Chapter 32
An Evaluation Computing Method Based on Cloud Model with Core Space and its Application: Bridges Management Evaluation

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Abstract In a multi-factor comprehensive evaluation, the factors related to objects are always various and most of them have the characteristics of uncertainty. Taking the mapping between qualitative and quantitative knowledge of cloud model, a high dimensional cloud model with core space was built. And then based on a sample set of maintenance and management of the 55 bridges in Chongqing and an index system with six first-level indices, parameters of the high dimensional cloud model with core space and mean membership of every bridge sample were computed and gotten. Compared with the results of cloud model, experts experience and support vector machine for this sample, it indicated the cloud model with core space could be applied to a multi-attribute evaluation well. Finally, according to the evaluation, some suggestion was given.

Keywords Core space · High dimensional cloud model · Performance evaluation · Bridges management

32.1 Introduction

In practice, one object will be influenced by many factors and most factors are from language description of realistic world and are with the characteristic of qualitative. Thus an evaluation is featured with multi-attribute and qualitative. For most evaluation, every attribute or weight of indicator should be confirmed at the very beginning, such as weighted average model, fuzzy synthetic evaluation model

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and analytic hierarchy process [1–3], which are based on experts' grade or experts' weighted experience and are of randomness and subjectivity to some degree. Artificial intelligence, which is very popular among present researchers [4–6], is to extract effective rules and knowledge from sample information of experts' evaluative experience to make evaluation. However, due to the limitation of sample amount and obtainable experts' experience, the effectiveness of evaluation which is based on rule extraction and classification is not satisfied well.

In this paper, considering the uncertainty such as randomness, subjectivity and fuzziness in evaluation and cutting down the dependence on weighted information and sample amount, it is of great significance to introduce cloud model which is based on traditional fuzzy mathematics and probability statistics. A high dimensional cloud model with core space will be established to evaluate and analyze real condition in Chongqing's bridges maintenance and management.

The remaining sections of this paper are organized as follows. Section 32.2 introduces the new high dimensional cloud model with core space. Section 32.3 describes the general problem of evaluating bridge management quality, and presents the index system for evaluations. Section 32.4 describes our experimental design for data collection and performance comparison. Section 32.5 concludes the paper and suggests directions for future work.

32.2 A High Dimensional Cloud Model with Core Space

32.2.1 The Main Principle of Cloud Model

Could model is an uncertain transformation model between one qualitative concept which is expressed by natural language value and quantitative representation. Given U as a domain expressed by exact number, U is corresponding to qualitative concept A, for every element x in domain, there is a random number with stable tendency $y = \mu_A(x)$, y, is the certainty of x to concept A, the distribution of certainty y in domain is named cloud model [7–9].

The number characteristics of cloud are represented by expectation E_x, entropy E_n, and hyper entropy H_e, which reflect the quantitative feature of qualitative concept A. E_x means the dot which can best represent this qualitative concept in number field, reflecting the position of cloud center. On one hand, E_n reflects the scope of number field space being accepted by language value, being indistinguishable measure of qualitative concept; on the other hand, reflects that the dot in number field space can represent the probability of this language value, showing cloud droplets of qualitative concept having randomness. H_e is the uncertain measure of entropy, reflecting coherency of uncertain degree of all data dots representing this language value in number field space, namely coherency of cloud droplets. The larger the hyper entropy is, the larger the dispersion of cloud droplets is, the larger the randomness of certainty degree is and the thicker the cloud is.

The three number characteristics of cloud model integrate fuzziness and randomness, making up of mapping between qualitative and quantitative, so a cloud model can be $C(E_x, E_n, H_e)$.

Generating algorithm of cloud is named cloud generator which consists of normal cloud generator [7], X condition cloud generator, Y condition cloud generator and reverse cloud generator. Normal and X condition cloud generators are usually used in model evaluation. Normal cloud generator refers to could droplets produced by number characteristics of cloud.

