A Mathematical model for web site service quality evaluation based on AHP and fuzzy methodology

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Abstract This paper proposes a mathematical model for web site service quality evaluation, which first applies analytic hierarchy process (AHP) to determine the weights of evaluation indexes of web site service quality and then analyzes web site service synthetically by means of fuzzy methodology. In this case, experts' knowledge cannot only be used but its subjective component can be eliminated. Hence, the web site service quality can be analyzed and evaluated more reasonably. After establishing this model, the experiment results will be given, which verify the feasibility and validity of the proposed model. The model proposed here is very simple and easy to implement and can provide a useful way to help developers evaluate their web site service quality efficiently.

Key Words : Web site service quality, Evaluation index, AHP, Fuzzy methodology

1. Introduction

Today's world is becoming more and more competitive daily. Having a "high-quality" web site is a necessary move to stay competitive in this fast paced world. Therefore, quality proves to be an essential factor in web site development. It thus becomes clear that there is an increasing need to evaluate the quality of web site service.

In fact, websites evaluation has already become a focus in recent years.

MiLE is a usability-focused evaluation method for hypermedia application, based on a combination of inspection from expert evaluator and empirical testing through panels of end users [1]. The evaluation model here is based on two heuristic concepts: abstract and concrete tasks.

WebQEM [2], Kwaresmi [3] and Web Tango [4] are relevant examples in evaluating quality on the web. WebQEM [2] sees attributes as measurable properties of an entity and proposes using a linear quality model following linear additive and non-linear multimedia scoring criteria to specify them. Kwaresmi [3] is a framework that defines a systematic and consistent way for structuring guidelines in order to enable their automatic evaluation. Web Tango of Ivory [4] presents a synthesis of usability and performance evaluation techniques, which together build an empirical foundation for automated interface evaluation.

In 2003, Luisa Mich, Mariangela Franch, and Loris Gaio proposed a model named 2QCV3Q model to help site owners and developers evaluate web site quality and incorporate those findings into site design [5]. This model is a conceptual model based on seven dimensions: who-what-why-when-where-how, and feasibility.

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In 2004, a mathematical model for web site evaluation by means of AHP is given in [6]. After giving the weights, the authors apply a weighted summation method to evaluate the total score of the web site, which is on a linear basis.

In 2005, Oreste Signore proposed a comprehensive model for web sites quality. Correctness, presentation, content, navigation and interaction are the five dimensions considered by this quality model [7]. Chang Jinling and Xia Guoping evaluated e-commerce website based on Concordance analysis. The goal of this paper is to find out the most benefic website among several websites by considering both the advantages and disadvantages [15].

Standardization bodies such as ISO or CEN are trying to integrate different approaches to the definition of quality. [8], [9], [10] describe the standards for usability aspects, quality of software, and user-centered production.

While each approach mentioned above has its strength and limitation. One of the key limitations that we observed is the lack of the mathematical model for evaluation.

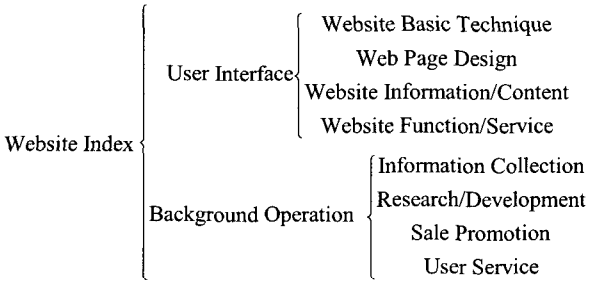
This paper tries to seek a mathematical method to solve quality evaluation problems. So in this paper, a mathematical model is proposed, in which, the qualitative and quantitative are combined to analyze and evaluate the web site service quality. In this case, experts' knowledge cannot only be used but its subjective component can be eliminated. First, a system engineering approach is used to apply AHP to establish an index system of web site service quality, and then determine the weights of the indexes and the synthetic weights. Finally, the web site service quality is evaluated synthetically by means of fuzzy theory. The results of this research will help developers analyze the deficiency in their web sites and thereby provide a foundation for taking further efficient steps to meet users' requirements better.

This paper is organized as follows: Section 2 establishes an index system and describes how to compute weights based on AHP. Section 3 designs fuzzy set and membership function aiming at this problem. Section 4 gives the results obtained from the experiment. Section 5 and 6 analyze the results and presents the main conclusions, respectively.

2. Computing Weights for Web site Indexes based on AHP

2.1 Establishing an evaluation index system

The first step of evaluating web site service quality should be to establish an evaluation index system. First, it is tried to analyze the whole index system of a web site, and then to select the indexes concerning service quality. The indexes reflecting a web site's characteristics can usually be divided into two parts: user interface and background operation. The former mainly considers the degree of users' impression on a web site, including web site basic technique, web page design, web site information/content and web site function/ service. While the latter means the business which doesn't face to users directly, including information collection, research/ development, sale promotion and user service (Fig.1).



<Fig. 1> Whole index system of a web site

The meaning of each concrete classification is explained as follows:

Website basic technique is mainly about some parameters related with internet, browser, etc, when accessing internet.

Web page design is mainly about visual effect of a web page and degree of amity embodied by color way, column, and some other aspects.

Web information/content is mainly about professional information or contents of a web site.

