Fuzzy Evaluation Modeling and Simulation Research on the Skin Condition Based on CRITIC

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Abstract.

Evaluating the skin condition objectively and effectively is not only conducive to the maintenance and improvement of individual skin and making evaluation of skin care products to use utility, but also could be powerful evidence on human health degree. Because a lot of factors have affected the skin condition, it is biased with evaluation by using only a single index. This paper firstly introduced CRITIC method which is based on the data to determine the weight of each single index to maximize the use of test data and information; then synthesize the skin condition index distribution characteristics and the experience of experts and decide to use the normal distribution of the membership function to characterize different index; finally set the membership vectors corresponding to the maximum value as the evaluation grade of the skin condition by the fuzzy matrix synthesis algorithm. The results of the actual test and analysis in lab indicate the effectiveness of the proposed evaluation method.

Keywords: Skin Condition, Fuzzy Comprehensive Evaluation, CRITIC

Introduction

The pursuit of health promotes rapid development of dermatology. The quality of skin and the safety of cosmetics' uses make us attach an importance to face nursing care. For the deepening of recognizing and studying about skin condition and the physiological function of cutaneous appendages, it's an urgent demand to evaluate the quality of skin effectively. The division of the skin quality was necessary to be solved in cosmetics industry. The accurate evaluation of skin condition as well as the division can provide a good solution, especially in the improvement of feminine skin and the uses of cosmetics[1-2].

At present, most of the skin condition evaluation depends on the expert experience which lack of accuracy and have certain subjectivity. So it is difficult to give criterion objectively for evaluation of the skin. Skin condition evaluation of existing algorithms is not a lot, Chen jin et al made study on quantitative evaluation of skin roughness and application to the medical cosmetic industry. They point out the importance of evaluation of facial skin texture objective and quantitative in cosmetology and nursing care field in this respect from the physiological mechanism of human skin[3]. Wen Xiang et al provide 3 types of noninvasive method to build the relationship between the age and skin texture, roughness, elasticity of women which could provide a reference for determining the evaluation index of the skin[4]. Zhang Mi et al set a skin image collection evaluation management system to evaluate facial skin of the 24 year old woman by the skin image feature parameters, which can accurately reflect the current state of the skin[5]. Xu Pengxiang proposed using index of image extraction to value the skin condition and made a study of the degree on skin aging by neural network which has certain guiding significance[6]. At present in the skin quality assessment field, analysis is mainly for one or several single index, while methods of comprehensive evaluation based a number of indicators of value were not reported. For human facial skin condition is a combined action result of complex multi-factor interaction，the single index evaluation is not comprehensive enough, so established multi index comprehensive evaluation method of skin condition is objective, reasonable to help people make aesthetic health care and to choose cosmetic effect.

In this papers starting from the analysis of multiple skin index test data, determine the relative value of each single index weight by CRITIC method and evaluate the multi-index of the skin by fuzzy comprehensive to indicate the skin condition more comprehensively and grade objectively which would support skin quality improvement and provide scientific decision basis for development of cosmetics later.

Fuzzy comprehensive evaluation based on CRITIC method

Weight of CRITIC method. CRITIC is a method t of weigh determination proposed by Diakoulaki which is a kind of objective weighting method based on the contrast intensity and index conflict to determine the objective weight [7]. The contrast intensity refers to each index corresponding to different standard deviation. The bigger standard deviation is, the more information the index contain. And index conflict is based on index relevance. If negative correlation coefficient of index is bigger, it indicates that the information reflected from indexes is quite different; the index carries more weight than others.

The symbol C_j means the amount of information contained in the index j, the formula of C_j is defined as follows:

$$C_j = \sigma_j \sum_{j=1}^{m} (1-\tau_{ij}) \left(j = 1, 2, \cdots, m \right)$$

(1)

Where σ_j is the standard deviation of the index *j*, and the τ_{ij} is the correlation coefficient of the index *i* and the index *j*.

According to the information from C_j ,the calculated formula of index weight is defined as follows:

$$w_j = C_j / \sum_{j=1}^{m} C_j (j = 1, 2, \cdots, m)$$

(2)

The fuzzy comprehensive evaluation matrix. $U = \{x_1, x_2, \cdots, x_n\}, V = \{y_1, y_2, \cdots, x_m\}$ are defined as two finite. *U* is the factor set, $x_1, x_2 \cdots$， x_n are skin index data using for the evaluation. *V* is the evaluation set， $y_1, y_2 \cdots y_m$ are the set of evaluation standard which corresponding with x_n. In this paper, *U* is a fuzzy vector, *V* is an index data matrix, *R* is a fuzzy relationship matrix, which is used to indicate the fuzzy relationship between evaluation universe *V* and factor universe *U*. Fuzzy matrix *R* is shown in formula（3）.

$$R = \left[r_{ij} \right] = \begin{Bmatrix} r_{11} \cdots r_{1n} \\ \vdots \\ r_{1m} \ldots r_{mn} \end{Bmatrix}$$

(3)

Where r_{ij} indicates the possibility that the skin index *i* is set as the level *j* of skin quality，namely fuzzy membership degree of *i* to *j*， $0 \le r_{ij} \le 1$.

