Extension of Grey Random Model based on Cloud Model and Its Application in Software Evaluation of Users

Hongli Wang
School of Ecnomic and Management, Zhongyuan University of Technology. Zhengzhou, China
E-mail : graduated852@163.com

***Abstract*—In order to overcome the shortcoming of ablation function in dealing with the complex problem in classic gray decision, this paper studies on improved ablation function based on the gray cloud model and its applicant in the gray decision. At first the classic ablation function and its shortcoming are given. Then the gray cloud model integrating gray with randomcity is proposed. The numerical character of gray cloud and the method of creating grey model with normal school and are given. Gray number ablation model based on gray cloud is used to replace of the classic ablation function. At last the applicant of ablation model of gray number based on the gray cloud with normal school in the gray clustering decision making is given. And the application case is provided to estimate the validity of method.**

***Index Terms*— Gray Decision Making; Gray Cloud; Ablation Model; Gray clustering; Group Decision making**

I. INTRODUCTION

Grey system theory is created by the Chinese scholar whose name is Dengjulong. In grey system the information is incompletely known [1]. The grey number and its' ablation model theory is proposed in grey system theory. The grey number is the number with the incomplete and uncertain information. The grey number has three kinds of types: information type, concept type and level type [2]. The grey number is a number set in which the possible value is the ablation value. The grey number is represented as $\otimes(x_i)$ in which x_i is the ablation value. The ablation value is also represented as $\tilde{\otimes}(x_i)$. The importance of ablation value of grey number is difference according to difference of the completion of information. The importance of ablation value of grey number is called as the weight of ablation value. The function of weight of ablation value of grey number is called as the function of weight of ablation. It is recorded as $f(x)$. Grey system can precede system problem with poor information to find the behavior and regulation of system [3]. The grey system gain the applications in many science fields as a kind of excellent mathematic method[4-6].

Classic function of weight of ablation has three basic kinds of types(shown in Figure 1). Three kinds of types are respectively used to represent the "big", "medium" and "small" concepts. In Figure 1 the Y-axis $f(x) \in [0,1]$ is the value of weight of ablation value of grey number, the X-axis is the value of grey number.

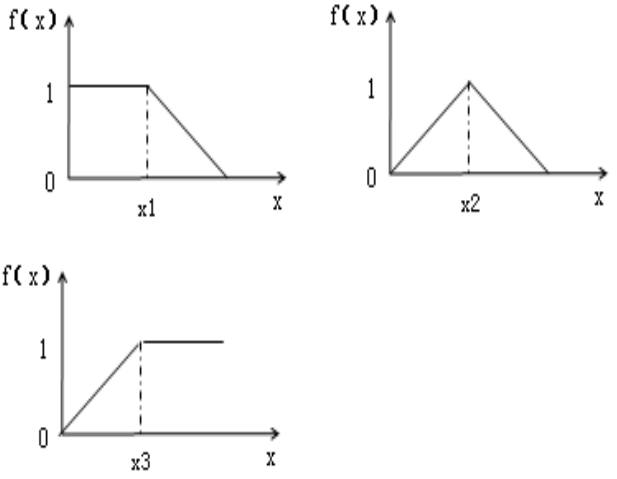

Figure 1. Three basic forms of classic ablation function

Except the three basic types the function of weight of ablation may be linear or curve if there is much information to be added. The common formula of linear function of weight of ablation is in the following in formula (1), and its formation is shown in Figure 2.

$$f(x) = \begin{cases} L(x) & x \in (a_2, b_1) \\ R(x) & x \in (b_2, c_1) \\ 1 & x \in (b_1, b_2) \end{cases} \quad (1)$$

For the particular grey conception and its ablation function the weight of ablation of grey number x_i is calculation using the following formula (2):

$$\tilde{\otimes}(x_i) = x_i * f(x_i) \quad (2)$$

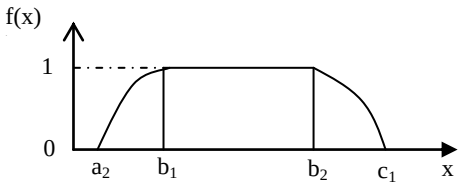

Figure 2. Classic graph of linear ablation function

The ablation function of grey number in grey system

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theory has the following shortcoming:

(1) The ablation function only gives the transfer between qualitative information and quantitative information on the condition of incomplete information. But in reality the grey and randomcity is not divided and separated. The classic ablation function can not express the random information.