Web function/service is mainly about service items and measures set for a web site.

Information collection is mainly about sources of information and publishing ways.

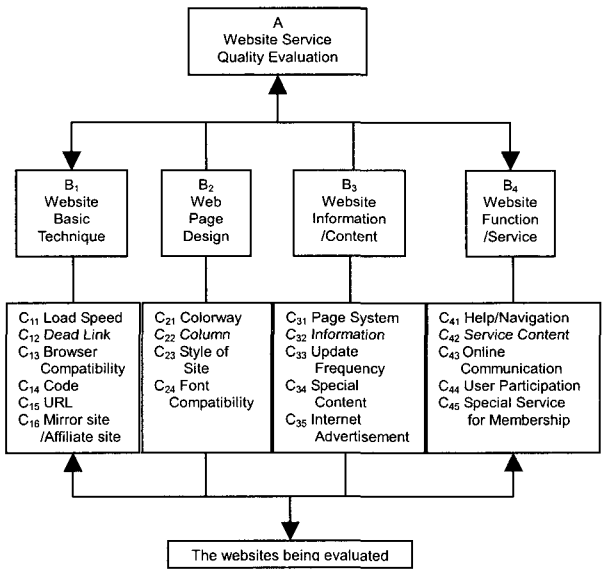
Research/Development is about condition of a web site program developing and system maintenance.

Sale Promotion means market promotion and product sale superiority of a web site.

User service is mainly on the aspects webmaster replies and reduces user's complaint, and also whether a web site has a call centre and the effect of the centre.

Background operation reflects the strength of a web site on capital and process, while our evaluation system here is mainly for web site service quality. Therefore, it is preferred to consider the factors related to user interface rather than consider background operation in this paper.

Every user interface related classification also includes some categories. These classifications and categories are organized in the form of a hierarchic structure based on AHP (Fig.2). In Fig.2, the first level is called the goal level, the second and the third level are called index and sub-index level, respectively. The corresponding meaning of every sub-index is specified in Table1.



<Fig. 2> Hierarchic structure

<Table 1> Specification of every sub-index

Sub-index	Specification
Load speed	Mainly consider complete download time of homepage.
Dead link	Correspondence error or without inter linkage between link address and target page.
Browser compatibility	Display condition of different resolutions or different browsers, such as IE, NETSCAPE.
Code	Just consider the factors as concision of program code and error frequency.
URL	Just consider the relationship between URL and band, business, and also the impression on URL.
Mirror site/ Affiliated site	Consider the condition of mirror site or affiliate site set by website.
Color way	Consider color setting and coordinating degree of match.
Column	Consider whether set type is compact and harmonious.
Style of site	Mainly about characteristics on webpage handling.
Font compatibility	Mainly about whether the fonts are reasonable and the degree they adapt to different browsers.
Page system	Mainly about whether the number of columns and the types of information are clear.
Information	Mainly about whether the information and the corresponding description is abundant in each webpage.
Update frequency	About the frequency of updating information every time.
Special content	Mainly about having special contents which other web sites of this kind do not have.
Internet advertisement	About quantity of advertisement positions on webpage.
Help/navigation	Mainly about help information set by website in order to make convenience for users' visiting, including website navigation, key words search and help explanation.
Service content	Means service contents which websites of a kind should supply.
Online communication	Means service by taking real time way.
User participation	Means individuation service supplied to users.
Special service for members	Means special service supplied if charged.

2.2 Construction of judgment matrix by pair wise comparison

In order to construct a judgment matrix, the relative importance of the indexes in the same level regarding the upper level should be compared pairwise. Experts can rate the comparison qualitatively as equal, marginally important, strong important, very important, and extremely important [11], and then the comparisons can be converted into quantitative numbers according to Table2. All the numbers of the pair wise comparisons can be organized into a square matrix (Table3). If $a_{ij}>1$, it means index A_i is more important than A_j regarding the criteria P, otherwise, A_j is more important than A_i. a_{ji} is the reciprocal of the a_{ij}.

<Table 2> Gradation scale for quantitative of indexes

Option	Numerical value(s)
Equal	1
Marginally important	3
Important	5
Very important	7
Extremely important	9
Intermediate values to reflect fuzzy inputs	2,4,6,8
Reflecting dominance of second index compared with the first	Reciprocals

<Table 3> Judgment matrix by pair wise comparison

P	A_1	A_2	L	A_n
A_1	1	A_{12}	L	A_{1n}
A_2	$1/A_{12}$	1	L	A_{2n}
M	M	M	1	M
A_n	$1/A_{1n}$	$1/A_{2n}$	L	1

2.3 Computing methods of weights

The principal eigenvalue and the corresponding normalized right eigenvector of the judgment matrix give the relative importance of the various indexes being compared. The elements of the normalized eigenvector are termed weights. Four methods [12] are given to compute weights and eigenvalue approximately in the following:

2.3.1 NRA method (Normalization of Row Average)

NRA is to sum the elements in each row and normalize by dividing each sum by the total of all the sums. In mathematical form, it is

$$w_i = \sum_{j=1}^{n} a_{ij} \Big/ \sum_{i=1}^{n}\sum_{j=1}^{n} a_{ij} \quad i,j=1,2,\mathrm{L}\ ,n \tag{1}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)}{nw_i} \quad i,j=1,2,\mathrm{L}\ ,n \tag{2}$$

