A Multi-granular Fuzzy Comprehensive Evaluation Model for E-commerce Enterprise Image

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***Abstract*—The enterprise image is the general impression that the public gets in association with an enterprise directly. In the imformation age, the emergency of e-commerce provides a new way for the construction of enterprise image by the help of network technology. However, because of its abstraction, intangiblity, and complexity, it is become diffcult to get to know the enterprise image all-round. In order to find out the disadvantages and make the enterprise image more specific, this article provided a new model, a multi-granular fuzzy comprehensive evaluation model (MFCEM). Firstly, we bulit a new evaluation index system about e-commerce enterprise image. Then, a multi-granular fuzzy comprehensive evaluation method is designed based on the theory of granular computing, which has more flexible evaluation process. Finally, we put the model into application. From the result, the MFCEM has been proved to be effective on the evaluation of e-commerce enterprise image.**

***Index Terms*—Comprehensive Evaluation, Enterprise Image, Fuzzy, Multi-granular**

I. INTRODUCTION

For better survival and development, a modern e-commerce enterprise must establish a good enterprise image in the market economy and increasing competition among enterprises. In practice, the enterprise image has become a main part of intangible assets and motive forces for every modern e-commerce enterprise. It is the comprehensive impression, which reflects main characters of an e-commerce enterprise, on the public's memory. Therefore, evaluation of modern e-commerce enterprise image is a complex system, which includes many factors. Since some factors can not be directly or easily measured, and people at different ages, of different sexes, in different social classes, see those factors in their own perspectives, those factors are characterized with particularity and fuzziness. Therefore, it is difficult for a conventional evaluation model to make a comprehensive evaluation on the complex system. To overcome those difficulties, the fuzzy logic techniques have been successfully utilized in the comprehensive evaluations, and a lot of achievements on the fuzzy comprehensive evaluation models are obtained. Yu [1] proposed the principle of trying to be purposeful, scientific, systematic and practical in evaluating the value of enterprise image under network circumstances. Tan et al. [2] proposed a multi-layered fuzzy comprehensive evaluation model and algorithm which are effective for comprehensive evaluation of modern enterprise image. Feng et al. [3] developed a fuzzy multi-criteria evaluation model to study the trend of urban development, and the model has been integrated into an intelligent decision support system which has made the great achievements in public decision making on the urban planning of some cities. Yuan et al. [4] applied fuzzy comprehensive evaluation principle for classification management on plant successfully, and developed a feasible computer-aided system of classification management. Except for all of above, there are still many other studies of fuzzy comprehensive evaluation model for solving the qualitative and quantitative complex problems with fuzzy conceptions. Although these achievements can improve the performance of fuzzy comprehensive evaluation more or less, the limitations still exist unavoidably. These models are all bottom-up ones, that is, they always make evaluations from the lowest layer of indexes to the highest layer of evaluation objective, whether it is necessary and possible for the lowest index layer to do the calculations or not. Therefore, much time will be wasted or the comprehensive evaluations will be failed.

In order to provide a relatively perfect comprehensive evaluation on the complex systems, it is necessary to develop appropriate index systems and models. In this paper, based on the theory of granular computing (GrC), a multi-granular fuzzy comprehensive evaluation model (MFCEM) is proposed, which is a top-down model for the multi-layer evaluation index system and uses the different layers of information granularity to attain the final evaluation result. As the evaluation process moves

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from high layer to low layer, the information granularity to the comprehensive evaluation becomes finer. This process of successive refinement continues until the final evaluation result is obtained. If only possible, the evaluation work will be finished depending on the part of index hierarchy, and it is not necessary to do the calculations for all the indexes.

II. The Multi-layer Index System

In order to provide an effective evaluation on a specific problem which will be evaluated, the main factors affecting the problem must be determined first. Then, it is necessary to establish a systematic, comprehensive index system according to the divided layers of these factors. As you know, modern e-commerce enterprise image can be evaluated from many factors or main indexes, which are further composed of some sub-indexes. After balancing seriously among all factors affecting modem e-commerce enterprise image, a general comprehensive evaluation index system with multi-layer indexes is illustrated in figure 1.

