A Novel Situation Assessment Model Based on Connection Potential

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***Abstract*—Situation assessment is important for the prediction of a complicated problem involving numerous fuzziness and uncertainty factors. A novel assessment model using connection probability and connection potential of set pair was introduced here to predict the transformation tendency and assess the individual level based on data distribution. Connection probabilities of the certainty and uncertainty relationships and the transformation tendency were specified according to identity-discrepancy-contrary criteria and connection expectation based on connection potential. The results of a case study of students' achievements suggest that this model can be viewed as concise and quantitative expressions of certainty and uncertainty of the complex problem as a whole and dynamic transformation.**

Keywords-situation; set pair analysis; connection potential; uncertainty

I. INTRODUCTION

Situation assessment, a fundamental topic of decision-making problem, is comprehensive processes of data collection, correlation analysis and trend prediction. It plays a remarkable role in the improvement of the assessment system and has aroused wide concerns in academia. The overall level of study object was often assessed by means of the average method and then classified into numerous categories such as single numerical scores usually referring to 100 percent, single letter grades (e.g. A, B, C, D, or F) [1]. However, the result from the average method is raw static and unable to depict the actual data distribution that might neglect the discrepancy among samples, and to address the transformation tendency. And it will not distinguish the ranking order any more when samples had the same score. Accordingly, to forecast situation of study object, researchers have developed various analytical methods such as time series analysis method [2], support vector machine method [3], fuzzy set and grey methods [1, 4], and intelligent method [5]. However, these methods concentrate on a single mechanism and have their limitations. For instance, the calculation process of time series analysis is complex and the error may be large for the medium and long term predictions. The evaluation strategy of fuzzy set method requires a careful consideration of the membership function. Intelligent method has the shortcomings of local minima and low generalization ability and support vector machine method is too dependent on penalty parameter and insensitive loss function. It is thus clear that the above methods are mainly static analytical methods lack of ability to reflect the uncertainty, incomplete, and ambiguous information. However, as we know, situation assessment needs the objectivity, easy computer implementation, and involves uncertainty factors. Therefore, to achieve a proper trend of the uncertainty problem, how to depict certainty and uncertainty relationships between the sample and evaluation standard according to the actual data distribution is an essential problem.

In this paper, a new situation assessment method based on the connection probability and connection potential was presented to predict the transformation tendency of uncertainty problem, and the author attempts to create a new idea to analyze complex problems for the purpose of making the results of evaluation better and consistent with the actual distribution of measured data, providing wider and deeper information.

II. THEORY AND METHOD

A. Connection number of a Set Pair

On the principle of interconnectedness, there are a variety of relations or connection in attributes among things. According to the set pair theory put forward by Zhao [6], the certainty and uncertainty relationships among the practical matters consist of the relationships of identity, discrepancy and contrary, which are interaction, interdependent, associated with each other at macro and micro scales. And the connection number is used to depict and analyze the identity-discrepancy-contrary (IDC) relationship of the set pair defined as two interrelated sets [6, 7]. The corresponding mathematical model is written as follows,

$$\mu = a + b\mathrm{I} + c\mathrm{J} \quad (1)$$

where μ is the connection number; a, b and c denote the identical degree, the discrepancy degree and contrary degree, respectively, and $a+b+c=1$; $b\mathrm{I}$ represents the uncertainty item to take account of randomness, fuzziness, grey, and other crossed and integrated uncertainty information in the measured data as a whole; I is a coefficient of discrepancy degree, $\mathrm{I}\in[-1, 1]$; J is a coefficient of contrary degree, J=-1.

B. Connection Probability

As we know the randomness of events is associated with the relation of things. It needs to make decisions whether the certainty and uncertainty are worthy to simultaneously depict or not during the cognitive process. Herein, connection probability is presented to display the randomness and interaction of study object. According to the principle of IDC analysis, the IDC criteria used to depict the relations of the

possibility, certainty and impossibility between the study object and the given grade is defined as follows: When the sample locates in the discussed grade, the relationship is defined as identity, the corresponding sample can be assigned to the calculation of the identical probability, p_i; When it locates in nonadjacent classes, the relationship is called as contrary, the sample can be included the calculation of the contrary probability, p_c; In addition to the above situations, it is defined as discrepancy and classified as the discrepancy probability, p_d. Let N objects be in study object and grades be K, n_1, n_2, and n_3 be the numbers of object in the discussed kth grade, in separated grades and in adjacent grades, respectively, connection probability for practical problem can be constructed as follows,

