The Quality Assessment of Student Learning Based on Cloud Model

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***Abstract*—In traditional tutoring system, the quality assessment of student learning is identified by hard division regardless of the uncertainty of results. In the paper, Cloud Model Theory was applied to build student model in Intelligent Tutoring System. And a quality assessment approach of student learning based on cloud model was proposed. Students' test scores are regarded as cloud droplets, and data is discretized according to contribution of the cloud concept in the research. Furthermore, cloud transform algorithm is introduced to compute membership cloud. Finally, maximum determination algorithm is used to obtain more actual grade division of learning quality. Experimental results show that membership concept can reflect not only the mastery level of knowledge points but also the stability and psychology in the process of student learning. The study will help improve the efficiency of Intelligent Tutoring System.**

***Index Terms*—cloud model, student learning quality evaluation, student model**

I. INTRODUCTION

With the rapid development of computer information technology and network technology, people have higher expectations of education. Traditional educational style has been unable to meet current teaching needs of humanity and intelligence. Then Intelligent Tutoring System (ITS) is gradually paid attention for its intelligence, efficiency, reliability, personalization and sharing features[1]. However, it not only provides many potential advantages for students, but also shows some deficiencies in practical application. Furthermore, the current tutoring systems focus on the monotonous mechanical evaluation of acquiring knowledge unilaterally[2]. So students could not find the problems and factors of restricting their learning efficiency. And the teacher also could not get learners' states from the system. In view of the above problems，cloud model was brought to the application of ITS to achieve effective interaction among students, teacher and system based on Cloud Theory in the paper.

Qualitative assessment has been paid attention in many application, such as assessing student grade, complex projects and so on[3]. Tutoring system assess the quality of student learning qualitatively so as to understand held knowledge level. The assessment not only enhances the enthusiasm of students, but also can test the quality of learning. As we know, the Cloud Theory in which cloud model is core is put forward in the early 1990s. It is a kind of important method of converting qualitative linguistic values into quantitative numerical values. The idea that cloud model is used to establish the quality assessment is effective on student grade soft division. It can carry out fuzzy division and improve the trust of assessment. So Cloud Theory provides a new vision and perspective for constructing model of quality assessment of student learning.

II. CLOUD MODELTHEORY

Early 1990s, Professor Li Deyi presented Cloud Theory, which core is cloud model. Cloud model considers that concept is cognitive basic element, and factor that is formed by concept is regarded as data. Suppose U is a quantitative domain that is expressed by precise numerical value, C is qualitative concept on U. If quantitative value $x \in U$, x is a random realization of qualitative concept C, determine the degree $\mu(x) \in [0,1]$ is the random number of stable tendency, $\mu : U \to [0,1]$, $x \in U$, $x \to \mu(x)$, then distribution of x is called cloud on the domain U, each x is called a cloud droplet, and several cloud droplets make up cloud. A map from qualitative concept to domain space as cloud droplet is usually a concrete realization of the cloud in fact. It has some uncertainty, and is put membership degree by cloud model. In addition, number feature of cloud can reflect properties of whole cloud. That is, expectation Ex_1, expectation Ex_1, entropy En and super entropy He.

In the theory, the expectation expresses the distribution of cloud droplets in their domain space, entropy shows uncertainty measurement, and super entropy is entropy of the entropy to figure the uncertainty of the entropy. Furthermore, cloud concept denoted by $C(E_{x_1}, E_{x_2}, E_n, H_e)$. When $Ex_1 < Ex_1$, it is shown as trapezoidal cloud model else if $Ex_1 = Ex_1$ it is regarded as normal cloud model. Now, cloud model is widely used in evaluation of overall performance and efficiency of complex systems, such as C41SR system, electronic products, military electronic information system and so on[4,5]. The various characteristics of qualitative variables and quantitative variables in assessment would be processed by cloud model of different directions and

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different types. In a multi-level and multi-purpose ITS, assessment of the quality of learning often involves many kinds of factors. And a simple traditional mathematical model is difficult to assess accurately and completely. Therefore, it's necessary to improve the insufficiency of existing assessment model by introducing Cloud Theory.

A. The Universality of the Normal Cloud Model

Cloud model combines randomness with fuzziness, and reveals the intrinsic relationship between them. As we know, cloud model of normal distribution shows uncertainty of concept. And the model is universal, can transform between qualitative and quantitative directly or simply. So the universality of the normal cloud is used to assess learning quality in the paper.

