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The Application of the System Parameter Fusion Principle to Optimizing an Integrated System for Library Management

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Abstract: - Modern technology provides a great amount of information. But for computer monitoring systems or computer control systems, in order to have the situation in hand, we need to reduce the number of variables to one or two parameters, which express the quality and/or security of the whole system. In this paper the authors introduce the system parameter fusion principle put forward by the second author and present how to apply it to optimizing an integrated system for library management combining with the Delphi technique and AHP.

Keywords: - Data fusion, Library management, Delphi technique, Analytical Hierarchy Process

1 Introduction

The computer integrated system for library management (CISLM) is a complicated system which concerns the function of library management, the performance of the system hardware and software, and the investment for the system[1]. During the development of library automation, there are several schemes and targets in selecting and introducing the scheme of the library integrated system. The problem of choosing which one is decided by optimizing decisions. Since in the factors connected with the integrated system there exist many interactions and contradictions, which are only qualitative targets. This brings a lot of difficulty to the user's subjective judge and decision. We must have a systematic and practical evaluation target system, and we must have a set of scientific auxiliary decision methods. The Analytical Hierarchy Process(AHP) is a convenient way for quantitative analysis to un-quantitative matters in system engineering, it is also an effective method for people to objectively subscribe the subjective judge. In this paper the authors introduce the system parameter fusion principle put forward by the second author, and present how to apply the system parameter fusion principle to optimizing an integrated system for library management combining with the Delphi technique and AHP.

2 The System Parameter Fusion Principle

Modern technology provides a great amount of information. It appears in various forms such as texts, graphics, images, and even sounds. This great amount of information in various forms will submerge useful data, which must be easy to process and present to human supervisors. In computer monitoring systems, especially real-time expert systems, we need one or two parameters to express the quality and/or security of the whole system.

Let M_i be the measurement value of the i^{th} variable ($i = 1,2,...,n$), O_i the optimum of the i^{th} variable, H_i the upper limit of the i^{th} variable, L_i the lower limit of the i^{th} variable, W_i the weight of the i^{th} variable. W_i indicates the importance of this variable in the system,

$$\sum_{i=1}^{n} W_i = 1. \tag{1}$$

The more important the variable in the system is, the greater value we ascribe to the W_i.

There are two synthesized parameters, G, which indicates the quality of the system, and S, which indicates the security of the system.

$$G = \sum_{i=1}^{n} W_i \cdot f(M_i) \tag{2}$$

$$S = \prod_{i=1}^{n} f(M_i)^{W_i} \tag{3a}$$

$$\text{i.e.,} \quad \ln S = \sum_{i=1}^{n} W_i \cdot \ln f(M_i) \tag{3b}$$

In which, $f(M_i)$ is the quality function, the value limits are from 0 to 1. $f(M_i)$ can be the linear function of M_i, or other quadratic function of M_i. First this paper gives two simple forms:

(1) $f(M_i)$ can be the simplest linear function of M

$$f(M_i) = \begin{cases} \dfrac{M_i - L_i}{O_i - L_i} & (\text{if } L_i < M_i < O_i) \\ \dfrac{M_i - H_i}{O_i - H_i} & (\text{if } O_i < M_i < H_i) \\ 0 & (\text{otherwise}) \end{cases} \tag{4}$$

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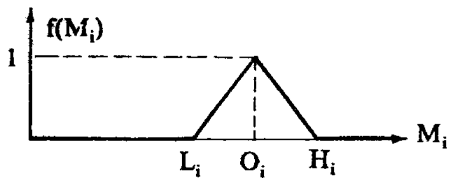

Figure 1. f(M_i) can be the simplest linear function of M_I

(2) f(M_i) can be the semicircular function of M_i,

$$f(M_i)=\begin{cases}\sqrt{1-(\frac{M_i-O_i}{O_i-L_i})^2} & (\text{if } L_i<M_i<O_i)\\ \sqrt{1-(\frac{M_i-O_i}{H_i-O_i})^2} & (\text{if } O_i<M_i<H_i)\\ 0 & (\text{otherwise})\end{cases} \quad (5)$$

If $O_i - L_i = H_i - O_i$, then

$$f(M_i)=\begin{cases}\sqrt{1-(\frac{M_i-O_i}{O_i-L_i})^2} & (\text{if } L_i<M_i<O_i) \quad (6)\\ 0 & (\text{otherwise})\end{cases}$$