2.3.2 NRC method (Normalization of the reciprocal sum of columns)

NRC is to take the sum of the elements in each column and form the reciprocals of these sums. Then normalize by dividing each reciprocal by the sum of the reciprocals. In mathematical form, it is

$$w_i = \left(1 \Big/ \sum_{i=1}^{n} a_{ij}\right) \Big/ \sum_{j=1}\left(1 \Big/ \sum_{i=1}^{n} a_{ij}\right) \quad i,j=1,2,\mathrm{L}\ ,n \tag{3}$$

$$\lambda_{\max} = \sum_{i=1}^{n} \frac{(AW)}{nw_i} \quad i,j=1,2,\mathrm{L}\ ,n \tag{4}$$

2.3.3 ANC method (Average of Normalize Columns)

ANC is to divide the elements of each column by the sum of that column and then add the elements in each resulting row and divide this sum by the number of elements in the row (n). This is a process of averaging over the normalized columns. In mathematical form, the vector of priorities can be calculated as

$$w_i = \frac{1}{n} \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}} \quad i, j = 1, 2, \mathrm{L}\ , n \tag{5}$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)}{n w_i} \quad i, j = 1, 2, \mathrm{L}\ , n \tag{6}$$

2.3.4 NGM method (Normalization of the geometric mean of the rows)

NGM is to multiply the n elements in each row and take the nth root. Then normalize the resulting numbers as follows:

$$w_i = \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n} \Big/ \sum_{i=1}^{n} \left(\prod_{j=1}^{n} a_{ij} \right)^{1/n} \quad i, j = 1, 2, \mathrm{L}\ , n \tag{7}$$

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(AW)}{n w_i} \quad i, j = 1, 2, \mathrm{L}\ , n \tag{8}$$

2.4 Consistency evaluation of judgment matrix

The consistency of the judgment matrix of order n should be evaluated. Comparisons made by this method are subjective and the AHP tolerates inconsistency through the amount of redundancy in the approach. If this consistency index fails to reach a required level then answers to comparisons may be re-examined. The consistency index, CI, is calculated as

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{9}$$

where λ_{max} is the maximum eigenvalue of the judgment matrix. This CI can be compared with that of a random matrix, RI (Table4). The ratio derived, CI/RI, is termed the consistency ratio, CR. Saaty [11] suggests the value of CR should be less than 0.1.

<Table 4> The value of RI corresponding to n

n	1	2	3	4	5	6	7
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32
n	8	9	10	11	12	13	14
RI	1.41	1.45	1.49	1.51	1.54	1.56	1.58

2.5 Computing weights of the proposed evaluation index system

All of the data in our judgment matrixes are collected from expert consults and questionnaires. The weights and the maximum eigenvalue are computed by (5) (6), and the consistency is evaluated by (9). The computing results are shown to six decimal places in (Table5) ~ (Table9).

<Table 5> A-B judgment matrix

A	B_1	B_2	B_3	B_4	ω_{B_i}
B_1	1	1/2	1/3	1	0.141140
B_2	2	1	1/2	2	0.263049
B_3	3	2	1	3	0.454670
B_4	1	1/2	1/3	1	0.141140

λ_{max} =4.010359, CI=0.003, RI=0.9, CR=CI/RI=0.004<0.1

<Table 6> B_1-C judgment matrix

B_1	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	ω_{1j}
C_{11}	1	1/2	5	1	3	4	0.221486
C_{12}	2	1	7	2	3	5	0.345849
C_{13}	1/5	1/7	1	1/5	1/4	1/3	0.036778
C_{14}	1	1/2	5	1	3	4	0.221486
C_{15}	1/3	1/3	4	1/3	1	2	0.106567
C_{16}	1/4	1/5	3	1/4	1/2	1	0.067833

λ_{max} =6.174468, CI=0.035, RI=1.24, CR=CI/RI=0.028<0.1

<Table 7> B_2-C judgment matrix

B_2	C_{21}	C_{22}	C_{23}	C_{24}	ω_{2j}
C_{21}	1	2	1/2	3	0.277140
C_{22}	1/2	1	1/3	2	0.161070
C_{23}	2	3	1	4	0.465819
C_{24}	1/3	1/2	1/4	1	0.095970

λ_{max} =4.03104, CI=0.01, RI=0.9, CR=CI/RI=0.011<0.1

<Table 8> B_3-C judgment matrix

B_3	C_{31}	C_{32}	C_{33}	C_{34}	C_{35}	ω_{3j}
C_{31}	1	2	2	2	4	0.363636
C_{32}	1/2	1	1	1	2	0.181818
C_{33}	1/2	1	1	1	2	0.181818
C_{34}	1/2	1	1	1	2	0.181818
C_{35}	1/4	1/2	1/2	1/2	1	0.090909

λ_{max} =5, CI=0, RI=1.12, CR=CI/RI=0<0.1

<Table 9> B_4-C judgment matrix

B_4	C_{41}	C_{42}	C_{43}	C_{44}	C_{45}	ω_{4j}
C_{41}	1	3	3	2	5	0.410053
C_{42}	1/3	1	1	1/2	2	0.133603
C_{43}	1/3	1	1	1/2	2	0.133603
C_{44}	1/2	2	2	1	4	0.253122
C_{45}	1/5	1/2	1/2	1/4	1	0.069618

λ_{max} =5.018181, CI=0.005, RI=1.12, CR=CI/RI=0.004<0.1

2.6 Computation of synthetic weights

The weight of every index has been computed, but it is just the relative importance of the index regarding its upper level. So in order to evaluate the web site service quality, the synthetic weights regarding the goal level should be computed.