(2) The relation between grey number and its ablation value is difficult to be ascertained. The cause is that the function relation is difficult to gain.

(3) The classic ablation value is calculated by the formula (2), so the weight of ablation is fixed which does not accord with the real situation. The weight of ablation should be a random number according to the subjective judgments of human.

In this paper the uncertain model of ablation function of grey number and its extension are proposed based on cloud model in order to overcome its above shortcomings because the cloud model is the objective model representing uncertainty[7] and has many applications[8-12] in all kinds of fields. Firstly grey random model is given based on cloud model. Then grey random model is mainly studied. Lastly the conclusions are given at the end of article.

II. GREY RANDOM MODEL AND NORMAL GREY RANDOM MODEL

A. *Grey Random Model*

In order to express the grey and randomcity of information the grey uncertain is given in the following (shown in Figure 3). In the grey random model $U(x) \in [0,1]$ is used to represent the weight of ablation of grey number. The model of weight of ablation in Figure 3 is expressed as the random curve with the uneven thickness which is called cloud. Supposing the U is a region $U = \{x\}$, T is the grey language related with U, degree of membership of the element x in U for the grey language expressed by T is a random number with the stable tendency. Its formation definition is in the following[13]:

$U(x) = GL(x)$ gain the value from [0,1], the grey random model is the mapping form U to region [0,1] which is defined as formula (3) in following:

$$U(x) = GL(x) : U \to [0,1] \tag{3}$$

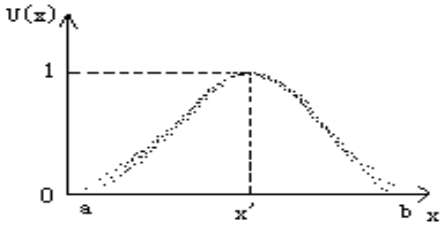


Figure 3. Grey random model

The above grey random model supplements the depiction of random of information. In the following the classis grey number may be expressed by the grey random model in Figure 4. In Figure 4 the three sub-figure is respectively used to represent the concepts of “big”, ”medium” and ”small” and so on.

Using the same principle, the other grey random models can be created. They include region-peak-value grey random model, triangle grey random model, left semi-triangle grey random model, right semi-triangle grey random model and ladder-shape grey random model and so on (shown in Figure 5). The ablation function formula based on grey random model is same to formula (2). But $f(x_i)$ is one of random number. So the weight of ablation is different every time. But the weight of ablation is the random number with stable tendency.

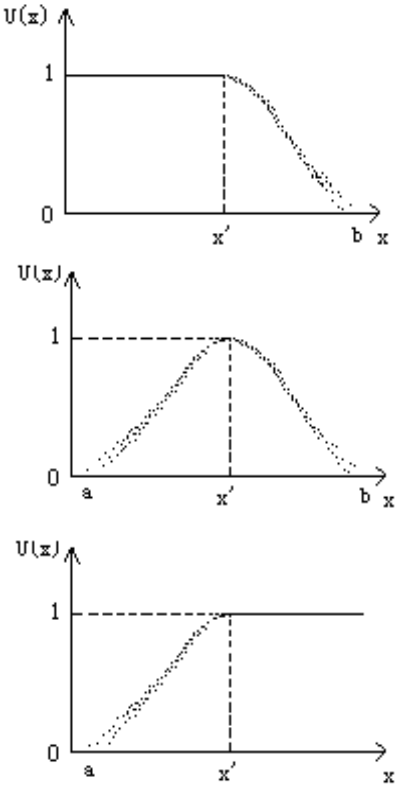


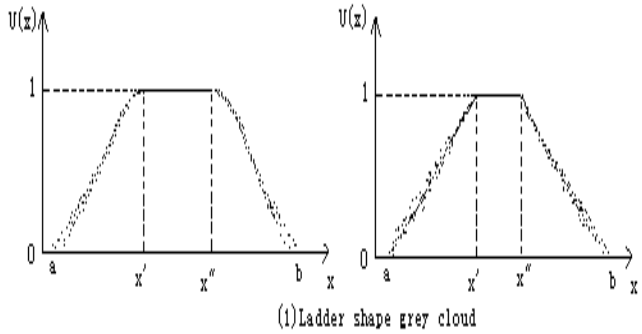
Figure 4. Classic ablation function based on grey uncertain cloud