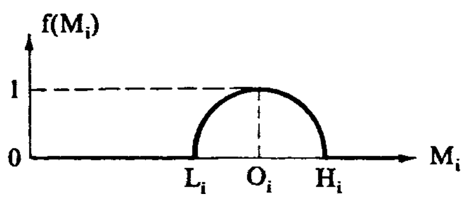

Figure 2. f(M_i) can be the semicircular function of M_i

The users may choose any kind of f(M_i), such as the S-curve quality function [2]. No matter what kind of function f(M_i) is, when all the measurement values reach their optima, the quality of the system will be 1. If any of the measurement values exceeds its limits, the security of the system will be 0; the system should set an alarm and show which sensor is out of limits or in failure. The nearer the quality of the system reaches 1, the better the system. The nearer the security of the system reaches 0, the more dangerous the system is. Some systems should set an alarm when the security of the system approaches 0.

The idea of this principle was successfully applied in monitoring an ultra-energy efficient house at Noble-Kirk farm in Canada [3] and other applications [4]. This paper presents its application to optimizing an integrated system for library management.

2 The Analytic Hierarchy Model For Optimization of an Integrated System

Using AHP to solve the problem, first we must make the problem hierarchic, separate it into several different factors according to its quality and target, and then group the factors into several levels according to their mutual influence and their subordinate relationship in order to form a multi-hierarchy analysis model, and, finally, sum up the system analysis as the determination of the weight which represents the importance of the lowest level (the scheme for decision) relative to the highest level (system target) or as the queuing process of system quality[1].

The AHP model shown as Figure 3[1] has three levels: A is the target level, selection of integrated system; Ci is the criteria level, (i=1,2,...,5), the criteria of integrated system selection evaluation, in five aspects, which contains 23 practical function targets (Cij); the lowest level is the scheme of integrated system to be selected.

Obviously, the weight (relative importance) of the five aspects of criteria and 23 function targets are different. To decide the weight that represents the relative importance of the whole system, we must use the AHP method in which the judge matrix is set up by comparing to their importance pairs. Then, solve it as an eigenvalue problem of the matrix to find out the relative important weight of a level compared with the upper one. After finding out the single queuing weight of each factor of the level compared with the upper one, sum up the weight of the upper level factors itself, then we can find out the relative important weight of the factors of the level compared with the weight of the whole upper level, that is the total queuing weight. In this way, from the upper one to the lower one, the weight that represents the importance of the lowest level relative to the highest level or as the queuing process of the system could be found. It can be referred to by the decider.

3 Application of the System Parameter Fusion Principle to Optimization of an Integrated System

One possible way of presenting the results of the analytic hierarchy model for optimization of an integrated system is by means of a vector with co-ordinates C_i. In this way, a convenient way of representing the co-ordinates is by using various graphics options.

However, based on the System Parameter Fusion Principle, the vector of the co-ordinates of the results can be presented by the fused result G:

