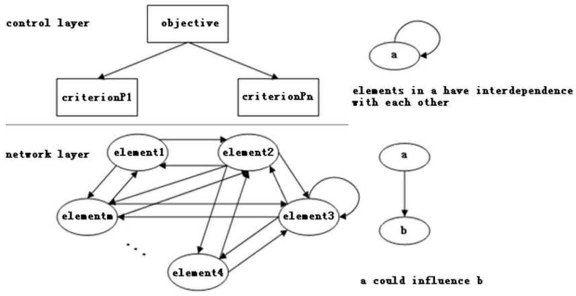

Fig. 2: Typical structure of ANP

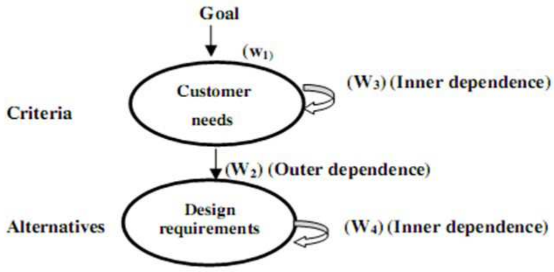

Fig. 3: The network relationship in QFD

having identified critical PTRs that demand change, they will be driven to the next matrix as WHATs to identify the critical parts characteristics.

3 The analytic network process (ANP) and its usage in QFD

Analytic network process is a widely used multi-attribute decision-making approach, which expands the network relationships of elements in AHP to the network relationships to analyze problems. AHP is a special case of analytic network process. The core of AHP is to make level for the system and only takes the dominant role from the upper level to the lower level into consideration, the elements on the same hierarchy is considered to be independent of each other. However, in many cases, the relationship between elements of the system is not a simple hierarchy, but a complex network of relationships, so AHP is not suitable to analyze the complex network relationships[4,6,8].

The decision-making level in AHP is an unidirectional hierarchy, but analytic network process can take the inter-relationship into account between decision-making level and elements, and there is no strict hierarchy, shown in Fig 2, nodes representing the system components, arrows indicating the relationship between them, the arrows indicating the direction of dependency.

The method of determining the value of relative importance of elements in analytic network process is similar to level analysis, which is by the way of comparing. It applies the range standard of 1-9, in which 1 represents the same value of importance between two elements, and 9 represents one element is far more important than the other one. If a_{ij} represents the relative importance from the ith element to the jth element,

$$a_{ji} = \frac{1}{a_{ij}} \quad (1)$$

represents the relative importance from the jth element to the ith element[7,11,13].

Generally speaking, ANP is composed of two stages. The first stage is the composition of network, and the other is to calculate the priority value of each element. Constructing the architecture of network should take the relationships of all elements into consideration. Super-matrix is used to represent the interaction of elements. A super- matrix which has three hierarchies is shown as follows:

$$W = \begin{array}{r} \\ Goal(G) \\ Criteria(C) \\ Alternative(A) \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{pmatrix} 0 & 0 & 0 \\ w_{21} & 0 & 0 \\ 0 & W_{32} & I \end{pmatrix} \end{array}$$

The Vector w_{21} represents the influence from target level to the criterion level, and matrix W_{32} represents the influence from criterion level to each attribute element. I is unit matrix [4,10].

4 The decision methodology

The decision algorithm addresses the problem of selecting the PTRs which are focused on in the design process considering the predetermined goals. The algorithm can be divided into two major phases. In the first phase, the HoQ is constructed by using the ANP approach, and in the second phase, we determine the set of PTRs that the design team needs to concentrate on based ANP.

The network relationships in QFD is implemented by adding the internal links between elements. In the structure of QFD, customer needs (CNs) corresponds to the criteria in ANP, and there are interdependent relationships between customer needs. The network representation in QFD model is based on the structure of a hierarchy with inner dependencies within components and no feedback. In this situation, the CNs correspond to the alternatives, which have inner dependencies within themselves, as shown in Fig.3:

The first step of the network representation in QFD model is the identification of the CNs and PTRs. Then, the importance of the CNs is determined, which corresponds to the matrix manipulation concept of the ANP in the first step. Next, the body of the house will be filled through comparing the PTRs with respect to each

CN. Finally, the interdependent priorities of the PTRs will be obtained by analyzing dependencies among the CNs and PTRs. The supermatrix representation of the QFD model used in this study is as follows:

$$W = \begin{matrix} \\ Goal(G) \\ CustomerNeeds(CNs) \\ ProductTechnicalRequirements \end{matrix} \begin{matrix} G & CNs & PTRs \\ \left(\begin{matrix} 0 \\ w_1 \\ 0 \end{matrix}\right. & \begin{matrix} 0 \\ W_3 \\ W_2 \end{matrix} & \left.\begin{matrix} 0 \\ 0 \\ W_4 \end{matrix}\right) \end{matrix}$$

where W_1 is a vector on the CNs that represents the impact of the goal, namely manufacturing a product that satisfies the customer.W_2 is a matrix that denotes the impact of the CNs on each of the PTRs.W_3 and W_4 are the matrices that represent the inner dependence of the CNs and the inner dependence of the PTRs respectively[3,4,14,15].