Some notations are introduced: the evaluation objective, e-commerce enterprise image, is denoted by O; the index set U_{11} = (product image (u_{111}), market image (u_{112}), web image (u_{113}), staff image (u_{114}), service image (u_{115})) in the first layer, and in the second layer, U_{21} = (popularity (u_{211}), reliability (u_{212}), advanced (u_{213}), abundance (u_{214})), U_{22} = (advertisement (u_{221}), sales (u_{222}), payment (u_{223}), bargains (u_{224}), custom satisfactory (u_{225})), U_{23} = (designment (u_{231}), navigation (u_{232}), search engine (u_{233}), network security (u_{234})), U_{24} = (employer (u_{241}), web designer (u_{242}), web administrator (u_{243}), salesmen (u_{244})), U_{25} = (contents (u_{251}), quality (u_{252}), attitude (u_{253}), efficiency (u_{254})).

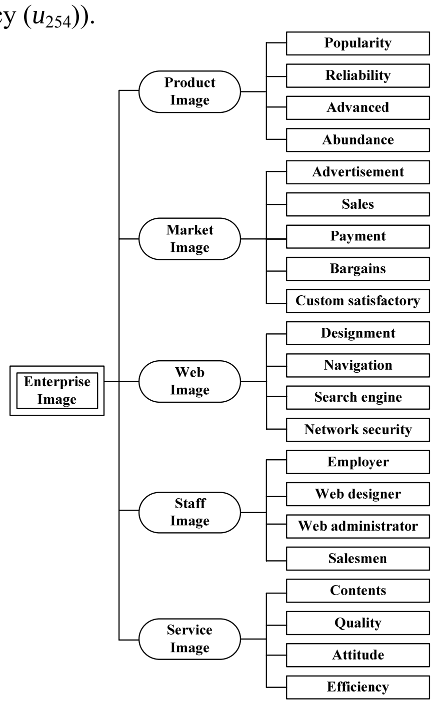

Figure 1. The index system.

III. Analysis of the MFCEM

The MFCEM is constructed based on the theories of GrC and fuzzy logic. The fuzzy comprehensive evaluation is one of the basic methods of fuzzy system analysis and is the method of comprehensive decision-making on an affair influenced by many factors in fuzzy circumstances. The GrC has excellent effect on the problems solving of mankind, which guarantees the reasonable evaluation processes and results in the case of certain class of complex systems. The ability of GrC to solve problems flexibly can be used to make the fuzzy comprehensive evaluations more reliable. So far, many methods and models of GrC have been proposed including of rough set theory, computing with words and quotient space theory, etc. In these theories, quotient space theory [5] is an appropriate model that reflects basic characteristics of human problem solving, namely, conceptualizing the world at different granularity and translating from one abstract level to the others freely.

Obviously, the three-layer comprehensive evaluation index system in figure 1 is characterized by the multi-granular space. The higher layer is, the coarser granularity is. As the evaluation process moves from high layer to low layer, the information granularity to the comprehensive evaluation becomes finer. And the granules in high layers, the combined indexes, can be formed from the granules in low layers, the sub-indexes, under the clustering reaction with the fuzzy equivalence relations. Starting from the evaluation objective O of the overall system, a rough evaluation plan is generated to reach the final goal firstly. Then, the plan is decomposed to many sub-goals which are submitted to the next lower layer of the index hierarchy. It's fortunate that the sub-goal can be reached directly, that is, the comprehensive evaluation value of the combined index corresponding to the sub-goal can be easily obtained. Otherwise, the more refined evaluation plans to reach these sub-goals must be determined. The process of successive refinement continues until the final evaluation result is obtained.

