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Research Article

Application on the Entropy Method for Determination of Weight of Evaluating Index in Fuzzy Mathematics for Wine Quality Assessment

Hanping Zhang
Computer Department, Wuhan Polytechnic, Wuhan 430074, China

Abstract: Considering the fuzzy comprehensive evaluation method often adopted characteristic vector method of two judgment matrix between indicators for multiple factor empowerment, which has some problems such as strong subjectivity, large amount of calculation, failed to consider the relationship between multiple targets and so on, this and puts forward the target factor of multiple evaluation by entropy method of empowerment, using the sensory evaluation data given by wine sommelier, to carry on the comprehensive evaluation of the wine quality. The result shows that using the entropy weight method empowerment factors of fuzzy comprehensive evaluation, the process is simple with small amount of calculation and the result is objective and reasonable.

Keywords: Entropy weight method, fuzzy evaluation, the weight, wine evaluation

INTRODUCTION

As a kind of delicate flavor drinks wine, it can not only satisfy people's sensual pleasure, but also has very high nutrition and health value (Wang, 2007). Due to the numerous grape varieties, all kinds of climate, soil and other ecological conditions and different characteristics of brewing methods and different ways of aging, there are great differences between the various types of wine in the production. Because smell and taste of wine has changed a lot for its variety and complex composition, people have made great efforts on how to make use of modern instrumental analysis to determine the quality of the wine and also made a breakthrough, but the sensory evaluation is still the most effective way to evaluate its sensory quality.

Sensory evaluation of wine also called wine tasting or evaluation of wine, which is an analysis method of the evaluators of liquor to evaluate the sensory characteristics of wine's appearance, aroma, taste and balance by sense organ such as eyes, nose and mouth. In the sensory evaluation of wine, there are differences between the different members of liquor for evaluation of the same kind of wine because of the different evaluation scale, location and direction of assessments. Determining the quality of wine is generally by hiring a group of qualified evaluators of liquor. Each liquor evaluator has review on wine's classification index after tasting it and then get its total sum, to determine the quality of the wine. Therefore, it must be carried out on the original data of members of liquor corresponding processing, when the sensory evaluation results were statistically analyzed, in order to reflect the differences between the samples.

In recent years, the fuzzy comprehensive evaluation method for Wine Quality Assessement has been widely researched and applied (Hui, 2013; Feng and Wang, 2011; Yao and Zhou, 2013). With a review of the judges' score data, according to wine quality characteristics of the gradual transition from good to bad and the fuzzy comprehensive evaluation method, more scientific and reasonable evaluation and classification results are obtained. In this process, we need to analyze sensory factors affecting the quality of wine, also the evaluation factor criterion layer, scheme and membership function, coupled with the weight of each factor and the membership degree to determine the level of wine. In the fuzzy comprehensive evaluation, the calculation of weight is an important content, directly affect the final result. Now generally adopt two factors to determine its eigenvalue and eigenvector matrix method.

Using this method will encounter some problems, such as when the layer number of evaluation and evaluation factors is too large, computing the weight one by one is a large amount of calculation and it's very subjective for experts to have a pairwise comparison between the importance of factors. For failing to integrated all the data relationship, there will be a consistent check does not meet the case and the method fails. The existing fuzzy comprehensive evaluation method has some defects.

In order to solve the problems above, this and gives the entropy method for determination of weight of evaluating index in fuzzy mathematics, which conbines the opinions of the professional expert (Committee of the National College Students' Mathematical Modeling Competition Organization, 2012) with fuzzy analysis, resulting in a certain level and then to sort. It is a combination method of qualitative analysis and quantitative analysis (Cheng, 2010).

MATERIALS AND METHODS

Empowerment entropy weight method of fuzzy comprehensive evaluation model applied in the evaluation of wine:

The data source and data processing: This and chose data (Committee of the National College Students' Mathematical Modeling Competition Organization, 2012) of the annex 1 from the 2012 national college students' mathematical modeling problem A. Selecting the second group of serial number 1-12 kinds of red wine as sample, the evaluation indicators are the appearance, aroma, taste and the whole and so on. The data value of indicators is the average value of 10 judges, as shown in Table 1.

Each evaluation index will be given 4 evaluation class, such as excellent, good, medium and poor evaluation and each class defines a score range, as shown in Table 2.