Generally the computing method is as follows:

Assume that the weights of the m elements in the (k-1)th level regarding the goal level have been computed, the corresponding weight vector is $W_{1xm}^{(k-1)}$, and the weights of the n elements in the kth level regarding the (k-1)th level have also been computed, the corresponding weight vectors constitute a matrix named P_{mxn}^{k}.

Then synthetic weight vector= $W_{1xm}^{(k-1)}$ P_{mxn}^{k} (10)

It is important to note that if there is no relationship between an element, let it be A, with some element in its upper lever, call it B, then the weight of A is 0 regarding B.

The synthetic consistency should also be evaluated.

$CI^{(k)}=(CI_1^{(k-1)}, CI_2^{(k-1)},\cdots\cdots, CI_m^{(k-1)})\ [W_{1xm}^{(k-1)}]^T$ (11)

$RI^{(k)}=(RI_1^{(k-1)}, RI_2^{(k-1)},\cdots\cdots, RI_m^{(k-1)})\ [W_{1xm}^{(k-1)}]^T$ (12)

$CR^{(k)}=CI^{(k)}/RI^{(k)}$ (13)

If $CR^{(k)}<0.1$, then the synthetic consistency can be thought satisfying.

The synthetic weights of the proposed index system are obtained by applying (10) (Table10) and the consistency is evaluated according to (11), (12), (13) (Table11).

<Table 10> Synthetic weights of the sub-indexes

	B_1 ω_{B_1} 0.141140	B_2 ω_{B_2} 0.263049	B_3 ω_{B_3} 0.454670	B_4 ω_{B_4} 0.141140	Syntheti c Weights ω'_{ij}
C_{11}	0.221486				0.031261
C_{12}	0.345849				0.048813
C_{13}	0.036778				0.005191
C_{14}	0.221486				0.031261
C_{15}	0.106567				0.015041
C_{16}	0.067833				0.009574
C_{21}		0.277140			0.072901
C_{22}		0.161070			0.042369
C_{23}		0.465819			0.122533
C_{24}		0.095970			0.025245
C_{31}			0.363636		0.165334
C_{32}			0.181818		0.082667
C_{33}			0.181818		0.082667
C_{34}			0.181818		0.082667
C_{35}			0.090909		0.041334
C_{41}				0.410053	0.057875
C_{42}				0.133603	0.018857
C_{43}				0.133603	0.018857
C_{44}				0.253122	0.035726
C_{45}				0.069618	0.009826

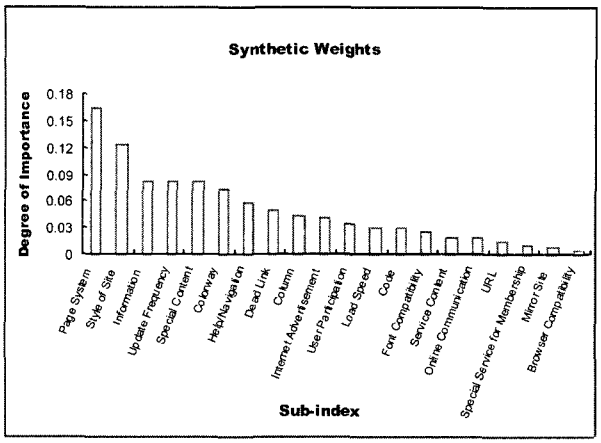
<Table 11> Synthetic consistency evaluation

	B_1	B_2	B_3	B_4
CI	0.035	0.01	0	0.005
RI	1.24	0.9	1.12	1.12
ω_{B_i}	0.141140	0.263049	0.45467	0.141140

CI'=0.008276, RI'=1.079065, CR'=CI'/RI'=0.00767<0.1

(Fig. 3) displays all the sub-indexes intuitionally,

in decreasing order of importance computed. This figure shows that the computing results are reasonable.



<Fig. 3> Importance of sub-indexes

3. Fuzzy synthetic evaluation on web site service quality

In this part, it will be tried to use fuzzy theory to evaluate web site service quality based on the weights of indexes and the synthetic weights of sub-indexes.

The fuzzy theory is inspired by the way the human brain acquires and processes information at low cost and high efficiency [13], that is, the manner in which the human mind deals with subjective concepts such as high, low, old, and new, and its natural inclination toward organizing, classifying and grouping into sets objects that share common characteristics or properties [14].

3.1 Definition of the total index set

The total index set of web site service quality includes index set $B=\{B_i\}$ $(i=1,2,\cdots,4)$ and sub-index set $C=\{C_i\}(i=1,2,\cdots,4)$, in which $C_1=\{C_{1j}\}$ $(j=1,2,\cdots,6)$; $C_2=\{C_{2j}\}$ $(j=1,2,\cdots,4)$; $C_3=\{C_{3j}\}$ $(j=1,2\cdots,5)$; $C_4=\{C_{4j}\}$ $(j=1,2\cdots,5)$.