In the index system, the evaluation objective O is determined by five major indexes, $u_{111}, u_{112}, \dots, u_{115}$, and the evaluation for u_{11j} is further determined by m indexes, $u_{2j1}, u_{2j2}, \dots, u_{2jm}$. That is,

$$\widetilde{B}(u_{11j})=F(u_{2j1}, u_{2j2}, \dots, u_{2jm}). \quad (1)$$

Where, $\widetilde{B}(u_{11j})$ denotes the comprehensive evaluation for the combined index u_{11j} by using the fuzzy comprehensive evaluation algorithm F, and the index u_{11j} represents the j-th index in U_{11}, j = 1, 2, … , 5. The m denotes the number of indexes of the j-th sub-index set.

Suppose that the weight set of the i-th index set in the k-th layer is $\widetilde{A}_{ki} = (a_{ki1}, a_{ki2}, \dots, a_{kim})$, $a_{kij} > 0$, $\sum_{j=1}^{m} a_{kij} = 1$. The weight means a relatively important degree of index in the evaluation index set. The methods of weights distributing include experience method of reading up tables, statistical testing method, gradation analysis method, etc. And the weights must be adjusted until they are satisfactory. Let evaluation set be $V = (v_1, v_2, \dots, v_t)$. The i-th index set $(u_{ki1}, u_{ki2}, \dots, u_{kim})$ of the k-th layer can be represented by U_{ki}. The evaluation vector $\widetilde{R}_{ki}(u_{kij}) = (r_{kij1}, r_{kij2}, \ldots, r_{kijt})$ denotes a fuzzy mapping vector from U_{ki} to V, and the r_{kijs} ($s = 1, 2, \ldots, t$) denotes the subordinate degree of the j-th index u_{kij} of U_{ki} for the s-th evaluated result v_s. And, there are many ways to reach r_{kijs}, such as experts' appraisal statistics, experience method of reading off table, etc.

The evaluation process for an index u_{kij} can be described with the flow chart of algorithm F in figure 2.

Complementary statements on the algorithm F are given as follows:

S1) The word 'failed' means the evaluation for u_{kij} is failed.

S2) The evaluation matrix $\widetilde{R}_{(k+1)q}$ of fuzzy subordinate degree can be constructed by ranking the evaluation vector corresponding to each index in $U_{(k+1)q}$, that is,

$$\widetilde{R}_{(k+1)q} = \begin{bmatrix} r_{(k+1)q11} & r_{(k+1)q12} & \cdots & r_{(k+1)q1t} \\ r_{(k+1)q21} & r_{(k+1)q22} & \cdots & r_{(k+1)q2t} \\ \cdots & \cdots & \cdots & \cdots \\ r_{(k+1)qm1} & r_{(k+1)qm2} & \cdots & r_{(k+1)qmt} \end{bmatrix} = [r_{(k+1)qjs}]_{m\times t}. \quad (2)$$

S3) The weights distribution set for $U_{(k+1)q}$ can be obtained by choosing a weighting method stated before according to the actual conditions, and then

$$\widetilde{A}_{(k+1)q} = (a_{(k+1)q1}, a_{(k+1)q2}, \ldots, a_{(k+1)qm}). \quad (3)$$

S4) Make comprehensive evaluation with the weight vector $\widetilde{A}_{(k+1)q}$ and matrix $\widetilde{R}_{(k+1)q}$ by using the fuzzy model that corresponds to the appropriate compound operators. Therefore,

$$\widetilde{B}(u_{kij}) = \widetilde{B}_{(k+1)q} = \widetilde{A}_{(k+1)q} \circ \widetilde{R}_{(k+1)q} = (b_{(k+1)q1}, b_{(k+1)q2}, \ldots, b_{(k+1)qt}). \quad (4)$$

Where, $b_{(k+1)qs}$ is the result of fuzzy comprehensive evaluation of $U_{(k+1)qs}$ corresponding to the remark v_s. It is calculated as follows:

$$b_{(k+1)qs} = (\mathop{\oplus}_{j=1}^{m} a_{(k+1)qj} \otimes r_{(k+1)qjs})$$

$$(b_{(k+1)qs} \in [0, 1], j = 1, 2, \ldots, m; s = 1, 2, \ldots, t). \quad (5)$$

In formula (5), $\oplus$ and $\otimes$ are the generalized fuzzy operators. They are the extensions of the compound max-min operator of the fuzzy matrix.