The mathematic expectation curve of normal grey random model is the following:

$$f_1(x) = e^{-\frac{(x-Ex)^2}{2En^2}}$$

The qualitative concept based on grey random model can be expressed by the three digital character values including about Ex(Expected value),En(Entropy), He(Hyper entropy). Ex(Expected value) is the expectation of distribution. It is the maximal point of region and the classic sample of region. En(Entropy) is the measure of uncertain degree of qualitative concept. He(Hyper entropy) is the measure of uncertain degree of En(Entropy). Mutual transfer between qualitative concept and quantitative value can be realized by the grey random model. Using the normal grey cloud operator the qualitative concept can be transferred into the set of drops of grey cloud. Some applications estimate the validation of grey random models. Li Deyi estimated the universality of normal cloud model. So

currently the grey random model is the most objective expression model of uncertain qualitative information.



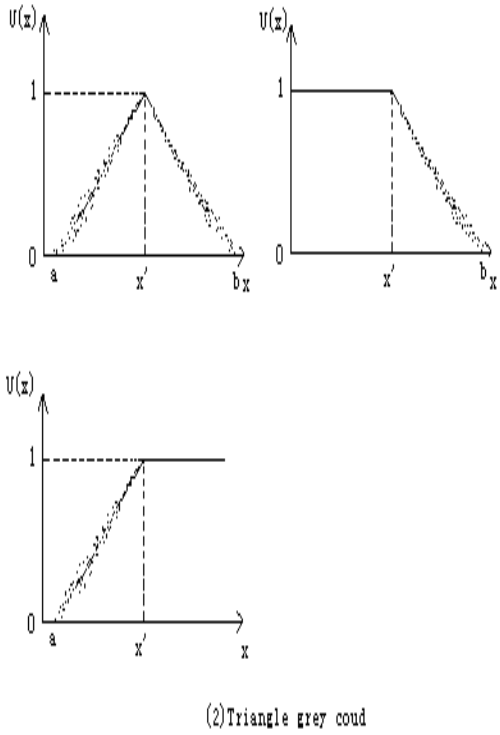


Figure 5. Other forms of classic ablation function based on gray cloud

B. Normal Grey Random Model

The normal grey random model is the model distribution of which accord with the normal curve. The mathematic exception curve formula is in the following:

$$NGL(x) = \exp[-\frac{(x - Cx)^2}{2(\frac{Rx - Lx}{6})^2}] \quad (4)$$

The algorithm of creation of normal grey random model is in following:

(1) In the region [Lx,Rx],creating the normal random number x_i expectation of which is Cx,and standard deviation of which is $En = \frac{Rx - Lx}{6}$.

(2)creating the normal random number En' expectation of which is $En = \frac{Rx - Lx}{6}$,and standard deviation of which is He.

(3)Calculating $u_i = \exp[-\frac{(x_i - Cx)^2}{2(En')^2}]$,ordering (x_i, u_i) as drops of cloud.

In the grey random ablation model the mathematic formula of ablation function of grey number is in the following:

$$\tilde{\otimes}(x_i) = x_i * U(x_i) = x_i * \exp[-\frac{(x_i - Cx)^2}{2(En'_i)^2}] \quad (5)$$

III. Extension of Grey Random Model

Above grey random model adds the randomcity in the model, but there are other shortcomings in the following: This mode is only suitable for the transfer of concept type grey number. For the concept grey numbers, for example, ”big”, ”small” and so on, their shape is suitable to be depicted as left-right-symmetrical single peak-value curve. But for the other grey numbers including about information type and level type this representation is not suitable. The reason is that in the information type grey number the peak-value is decided by the importance. The measurement of importance is decided by the objective facts and subjective judgments. So there maybe be many peak-value points or not left-right-symmetrical in the model for information type or level type grey number. In the following the other models are given for some situation where the information type and level type grey number is suitable.