In theoretical research and application of probability and random process, the normal distribution has a very important position. Normal distribution function is just as follows.

$$F\left(x,\mu,\delta^2\right)=\frac{1}{\sqrt{2\pi}\delta}\int_{-\infty}^{x}\exp\left[-\frac{(x-\mu)^2}{2\delta^2}\right]dx \quad (1)$$

In the equation (1), μ is the expectation of a normal distribution, and it denotes most likely value in random variables. δ^2 is the variance, to express dispersive degree in all likely values. As we know, many actual phenomena, such as annual average temperature or an average annual rainfall of a region, are all normally distributed. And normal distribution has already been widely used in reality. However many random phenomena can't be aptly described by normal distribution. Because self-effect of the factors of determining random phenomena is not little evenly, and to a certain extent, they are also interdependent, it is not in line with production conditions of normal distribution. These phenomena approximate a normal distribution, but not. As a rule, the joint probability distribution is difficult to determine, so it is not fully applied in practical application.

Cloud model adopts super entropy parameters that measure the degree of deviation from the normal distribution to describe the problems of fuzziness and randomness. So it is easy to express and operate with lower condition of normal distribution.

For the mathematical feature of the normal cloud model, the expectation of random variable *X* formed by cloud droplets is *EX=Ex;* variance is $DX = E_n^2 + H_e^2$. Therefore, the prerequisite of the normal distribution is that the separate function between some independent and small random factors is weak and relatively uniform. Then the phenomenon may be regarded as the normal distribution approximately. According to the above conditions, it is easy to determine random distribution of *X* as non-normal distribution. However, only one or several interrelated prominent factors affect result in many cases. So the analysis of simple normal distribution can not truly reflect the objective situation. In view of these problems, super entropy *He* provided by normal cloud model is used to weaken the conditions of forming normal distribution.

Pan-normal distribution conditions are less strict than them of normal distribution[6]. Many actual cases do not satisfy normal distribution conditions though they are approximatively processed according to normal distribution in real research and application. But the Pan-normal distribution is just closer to the objective reality. That is, the universality of pan-normal is more widespread than normal distribution. When H_e=0, the cloud *X* distribution will become normal distribution. In addition, the probability density function of the normal droplet is fixed, and it has no relation with numerical characteristics. The above description has different meanings for any concept expressed by language value, the distribution in universal space and physical meaning are also different., and all the performance of cloud droplets have a different degree of certainty in [0,1].

For any concept that expressed in language value, the above described have different meanings, the distribution in universal space and physical meaning are also different and all the performance of cloud droplets have a different confirmation in [0,1]. The universality theory of normal cloud model is based on the universality of normal distribution and bell-shaped membership function[7].

B. The Uncertainty of Cloud Model

In ITS，the quality assessment of student learning involves many aspects that mainly divide grades of assessment objects by a certain rule-making score. The hard division always results in strong subjectivity. In addition, the description of assessment indicators mostly uses the qualitative natural language, which has strong fuzziness and randomness. Therefore, the cloud model that exchange between qualitative state and quantitative situation was proposed based on the traditional fuzzy mathematics and probability statistics. The model can overcome the above shortages by swapping each other to receive the better usability and effectiveness.

The probability theory is the earliest and the most mature one in many uncertain research methods. It studies uncertainty by different views based on the necessity and contingency of events[8]. There it has significant constraint boundary condition and the starting point so that it is more advantageous for the deep research of the problem. Simultaneously the concept is qualitative in natural language, so understanding the uncertainly of the natural language concept, it is unnecessary to carries on the classification from its randomness and fuzziness angle. In the same, he concept is qualitative in natural language, so the uncertain understanding of the natural language concept is unnecessary to classify according to its randomness and fuzziness angle. Furthermore it is more important to establish an uncertainty transformation model between qualitative concept and quantitative description, and to transform the uncertainly of quantity to carry out reality and universality based on the way of concept.