It's not difficult to find that the above algorithm F is a recursive procedure. The function of F is to calculate the fuzzy comprehensive evaluation result of the specified evaluation objective like the index u_{kij}. This is a fuzzy comprehensive evaluation by using the index u_{kij} as the evaluation objective and its whole sub-tree as the index system. Similarly, we can obtain the fuzzy comprehensive evaluation result of the final evaluation objective O as follows:

$$\widetilde{B}(O) = \widetilde{B}_{11} = F(u_{111}, u_{112}, \ldots, u_{115}) = (b_{111}, b_{112}, \ldots, b_{11t}). \quad (6)$$

After $\widetilde{B}(O)$ is normalized, the evaluation conclusions can be usually obtained according to maximum principle of subordination degree. Of course, for more accurate and reasonable conclusions, we can also transform $\widetilde{B}(O)$ into a concrete numerical value by using one of the combining methods, such as sum of weighted remark products.

The idea of MFCEM is based on the human operator's behavior or problem solving methods. The operator would try to bring the comprehensive evaluation process 'roughly' to a desirable situation and then to a precisely desirable one. Thus time for evaluation is saved greatly, and many comprehensive evaluation problems there are ever no way to process can be solved now. In the next section, we will apply the MFCEM practically.

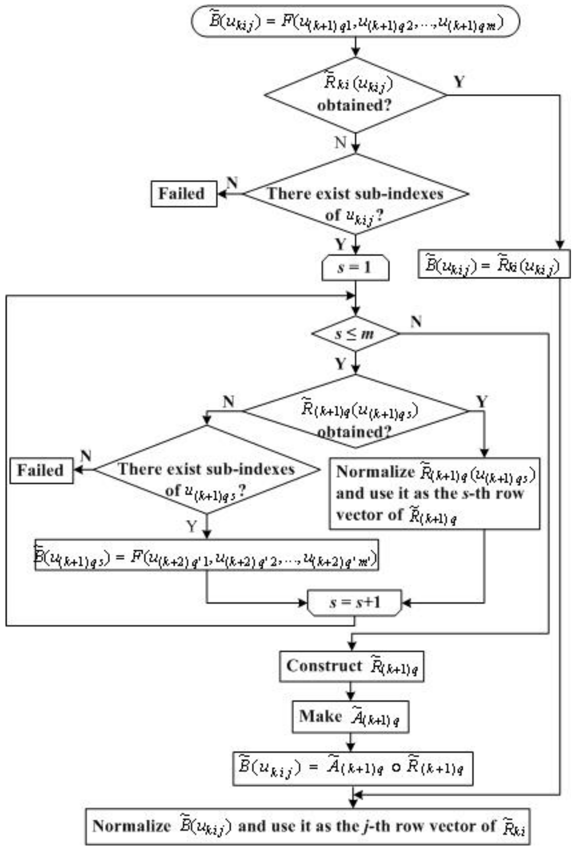

Figure 2. Flow chart of the algorithm F.

IV. APPLICATIONS

Take a famous e-commerce enterprise in Beijing as an example. According to the opinions of experts and results of a 476 valid answers to a questionnaire performed by us, the following data are obtained in statistical method. Here, the MFCEM will be used to evaluate enterprise image according to the characters of modem enterprise image. Suppose the evaluation set $V = (v_1, v_2, v_3, v_4, v_5)$ = (better, good, general, bad, worse).

A. The Weight Vectors

The weight vector of U_{11} is $\widetilde{A}_{11} = (0.15, 0.19, 0.21, 0.25, 0.20)$. From U_{21} to U_{25}, the weight vectors are $\widetilde{A}_{21} = (0.25, 0.30, 0.20, 0.25)$, $\widetilde{A}_{22} = (0.16, 0.20, 0.22, 0.24, 0.18)$, $\widetilde{A}_{23} = (0.30, 0.17, 0.25, 0.28)$, $\widetilde{A}_{24} = (0.26, 0.21, 0.20, 0.33)$, $\widetilde{A}_{25} = (0.21, 0.22, 0.31, 0.26)$, respectively.