3.2 Definition of weight set

Let the weight set of B be $\tilde{W}_B=\{\omega_{B_i}\}$ $(i=1,2,\cdots,4)$ and the weight set of C be $\tilde{W}_C=\{\tilde{W}_{C_i}\}$ $(i=1,2,\cdots,4)$, in which, $\tilde{W}_{C_1}=\{\omega_{1j}\}(j=1,2,\cdots,6)$; $\tilde{W}_{C_2}=\{\omega_{2j}\}(j=1,2,\cdots,4)$; $\tilde{W}_{C_3}=\{\omega_{3j}\}(j=1,2,\cdots,5)$; $\tilde{W}_{C_4}=\{\omega_{4j}\}(j=1,2,\cdots,5)$ (Table5) ~ (Table9).

Also let the synthetic weight set of C be $\tilde{W}_S=\{\omega'_{ij}\}$ $(i=1\ j=1,2,\cdots,6;\ i=2\ j=1,2,\cdots,4;\ i=3,4\ j=1,2,\cdots,5)$ (Table10).

3.3 Determining domain of choice comment

Web site service quality can be classified into five grades that can be expressed as V= {v_1, v_2, v_3, v_4, v_5} = {best, better, common, worse, worst}. The corresponding score set is E= {e_1, e_2, e_3, e_4, e_5} = {90, 70, 50, 30, 10} (hundred mark system).

3.4 Determining membership function

A fuzzy set is characterized by a member function, which maps the elements of a domain, space or discourse universe X for a real number in [0, 1]. Formally, $\tilde{A}: X \rightarrow [0,1]$. In extreme cases, the degree of membership is 0, in which case the element is not a member of the set, or the degree of membership is 1, if the element is a 100% member of the set [13].

Parabola of order k is chosen as the membership function in this paper. After a great lot of experiments, it is found that when k=1.2, the normality is good and the results are reasonable. The image of the membership function is shown in Fig.4 made by matlab software.

(1) The membership function of v_1 is determined as partial-to-large distribution

$$v_1(x)=\begin{cases} 0 & x<70 \\ \left(\frac{x-70}{20}\right)^{1.2} & 70\le x\le 90 \quad (14) \\ 1 & x>90 \end{cases} \qquad (14)$$

(2) The membership functions of v_2, v_3, v_4, are determined as partial-to-central distribution

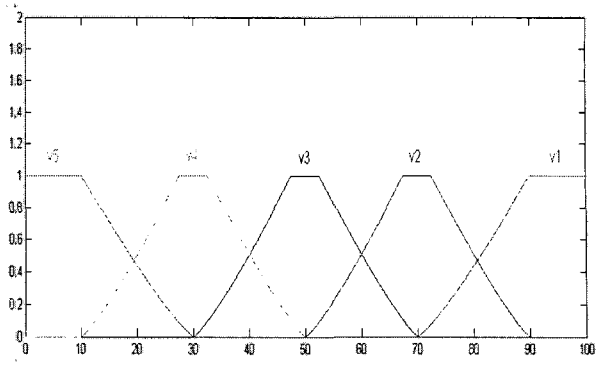
$$v_2(x)=\begin{cases} 0 & x<50 \\ \left(\frac{x-50}{17.5}\right)^{1.2} & 50\le x<67.5 \\ 1 & 67.5\le x<72.5 \quad (15) \\ \left(\frac{90-x}{17.5}\right)^{1.2} & 72.5\le x<90 \\ 0 & x\ge 90 \end{cases} \qquad (15)$$

$$v_3(x)=\begin{cases} 0 & x<30 \\ \left(\frac{x-30}{17.5}\right)^{1.2} & 30\le x<47.5 \\ 1 & 47.5\le x<52.5 \quad (16) \\ \left(\frac{70-x}{17.5}\right)^{1.2} & 52.5\le x<70 \\ 0 & x\ge 70 \end{cases} \qquad (16)$$

$$v_4(x)=\begin{cases} 0 & x<10 \\ \left(\frac{x-10}{17.5}\right)^{1.2} & 10\le x<27.5 \\ 1 & 27.5\le x<32.5 \quad (17) \\ \left(\frac{50-x}{17.5}\right)^{1.2} & 32.5\le x<50 \\ 0 & x\ge 50 \end{cases} \qquad (17)$$

(3) The membership function of v_5 is determined as partial-to-small distribution

$$v_5(x)=\begin{cases} 1 & x<10 \\ \left(\frac{30-x}{20}\right)^{1.2} & 10\le x\le 30 \quad (18) \\ 0 & x>30 \end{cases} \qquad (18)$$