$$p^k = \frac{n_1}{N} + \frac{n_2}{N}\mathrm{i} + \frac{n_3}{N}\mathrm{j} = p_\mathrm{i} + p_\mathrm{d}\mathrm{i} + p_\mathrm{c}\mathrm{j}. \tag{2}$$

where p_i, p_d and p_c are the probabilities of certainty, uncertainty and impossibility that study object located in grade k, respectively; i is the coefficient of uncertainty, which represents the converter between main events and neighboring events; j indicates the certainty that it does not belong to the given grade. So the connection probability enables us to consistently express the possibility of certainty and uncertainty.

C. Connection Potential

The connection probability is capable of depicting the possibility of appearance, but fails to display the possibility of transformation. To overcome the shortcoming, a concept of connection potential is introduced to depict the transformation tendency of the IDC relationships. The corresponding model is given by

$$\mathrm{CP_i} = p_\mathrm{i}/(p_\mathrm{d} + p_\mathrm{c}), \tag{3}$$

$$\mathrm{CP_d} = p_\mathrm{d}/(p_\mathrm{i} + p_\mathrm{c}), \tag{4}$$

$$\mathrm{CP_c} = p_\mathrm{c}/(p_\mathrm{i} + p_\mathrm{d}). \tag{5}$$

where $\mathrm{CP_i}$, $\mathrm{CP_d}$, and $\mathrm{CP_c}$ are the connection potential of identity, discrepancy and contrary, respectively. Bigger identical degree over the discrepancy degree and contrary degree and the more the system tends to the identity, on the contrary, the bigger contrary degree relative to the identical degree and discrepancy degree is, the more the system is close to contrary. Obviously, there is a partiality for identical or contrary during the development of a thing. The tendency for identical degree can be defined as forward biased potential and for contrary degree defined as reverse biased potential based on a two-element connection number. Then the transformation of the connection component within a certain condition can be described by the ratio of the mutual transformations among identical, discrepancy and contrary,

$$p^+ = p_\mathrm{i}/(p_\mathrm{i} + p_\mathrm{d}) + p_\mathrm{d}\mathrm{i}/(p_\mathrm{d} + p_\mathrm{c}), \tag{6}$$

$$p^- = p_\mathrm{d}/(p_\mathrm{i} + p_\mathrm{d}) + p_\mathrm{c}\mathrm{i}/(p_\mathrm{d} + p_\mathrm{c}). \tag{7}$$

where p^+ and p^- are forward biased potential and reverse biased potential, which are used to describe the transformation tendency of uncertainty system. It is obvious that the parameters represent the changing of each connection component for the best and worst trends, when i= -1 in the above equation. The discussed parameters can display the transformation tendency from two perspectives.

III. Development of Assessment Model

A. Basic Principle

Evaluation of practical problem is the process of determining the evaluation indicator of sample in relation to classification standard. So to determine the certainty and uncertainty relationships between sample and the classification standard is fundamental issue. Herein, depending on the actual distribution of study object, the connection probabilities are determined based on the identical-discrepancy-contrary criterion to integrate the connection expectation, then to specify the good and bad trends.

B. Evaluation Procedures

The detailed procedures of the proposed method are depicted as below:

- Set up the classification standard of practical problem and count the frequency that the samples belong to the given grade.
- Based on the identity-contrary-contrary criteria and the connection probability, analyze the probabilities of the certainty and uncertainty relationships between sample and each grade.
- Set up the calculation model to obtain the connection expectation in each grade, and calculate the corresponding connection potential, forward biased potential and reverse biased potential. Let m (m=1, 2 … M) and l (l=1, 2 … L) represent the number of samples and evaluation indicators, respectively. The connection expectation is written as,

$$\mu_{ml} = \sum_{k=1}^{K} \bar{x}_{ml}^k p_{ml,\mathrm{i}}^k + \mathrm{i}\sum_{k=1}^{K} \bar{x}_{ml}^k \lambda_{ml,\mathrm{d}}^k + \mathrm{j}\sum_{k=1}^{K} \bar{x}_{ml}^k \lambda_{ml,\mathrm{c}}^k, \tag{8}$$

$$\lambda_{ml,\mathrm{d}}^k = p_{ml,\mathrm{d}}^k \Big/ \sum_{k=1}^{K} p_{ml,\mathrm{d}}^k, \tag{9}$$