C. Improved Cloud Transformation Algorithm

Each cloud droplet is a point that qualitative concept *C* mapped to number domain space, that is, cloud droplets achieve a quantitative. In the learning quality assessment

model, the test score of student is regarded as a cloud droplet, we can't see anything from a cloud droplet, but it's easy to study for a lot of cloud droplets. So, the test scores of many times can be formed cloud droplets clusters. The more the cloud droplets concentrate, the greater the considerable possibility is, and the discrete cloud droplets may be ignored. With statistical analysis, the cloud droplets that contribute to the qualitative concept of the domain *U* are mainly fallen the area [Ex-$3E_n$， Ex+$3E_n$], and the contribution rate is 99.74%. Therefore the contribution of cloud droplet outside above area can be ignored, this is the so-called "$3E_n$ rules" of normal clouds. Cloud transform algorithm is as follows:

Step1： Input data set *D* of attribute *X*;

Step2： Transform permissible error amount θ ;

Step3： Output *n* discrete concepts:

$C_i(Ex_i, En_i, He_i)$ $(i = 1,2,...,n)$

According to the cloud transform algorithm, the concept of normal or semi-normal cloud is generated. But different generating methods of cloud correspond to dissimilar types of cloud model. So, cloud transformation algorithm was improved based on the traditional algorithm according to universality of description and understandable characteristic of representing concept of trapezoidal cloud in the paper. The improved way more suitable for the feature of assessing learning quality in ITS, because it can generates concept *C* of normal or semi-normal cloud, can also be trapezoidal or semi-trapezoidal cloud. Then a relative definition is presented.

Definition: Frequency distribution function $f(x)$ of data feature x is presented, a number of different size superimposed cloud were automatically generate according to the actual distribution of x attribute value frequency. The transform process from continuous range of values to discrete concepts is known as cloud transform. And its mathematical expression is as follows:

$$f(x) \to \sum_{i=1}^{n} (a_i \times C_i(E_{x1}, E_{x2}, E_n, H_e)) \qquad (2)$$

In the equation (2), a_i is a rate coefficient， n is the number of discrete concepts after transforming. The way can assess the value of the probability density function of one side is similar to the level of another according to the data distribution around the peak. Then the values of the probability density function of two sides are regarded as the mathematical expectation of cloud model, the section $[E_{x1}, E_{x2}]$ on the curve $f(x)$ is regarded as a point to calculate the entropy E_n of trapezoidal cloud by fitting curve $f(x)$, then subtract corresponding value of the qualitative concept from the original distribution to get new data distribution, and so on, finally, fitting error function $f(x)$ and distribution function of cloud model are obtained by known data frequency distribution function, and the ultra-entropy value is also get by calculating based on the cloud model. The cloud transformation algorithm is shown as follows:

Input: the probability density function $f(x)$ of data distribution (can be arbitrary data distribution), and the error threshold θ ;

Output: the cloud model set *Clouds* of concepts, including the normal cloud and trapezoidal cloud of concept cloud model set.

D. The Determining of Membership Concept

Cloud Theory reflects the uncertainty of qualitative concept set *C* can be composed of the basic concepts of the domain, that is, the concept set *C* is expressed as $C\{C_1(Ex_1, En_1, He_1), C_2(Ex_2, En_2, He_2), ..., C_n(Ex_n, En_n, He_n)\}$, and $C_1, C_2, ...C_n$ is the basic concept expressed by Cloud Theory. The distinctions among the concepts can have certain connection. Then all the attribute values are determined. Finally membership concept is determined according to the calculation of membership degree. Furthermore, the determining of membership concept was applied to the quality assessment model to obtain the students' average scores of the previous tests. In the approach, each average score belongs to the concept cloud model, and grade division is realized.

As we know, the two methods of determining membership conception are random determination and maximum determination. Random determination algorithm is randomly to select membership concepts from the top membership degree according to the proportion of attributes corresponding to all conceptual membership degrees in concept set. But maximum determination algorithm is to choice concept of maximal membership degree as membership conception based on the size of attributes corresponding to all conceptual membership degrees in set. In the two ways, maximum determination algorithm improved the accumulation method, so the algorithm avoids the defect that things may be judged as smaller membership concept.

Maximum determination algorithm is a special case in random determination. For any attribute value μ_i corresponding to the membership degree of each concept in the qualitative concept *C*, take $\mu_i = \max \mu_k, (k = 1,2,...,m)$, and then randomly assign μ_i to the concept C_i . With the random characteristics of cloud, we can see that μ_i is randomness，rather than fixed. So in the overlap area, the same attribute values may be assigned to different clouds in different circumstance, which is similar to the classification of recognize process. So, to input data set of attribute *X*, the concept set *C* based on the cloud model, *k* is the number of candidate concepts, and membership concepts will be obtained by maximum determination algorithm.