Analyzing the data of 10 evaluators ratings, conclude the statistics for each evaluation objects and each index into the frequency of all the evaluation range and get the membership function of each sample. Take the example of sample 1 and sample 2, the membership of various indicators frequency as shown in Table 3.

Write a membership matrix of sample 1 and sample 2 according to Table 3:

$$R_1 = \begin{bmatrix} 0.1 & 0.6 & 0.3 & 0 \\ 0 & 0.3 & 0.6 & 0.1 \\ 0 & 0.1 & 0.6 & 0.3 \\ 0 & 0.8 & 0.2 & 0 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 0 & 0.4 & 0.6 & 0 \\ 0 & 0.6 & 0.4 & 0 \\ 0 & 0.2 & 0.7 & 0.1 \\ 0 & 0.2 & 0.8 & 0 \end{bmatrix}$$

Similarly, other samples of membership matrix can be obtained, not listed one by one here.

The way of entropy weight method to calculate weight factor:

The introduction of entropy weight method: The entropy weight method was originally a concept of thermodynamics, which firstly added into the information theory by C.E.S hannon and it is now applied widely in the field of engineering technology, social economy, etc. Based on the basic principle of information theory, the information is a measure of system orderly degree, but the entropy is a measure of the system's disorder. Their absolute value is equal, but the symbol instead.

If the smaller information entropy of the indicators is, the larger amount of information provided by indicators and play a more important role in the comprehensive evaluation and the higher weight should be. On the contrary, the result will be the same:

$$E = -\sum_{i=1}^{m} p_i \ln p_i$$

If the system may be in a variety of different states and the probability of each state to appear is p_i(i = 1, 2, … m), the entropy of the system can be defined as:

$$E = -\sum_{i=1}^{m} p_i \ln p_i$$

Obviously, when $p_i = 1/m$ (i = 1, 2, … m), namely when the probability of each state is equal, the maximum entropy is:

$$E_{\max} = \ln m$$

The step of the entropy weight method to calculate weight (Ren *et al*., 2005): If presently there are m units waited for evaluation and n evaluation indicators, the original data matrix is:

$$X = (x_{ij})_{m\times n} \tag{1}$$

Because the measurement unit of each index in the evaluation system is different and the value range is different, it is necessary to standardize indicators. The standardization of matrix X is:

$$R = (r_{ij})_{m\times n} \tag{2}$$

r_{ij} is the standard values of indicators of i^{th} sample, it can be calculated by the following formula:

$$r_{ij} = \frac{x_{ij} - \min_i\{x_{ij}\}}{\max_i\{x_{ij}\} - \min_i\{x_{ij}\}} \tag{3}$$

Again to normalized the matrix R:

$$P = (p_{ij})_{m\times n} \tag{4}$$

Among them:

$$p_{ij} = r_{ij} / \sum_{i=1}^{m} r_{ij} \tag{5}$$

The information entropy of indicators r_j is:

$$E_j = -\frac{1}{\ln m}\sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{6}$$

If p_{ij} = 0, we can define $\lim_{p_{ij}\to 0} p_{ij} \ln p_{ij} = 0$

After calculating, the information entropy of indicators are E_1, E_2, … E_n and the information entropy weights of every indicators are:

Table 1: The scores of data about 12 kinds of red wine evaluation objects in four sensory evaluation factors

Sample number	Appearance analysis	Aroma analysis	Texture analysis	Overall /balance
1	10.7	20.1	27.9	8.4
2	10.1	22.1	32.7	9.1
3	10.1	22.6	28.5	8.9
4	10.7	20.7	30.0	8.8
5	10.8	20.9	31.5	8.9
6	7.70	20.1	28.8	8.6
7	7.50	20.1	29.3	8.4
8	9.80	19.4	28.0	8.4
9	11.0	25.5	32.3	9.4
10	11.0	21.0	28.2	8.4
11	7.00	21.1	25.9	8.1
12	9.80	19.8	31.1	8.7

Table 2: Four indicators rating scoring criteria

Indicators	Excellent	Good	Medium	Poor
Appearance	≥13	11≤, <13	6<, <11	≤6
Aroma	≥26	22≤, <26	15<, <22	≤15
Texture	≥40	36≤, <40	29<, <36	≤29
Overall/balance	≥10	8≤, <10	5<, <8	≤5

Table 3: Membership frequency in every indicators of sample 1 and sample 2

Sample number		Appearance analysis	Aroma analysis	Texture analysis	Overall /balance
Sample 1	Excellent	1	0	0	0
	Good	6	3	1	8
	Medium	3	6	6	2
	Poor	0	1	3	0
Sample 2	Excellent	0	0	0	2
	Good	4	6	2	8
	Medium	6	4	7	0
	Poor	0	0	1	0