A. Dissymmetrical and Single-peak-value Normal Grey Random Model

For the information type and level type grey number their measurement of importance is decided by the objective facts and subjective judgments. So their curves maybe are dissymmetrical. When there is a point importance of which is maximal the model is shown in Figure 6.

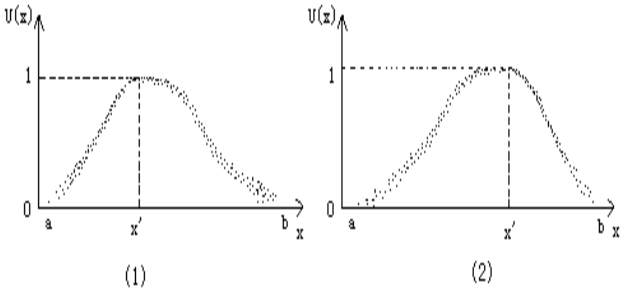


Figure 6. Dissymmetrical and single-peak-value normal grey model

In figure 2 the ablation function of dissymmetrical and single-peak-value normal grey random model composed of two parts including about left part grey cloud and right part grey cloud. Their digital characters respectively are C(Ex_l, En_l, He_l) and

C(Ex_r, En_r, He_r). The mathematic expectation curves of left part grey cloud and right part grey cloud respectively are in following formula (6) and formula (7).

$$NGL^{l}(x) = \exp[-\frac{(x - Ex_l)^2}{2(\frac{x' - a}{3})^2}] \quad (x \in (a \quad x')) \tag{6}$$

$$NGL^{r}(x) = \exp[-\frac{(x - Ex_r)^2}{2(\frac{b - x'}{3})^2}] \quad (x \in (x' \quad b)) \tag{7}$$

For the grey numbers x_i in the region(a b),their ablation value $\tilde{\otimes}(x_i)$ is calculated by the following formula (8):

$$\tilde{\otimes}(x_i) = x_i * U(x_i) = \begin{cases} x_i * \exp[-\frac{(x_i - Ex_l)^2}{2(\frac{x' - a}{3})^2}] & \text{if } x \in (a\ x') \\ x_i * \exp[-\frac{(x_i - Ex_r)^2}{2(\frac{b - x'}{3})^2}] & \text{if } x \in (x'\ b) \end{cases} \tag{8}$$

The creation algorithm of left part grey cloud is in the following:

(1)In the region [a, x'],creating normal random number x_i with the expectation $Ex_l = x'$ and with the standard deviation $En_l = \frac{x' - a}{3}$.

(2)Creating normal random number En' with the expectation $En = \frac{x' - a}{3}$ and with the standard deviation He.

(3)Calculating $u_i = \exp[-\frac{(x_i - Ex_l)^2}{2(En')^2}]$,ordering (x_i, u_i) as drops of cloud。

The creation algorithm of right part grey cloud is in the following:

(1)In the region [x' ,b],creating normal random number x_i with the expectation $Ex_r = x'$ and the standard deviation $En_r = \frac{b - x'}{3}$.

(2)Creating normal random number En' with the expectation $En = \frac{b - x'}{3}$ and with the standard deviation He.

(3)Calculating $u_i = \exp[-\frac{(x_i - Ex_r)^2}{2(En')^2}]$, ordering (x_i, u_i) as drops of cloud。

B. Multi-peak-value normal Grey Random Model

According to grey theory dissymmetrical and single-peak-value normal grey random model maybe is a kind of grey random model for some situation. But there maybe are some special situations. There maybe are many points importance of which is same. For example, the future salary, future stature and future price of stock etc. should be represented by the multi-peak-value normal grey random model because there maybe are many points importance of which are all maximal. For the future stature of normal human should be between 150cm and190cm But for man maximal importance of its' value is 170cm. For women it is 160cm. So for the grey concept "the future stature of normal human" 160cm and 170cm are the maximal importance value. For the salary the level maybe is between 2000RMB and 3000RMB. If the scores is good the salary is 3000RMB and if the scores is medium the salary is 2600RMB. If the score is common the salary is 2000RMB. So the 2000RMB, 3000RMB and 2600 are the maximal importance value for this grey concept. Multi-peak-value normal grey random model is shown in Figure 3(in which there two peak-values).