□. THE LEARNING QUALITY ASSESSMENT APPROACH BASE ON CLOUD MODEL

Assessment model of student learning quality is an important part of the student model, and it is the basis of organizing learning in ITS. Because the learning quality

assessment has come characteristics such as fuzzy boundaries and uncertain features, and the traditional single numerical assessment method reflects the learning quality unilaterally. Therefore, applying the uncertainty and fuzziness of cloud model concept, the paper presents a new method of student learning quality assessment, called CM-SLQA(Cloud Model Based Student Learning Quality Assessment) . The new way solves the fuzzy uncertainty of evaluation process to achieve more realistic assessment result.

The learning quality evaluation model CM-SLQA is constructed based on cloud model in the paper. The model can assess the average scores aim at a curriculum in a certain stage and mine valuable information, such as the exerting situation, the psychology and the mastery level of knowledge in the process of student learning, to solve uncertainty and dynamic of assessment. Then, the model further corresponds to teaching strategies based on above information to obtain better educational effect. The qualitative quality assessment of student learning based on cloud model is showed in Fig. 1, and algorithm operative steps are described as follows:

Step1：By using the pre-historical data, the qualitative concept A_i which can qualitatively describe the proficiency level of student learning is got. Then a certain amount of test results is selected as training data. Finally, cloud transform algorithm is used to process these data to obtain the knowledge of qualitative concept $A_i\left(E_{x_1}, E_{x_2}, E_n, H_e\right)$. In the step, pre-historical data is fully applied to obtain qualitative concept, the result can qualitatively describe the mastery level of knowledge in the process of student learning.

Step2: Firstly, test score, that is cloud droplets, is regarded as approximate normal distribution. Then normal cloud concept $C_i\left(E_x, E_n, H_e\right)$ is got by reverse normal cloud generator to reflect psychology and the stability of exerting in student learning. The larger E_n and H_e is, the worse the stability of exerting and psychology of student learning is. In the step, results of several tests in one curriculum are regarded as approximative normal distribution in a certain stage. Then normal cloud concept can reflect the stability and psychology of student learning inversely with the value of E_n and H_e.

Step3: Input *X* condition cloud generator separately into some normal cloud models obtained from step2 with the maximum determination algorithm of membership degree. Then, the qualitative concept A_i and membership degree μ_i that correspond to students' test scores is determined, they reflect student's exerting levels for the curriculum knowledge. In the step, maximum determination algorithm of membership degree is used to confirm qualitative concept corresponding to test score of students, that is, to determine the mastery degree of student learning in the course.

Step4: Followed by cycle, the qualitative concept A_i corresponds to each of the test results of student learning for a curriculum is obtained, and grade division of student learning quality is finally realized.

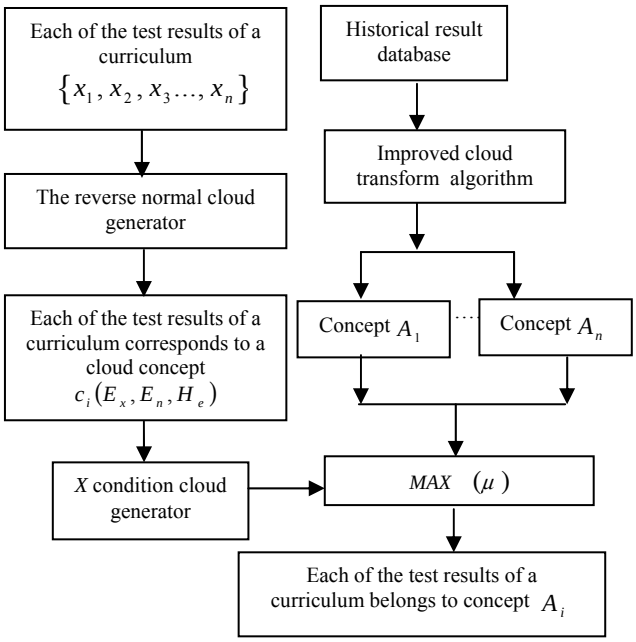

Figure 1. Qualitative quality assessment of student learning based on cloud mode

□. EXPERIMENTS AND ANALYSES

The CM-SLQA method can make students' test results as cloud droplets cluster, and further introduce the cloud transform algorithm to discretize data, finally construct cloud model to assess learning quality of students learning. To prove the effectiveness of the method, the experiment assessed learning quality of Higher Mathematics curriculum at Capital Normal University. Firstly, 1000 students' test scores of were randomly selected to be processed by cloud transform algorithm. Then qualitative concepts of mastery of five knowledge points were obtained as follows:

$A_1(0,22,6,0.8)$ indicates poor mastery of knowledge;

$A_2(25,30,5,0.7)$ indicates fair mastery of knowledge;

$A_3(31,52,6,0.5)$ indicates average mastery of knowledge;

$A_4(57,72,6,0.5)$ indicates good mastery of knowledge;

$A_5(74,100,6,0.5)$ indicates excellent mastery of knowledge.

