Most Optimum Component Composition Based on Multi-attribute Utility Function

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Summary
In component-based software development, component composition is one of the important factors to ensure the successful system development. Among component combination, a variety of factors must be taken into consideration. However, these factors are always incomparable so that it is difficult to make an effective choice. This paper introduces multi-attribute utility function to improve the accuracy of decision-making. By converting incommensurable objective function or criteria to single objective function, and combining with the AHP method, our appraoch can achieve the most optimum combination of components.

Key words:
CBD; component composition; AHP; multi-attribute utility function

1. Introduction

With the development of software engineering, component-based software reuse is considered to be one of the effective ways to improve software productivity. Component-based development has become the latest hot spot in the field of software engineering in recent years. Its main contribution is to improve productivity, reduce time to market, improve software quality, decrease maintenance cost. It is allowed interaction between different applications, at the same time, it reduces risk improve the system's functionality eventually. The precondition of achieving the above-mentioned is optimal reuse and optimal component combination. Then question is how to combine component to achieve biggest advantage after combination.

Optimal component combination is one of the key technologies for component-based development successfully. At present, some improvement must be made in the field of Component combination. Developers always make decision of component selection and combination according to their own subjective judgments, Lacking of certain objectivity and combination standards. many behaviors and attributes are really difficult to express quantitatively, which causes incredible and hardly convincing. The multi-objective decision-making utility function has large advantages of improving the accuracy of decision-making in component selection and composition. Multi-attribute utility analysis method applying experimental psychology principles, can convert incommensurable objective function or criteria to a single objective function.

In this paper, we discuss optimal component combination method in detail. By applying multi-property analysis based on utility function and AHP method, it can make most optimal component combination so that all components have been reached the optimal status and reduced the emergence of conflicts.

The rest of the paper is organized as follows. In section 2, we talk about principle and model of multi-attribute utility function. In section 3, we give a detailed description of the AHP method. In section 4, we focus on the combination of the two methods. In section 5, we present an application of our most optimum component combination scheme. Finally, conclusions are drawn in section 6.

2. Multi-attribute utility function analysis method

Multi-attribute utility function is a main method of multi-objective decision-making, which applies experimental psychology principles to convert incommensurable objective function or criteria to a single objective function. It is mainly used to improve the accuracy of decision-making, letting every aspect be the best status and avoid collision. The biggest advantage of multi-attribute utility function analysis method is that it can be used to compare incomparable objects, such as questions like “which is better, apple or banana?” For analysis of such problems, analysis method based on utility function is very valuable.

Multi-attribute utility analysis implies three assumptions. Firstly, questions involved in the decision-making are multi-attribute. When making decisions, we must take a series of criteria into consideration. Secondly, criteria referred to decision-making can not makes physical measurement, which only can be carried out by subjective judgments, such as job-seekers ’ work experience, comfort of car and so on. Thirdly, a series of quantitative procedures will give us a more satisfactory decision.

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2.1Principle and model

Suppose several attributes are $f_1, f_2 \cdots f_n$, some of which are the bigger the better, but some others are the smaller the better. What's more, some indexes require medium, so too big or too small are also bad. For these indexes f_n^*, utility functions (score) d_i ($0 \le d_i \le 1$) are separately given to describe the relationship between d_i and index value f_i, which is called utility function. That is $d_1 = F(f_1)$.

Suppose there are m alternative options $A_1, A_2 \dots A_n$, and each one has n evaluation index on average. Among these indexes, there are qualitative and quantitative indicators. For qualitative indicators, we must do quantification treatment firstly, and the ways is determined according to indicators' specific nature. We can adopt experts playing fraction approach or analog function method to get quantitative data of qualitative indexes. Suppose the value of project A_i is a_{ij} under the index a_j, then the following indicators matrix can be constructed.

$$A = \begin{matrix} A_1 \\ A_2 \\ \cdots \\ A_m \end{matrix} \begin{bmatrix} a_1 & a_2 & \cdots & a_n \\ a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}_{m\times n} = \left(a_{ij}\right)_{m\times n} \qquad (1)$$

Since there are different dimensional values, the indicators', value must be turned from dimensional values to non-dimensional ones.