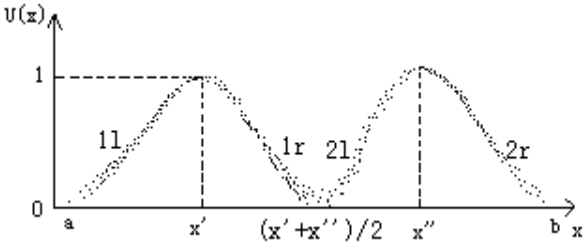


Figure 7. Multi-peak-value normal grey random model

In figure 3 there is the region[a,b], the maximal importance value is x' and x''。In the region [a x'], the ablation model is 1l,In the region [x' (x'+x'')/2] the ablation model is 1r,in the region[(x'+x'')/2 x'], the ablation model is 2l,In the region [x'' b] the ablation model is 2r。1r and 2l have same digital character. The mathematic expectation curve is in the following:

$$NGL(x) = \begin{cases} \exp[-\frac{(x - Ex_{1l})^2}{2(\frac{x' - a}{3})^2}] & x \in (a \quad x') \\ \exp[-\frac{(x - Ex_{1r})^2}{2(\frac{x'' - x'}{6})^2}] & x \in (x' \quad \frac{x' + x''}{2}) \\ \exp[-\frac{(x - Ex_{2l})^2}{2(\frac{x'' - x'}{6})^2}] & x \in (\frac{x' + x''}{2} \quad x'') \\ \exp[-\frac{(x - Ex_{2r})^2}{2(\frac{b - x''}{3})^2}] & x \in (x'' \quad b) \end{cases} \tag{9}$$

For the grey numbers x_i in the region(a b),their

ablation value $\tilde{\otimes}(x_i)$ is calculated by the following formula (10):

$$\tilde{\otimes}(x_i) = x_i * U(x_i) = \begin{cases} x_i \exp[-\frac{(x_i - Ex_{1l})^2}{2(\frac{x' - a}{3})^2}] & x \in (a \quad x') \\ x_i \exp[-\frac{(x_i - Ex_{1r})^2}{2(\frac{x'' - x'}{6})^2}] & x \in (x' \quad \frac{x' + x''}{2}) \\ x_i \exp[-\frac{(x_i - Ex_{2l})^2}{2(\frac{x'' - x'}{6})^2}] & x \in (\frac{x' + x''}{2} \quad x'') \\ x_i \exp[-\frac{(x_i - Ex_{2r})^2}{2(\frac{b - x''}{3})^2}] & x \in (x'' \quad b) \end{cases} \tag{10}$$

The creation algorithm of cloud in formula (10) is same to the method in Ⅱ.B and Ⅲ.C.

C. Other Grey Random Model

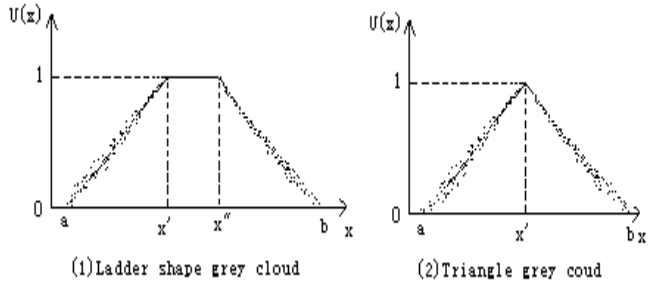


Figure 8. Other grey random model

For the grey random model in 2.1, there are un-normal grey cloud for example triangle grey cloud and ladder-shape grey cloud(shown in Figure 4). The creation algorithm of triangle grey cloud is in the following:

The digital character of triangle grey cloud is(a,x',b,He),The creation algorithm of left-part of triangle grey cloud is in the following:

(1)In the region [a x'],Creating the even random number x_i.

(2)Creating normal random number En' with the expectation $En = \frac{x' - a}{3}$ and with the standard deviation He.

(3)Calculating $u_i = (x_i + En') * (1/x' - a) - a/(x' - a)$,Ordering (x_i, u_i) as drops of cloud.

The creation algorithm of left-part of triangle grey cloud is same to above method. The creation algorithm of ladder-shape grey cloud is same to triangle grey cloud.