<Fig. 4> Image of membership function by matlab

3.5 Carrying out fuzzy synthetic evaluation

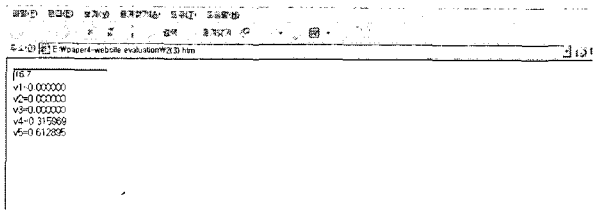
If a sub-index is marked, then the marked score can be mapped to 5 values based on the membership function (14), (15), (16), (17), and (18). In order to calculate easily, a program designed by html and javascript languages is given in Appendix. This program implements the function that once a number between 0 and 100 is input, the 5 computing results can be displayed to six decimal places (Fig.5). If an index set is $A=\{A_i\}$ (i=1,2,⋯,n), its criteria is P, and the marked score of A_i is g_i, then g_i can be mapped to $v_{i1}, v_{i2}, v_{i3}, v_{i4}, v_{i5}$, which constitute a relationship matrix of A named $\tilde{V}=\begin{bmatrix} v_{11} & v_{12} & \cdots & v_{15} \\ v_{21} & v_{22} & \cdots & v_{25} \\ \cdots & \cdots & \cdots & \cdots \\ v_{n1} & v_{n2} & \cdots & v_{n5} \end{bmatrix}$. Let the weight set of A be $\tilde{W}=\{\omega_i\}$ (i=1,2,⋯,n), then the fuzzy judgment vector of criteria P is defined as

$$\tilde{F}=[f_1\ f_2\ f_3\ f_4\ f_5]=normalize(\tilde{W}\circ\tilde{V})=normalize\left(\bigvee_{k=1}^{n}(w_k\wedge v_{ki})\right)$$
$$=normalize\left(\max_k(\min(w_k,v_{ki}))\right) \quad (19) \qquad (19)$$

The value of weighted fuzzy judgment of P is defined as:

$$VAL(\tilde{F}) = [f_1 \ f_2 \ f_3 \ f_4 \ f_5] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} \quad (20) \qquad (20)$$

which can be viewed as the evaluation score of the criteria P.



<Fig. 5> An example computing result of the program

4. Experiment and results

In this paper, the web site "www.sudopharm.co.kr" was evaluated to verify the validity and feasibility of the proposed model. Marked scores of 20 sub-indexes were obtained from questionnaires and experts (6th column in Table12). One of these scores was input into the blank (Fig.5) acquired by the program (Appendix) every time and the corresponding output values: v_1, v_2, v_3, v_4, v_5 were recorded in the 7th-11th columns in Table12.

The relationship matrixes of C_i and C are named $\tilde{V}_i$ and $\tilde{V}$, and the fuzzy judgment vectors of B_i and A are expressed as $\tilde{F}_i$ and $\tilde{F}$. $(i = 1,2,\cdots,4)$

According to the formula (19), we have

$\tilde{F}_1 = normalize(\tilde{W}_{C_1} \circ \tilde{V}_1)$. $\tilde{F}_2 = normalize(\tilde{W}_{C_2} \circ \tilde{V}_2)$.

$\tilde{F}_3 = normalize(\tilde{W}_{C_3} \circ \tilde{V}_3)$. $\tilde{F}_4 = normalize(\tilde{W}_{C_4} \circ \tilde{V}_4)$.

$\tilde{F} = normalize(\tilde{W}_S \circ \tilde{V})$.

The computing results of $\tilde{F}_1$, $\tilde{F}_2$, $\tilde{F}_3$, $\tilde{F}_4$, $\tilde{F}$ were shown in Table13. The values of weighted fuzzy judgment are calculated by applying (20) and the results of $\tilde{F}_1$, $\tilde{F}_2$, $\tilde{F}_3$, $\tilde{F}_4$, $\tilde{F}$

The value of weighted fuzzy judgment of B_1 is:

$$Val(\tilde{F}_1) = [0.544500 \ 0.348705 \ 0.000000 \ 0.000000 \ 0.106795] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 74.48228$$

The value of weighted fuzzy judgment of B_2 is:

$$Val(\tilde{F}_2) = [0.626978 \ 0.373022 \ 0.000000 \ 0.000000 \ 0.000000] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 82.53956$$

The value of weighted fuzzy judgment of B_3 is:

$$Val(\tilde{F}_3) = [0.500000 \ 0.250000 \ 0.250000 \ 0.000000 \ 0.000000] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 75$$

The value of weighted fuzzy judgment of B_4 is:

$$Val(\tilde{F}_4) = [0.322295 \ 0.174796 \ 0.105010 \ 0.198950 \ 0.198950] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 54.451$$

The value of weighted fuzzy judgment of A is:

$$Val(\tilde{F}) = [0.411156 \ 0.205578 \ 0.205578 \ 0.088844 \ 0.088844] \begin{bmatrix} 90 \\ 70 \\ 50 \\ 30 \\ 10 \end{bmatrix} = 65.22715$$

5. Discussions

These weighted fuzzy judgment values give us a comprehensive idea of this site's service quality. From the view of synthetic evaluation, the score of this web site service quality is 65.22715. Grade: better. In the following, the conditions of this web site are analyzed from

the view of indexes and their marked scores.

The score of this site's basic technique is 74.28228, which is found to be of a better grade. But the marked score of mirror site/affiliate site item is 0. So it is suggested to construct a mirror site for backup, in case the data are lost during the web site paralysis, and also to promote the users' visiting speed.

The score of this web site' web page design is 82.53956. Grade: best. That is because there appears to be good variety in the images within this web site (an average of 8 images can be found per page) and the fonts are used appropriately.

The score of this web site's information/ content is 75. Grade: better, not belonging to the best grade. It is attributed to the low update frequency and lack of special contents. If both the above functions are improved, the web site can be more attractive.