B. The Evaluation Vectors

The evaluation vectors from U_{21} to V are $\widetilde{R}_{21}(u_{211})$ = (0.35, 0.38, 0.17, 0.07, 0.03), $\widetilde{R}_{21}(u_{212})$ = (0.37, 0.40, 0.10, 0.09, 0.04), $\widetilde{R}_{21}(u_{213})$ = (0.24, 0.39, 0.20, 0.11, 0.06), $\widetilde{R}_{21}(u_{214})$ = (0.40, 0.31, 0.14, 0.09, 0.06), respectively. Since the informants are also unfamiliar with the sub-indexes of the combined index of market image, including of sales, payment, etc., they evaluate the combined index of market image directly and approximately. Thus, the evaluation vector of the combined index from U_{11} to V is $\widetilde{R}_{11}(u_{112})$ = (0.31, 0.36, 0.18, 0.10, 0.05). The evaluation vectors from U_{23} to V are $\widetilde{R}_{23}(u_{231})$ = (0.29, 0.36, 0.21, 0.09, 0.05), $\widetilde{R}_{23}(u_{232})$ = (0.34, 0.31, 0.18, 0.10, 0.07), $\widetilde{R}_{23}(u_{233})$ = (0.33, 0.39, 0.16, 0.06, 0.06), $\widetilde{R}_{23}(u_{234})$ = (0.20, 0.32, 0.36, 0.08, 0.04), respectively. Similar to u_{112}, the evaluation vector of the combined index of staff image is $\widetilde{R}_{11}(u_{114})$ = (0.24, 0.40, 0.25, 0.08, 0.03). The evaluation vectors from U_{25} to V are $\widetilde{R}_{25}(u_{251})$ = (0.29, 0.36, 0.21, 0.09, 0.05), $\widetilde{R}_{25}(u_{252})$ = (0.34, 0.31, 0.18, 0.10, 0.07), $\widetilde{R}_{25}(u_{253})$ = (0.33, 0.39, 0.16, 0.06, 0.06), $\widetilde{R}_{25}(u_{254})$ = (0.13, 0.44, 0.39, 0.03, 0.01), respectively.

Accordingly, the fuzzy comprehensive evaluation process for the evaluation objective O, enterprise image, by using the algorithm F can be described as follows.

1) Since the O is determined by the index set U_{11}, namely, $\widetilde{B}(O) = F(u_{111}, u_{112}, u_{113}, u_{114}, u_{115})$, the evaluation process will be moved from the highest evaluation objective layer to the lower layer, the first layer.

2) For the combined index of product image u_{111}, because the evaluation vector of u_{111} corresponding to V isn't directly obtained, and the u_{111} is determined by the index set U_{21}, namely, $\widetilde{B}(u_{111}) = F(u_{211}, u_{212}, u_{213}, u_{214})$, the evaluation process will be continuously moved from the first layer to the second layer.

Because all of the evaluation vectors of U_{21} are obtained, rank the evaluation vector corresponding to each index in U_{21}, we obtain matrix $\widetilde{R}_{21}$ of fuzzy subordinate degree as follows:

$$\widetilde{R}_{21} = \begin{bmatrix} 0.35 & 0.38 & 0.17 & 0.07 & 0.03 \\ 0.37 & 0.40 & 0.10 & 0.09 & 0.04 \\ 0.24 & 0.39 & 0.20 & 0.11 & 0.06 \\ 0.40 & 0.31 & 0.14 & 0.09 & 0.06 \end{bmatrix}.$$

Therefore, the comprehensive evaluation result using the weighted average operator for u_{111} is $\widetilde{B}(u_{111}) = \widetilde{B}_{21} = \widetilde{A}_{21} \circ \widetilde{R}_{21}$ = (0.35, 0.37, 0.15, 0.09, 0.04). Then, use $\widetilde{B}(u_{111})$ as the 1-th row vector of the higher-layer evaluation matrix $\widetilde{R}_{11}$.