$$G= \sum_{i=1}^{5} W_{Ci} \bullet f(Ci) \quad (7)$$

with W_{Ci}=the weights

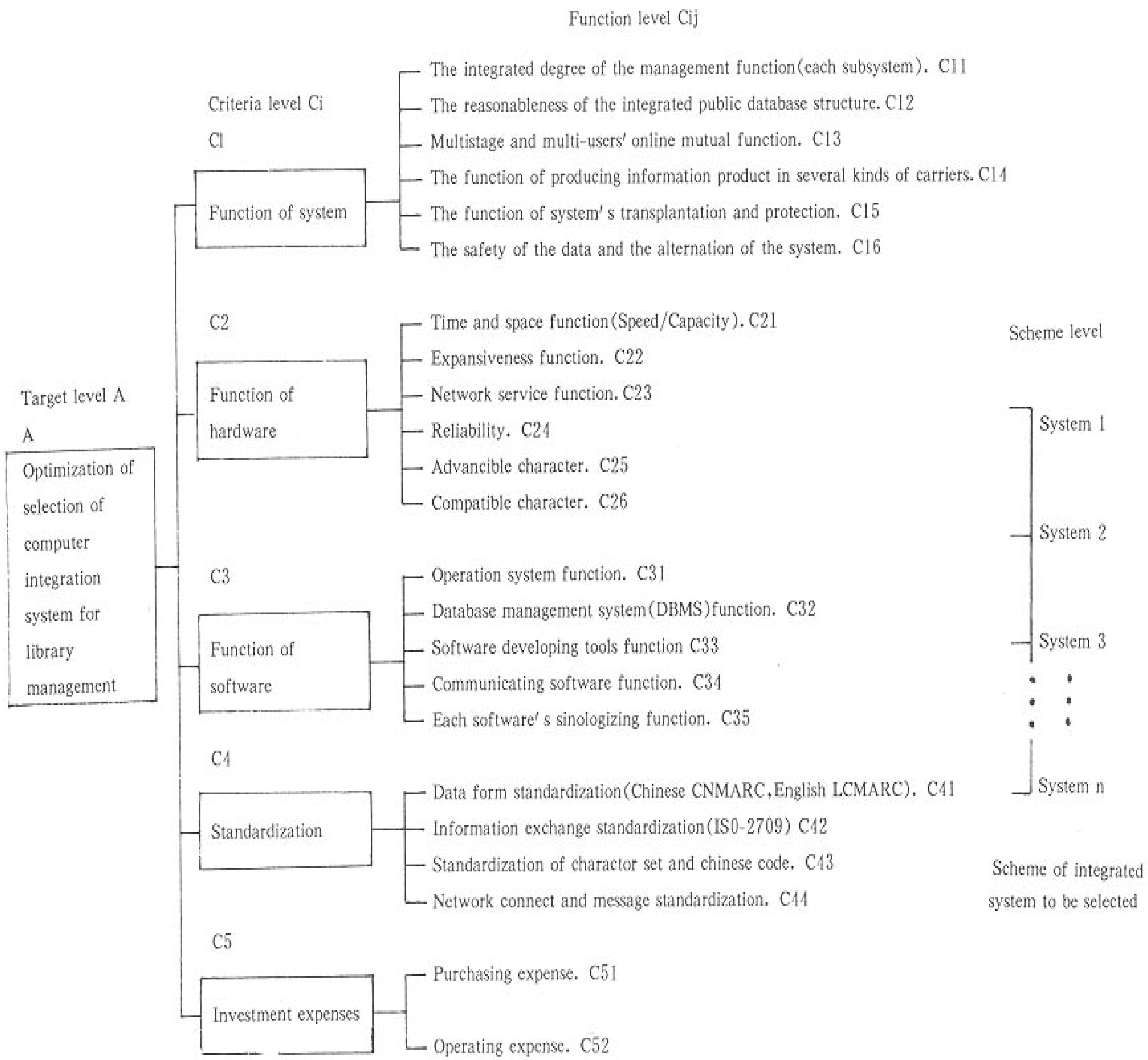

Figure 3. Hierarchy model of computer integrated system for library management[1]

The results of the evaluation of each dimension are obtained with the help of a similar formula. Consequently, for each dimension C_i the formula to be used is:

$$Ci=\sum_{j=1}^{n} W_{Cij} \cdot f(Cij) \tag{8}$$

with n= the number of parameters for the dimension being considered

and Cij= the classification of the j parameter (j ranges from 1 to n)

and W_{Cij}=the weights

We take the USTS Library as an example for optimization of an integrated system.

3.1 Determination of the Weights

The weight refers to the numerical indication of the relative importance of each parameter in the whole system. Whether the weight determination is reasonable or not will it exert a decisive influence on the combined evaluation results and evaluation quality. Since the parameter system of optimization of an integrated system is comparatively large, so the Analytical Hierarchy Process (AHP) [5] and Delphi technique are adopted to determine the weight of each parameter.

(1) Determination of the criteria level

The weight of the criteria level is determined by adopting AHP, combined with Delphi technique.

AHP is a systematic method for comparing a list of objectives. When used in the systems engineering process, AHP can be a powerful tool for comparing alternative design concepts. Assume that a set of objectives has been established and that we are trying to establish a normalized set of weights to be used when comparing alternatives using these objectives. We have 5 objectives: C_1, C_2, C_3, C_4, and C_5. Form a pairwise comparison matrix A, where the number in the i_{th} row and j_{th} column gives the relative importance of C_i as compared with C_j using a 1–9 scale, with

–a_{ij} = 1 if the two objectives are equal in importance;
–a_{ij} = 3 if C_i is weakly more important than C_j;
–a_{ij} = 5 if C_i is strongly more important than C_j;
–a_{ij} = 7 if C_i is very strongly more important than C_j;
–a_{ij} = 9 if C_i is absolutely more important than C_j;
–a_{ij} = 1/3 if C_j is weakly more important than C_i;
…

Delphi technique is not new. It stems from United States defense developments in the late 1950s [6] and work done to develop the technique carried out by the Rand Corporation. Significantly, Rand selected the Delphi technique because it provided "the most reliable consensus of opinion of a group of experts" [7].

