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The Application of the System Parameter Fusion Principle to Assessing Quality in Digital Reference Services

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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 assessing quality in digital reference services combining with the Delphi technique and AHP.

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

1 Introduction

At the Virtual Reference Desk (VRD) Conference in Seattle in October 2000, the growing digital reference community identified assessment of quality as a top research priority. As patrons demand more services online, and as reference librarians seek to better meet patrons' information needs through the Internet, it has become essential to determine common definitions of success and quality. Library administrators need strong, grounded metrics and commonly understood data to support digital reference services, assess the success of these services, determine resource allocation to services, and determine a means for constant improvement of digital reference within their institutions. Based on the quality assessing process currently involved in the reference services by real-time software technology in the libraries at home and abroad and taking into consideration seven related aspects of service systems, service process, answers quality, user satisfactory degree, service statistics, cost measurement and service opening degree, Jing Guo[1] brings forward a three-level indicator system for service quality assessing and sets out a detailed index. 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 assessing quality in digital reference services 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,

$$\sum_{i=1}^{n} W_i = 1. \qquad (1)$$

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.

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

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

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

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

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

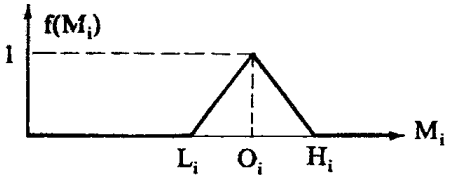

Figure 1. $f(M_i)$ can be the simplest linear function of M_I

(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

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

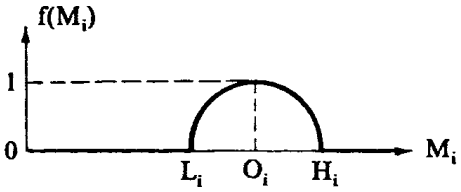

Figure 2. $f(M_i)$ can be the semicircular function of M_i

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.

3 The Analytic Hierarchy Model For Assessing Quality in Digital Reference Services

With the rapid rise of the libraries' real-time reference services on the web, the study on the quality assessing standards for digital reference services has been given to more and more attention for its future development. Based on the quality assessing process currently involved in the reference services by real-time software technology in the libraries at home and abroad and taking into consideration seven related aspects: service systems, service process, answers quality, user satisfactory degree, service statistics, cost measurement and service opening degree, Jing Guo brings forward a three-level indicator system for service quality assessing and sets out a detailed index.

This section is divided into two parts. In the first, the structure of Guo's model is introduced. The second introduces the dimensions, focuses on a hierarchy tree with the parameters and sub-parameters, as shown in Table 1[1]..

3.1 Structure of the Model

The model is based on six dimensions. The maximum classification for each dimension is 1 (one). The classification of the presence of a certain library in relation to a certain dimension ranges from 0 (zero) to 1 (one). Each dimension is divided into several parameters. Each parameter is divided into two or more sub-parameters of the same level when they are sufficiently important for that, as occurs with the dimensions.

3.2 Dimensions, Parameters and Sub-Parameters of the Model

The dimensions of the model are:

- C_1: service system measurement, the measurement for software and hardware standard of various system platforms used in the digital reference service.
- C_2: service process measurement, the measurement for the entire consultation process of each links, including assessment from the beginning to the end, user authentication and service policy etc.
- C_3: reply quality measurement, the quality measurement for the reply degree and effect to the consulted questions.
- C_4: user satisfaction, the degree of users' satisfaction assess by standard questionnaire survey to users, including consultant's operation, usability and effect, .
- C_5: service statistics measurement, the measurement for service information such as statistics report forms and so on used in the digital reference service
- C_6: cost measurement, the measurement for income and payout situation according to economic target.
- C_7: service opening degree, the influence of the service including service time length, region scope of the service and the cooperation situation with cooperative organizations.