3) For the combined index of information image u_{112}, the evaluation vector of u_{112} corresponding to V has been directly obtained, that is $\widetilde{B}(u_{112}) = \widetilde{R}_{11}(u_{112})$ = (0.36, 0.39, 0.18, 0.4, 0.3). Then, use $\widetilde{B}(u_{112})$ as the 2-th row vector of $\widetilde{R}_{11}$.

4) For the combined index of market image u_{113}, same as (2), the comprehensive evaluation result for u_{113} is $\widetilde{B}(u_{113}) = \widetilde{B}_{23} = \widetilde{A}_{23} \circ \widetilde{R}_{23}$ = (0.29, 0.38, 0.21, 0.08, 0.04). Then, use $B(u_{113})$ as the 3-th row vector of $\widetilde{R}_{11}$.

5) For the combined index of appearance image u_{114}, same as (3), the comprehensive evaluation result for u_{114} is $\widetilde{B}(u_{114}) = \widetilde{R}_{11}(u_{114})$ = (0.31, 0.34, 0.20, 0.11, 0.04). Then, use $\widetilde{B}(u_{114})$ as the 4-th row vector of $\widetilde{R}_{11}$.

6) For the combined index of market image u_{115}, same as (2), the comprehensive evaluation result for u_{115} is $\widetilde{B}(u_{115}) = \widetilde{B}_{25} = \widetilde{A}_{25} \circ \widetilde{R}_{25}$ = (0.25, 0.40, 0.21, 0.11, 0.03). Then, use $B(u_{115})$ as the 5-th row vector of $\widetilde{R}_{11}$.

7) Because all of the evaluation vectors of U_{11} are obtained, rank the evaluation vector corresponding to each index in U_{11}, we obtain matrix $\widetilde{R}_{11}$ of fuzzy subordinate degree as follows:

$$\widetilde{R}_{11} = \begin{bmatrix} 0.35 & 0.37 & 0.15 & 0.09 & 0.04 \\ 0.36 & 0.39 & 0.18 & 0.04 & 0.03 \\ 0.29 & 0.38 & 0.21 & 0.08 & 0.04 \\ 0.31 & 0.34 & 0.20 & 0.11 & 0.04 \\ 0.25 & 0.40 & 0.21 & 0.11 & 0.03 \end{bmatrix}.$$

Hence, the fuzzy comprehensive evaluation result for evaluation objective O, enterprise agility, is $\widetilde{B}(O) = \widetilde{B}_{11} = \widetilde{A}_{11} \circ \widetilde{R}_{11}$ = (0.34, 0.39, 0.18, 0.06, 0.03).

At last, we use the combining method, sum of weighted remark products, to transform $\widetilde{B}(O)$ into a concrete numerical value. That is, a score set M = (1, 0.8, 0.5, 0.2, 0) is assigned for V, then the weighted sum of scores is

$$P = \widetilde{B}(O) \circ M^{\mathrm{T}} = 0.75.$$

From the above comprehensive evaluation value, we can draw a conclusion that the e-commerce enterprise image is nearly good.

More examples about fuzzy comprehensive evaluation are not listed here because of limitations of paper length. However, all the results show that the MFCEM can be effectively used to the comprehensive evaluation problems with more time saved. At the same time, for those problems which ever can not be evaluated, the model proposed in this paper represents more advantages.

V. Conclusions

In a word, the MFCEM has a simple and intuitively understandable structure, an effective algorithm, and can be used to comprehensive evaluation problems of e-commerce enterprise image. However, it should be known that the model can also be applied in other areas with reduction of the evaluation difficulties for basing on the theory of GrC. In future, our emphases of work are mainly in the improvement of the MFCEM.

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