IV .Application of Grey Random Model in Software Evaluation of Users

A. Grey Evaluation based Grey Random Model

The evaluation information which can be represented based on grey random model is given by the users of software. The information is classified into different grey classification. In order to verify the grey random model the grey cluster evaluation based grey random model is given in the following.

(1)Assuming that $T_1, T_2, T_3, ..., T_m$ are the software users which are using the software. $P_1, P_2, P_3, ..., P_n$ are the attributes of software for example the friendly of interface and complex of software and so on. d_{ij} is the value of grey random model of P_j of T_i. v_{ij} is given by the users of software. $C_1, C_2, C_3, ...C_h$ are the grey classifications. The decision matrix is in the following:

$$D = \begin{array}{c} \\ T_1 \\ T_2 \\ ... \\ T_m \end{array} \begin{array}{c} \begin{array}{ccccc} P_1 & P_2 & P_3 & ... & P_n \end{array} \\ \begin{bmatrix} v_{11} & v_{12} & v_{13} & ... & v_{1n} \\ v_{21} & v_{22} & v_{23} & ... & v_{2n} \\ ... & ... & ... & ... & ... \\ v_{m1} & v_{m2} & v_{m3} & ... & v_{mn} \end{bmatrix} \end{array}$$

The normal model is used to create the grey qualitative space of software evaluation. The hint figure is shown in Figure 2 in which the representation space of one of system variable is created. There are 9 qualitative language variable in Figure 2. The qualitative variable space can be created by cloud model transfer based on history data or group decision. The detailed cloud transfer method can be seen in literature.

In the qualitative space of system variable the case of inclusion between two cloud models should not be included in the qualitative space. Because the relation between two cloud model is not the sequence set relation.

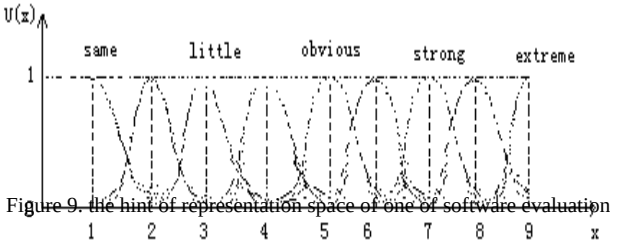


Figure 9. the hint of representation space of one of software evaluation

(2)Ascertaining the grey random model

Firstly the classification standard of P_j is given. And the grey random model is given. Commonly the normal grey random is created. Its number character and curve are given. According to above matrix calculating the times of value experts give. And creating the

following table 1 in which

TABLE 1
THE TIMES OF VALUE EXPERTS GIVE

Value v_i	v_1	v_2	…	v_k
Times q_k	q_1	q_2	…	q_k

For the table 1, calculating the proportion of times of value which experts give $p_i = \frac{q_i}{\sum_{j=1}^{m} q_j} (i = 1,2,...,m)$ to gain the following table 2.

TABLE 2
THE PROPORTION OF TIMES OF VALUE EXPERTS GIVE

v_i	v_1	v_2	…	v_m
p_i	p_1	p_2	…	p_m

In table 2 p_i is the probability of v_i, the more experts to chose the v_i, the more p_i is. when p_i is max the v_i is recorded as $v_{\max(p_i)}$.

If in table 2 the number of v_i is enough much then the table 2 can be depicted as the figure(x axis is v_i, y axis is q_k). The grey random model can be created by the following method:

Step1:Ordering the expectation of grey random model is $Ex = v_{\max(p_i)}$. If there more one same $v_{\max(p_i)}$, then the grey random can be created as the extensive grey random model which is studied in this article in previous section Ⅱand Ⅲ.

Step 2:Form the left expectation to left and form the right expectation to right, set the step length is trivial value. The entropy is step by step added according the step length until the minus between the function value of left or right grey cloud model and the figure is lower than the threshold value. Recording respectively the entropy of left and right grey cloud model as En_l、En_r.