Table 1. Three-level indicator system for service quality assessing and detailed indexes

Dimension	Parameters	Sub-parameters
C_1 - service system measurement	C_{11} - system performance	C_{111} - stability
		C_{112} - compatibility
		C_{113} - usability
		C_{114} - expandability
	C_{12} - standard executed	C_{121} - whether or not for national standard
		C_{122} - whether or not for international standard
		C_{123} - whether or not for element data standard
		C_{124} - whether there is a cooperative organization exchange standard
C_2 - service process measurement	C_{21}- service form	C_{211} - Email consultation
		C_{212} - BBS consultation
		C_{213} - Web consultation form
		C_{214} - FAQ base
		C_{215} - real-time explanation
	C_{22} - service routine	C_{221} - how easy to get service
		C_{222} - response time
		C_{223} - service routine clarity
		C_{224} - user authentication
	C_{23} - service personnel	C_{231} - the problem scope to be solved
		C_{232} - staff training and assess
	C_{24} - service policy	C_{241} - regular summary and appraisal for the service
		C_{242} - reasonable service policy
	C_{25} - service objects	C_{251} - user information privacy
		C_{252} - user cognition degree
C_3 - reply quality measurement	C_{31} - reply quality	C_{311} - answer accuracy
		C_{312} - interaction
	C_{32} - value of answers	C_{321} - instructive
		C_{322} - educational
		C_{323} - influence
	C_{33} - reply language	C_{331} - normative
		C_{332} – unanimous response
		C_{333} - language multiplicity
C_4 - user satisfaction	C_{41} – consultant's operation and effect	C_{411} - reply accuracy
		C_{412} - response time length
		C_{413} - service attitude
	C_{42} - usability and effect	C_{421} - technology usability
		C_{422} - user confidence
		C_{423} - user receptivity
		C_{424} - service effect
C_5 - service statistics measurement	C_{51} - real-time consultation system	C_{511} - log-in user information statistics
		C_{512} - investigation report for user satisfaction
	C_{52} - other service statistics	C_{521} - statistics for the use of knowledge base
		C_{522} - statistics for the use of courseware
C_6 - cost measurement	C_{61} - single item digital referral service cost	C_{611} - cost for a single item of advisory service
	C_{62} - entire digital referral service cost	C_{621} - facility maintenance expenses for entire digital referral service
		C_{622} - influence of this cost to other expenses of the library
C_7 - service opening degree	C_{71} - range of service	C_{711} - service time length
		C_{712} - region scope of the service
	C_{72} - cooperation situation	C_{721} - whether or not an area cooperative organization member
		C_{722} - whether or not a global cooperative organization member

4 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 assessing quality in digital reference services 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:

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

with W_{Ci}=the weights

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:

$$C_i = \sum_{j=1}^{n} W_{Cij} \cdot f(C_{ij}) \quad (8)$$

with n= the number of parameters for the dimension being considered
and C_{ij}= 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 assessment of quality in digital reference services.

4.1 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 results and quality of the assessment. Since the parameter system for assessment of quality in digital reference services 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(dimensions)

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. Now we have 7 objectives: C_1, C_2, C_3, C_4, C_5, C_6 and C_7. 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:

$$A = \begin{pmatrix} 1 & 1 & 3 & 3 & 5 & 5 & 5 \\ 1 & 1 & 3 & 3 & 5 & 5 & 5 \\ 0.333 & 0.333 & 1 & 1 & 3 & 3 & 3 \\ 0.333 & 0.333 & 1 & 1 & 3 & 3 & 3 \\ 0.2 & 0.2 & 0.333 & 0.333 & 1 & 1 & 1 \\ 0.2 & 0.2 & 0.333 & 0.333 & 1 & 1 & 1 \\ 0.2 & 0.2 & 0.333 & 0.333 & 1 & 1 & 1 \end{pmatrix} \quad (9)$$