Table 4: The standardization data for evaluation objects about 12 kinds of red wine in four sensory evaluation factor

Sample number	Appearance analysis	Aroma analysis	Texture analysis	Overall /balance
1	0.925	0.112	0.308	0.231
2	0.775	0.450	1.000	0.769
3	0.775	0.533	0.400	0.615
4	0.925	0.212	0.631	0.538
5	0.950	0.250	0.862	0.615
6	0.175	0.112	0.446	0.385
7	0.125	0.112	0.523	0.231
8	0.450	0.000	0.323	0.231
9	1.000	1.000	0.985	1.000
10	1.000	0.267	0.354	0.231
11	0.000	0.283	0.000	0.000
12	0.700	0.067	0.800	0.462

$$w_i = \frac{1-E_i}{\sum_{i=1}^{n}(1-E_i)} \quad (i=1,2,\cdots n) \tag{7}$$

The calculation of index weight: First of all, standardize the data of the Table 1 in accordance with the Eq. (3) to get Table 4.

According to the Eq. (4) (5) (6) to calculate the entropy and entropy weight of each evaluation index (Table 5).

So we can get weight vector of the appearance, aroma, taste, sensory evaluation factors/balance of wine is W = [0.29, 0.21, 0.15, 0.35].

RESULTS AND DISCUSSION

Fuzzy evaluation results:

Method 1: Processing operations of fuzzy operator for each sample, we get four grades of membership degree. Such as sample 1 and sample 2:

Table 5: Each indicators information entropy and entropy weight

Indicators	Information entropy	Entropy weight
Appearance analysis	0.926	0.29
Aroma analysis	0.946	0.21
Texture analysis	0.963	0.15
Overall/balance	0.911	0.35

$$A_1 = WR_1 = \left[0.29, 0.21, 0.15, 0.35\right]\begin{bmatrix} 0.1 & 0.6 & 0.3 & 0 \\ 0 & 0.3 & 0.6 & 0.1 \\ 0 & 0.1 & 0.6 & 0.3 \\ 0 & 0.8 & 0.2 & 0 \end{bmatrix} =$$

$$\left[0.029, 0.532, 0.373, 0.066\right],$$

$$A_2 = WR_2 = \left[0.29, 0.21, 0.15, 0.35\right]\begin{bmatrix} 0 & 0.4 & 0.6 & 0 \\ 0 & 0.6 & 0.4 & 0 \\ 0 & 0.2 & 0.7 & 0.1 \\ 0 & 0.2 & 0.8 & 0 \end{bmatrix} =$$

$$\left[0, 0.342, 0.643, 0.15\right]$$

According to maximum membership degree principle, sample 1 is in good grade, sample 2 is in medium grade. Similarly each sample can be available to get the evaluation level.

Method 2: If the four indexes' standard vector are $R^i = [r_1^i, r_2^i, r_3^i, r_4^i]$ in a sample, we can get specific evaluation score of each sample by $W(R^i)^T$, which can be applied into the wine rank competition. Such as the score calculation of sample 1 and sample 2:

$$W(R^1)^T = [0.29, 0.21, 0.15, 0.35][0.925, 0.112, 0.308, 0.231]^T = 0.419$$
$$W(R^2)^T = [0.29, 0.21, 0.15, 0.35][0.775, 0.45, 1, 0.769]^T = 0.7384$$

Sample 2 Score higher than sample 1. It seems that the results of two methods contradict, actually it is not true. Method 1 is grade evaluation and each level has bottom limit. Method 2 is the empowerment of average, hiding the differences, even comparison, should also process classification firstly and then rank. That will be more scientific.

CONCLUSION

- Compared with the traditional fuzzy comprehensive evaluation method, through the entropy weight method to empower each evaluation factor and assess wine quality of several samples above, just calculating one time will be suitable for the weight of all samples, which greatly reduce the workload required for evaluation.
- Using the entropy weight method can combine the multiple evaluation samples of the same monitoring indicators to determine weight, considering the contact between the multiple samples can weaken the influence of the outliers and make evaluation result more accurate and reasonable.
- The calculation result shows that the entropy weight method is a effective way of empowerment and has important value in the fuzzy comprehensive evaluation of wine quality.

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