32.2.2 Building the New Model with Core Space

Definition 1 If domain U, $U \in R^m$, $x_i = [x_{i1}, x_{i2}, \cdots, x_{im}]$ is any element in U, and if subset H of U exists, $H \in R^m$, any elements $x_{ik}(\mathrm{k} = 1, 2, \ldots \mathrm{m})$ in H is $a_{k1} \le x_{ik} \le a_{k2}$, and the certainty degree of the element in H by high dimensional cloud model $\mu = F(x_i)$ is $\mu < 1$, and the other elements' certainty degree in U is $\mu < 1$, then H is the core of domain U. Elements' certainty degree of high dimensional cloud model shows in Eq. (32.1):

$$\mu = F(x_{i1}, x_{i2}, \ldots x_{im}) = \begin{cases} 1 & a_{k1} \le x_{ik} \le a_{k2} \quad k = 1, 2, \ldots m \\ \exp\left(-\sum_{k=1}^{m} \frac{(x_{ik} - a)^2}{2E'_{nk}}\right), & x_{ik} < a_{k1} \cup x_{ik} > a_{k2} \end{cases} \tag{32.1}$$

In which

$$a = \begin{cases} a_i, & x_{ik} < a_i \\ b_i, & x_{ik} > b_i \\ E_{xi}, & a_i = b_i \end{cases} \tag{32.2}$$

In the specific attribute consideration, H can be seen as assemblage of all attributes' most excellent chosen interval [8], and when in evaluation, H can be supposed as a set of all attributes' most excellent evaluation.

High dimensional cloud evaluation model with core space and multi attributes are established as:

1. Make sure co-domain of evaluative value of all attributes $[d_{i\min}, d_{i\max}](i = 1, 2, \ldots m)$ and the best value interval $[a_i, b_i](i = 1, 2, \cdots m)$ are the most excellent evaluative core space$H$, and establish every attribute's most excellent evaluative trapezoid cloud model.
2. According to $3E_n$ rules of normal cloud, Eq. (32.3) shows the number characteristics of every dimensional cloud model, when $a_i \ne b_i$, trapezoid cloud model will be formed, and when $a_i = b_i$, normal cloud model will be formed.

$$\begin{cases} E_{xi} = a_i,\ E_{ni} = (E_{xi} - d_{i\min})/3,\ H_{ei} = E_{ni}/6 & when \quad d_{i\min} \le x_i < a_i \\ E_{xi} = b_i,\ E_{ni} = (d_{i\max} - E_{xi})/3,\ H_{ei} = E_{ni}/6 & when \quad b_i < x_i \le d_{i\max} \\ E_{xi} = x_i,\ \mu = 1 \quad when \quad a_i \le x_i \le b_i & in\ which \quad i = 1,\ 2,\ \ldots m \\ E_{xi} = a_i = b_i,\ E_{ni} = (d_{i\max} - d_{i\min})/6,\ H_{ei} = E_{ni}/6, & when \quad a_i = b_i \end{cases} \tag{32.3}$$

3. The data assemblage of all dimensional attributes which form m dimension high dimensional cloud space.

$$X_i = C(a_i,\ E_{ni},\ H_{ei}) \cup C(b_i,\ E_{ni},\ H_{ei}) \cup [a_i,\ b_i],\ (i = 1,\ 2\ldots m) \tag{32.4}$$

4. If sample $x_i = [x_{i1}, x_{i2}, \ldots, x_{im}]$ is in core space H, the certainty of core space of this sample to the most excellent evaluation should be $\mu = 1$.
5. If sample $x_i = [x_{i1}, x_{i2}, \cdots, x_{im}]$ is not in core space H, the certainty of core space of this sample to the most excellent evaluation should be calculated according to Eqs. (32.1) and (32.2).
6. On the basis of samples, order the most excellent evaluation core space, namely, sample evaluation result order.