Let $r_{ij} = a_{ij}(c\sum_{i=1}^{m} a_{ij}^2)^{1/2} \quad i=1,2\cdots m, j=1,2\cdots n$, we can obtain matrices R

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}_{m\times n} = (r_{ij})_{m\times n} \qquad (2)$$

Selecting $r_{\max,j} = \max(r_{ij})$ as the j[th] Maximum, and $r_{\min,j} = \min(r_{ij})_n$ as the j[th] minimum value, we can form utility function.

$$d_{ij} = \begin{cases} \dfrac{r_{nj}}{r_{\min,j}} & f_n^* = 1 \\ 1 + \dfrac{r_{\min,j} - r_{i,j}}{r_{\max,j}} & f_n^* = 0 \end{cases} \qquad (3)$$

Where i=1,2,…,m

If indexes f_n^* is not too big, nor too small, it should be maintained in the range between $\left[r_1, r_2\right]$. The utility function value d_{nj} should be 1 in the range of $\left[r_1, r_2\right]$, so the utility function is showed in formula (4).

$$d_{ij} = \begin{cases} \dfrac{r_{ij}}{r_i} r_{ij} \in [r_{\min j}, r_1) \\ 1 r_{ij} \in [r_1, r_2) \\ \dfrac{1 + r_2 - r_{ij}}{r_{\max,j}} \end{cases} \qquad (4)$$

In this way, utility function consisting of m projects which have n indexes can form utility function indicator matrix as the following form $D = \left(d_{ij}\right)_{m\times n} \left(0 \le d_{ij} \le 1\right)$. We will get total weight $c\left(A_i\right) = \sum_{j=1}^{n} w_j \cdot d_{ij}$ from index weight $\left(w_1, w_2 \cdots w_n\right)$ of every project index $d_{11}, d_{12} \cdots d_{1n}$ respectively and then decide the most optimal project according to the value $c\left(A_i\right)$.

2.2 Optimum procedure

The first step: qualitative technology economy means to gain corresponding quantitative data after quantify treatment

The second step: we will form indicator matrix using the data which is treated by the first step and original data according to corresponding project.

The third step: non-dimensional treatment. We can get a new non-dimensional matrix through the formula $r_{ij} = a_{ij}(c\sum_{i=1}^{m} a_{ij}^2)^{1/2}\ i = 1, 2 \cdots m,\ j = 1, 2 \cdots n$ [3].

The fourth step: getting the value indicator matrix of utility function. According to the characteristics of different index factors , the standardized treatment will be carried out by formula (1), (2), (3). Then, we can get all values $d_{ij}\left(0 \le d_{ij} \le 1\right)$ of the utility function. In the end we can gain $D = \left(d_{ij}\right)$ which is the value of utility function.

The fifth step: calculating every index weight. Through expert point, we can obtain every index weight w $= \left(w_1, w_2 \cdots w_n\right)$.

The sixth step: calculating general weight of every project $c\left(A_i\right)$. And then sort the result according to general weight of every project, which is considered to be the most optimal project with the largest weight value.

3. AHP method

Analytic Hierarchy Process method was established by professor T.L.Saaty in 1970's at the University of Pittsburgh. Analytic Hierarchy Process method is abbreviated as AHP. The method aims to solve complex decision-making problem, which is also a multi-criteria decision-making analysis with characteristics qualitative and quantitative.