Step 3:Respectively calculating the even value of v_i^L which is in the left of left expectation and the the even value of v_i^R which is in the right of right expectation:

$$\bar{v} = \frac{1}{k}\sum_{i=1}^{k} v_i ;$$

Calculating:

$$s^2 = \frac{1}{k-1}\sum_{i=1}^{k}(v_i - \bar{v})^2 .$$

Step 4:According to the following formula to calculate the super-entropy He:

$$He_l = \sqrt{S_l^{\,2} - En_l^{\,2}}$$

$$He_r = \sqrt{S_r^{\,2} - En_r^{\,2}}$$

(3) Repeating the above steps to gain the all grey random model of every attribute. Using the addition regulation of grey random model to calculate the aggregation value of all attribute:

If there are two grey random cloud models representing the qualitative values in the system space. Their digital characters are $A_1(Ex_1, En_1, He_1)$ and $A_2(Ex_2, En_2, He_2)$. The result of algebra calculation is the cloud model $A(Ex, En, He)$. The algebra addition calculation formula is in the following:

$$Ex = Ex_1 + Ex_2$$

$$En = \sqrt{En_1^2 + En_2^2}$$

$$He = \sqrt{He_1^2 + He_2^2}$$

Then the even value is calculated as $(Ex/n, En/n, He/n)$.$(Ex/n, En/n, He/n)$ is known as the lasted evaluation value based on grey random model. In the qualitative space the qualitative value which $(Ex/n, En/n, He/n)$ is adjacent is recorded as the evaluation result. The adjacent degree is called as similarity degree.

The similarity degree can be calculated by following method[14]:

(1)According to the number character of cloud model, using the cloud generator to generate the n grey cloud drops of $c_i^{z'}(Ex_i^{z'}, En_i^{z'}, He_i^{z'})$ and $c_i^{z}(Ex_i^{z}, En_i^{z}, He_i^{z})$, storing the x-axis value of grey cloud drops and sorting the x-axis value of grey cloud drops.

(2)Choosing the grey cloud drops which drops into the scope of [Ex -3 En , Ex + 3 En]. Gaining respectively n_1 and n_2 grey cloud drops, calculating Distance (i), ordering Distance (i) is the square of the minus of $Drop_{i=1...n_1}^{\,1}{}_i$ and $Drop_{i=1...n_2}^{\,2}{}_i$.

$$\text{Distance (i)} = (Drop_{i=1...n_1}^{\,1}{}_i - Drop_{i=1...n_2}^{\,2}{}_i)^2 -$$

(3) Ordering the even distance S_Distance:

S_Distance = SQRT(Σ Distance (i) / C_{n1}^{n2}) / n_1

(assuming $n_1 >= n_2$)

(4)Ordering the similarity between $c_i^{z'}(Ex_i^{z'}, En_i^{z'}, He_i^{z'})$ and $c_i^{z}(Ex_i^{z}, En_i^{z}, He_i^{z})$ is Similar .

Similar=1/S_Distance.

B. Application of Grey Evaluation based on Grey Random Model in Software Evaluation of Users

Software evaluation is the important content for improving the quality of software [15-16]. And fuzzy and

uncertain mathematic method often is used to evaluate the software for the users or experts [17] for the uncertainty of language given by the evaluators. In the following the grey random mathematic proposed in above section is used to evaluate it. The model objectively represents the uncertainty of evaluation of user. In this case there are 7 software users to evaluate the software. There are 8 attributes including about the easily using, the simple interface, the lower cost, the easy installing, the simple maintaining, the cross-operation system supporting, easy improvement and updating, cross-culture supporting.

(1)The evaluation matrix is in the following:

$$D = \begin{array}{c} \\ T_1 \\ T_2 \\ \dots \\ \\ \\ \\ T_7 \end{array} \begin{array}{c} \begin{array}{cccccccc} P_1 & P_2 & P_3 & \dots & & & & P_8 \end{array} \\ \begin{bmatrix} 4,5 & 7,9 & 5 & 7 & 2 & 5 & 4 & 2 \\ 4 & 3 & 3 & 2 & 8 & 6 & 8 & 3 \\ 6,7,8 & 8,9 & 6 & 4 & 2 & 6 & 5 & 1 \\ 7,8 & 6 & 5 & 9 & 7 & 3 & 5,7 & 3 \\ 4,5 & 7,9 & 9 & 5,7 & 5,7 & 6 & 5 & 4 \\ 7,8 & 1 & 2 & 6 & 2,3 & 4 & 9 & 3 \\ 4,5,6,7 & 8 & 6 & 5 & 3 & 1 & 1 & 1 \end{bmatrix} \end{array}$$

If in the matrix there are multi-values are given then the grey model should be created as the multi-max-value grey random model.