The evaluation algorithm steps for determining the overall priorities of the PTRs as follows:

Step 1. Identifying CNs and determining the PTRs matching the CNs.

Step 2. Determining the importance degrees of CNs with linguistic data by assuming that there is no dependence among the CNs: Calculation of W_1.

Step 3. Determining the importance degrees of PTRs with respect to each CN with linguistic data by assuming that there is no dependence among the PTRs: Calculation of W_2.

Step 4. Determining the inner dependency matrix of the CNs with respect to each CN with linguistic data by utilizing the schematic representation of inner dependence among CNs: Calculation of W_3.

Step 5. Determining the inner dependency matrix of the PTRs with respect to each PTR with linguistic data by utilizing the schematic representation of inner dependence among PTRs: Calculation of W_4.

Step 6. Determining the interdependent priorities of the CNs: Calculation of w_c=W_3*w_1.

Step 7. Determining the interdependent priorities of the PTRs: Calculation of w_A=W_2*W_4.

Step 8. Determining the overall priorities of the PTRs: Calculation of w^{ANP}=w_c*w_A.

5 Case study−empirical application

Search engines are widely used in internet as a tool of information search. In the paper the methods presented in previous will be used to analysis demand weight and technology weight of this information search. The house of quality used in this example is showed in Fig.4 [9]:

Step 1:The example including five user demands which are expandability, reliability, speed, correctness and usability via the demand analysis. The eight software feature that may impact the user demand respectively is response time, database size, accuracy, language number, unique hits, dead links, update time, format number.

Step 2:In this step, assuming that there is no any dependence among each user demand and the initial

	PTRs	RT	DS	PR	LA	UH	DL	UT	FRT
	Response Time		■						
	Database size	■			■		■		■
	Precision					■			
	Languages		■						
	Unique Hits			■					
	Dead Links		■						
	Update Time								
	Format Numbers		■						
CNs	RI								
expandibility	2.0		■		■				■
reliability	3.0			■			■	■	
speed	4.0	■							
correctness	1.0					■		■	
usability	5.0	■				■	■		

Fig. 4: The HoQ of Search engine

Table 1: Relative importance of the product characteristic relative to reliability

reliability	precision	dead links	update time	relative importance
precision	1	9	3	0.719
dead links	1/9	1	3	0.166
update time	1/3	1/3	1	0.115

relative importance of user demand can be obtained through the questionnaire for the users. In the example, the initial relative importance of user demand is obtained through the questionnaire C Which need is more important and how important it is in the design of this search engines, normalize the data and get the vector quantity w_1.

$$W = \begin{pmatrix} expandability \\ reliability \\ speed \\ correctness \\ usability \end{pmatrix} = \begin{pmatrix} 0.133 \\ 0.2 \\ 0.267 \\ 0.067 \\ 0.333 \end{pmatrix}$$

Step 3: Assuming that there is no any dependence among each product characteristic in the design of this search engines and acquiring the relative importance of the product characteristic relative to the user demand through the paired comparison. For example, for the reliability in the user demand, the relative importance of the product characteristic can be obtained through the questionnaire Cwhich is more important for reliability and accuracy relative to dead links and how important it is, which is showed in table 1. The same method can be used to obtain the relative importance of the other product characteristic relative to the user demand and then get the matrix W_2, which is showed in table 2.

Step 4: Analyzing the dependent relation among each user demand, which is showed in Fig.5. The relative importance of each user demand relative to the other user demand can be determined through the Paired comparison. For example, for the correctness in the user demand, the relative importance of the product characteristic can be determined through the

Table 2: Relative importance of the product characteristic relative to each user demand

W_2	expandabilit	reliability	speed	correctness	usability
response time	0.000	0.000	1.000	0.000	0.375
database size	0.600	0.000	0.000	0.000	0.000
precision	0.000	0.719	0.000	0.719	0.000
language number	0.200	0.000	0.000	0.000	0.000
unique hits	0.000	0.000	0.000	0.166	0.125
dead links	0.000	0.166	0.000	0.000	0.125
update time	0.000	0.115	0.000	0.115	0.000
format number	0.200	0.000	0.000	0.000	0.375

Table 3: Relative importance of each user demand relative to correctness

correctness	reliability	usability	correctness	relative importance
reliability	1	3/5	3/4	0.223
usability	5/3	1	5	0.59
relative importance	4/3	1/5	1	0.187