Applying this approach, policy-makers divided complex problems into several levels and many factors. We do comparison and calculation among various factors in order to get different options. And the weight values can provide scientific basis to select the best project. Basic process of AHP is as the following: ① Determine AHP level. This hierarchy structure commonly is expressed by a diagram. ②Single-level sort to every level successively. The aim of doing this is to determine importance weight value of every element which connects with this layer and upper layer. Specific ways is to set up a judgment matrix A

$$A=\begin{bmatrix} a_{11} & a_{12} & a_{13} & \cdots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & a_{n3} & \cdots & a_{nn} \end{bmatrix} \quad (5)$$

in which, a_{ij} indicates the important degree of A_i comparing with A_j , $a_{ij}>0$ $a_{ji}=\frac{1}{a_{ij}}$.

Calculate the largest eigenvalue and corresponding eigenvector of this matrix. Eigenvector is the single sort weight value. And the next step is to determine matrix consistency, in the end final weight value is synthesized. Using the result of all levels' single-sort in the same level, we can calculate all elements' importance weight value in the same layer. Finally, we can get a group of values, and choose the biggest value of this group.

4. A case study

With the development of enterprise informatization, more and more small and medium-sized companies want to have their own intranet platform for information exchange and interaction. Because of many factors, they do not have the ability of independently developing software, and they can only depend on the component library from a third party to select suitable component combined to satisfy their needs. Our overall goal is to realize minimum cost which can meet our requirements as shown in Figure 1

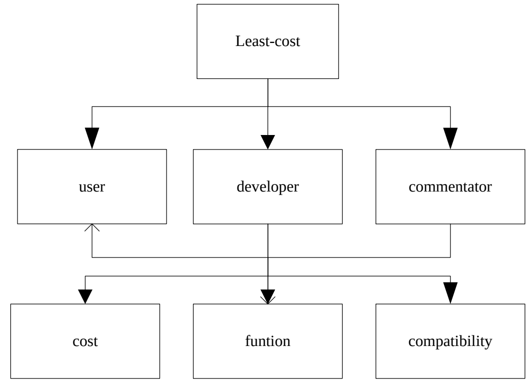

Fig. 1 Structure diagrams for minimum cost .

According to the structure diagram, properties to goal's priority sequence are given step-by-step: ① determine relative importance of every category participants; ② determine relative impact of attribute compares with each category participants; ③determine the priority sequence of attributes to target. The first two steps are realized by AHP method. Calculation results of judgment matrix are shown in table 1.

Table 1 Calculation results of judgment matrix

participant	***cost***	***compatibility***	***functionality***	***weight***
user	1	5	3	0.5568
developer	1/5	1	1/2	0.0798
commentator	1/3	2	1	0.2560

The largest matrix eigenvalue and eigenvalue's corresponding eigenvector are calculated. Calculation process is not detailed in the following. Finally we obtain a group of weight values (0.5568,0.0798,0.2560). After checking data table, we can see, utility function is $u(x) = 0.4579u_1(x_1) + 0.1503u_2(x_2) + 0.2054u_3(x_3) + 0.0886u_4(x_4)$ [4].

Options to be sorted according to property are showed in Table 2, and Utility values of option's attributes are showed in the Table 3.

Table 2 Alternative options to be sorted according to property

Alternative option	***cost***	***compatibility***	***functionality***
1	3.56	3.38	0.102
2	3.38	3．371	0.126
3	3.49	3.308	0.170

Table 3 Utility values of option's attributes

Project	***U1***	***U2***	***U3***	***U4***	***sort***
1	0.4684	0.970	0.0744	0.469	3
2	0.7885	0.778	0.6798	0.577	1
3	0.6022	0.567	0.1183	0.484	2

According to the data in the table, there are three different component combination projects. During these projects, the second combination project is the best of the three.

5. Conclusion and Future Work

Constructing utility function method is a kind of relatively intuitive analysis. Its advantage is that it can make a comparison between two indexes, such as the question, "which is better banana or apple". According to some regulations, they can be called quantified indexes which are comparable. This method can judge more projects with more technical and economic indexes.

It is the initial stage that the researchers apply this mathematical method to the component-based development. The method provides a theoretical guarantee to the problems in the areas of optimal selecting so that we can construct a new system consisting of optimal components we choose to be more powerful and stable.

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