(2)Ascertaining the grey random model

Firstly the classification standard of P_1 is given. And the grey random model is given. Commonly the normal grey random is created. Its number character and curve are given. According to above matrix calculating the times of value experts give. And creating the following table 3:

TABLE 3
THE TIMES OF VALUE EXPERTS GIVE ON P_1

Value v_i	4	5	6	7	8
Times q_k	4	3	2	4	3

For the table 3 calculating the proportion of times of value which experts give $p_i = \frac{q_i}{\sum_{j=1}^{m} q_j} (i = 1,2,...,m)$ to gain the following table:

TABLE 4
THE PROPORTION OF TIMES OF VALUE EXPERTS GIVE

Value v_i	4	5	6	7	8
Times q_k	0.25	3/16	1/8	0.25	3/16

Because in table 4 the value 4 and 7 has the same importance its grey random model can be viewed as multi-peak-value normal grey random model. Its grey random model can be represented as the following figure 10.

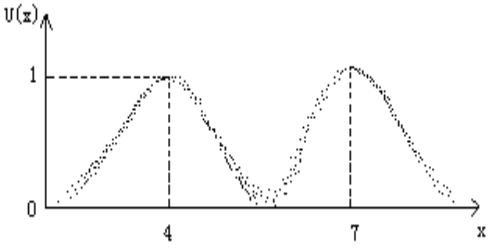


Figure 10. The grey random model of P_1

The grey random model can be created by the following method:

(1) Order the expectation is 4 and 7.

(2) Setting the threshold value is 0.9. Form the left expectation to left and form the right expectation to right, set the step length is 0.05. The entropy is step by step added according the step length until the minus between the function value of left or right grey cloud model and the figure is lower than the threshold value. Recording respectively the entropy of left and right grey cloud model as En_l, En_r. Gaining En_l=0.6, En_r=0.5

(3) According to the former steps 3 and step 4 calculating He_l=0.1, He_r=0.08.

(4) Calculating the aggregation value of all attribute The other attributes' grey random models can be created by the same method. These cloud models are respectively is P_2(CL(9,1.5,0.25), CR(9,0.2,0.05)), P_3(C(6,1,0.2)), P_4(C(7,1.2,0.2)), P_5(CL(2,0.3,0.05), CR(2,1,0.2)), P_6(C(6,1,0.3)), P_7(C(5,1,0.2)) and P_8(C(3,0.5,0.1)).

The grey random model of aggregation result of evaluation of software of users is calculated as (5.5, 1.17, 0.29).

(5) In the qualitative space the qualitative value which (5.5, 1.17, 0.29) is adjacent is recorded as the evaluation result. It is the qualitative value "obvious". So the result evaluation of software of users is the grey random qualitative value "obvious".

V. CONCLUSIONS

This paper proposes the grey random model and its extension. The grey random based on the normal cloud is given. The grey random model can express the grey and random character at the same time. The extensive grey random model can represent the random with dissymmetrical and single-peak-value or multi-peak-value. The grey random model express the uncertain information with random and grey character is objective. The creation algorithm is given to supply the possibility of application of grey random model. The future work is to use the grey random model to represent the uncertain concept in solving reality problems.

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Hongli Wang is birth in 20-12-1978 in China. Graduated from the major of information management and information system in Harbin Institute of Technology in April 2006 and gaining PH.D in Harbin of China. Graduated and gaining master degree from Liaoning University of Engineer and Technology in March 2003 in the major of enterprise management in Fuxin of China. Graduated from Heilongjiang University of Technology in August 2000 and gaining bachelor degree in the major of management science in Jixi of China.

Working now in the department of information management and information system of Zhongyuan University of Technology in Zhengzhou of China since August 2006. Studying in the post doctor research field of information management and information system in the major of management science and Engineer in Xi'an Jiaotong University in Xi'an of China from August 2009 to August 2012. Current and previous research interests include management information system, software engineer, decision support system, electronic business, simulation of management system etc.

Dr. Wang gained the excellent paper prize of nature science of prince of Henan in China in 2010.