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:

$$\bar{A} = \begin{pmatrix} 0.306 & 0.306 & 0.333 & 0.333 & 0.263 & 0.263 & 0.263 \\ 0.306 & 0.306 & 0.333 & 0.333 & 0.263 & 0.263 & 0.263 \\ 0.102 & 0.102 & 0.111 & 0.111 & 0.158 & 0.158 & 0.158 \\ 0.102 & 0.102 & 0.111 & 0.111 & 0.158 & 0.158 & 0.158 \\ 0.061 & 0.061 & 0.037 & 0.037 & 0.053 & 0.053 & 0.053 \\ 0.061 & 0.061 & 0.037 & 0.037 & 0.053 & 0.053 & 0.053 \\ 0.061 & 0.061 & 0.037 & 0.037 & 0.053 & 0.053 & 0.053 \end{pmatrix} \quad (10)$$

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=[0.296 0.296 0.129 0.129 0.051 0.051 0.051]^T

Note that by construction, $\sum_{i=1}^{7} Wc_i = 1$.

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

(2) Determination of the function level(parameters and sub-parameters)

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

The evaluations of f(C_i) are determined by users' on-line questionnaire survey, statistics and Delphi technique.

4.2 Method of the Combined Assessing

Based on the System Parameter Fusion Principle, we can consider 7 dimensions in the system as 7 parameters. We use the S-curve quality function as f(M_i) shown in figure 3 [2].

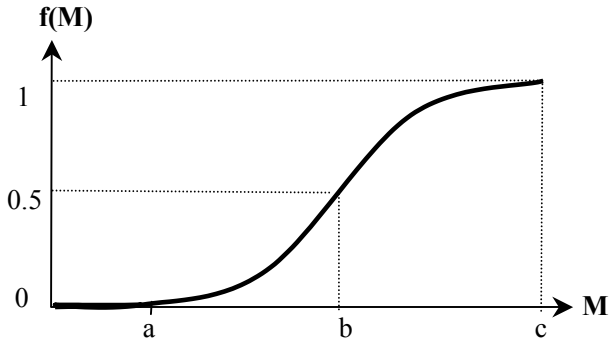

Figure 3 f(M_i) can be the S-curve function of M_i

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

Here, when M⩾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(C_i), at last calculate C_i, which includes C_1, C_2, C_3, C_4, C_5, C_6 and C_7. Then we use formula (7) to calculate G as shown in table 2.

Table 2. The calculation of G for USTS Library

Dimension	C_1	C_2	C_3	C_4	C_5	C_6	C_7
W_{Ci}	0.296	0.296	0.129	0.129	0.051	0.051	0.051
f(C_i)	0.941	0.774	0.756	0.873	0.785	0.881	0.758
W_{Ci} • f(C_i)	0.279	0.229	0.098	0.113	0.040	0.045	0.039

So the assessment of G, quality in digital reference services, for USTS Library, for USTS Library would be:

G =0.279+0.229+0.098+0.113+0.040+0.045+0.039 = 0.841 (12)

Each dimension, parameter and sub-parameter can be represented graphically (i.e. with bar charts) as shown in figure 4, along with the equivalent dimensions, parameters and sub-parameters of other systems used for comparison.

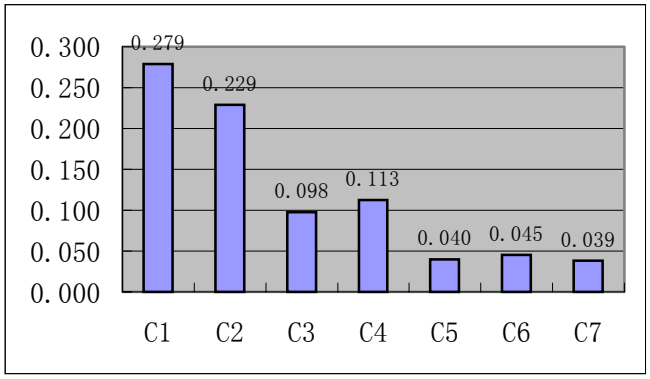

Figure 4 The assessment of G, quality in digital reference services, for USTS Library

5 Conclusion

This method can be used to assess quality in digital reference services of a group of libraries 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 libraries in finding out its order.

The authors find that it is absolutely usable to assess quality in digital reference services combining with the Delphi technique and AHP. The method could make the qualitative and quantitative analysis synthetically so that we could make comprehensive assessment of libraries.

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