The score of this web site function/service is 54.451. Grade: common. Several suggestions are given here. First, there is no special service for membership (0 point). To increase the number of customers, this service has to be added. Second, it is also suggested to add the function of registration for common members. In this way, the company can get the information of users, such as e-mail address, which is of great concern for the company, to issue the up-to-date information to its customers at proper time. Furthermore, the addition of Q&A service to the English version will increase the popularity of this web site for international users.

If the above suggestions are adopted by the web site developer, it is believed that the service quality of this web site can be improved greatly.

<Table 12> Marked score of every index and results of v_1, v_2, v_3, v_4, v_5

	criteria	index	synthetic weight	weight	score	v_1	v_2	v_3	v_4	v_5
Goal A	B_1	C_{11}	0.031261	0.221486	90.00	1.000000	0.000000	0.000000	0.000000	0.000000
		C_{12}	0.048813	0.345849	100.00	1.000000	0.000000	0.000000	0.000000	0.000000
		C_{13}	0.005191	0.036778	94.50	1.000000	0.000000	0.000000	0.000000	0.000000
		C_{14}	0.031261	0.221486	81.00	0.488017	0.450241	0.000000	0.000000	0.000000
		C_{15}	0.015041	0.106567	81.70	0.525517	0.408553	0.000000	0.000000	0.000000
		C_{16}	0.009574	0.067833	0.00	0.000000	0.000000	0.000000	0.000000	1.000000
	B_2	C_{21}	0.072901	0.277140	76.50	0.259573	0.732411	0.000000	0.000000	0.000000
		C_{22}	0.042369	0.161070	79.33	0.400518	0.552270	0.000000	0.000000	0.000000
		C_{23}	0.122533	0.465819	88.57	0.914826	0.049517	0.000000	0.000000	0.000000
		C_{24}	0.025245	0.095970	77.00	0.283715	0.699981	0.000000	0.000000	0.000000
	B_3	C_{31}	0.165334	0.363636	90.33	1.000000	0.000000	0.000000	0.000000	0.000000
		C_{32}	0.082667	0.181818	80.30	0.450992	0.492584	0.000000	0.000000	0.000000
		C_{33}	0.082667	0.181818	60.00	0.000000	0.510922	0.510922	0.000000	0.000000
		C_{34}	0.082667	0.181818	70.50	0.011954	1.000000	0.000000	0.000000	0.000000
		C_{35}	0.041334	0.090909	82.00	0.541728	0.390897	0.000000	0.000000	0.000000
	B_4	C_{41}	0.057875	0.410053	85.00	0.708066	0.222392	0.000000	0.000000	0.000000
		C_{42}	0.018857	0.133603	65.63	0.000000	0.873183	0.189205	0.000000	0.000000
		C_{43}	0.018857	0.133603	35.50	0.000000	0.000000	0.249339	0.798000	0.000000
		C_{44}	0.035726	0.253122	24.37	0.000000	0.000000	0.000000	0.789000	0.797987
		C_{45}	0.009826	0.069618	0.00	0.000000	0.000000	0.000000	0.000000	1.000000

<Table 13> Fuzzy judgment vector of A and B_i

Fuzzy judgment vector of B_1 ($\tilde{F}_1$)	Fuzzy judgment vector of B_2 ($\tilde{F}_2$)	Fuzzy judgment vector of B_3 ($\tilde{F}_3$)	Fuzzy judgment vector of B_4 ($\tilde{F}_4$)	Fuzzy judgment vector of A ($\tilde{F}$)
0.544500	0.626978	0.500000	0.322295	0.411156
0.348705	0.373022	0.250000	0.174796	0.205578
0.000000	0.000000	0.250000	0.105010	0.205578
0.000000	0.000000	0.000000	0.198950	0.088844
0.106795	0.000000	0.000000	0.198950	0.088844

6. Conclusions

The main indexes that influence the web site service quality are analyzed and classified to make the evaluation system reasonable and accurate.

The index weights of web site service quality were determined by AHP, which can eliminate the subjective component of experts' knowledge, and can easily be expressed in a quantitative form. Then the synthetic weights of the sub-indexes are computed by the results of all index weights.

The fuzzy synthetic judging method is introduced into the evaluation model for web site service quality, which makes the results more reasonable and accurate.

The results of the experiment on the pharm web site show that the proposed evaluation model is feasible and valid, and the evaluation process is easy to be programmed. In this paper, a program for the membership function has already been designed in html and javascript languages. The whole evaluating procedure based on this model is being expected to be programmed to implement the whole evaluation process automatically, which we have planned to pursue in the future.

By highlighting the site's weaknesses, this model furnishes site owners with constructive suggestions and thereby users' requirements can be met better.