After obtaining fuzzy vector A and fuzzy relation matrix *R* respectively, the fuzzy subset *B* of comprehensive evaluation could be obtained through complex operation with A and R[8-9].

Comprehensive fuzzy subset of the factor universe *U* is:

$$A = \frac{a_1}{x_1} + \frac{a_2}{x_2} + \cdots + \frac{a_m}{x_m}$$

(4)

Where a_i indicates the importance of single factor x_i played in all factors, namely the importance of the skin index i played in all skin indexes.

In evaluation universe V, fuzzy subset is:

$$B = \frac{b_1}{y_1} + \frac{b_2}{y_2} + \ldots + \frac{b_n}{y_n} \tag{5}$$

Where b_j indicates the degree of membership of y_j on comprehensive evaluation fuzzy subset, namely the skin quality belongs to the fuzzy membership degree of comprehensive skin quality level *j*.

According to the fuzzy vector *A* and fuzzy relation matrix *R* obtained previously, the fuzzy subset of comprehensive evaluation can be defined as follows:

$$B = (b_j) = (\bigcup_{i=1}^{m+1} a_i \bigcap r_{ij}) \; j = 1, 2, \cdots, n \tag{6}$$

Formula（6）can be expressed as formula（7） by fuzzy matrix synthesis algorithm or general matrix algorithm.

$$B = A \bullet R \tag{7}$$

In formula（7）, operation symbol is the synthesis operator.

Determination of membership function. At present there is no unified and effective standard to establish membership function, the construction of fuzzy membership are mainly based on the experience and numerical experiments. For the same fuzzy concept, we can use fuzzy statistical method, exemplification, expert experience method, dualistic contrast compositor to determine fuzzy membership function.

In this paper, according to the skin condition index distribution characteristics and the experience of experts, we determine that fuzzy membership function is normal distribution. The specific parameters are different at different level of different index. For example, the membership degree of Water content in grade I is shown in formula (8), the normal distribution membership is shown in figure 1.

$$\underset{\sim}{R}(x) = \begin{cases} 1, x \le a \\ e^{-(\frac{x-a}{\sigma})^2}, x > a \end{cases} \tag{8}$$

where *a* is a turning point when the membership degree is equal to 1, meanwhile it is the mean of normal distribution, σ is the standard deviation of normal distribution.

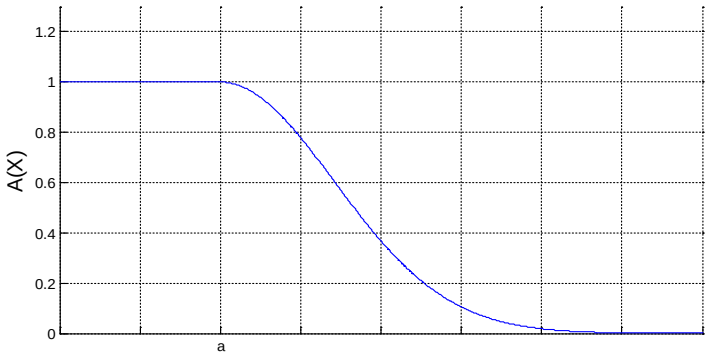

Fig1. The membership degree of Water content in grade I

Analysis of Application example

Sample selection. Samples on background of skin are taken from the test which was conducted in lab at Cosmetic Collaborative Innovation Center of BTBU in July 26, 2014. In the process of testing, we guaranteed that the participants' skin is clean and the test environment temperature is constant. We used professional skin test instrument such as Corneometer CM 825，Tewamater TM300, Subumeter SM810, Mexameter MX18, MPA 9, GL 200 to test the participants' forehead with many indexes (Water content, the loss of water, grease, melanin, skin color, gloss, elastic, roughness, etc.).The test results are shown in Table 1