We use the Delphi technique to form the pairwise comparison matrix A by inviting a group of experts to complete an importance questionnaire independently, asking them to state reasons and give corresponding scales. Thus we might arrive at the following matrix:

$$A = \begin{bmatrix} 1 & 3 & 3 & 5 & 5 \\ 0.333 & 1 & 1 & 3 & 3 \\ 0.333 & 1 & 1 & 3 & 3 \\ 0.200 & 0.333 & 0.333 & 1 & 1 \\ 0.200 & 0.333 & 0.333 & 1 & 1 \end{bmatrix} \quad (9)$$

To normalize the weights, compute the sum of each column and then divide each column by the corresponding sum. Using an overbar to denote normalization, we get:

$$\overline{A} = \begin{bmatrix} 0.484 & 0.529 & 0.529 & 0.385 & 0.385 \\ 0.161 & 0.176 & 0.176 & 0.231 & 0.231 \\ 0.161 & 0.176 & 0.176 & 0.231 & 0.231 \\ 0.097 & 0.059 & 0.059 & 0.077 & 0.077 \\ 0.097 & 0.059 & 0.059 & 0.077 & 0.077 \end{bmatrix} \quad (10)$$

In practice, one need to compute a consistency measure using the eigenvalues of the normalized comparison matrix.

The next step is to compute the average values of each row and use these as the weights in the Objective Hierarchy. For our case, the weights would be:

W=[0.462 0.195 0.195 0.074 0.074 $]^T$

Note that by construction, $\sum_{i=1}^{5} W_i = 1$.

These weights would be used in summing the measures as required in the evaluation of the dimension hierarchy.

(2) Determination of the function level

The weight of the function level is also determined by adopting AHP combined with Delphi technique. The process is almost the same.

3.2 Method of the Combined Evaluation

Based on the System Parameter Fusion Principle, we can consider 5 dimensions in the system as 5 parameters. We use the S-curve quality function as $f(M_i)$ shown in figure 4 [2].

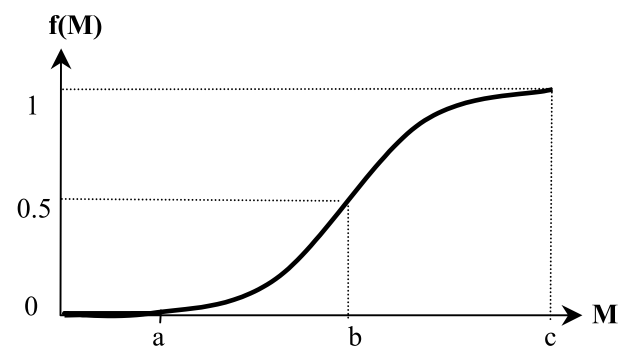

Figure 4 $f(M_i)$ can be the S-curve function of M_i

$$f(M) = S(M,a,b,c) = \begin{cases} 0 & for \quad M < a \\ 2\left[\frac{(M-a)}{(c-a)}\right]^2 & for \quad a \le M \le b \\ 1-2\left[\frac{(c-M)}{(c-a)}\right]^2 & for \quad b \le M \le c \\ 1 & for \quad M > c \end{cases} \tag{11}$$

Here, when $M \geqslant c$, the i^{th} variable reaches the optimum, $a=L_i$, the lower limit of the i^{th} variable. b is between a and c, b=(a+c)/2.

In formula (8), first we determine every W_{Ci}, then use formula (11) to calculate f(Ci), at last calculate Ci, which includes C1, C2, C3, C4 and C5. Then we use formula (7) to calculate G as shown in table 1.

Table 1. The calculation of G for USTS Library

Dimension	C1	C2	C3	C4	C5
W_{Ci}	0.462	0.195	0.195	0.074	0.074
f(Ci)	0.941	0.774	0.756	0.873	0.785
W_{Ci} • f(Ci)	0.435	0.151	0.147	0.065	0.058

So the evaluation G for USTS Library,

$$G = 0.435 + 0.151 + 0.147 + 0.065 + 0.058 = 0.856 \tag{12}$$

4 Conclusion

Each dimension, parameter and sub-parameter can be represented graphically (i.e. with bar charts) along with the equivalent dimensions, parameters and sub-parameters of other systems used for comparison.

This method can be used to evaluate a group of G simply by quantifying each of the dimensions and comparing them with each other or by taking the results of a specific G and comparing them with the results of a standard G used for comparison purposes It is suitable to the comparison of several systems in finding out its selecting order.

The authors find that it is absolutely usable as an auxiliary in the decision of introducing and selecting the computer integrated system for library management. The method could make the qualitative and quantitative analysis synthetically so that we could make a comprehensive evaluation of the integrated system to be selected.

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