Appendix

```
<script>
function change(num){
if(num>0&&num<1)
  { var str=new String(num).substring(0,8);
     var str2=new String(num).substring(8,9);
     var flag;
     if(parseInt(str2)>=5) {flag=true; }
     var n
     if(flag) {n=parseFloat(str)+0.000001; }
     else {n=parseFloat(str); }
     var s = new String(n);
     if(s.length>8) {s=s.substring(0,8); }
     else if(s.length<8)
          { var t=8-s.length;
            for(i=0;i<t;i++) {s+="0";} }
    return s;}
else {return num+".000000";} };
function get(obj){
     if(event.keyCode==13){
                         var a=get1(obj);
                         var b=get2(obj);
                         var c=get3(obj);
                         var d=get4(obj);
                         var e=get5(obj);
        a=change(a);
                         b=change(b);
                         c=change(c);
                         d=change(d);
                         e=change(e);
                         var  str="v1="+a+"<br>"+"v2="+b+"<br>
"+"v3="+ c+"<br>"+"v4="+d+"<br>"+"v5="+e+"<br>"
      document.getElementById("result").innerHTML=str; } }
function get1(obj){
          if(event.keyCode==13){
                         var v = obj.value;
                         if(v>90) {return 1; }
                         else if(v<70) {return 0; }
    else {return Math.pow((v-70)/20,1.2); } } }
function get2(obj){
          if(event.keyCode==13){
                         var v = obj.value;
                         if(v>=90) {return 0; }
                         else if(v<50) {return 0; }
          else if(v<72.5&&v>=67.5) {return 1; }
else if(v>=72.5&&v<90)
                          {return Math.pow((90-v)/17.5,1.2); }
                         else if(v>=50&&v<67.5)
```

```
                    {return Math.pow((v-50)/17.5,1.2); } } }
function get3(obj){
        if(event.keyCode==13){
                    var v = obj.value;
                    if(v>=70) {return 0; }
                    else if(v<30) {return 0; }
        else if(v<52.5&&v>=47.5) {return 1; }
else if(v>=30&&v<47.5)
                        {return Math.pow((v-30)/17.5,1.2); }
                    else if(v>=52.5&&v<70)
                    {return Math.pow((70-v)/17.5,1.2); } } }
function get4(obj){
        if(event.keyCode==13){
                    var v = obj.value;
                    if(v>=50) {return 0; }
                    else if(v<10) {return 0; }
        else if(v<32.5&&v>=27.5) {return 1; }
                    else if(v>=10&&v<27.5)
                        {return Math.pow((v-10)/17.5,1.2); }
                    else if(v>=32.5&&v<50)
                    {return Math.pow((50-v)/17.5,1.2); } } }
function get5(obj){
        if(event.keyCode==13){
                    var v = obj.value;
                    if(v>30) {return 0; }
                    else if(v<10) {return 1; }
    else {return Math.pow((30-v)/20,1.2); } } }
</script>
<input type="text" onkeyup="get(this)">
<div id="result"></div>
```

References

[1] N.Di Blas, HOC-DEI, Politecnico di Milano, M. P. Guermand, IBC, Istituto Beni Culturali, Emilia Romagna, Carolina Orsini, Università di Bologna, Paolo Paolini, Politecnico di Milano, Italy, Evaluating the features of museum websites: (The Bologna Report), Meseums and the web 2002

[2] L. Olsina and G. Rossi. Measuring web application quality with WebQEM. IEEE Multimedia (2002)

[3] A. Beirekdar, J. Vanderdonckt and M. Noirhomme-Fraiture. A framework and a language for usability automatic evaluation of web sites by static analysis of HTML source code. In: Kolski, Ch. Vanderdonkt, J. (eds.): Proc. Of 4th Int. Conf. on computer-aided design of user interfaces CADUI (2002)

[4] M. Ivory. Automated web site evaluation. Researchers' and practitioners'perspectives. Human-computer Interaction Series, Vol. 4, Kluwer Academic Pub.: Dordrecht (2003)

[5] L. Mich, M. Franch and L. Gaio. Evaluating and Designing the Quality of Web Sites. IEEE Multimedia, Jan-Mar,2003, pp. 34-43.

[6] Wang Dao-lin and Liu Shu-kun. The mathematical model of the website evaluation. Journal of Taishan university, May, 2004, vol.26, No.3

[7] Oreste Signore. A Comprehensive Model for Web Sites Quality. Proceedings of WSE2005-Seventh IEEE International Symposium on Web Site Evolution-Budapest, Hungary-September 26, 2005.

[8] ISO 13407 Human centered design processes for interactive systems(1999) http://www.usabilitynet.org/tools/r_international.htm#13407.

[9] ISO/IEC FDIS 9126-1: Software Engineering-product quality-part1: quality model (2000). http://www.usabilitynet.org/tools/r_international.htm#9126-1

[10] ISO 9241-11 Guidance on usability (1998) http://www.usabilitynet.org/tools/r_international.htm#9241-11.

[11] T.L.Saaty. The analytic hierarchy process, McGraw-Hill company, New York, 1980.

[12] Shih-Wen Hsiao. Concurrent Design Method for Developing A New Product. International Journal of Industrial Ergonomics 29 (2002), pp. 41-55.

[13] L. A. Zadeh, 1998, Fuzzy Logic, IEEE Transaction Compute., vol. 25.

[14] H. J. Zimmermann, 1991, Fuzzy Set Theory and Its Applications, Kluwer Boston, 2nd revised edition.

[15] Chang Jinling, Xia Guoping, "Comprehensive Evaluation of E-commerce Website Based on Concordance Analysis", Proceedings of the 2005 IEEE International Conference on

e-Business Engineering (ICEBE' 05).

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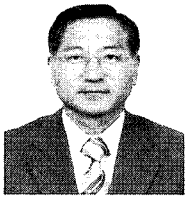

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