The mastery level of knowledge points is illustrated in Fig.2. We can see that A_1、A_2、A_3、A_4、A_5 are qualitative description of the mastery degree of the course knowledge. Furthermore we take each student's latest 12 times test scores as cloud droplets, and the domain is limited in (25,100), then, reverse normal could generator is used to get their corresponding normal cloud model, shown in Tab.1.

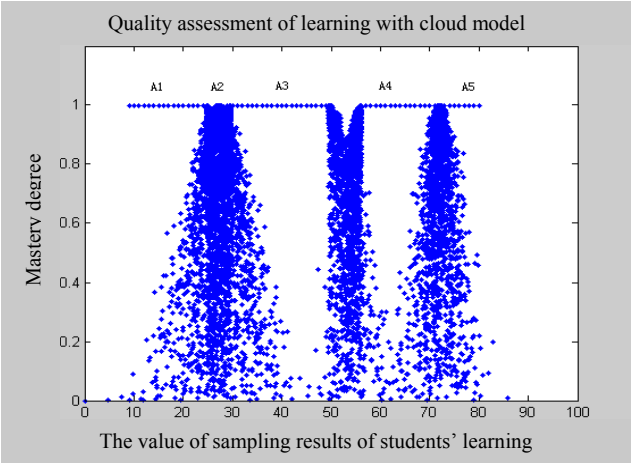

Figure 2. The qualitative concepts of mastery of knowledge points

TABLE I.
THE CLOUD CONCEPT TABLE OF TEST SCORES

ID	Normal 12 times test scores of a curriculum	Normal cloud
001	88,69,84,95,77,82 86,94,93,81,85,98	C(86,5.9,0.7)
002	90,92,89,84,91,97 95,88,87,85,86,96	C(90,3.6,0.2)
003	30,32,35,41,42,46 43,52,60,66,70,71	C(49,3.2,0.4)
…	……	……

The digital features of normal cloud model, corresponding to student learning quality, can be made out in the Tab.1. Even if, the higher digital features E_n and H_e, the better student score, may also has some causations of psychology or other factors to lead to exerting instability in the process of learning. In contrast, some students score low, but may also play a relatively stability. Now, the paper adopts the 3 $E_n$rule of the normal cloud model to calculate membership degree of qualitative concepts of A_1、A_2、A_3、A_4、A_5 corresponding to each student's test score. In the process, the cloud droplets that have great contribution to membership cloud are put in order of importance. Then maximum determination algorithm of membership degree is used to obtain corresponded concept results showed in Tab. 2.

TABLE II.
THE CONCEPT RESULT CORRESPONDING TO KNOWLEDGE MASTER

ID	μ_{A1}	μ_{A2}	μ_{A3}	μ_{A4}	μ_{A5}	Corresponding concept
001	0.02	0.03	0.32	0.56	0.83	A_5
002	0.01	0.02	0.36	0.46	0.98	A_5
003	0.02	0.03	0.84	0.36	0.46	A_3
…	……	……				

The knowledge mastery level of student learning can be seen in Tab. 2. For example, if the student corresponds to concept A_5, then he has an excellent mastery for his learning, and if corresponds to concept A_3, then he has an average mastery. The experiment shows that the membership concept obtained by quality assessment of cloud model reflects certain randomness and fuzziness, carries out a soft division for student learning grade, and presents a more realistic assessment of student's cognitive capacity and knowledge mastery level in ITS.

□. CONCLUSIONS

Cloud model is a good method to solve uncertain problems. Based on the theory, quality assessment model of student learning CM-SLQA was built in the paper to understand learning results with intuitive concepts, get rid of the traditional rigid division, and carry out a soft division of student learning grade. CM-SLQA regards students' test scores as cloud droplet clusters, and introduces to compute membership cloud by cloud transform algorithm. Furthermore, maximum determination algorithm is used to obtain more actual grade division of learning quality. Experimental results show the approach can reflect not only the mastery level of knowledge points, but also the stability and psychology of student learning.

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