Table 1 sample data of Laboratory test

Number	Water content	The loss of water	Grease	Melanin	Skin colour IAT	Gloss	Elastic R2	Roughness Rz
1	61.96	27.1	26	269.3	32.3	7.47	0.7406	0.1133
2	69.94	15.1	37	229.0	35.3	4.93	0.6634	0.0967
3	62.96	9.6	35	242.7	28.3	6.78	0.5644	0.1073
4	56.54	12.3	19	228.0	40.7	5.98	0.5822	0.0716
5	29.02	29.6	14	139.7	45.3	6.66	0.5699	0.1851
6	42.86	25.6	30	234.0	38.3	8.06	0.7341	0.0662

…	…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…	…
47	68.84	13.7	12	219.7	50.7	6.09	0.4828	0.0519
48	66.22	20.4	14	236.7	46.0	7.34	0.6202	0.0887
49	76.52	44.5	6	223.0	40.7	7.20	0.6513	0.0588
50	68.98	16.2	27	204.7	51.0	7.97	0.4586	0.0990
51	174.44	28.9	22	241.7	44.3	9.92	0.5850	0.0716
52	50.48	30.2	4	192.3	61.7	6.69	0.7616	0.0928

Dividing the skin quality condition of test indexes into four levels (I、II、III、IV)，the level I is the best，IV is the worst. The classification Standard of single skin factor is determined through consulting the relevant experts in skin care and the medical field as is shown in table 2.

Table 2 Classification Standard of single skin factor index

Level	Water content	The loss of water	Grease	Melanin	Skin colour IAT	Gloss	Elastic R2	Roughness Rz
I	65-	0-13	30-40	-150	45-	10-	0.9-	0-0.08
II	40-65	13-20	15-30,40-55	150-250	20-45	6-10	0.6-0.9	0.08-0.12
III	30-50	20-30	10-15,55-65	250-300	-5-20	3-6	0.3-0.6	0.12-0.16
IV	-20	30-	-10,65-	300-	-30-0	0-3	0-0.3	0.16-

Fuzzy comprehensive evaluation of the skin quality. Considering different skin index has different impacts on the classification of skin comprehensive level, there needs to determine the weights to distinguish the importance which different skin index plays in skin condition evaluation. Using CRITIC method to analysis the laboratory test data, the relative weights of water content, the loss of water, grease, melanin, skin color IAT, gloss, elastic R2 and roughness Rz can be obtained from formula (1) and formula (2) that is $A=\left(0.1544,0.145,0.2496,0.0690,0.0865,0.0869,0.0749,0.1336\right)^{T}$.

Due to the comprehensive evaluation of skin condition and skin grading standards are all vague boundary concept, so using the fuzzy membership function introduced in section 2.3 to evaluate is relative objective. Taking a laboratory test sample, the value of eight indicators were $P=\left[68.12, 15.5, 30, 286, 36.33, 8.56, 0.8708, 5.9, 0.167\right]$. According to the four

levels evaluation criteria of single skin factor identified by the experts and the normal distribution followed by the index in each level, calculating eight index's membership belonging to each level. We get the membership matrix as follows:

$$R=\left[r_{ij}\right]=\begin{bmatrix} 0.962 & 0.0375 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0.499 & 0.415 & 0 & 0 \\ 0 & 0.0519 & 0.824 & 0 \\ 0.0175 & 0.712 & 0 & 0 \\ 0.237 & 0.925 & 0.0162 & 0 \\ 0.306 & 0.523 & 0 & 0 \\ 0 & 0 & 0.154 & 0.846 \end{bmatrix}$$

Using formula (7) to calculate skin comprehensive level and evaluation value, that is $B=A\bullet R=[0.3182,0.439,0.0788,0.113]$. As can be seen from the comprehensive membership, the comprehensive membership in level II is 0.439, which is bigger than the other levels. Therefore, level II can be used as the evaluation result of the sample .Choosing 10 samples from the 52 known samples, comparing the results obtained from fuzzy comprehensive evaluation and experts' opinions, of which nine sample results are corresponding, and one is near to the experts' opinions, so fuzzy comprehensive evaluation based on CRITIC method has a certain accuracy and effectiveness in the calculating process of skin quality evaluation.

Conclusion

Evaluation of in vitro skin condition involving many factors, it is considered an important basis skin care functions and human health. Skin evaluation system was firstly established in this paper, and then the corresponding normal membership functions and parameters on a single index were determined with the experts experience on the single index grade classification. Combine with the measured data to calculate the relative weight of single indicator by CRITIC method, value the maximum membership degree of fuzzy comprehensive from vector results of fuzzy matrix synthesis algorithm as the corresponding sample skin level. The results are compared with the expert given which indicate the proposed CRITIC method based on the fuzzy comprehensive evaluation of the skin condition has certain practical significance.

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