32.3 The Problem of Bridge Management Evaluation

As China's economy has grown, bridge construction has developed rapidly in the Chongqing province. At present, China contains more than 570,000 bridges and In Chongqing province alone there are over 8000. While there is a drive to speed up construction, it is also necessary to improve maintenance management. By evaluating the status of bridge maintenance and the activities of management, we can quantify the effectiveness of current procedures and develop concrete measures for raising the managerial level.

32.3.1 An Index System for Quantifying Bridge Maintenance

Taking bridge maintenance and management of Chongqing as example, according to the experts' advice of Chongqing Bridge Association, Chinese bridge technical standard and related factors, the influencing factors of bridge maintenance and management are proposed, including six indexes which further divided into 25 sub-indexes and 113 qualitative and quantitative indexes. The six indexes are:

maintenance and management condition, maintenance and management expense, quality of technical staff, bridge's construction quality, daily average traffic flow, and service life. Due to limitation of length of this paper, the first level indexes are listed in the Table 32.1.

32.3.2 Experiment Data Set

According to bridge maintenance and management index system, designed examination chart is handed to technical staff, management staff and bridge association experts to evaluate pointed bridges. This chart is mainly designed to the description of bridge management condition, and then each bridge's maintenance and management will be evaluated by bridge experts who will combine the examination and objective condition of bridge (service life, traffic flow and maintenance expense). The evaluation result will be stored as a chart in the data base, and the table of comprehensive evaluation factors of examined 55 bridges' maintenance and management is obtained. "Daily average traffic flow" refers to the data of one year's traffic flow which is averaged to every day. Table 32.1 shows 10 bridges' data. The evaluation result is classified as 1, 2 and 3; class 1 refers to the best maintenance and management condition, 3 the worst.

32.4 Experiment Studying

Firstly, the most excellent evaluation interval of every attribute needed to be set. Table 32.2 shows the most excellent evaluation interval of every attribute, among

Table 32.1 The scores of maintenance and management factors of 20 large bridges in Chongqing

Bridges code	Rank from experts	Index1 Ages	Index 2 Quality of engineer and technician	Index 3 Mean vehicle flow per day	Index 4 Maintenance expenses	Index 5 Maintenance state	Index 6 Construction quality
1	1	4	12	60529	7	61	16
2	1	2	15	20000	8	69	11
3	1	1	15	15000	8	68	11
4	1	2	15	20000	8	76	12
5	1	4	12	64000	8	57	17
6	1	2	15	35000	5	57	8
7	1	15	10	54814	8	64	15
8	1	2	15	35000	5	61	13
9	1	3	9	3000	5	62	14
10	1	2	9	15000	5	60	10

Table 32.2 Optimal interval of every first level index

Index1	Index 2	Index 3	Index 4	Index 5	Index 6
[1, 4]	16	[0,15000]	9	76	17

which indexes 1 and 3 are interval values, the other indexes are maximum values of corresponding attributes Table 32.3.

Table 32.4 shows the certainty degree of bridge maintenance and management to core space, while the result compared with experts can be seen in Fig. 32.1. Due to limitation of length of this paper, Table 32.4 only contained 38 samples of 55 bridges.

The samples in Fig. 32.1 with (**) means that the rank evaluated by high dimensional cloud model with core space is different from experts' evaluation result. According to the certainty of high dimensional model with core space, the maintenance and management level of NO. 33 should be listed in class two, while experts' evaluation result is class three. After detail comparison of sample and inquiry of experts' advice, it is found that the difference is mainly because experts'

Table 32.3 cloud model of every first level index

Index1	Index2	Index3	Index4	Index5	Index6
C(1, 1, 0.1),$x_1 < 1$ C(4, 10, 1.7),$x_1 > 4$	C(16, 5, 0.8)	C(15, 5, 0.8),$x_3 < 15$ C(15, 27, 5),$x_3 > 15$	C(9, 3, 0.5)	C(76, 23, 4)	C(17, 6, 1)