Table 4: Relative importance among each user demand

W_3	expandability	reliability	speed	correctness	usability
expandability	0.286	0	0	0	0.133
reliability	0	0.333	0	0.223	0.2
speed	0	0	0.444	0	0.267
correctness	0	0.111	0	0.187	0.067
usability	0.714	0.556	0.556	0.59	0.333

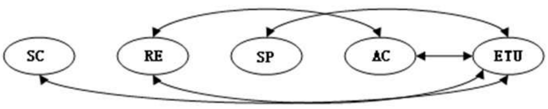

Fig. 5: codependent relations among each user demand

questionnaire Cwhich is more important for response time relative to usability and how important it is, which is showed in table 3. The same method can be used to obtain the relative importance of the other user demand and then get the matrix W_3 , which is showed in table 4.

Step 5: In this step the relative importance among the product characteristic is discussed and the dependent relation of the product characteristic is analyzed, which is showed in Fig.6. We also determine the relative importance of the product characteristic through the method of Paired comparison. For example, for the database size in the product characteristic, we determine the relative importance of the product characteristic through the questionnaire Cwhich is more important for database size with response time relative to language number and how important it is, which is showed in table 5. We can to obtain the relative importance of the other

Table 5: Relative importance of the product characteristic relative to database size

	response time	language number	dead links	format number	database size	relative importance number
response time	1	4.5/2	4.5/4	4.5/3.5	4.5/2	0.281
language number	2/4.5	1	1/2	2/3.5	1	0.125
dead links	4/4.5	2	1	4/3.5	2	0.25
format number	3.5/4.5	3.5/2	3.5/4	1	3.5/2	0.219
database size	2/4.5	1	1/2	2/3.5	1	0.125

Table 6: Relative importance among the characters of the product

W_4	database size	response time	accuracy	language number	special click	dead links	update time	format number
database size	0.692	0.281	0	0	0	0	0	0
response time	0.308	0.125	0	0.5	0	0.333	0	0.364
accuracy	0	0	0.4	0	0.4	0	0	0
language number	0	0.125	0	0.5	0	0	0	0
unique hits	0	0	0.6	0	0.6	0	0	0
dead links	0	0.25	0	0	0	0.667	0	0
update time	0	0	0	0	0	0	1	0
format number	0	0.219	0	0	0	0	0	0.636

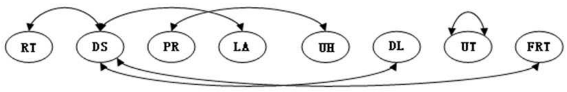

Fig. 6: Codependent relations among the product characteristic

user demand by the same method and then get the matrixW_4, which is showed in table 6.

Step 6: The initial weight of user demand and the relative importance among each user demand have been obtained in the previous step. The weight vector quantity w_c in the consideration of the dependent relation will be worked out in this step.

$$w_c = W_3 * w_1 = \begin{pmatrix} 0.082 \\ 0.148 \\ 0.208 \\ 0.057 \\ 0.505 \end{pmatrix}$$

Step 7: Working out the dependent matrix W_A of the product characteristic through the product characteristic relative to demand weight matrix which each user needed and the relative importance matrix among the product characteristic.

$$W_A = W_4 * W_2 = \begin{pmatrix} 0.169 & 0 & 0.692 & 0 & 0.26 \\ 0.248 & 0.055 & 0.308 & 0 & 0.294 \\ 0 & 0.288 & 0 & 0.354 & 0.05 \\ 0.175 & 0 & 0 & 0 & 0 \\ 0 & 0.431 & 0 & 0.531 & 0.075 \\ 0.15 & 0.111 & 0 & 0 & 0.083 \\ 0 & 0.115 & 0 & 0.115 & 0 \\ 0.259 & 0 & 0 & 0 & 0.239 \end{pmatrix}$$

Step 8: The total weigh number W^{ANP} of the product characteristic will be obtained, which can sufficiently show the correlation between the user demand of product in quality house and the product characteristic.

$$W^{ANP} = W_A * w_c = \begin{pmatrix} responsetime \\ databasesize \\ accuracy \\ languagenumber \\ uniquehits \\ deadlinks \\ updatetime \\ formatnumber \end{pmatrix} = \begin{pmatrix} 0.289 \\ 0.241 \\ 0.088 \\ 0.144 \\ 0.132 \\ 0.071 \\ 0.024 \\ 0.142 \end{pmatrix}$$

6 Conclusions

In this paper, the methods to determine the weight of customer needs and the weight of technical attributes of the software with ANP used in QFD have been studied. It is more accurate and comprehensive that the weight of the product characteristics and the user needs in HoQ (House of Quality) are analyzed by ANP, which can effectively improve the accuracy of software quality evaluation by applying this method to the software quality evaluation.

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