Table 32.4 Average membership of every bridge for core space

Rank from experts	Membership for core space	Bridges code	Rank from experts	Membership for core space	Bridges code
1	0.92095	4	2	0.40273	17
1	0.87916	2	2	0.36179	31
1	0.87708	3	2	0.36105	26
1	0.7439	8	2	0.3379	34
1	0.72532	9	2	0.32824	27
1	0.71778	7	3	0.31632	36
1	0.7011	1	3	0.2885	35
1	0.68209	16	3	0.27654	41
1	0.66562	5	2**	0.27295**	33**
1	0.64128	12	3	0.26888	40
1	0.63703	10	3	0.26863	39
1	0.5939	6	3	0.26849	37
1	0.57353	18	3	0.26795	38
1	0.57072	11	3	0.26696	45
2	0.56011	20	3	0.23027	43
2	0.51749	22	3	0.22978	42
2	0.50855	14	3	0.21656	46
2	0.50508	21	3	0.21169	48

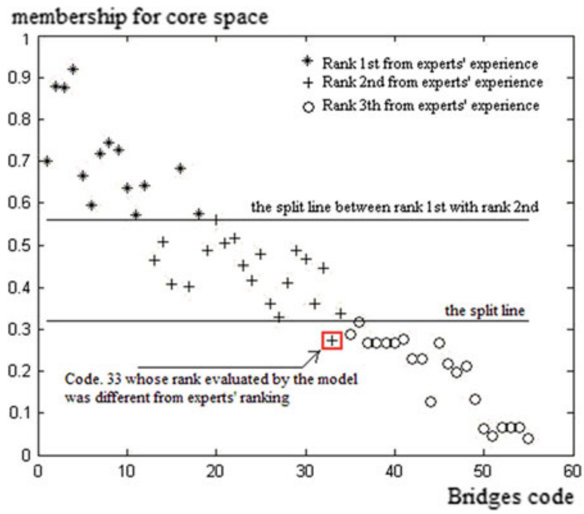

Fig. 32.1 Evaluation comparison with experts experience and cloud model with core space

evaluation on index 5 is "good". While the evaluation value of NO. 33 bridge's index 5 differs greatly from experts' evaluation value as class 2 bridge. However, from the analysis of cloud model with core space, NO. 33 bridge's overall level is close to class 2. Figure 32.1 clearly shows combined with experts' evaluation result and certainty to core space, the dividing line of certainty is very obvious between different classes, further illustrating that the evaluation method which is based on high dimensional cloud model with core space is effective.

To compare evaluation effects, SVM is adopted at the same time to normalize and classify 55 samples, among which 50 samples are training samples, five are testing samples. In this application, when the kernel was a radial basis function. The cross-validation parameter v was set to 3, the kernel function parameter C was 32,768, and g was 0.0019, classification accuracy was 0.6. When v was 7, C was 8,388,606 and g was 7.63e-6, the accuracy of the SVM was unchanged.

It shows that the certainty of each sample bridge can be obtained in high dimensional cloud model with core space evaluation method and the detail information of order are more than simple classification. Compared with experts' evaluation result, the effect is better. At the same time, the comparison of SVM to samples classification accuracy shows that sample amount and attributes uncertainty influences SVM classification.

32.5 Conclusion

The introduction of high dimensional cloud model with core space into bridge management evaluation can fully consider the existence of various uncertain errors, making the evaluation result more effective and reasonable.

The result above shows the high dimensional cloud model with core space for multi-attribute evaluation can enrich present information, and it can get not only accurate and reasonable evaluation classification, but also much delicate information of evaluation process. The method can be applied for a multi-attribute evaluation well.

With the development of Chinese economy and society, the reinforcement of bridge maintenance and management is very urgent and evaluation on the level of bridge maintenance and management is to understand and supervise the condition and process.

Though the division of core space can simplify weighted factor, the accuracy of core space is increased at the same time. So how to integrate weighted information of attribute into model still needs further study.

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