$$\lambda_{ml,\mathrm{c}}^{k} = p_{ml,\mathrm{c}}^{k} \Big/ \sum_{k=1}^{K} p_{ml,\mathrm{c}}^{k} \,. \tag{10}$$

where μ_{ml} is the connection expectation of the l-th indicator on sample m; $\bar{x}_{ml}^{k}$ is the median value of the study problem in the given grade k; $p_{ml,\mathrm{i}}^{k}$, $p_{ml,\mathrm{d}}^{k}$ and $p_{ml,\mathrm{c}}^{k}$ denote the certainty, uncertainty and impossibility probabilities of the l-th indicator on grade k, $\lambda_{ml,\mathrm{d}}^{k}$ and $\lambda_{ml,\mathrm{c}}^{k}$ are the normalized amounts of the uncertainty and impossibility probabilities.

- Combined with the indicator weight, w_l, calculate the integrated connection expectation of the indicators of m-th sample, and the corresponding transformation trends. The calculation model of the integrated connection expectation is

$$x_m = \sum_{l=1}^{L} w_l \mu_{ml} \,. \tag{11}$$

In brief, the connection expectation based on the connection probability can describe the distribution characteristics of problem and the IDC relationships to each grade. It can not only depict the differences and distribution characteristics of study object in the same and different grades, but also make fully use of the information and indicate the transformation relationships of certainty and uncertainty, the unified description of various types of uncertainties including the randomness, the certainty of "either-or", and the fuzziness of "both a and b" and so on.

IV. Case Study

Herein, the situation assessment of students' achievements was selected for case study to show how to apply this forecasting approach and to verify the validity and feasibility of the model proposed. The proper assessment of students' achievement is important for the decision of pass and failure standard in courses, the process of determining the performance levels of individual students in relation to scholastic learning objectives. Consequently, the proper system for evaluating the students' achievement is beneficial to gain factual performances of students, and the key to realizing the purpose of education. However, sometime the conventional methods were not sufficiently suitable for evaluating student learning achievement [1] when the assessment of students' achievement involves factors of randomness, fuzziness and discreteness. So to determine the certainty and uncertainty relationships between individual achievement and the classification standard of students' achievement is of great importance [4].

In the case, the score grades were divided into excellent (85-100), good (75-84.9), medium (65-74.9), pass (60-65.9), and fail (below 60). The statistical distribution of the actual scores was listed in Table I. According to the discussed model and IDC criteria, the connection probabilities of students' achievement of the two classes were obtained by the formula (2), and the corresponding results were listed in Table II. To simply show the application of the proposed model, the same weights for three courses was utilized to analyze the practical example. The expectation values of class achievement were calculated by the formulas (8) to (11), and then submitted them into the formulas (3) to (7), obtained the connection potential, forward biased potential and reverse biased potential as shown in Tables III and IV.

From Tables I, II and III, it could be seen that there were differences between class 1 and class 2 in the grade distribution of Chinese course in spite of their identical average score. Obviously, by means of the average method, it is difficult to distinguish the actual level of the two classes. However, by the proposed model, it was observed from Table III that their expectation values, 69.20+73.94i+68.76j in class 1 and 70.89+73.19i+67.50j in class 2, were clearly different. Moreover, through the model, for i=5%, the possible value of the Chinese scores might be got at intervals of [65.50, 72.90] for class 1 and [67.24, 74.55] for class 2, respectively, in spite of their same average value. And integrated expectation values of three courses, were 75.95+75.27i+65.91j for class 1 and 76.95+76.62i+66.38j for class 2, respectively, were not identical in spite of same average value. They suggested that students' achievements both tended to the contrary degree much weaker than to identity degree, but the probability that the students got good scores in class 2 was higher than in class 1. When i=-1, the amounts of forward biased potential for the classes 1 and 2 were -0.031 and -0.035, respectively (See Table IV), that showed that the change in score of class 1 tending to better was greater than that of class 2. Hence, these results indicate that the method proposed here is effective and beneficial to analyze and predict the transformation trend of students' achievement, and can obtain much more and wider information than the average method.

TABLE I. STATISTICAL DISTRIBUTION OF SCORES FOR CASE STUDY

Courses	**Classes**	**Distribution intervals of score / numbers of student**					**Mean values**
		Excellent(85-100)	***Good (75-84.9)***	***Medium (65-74.9)***	***Pass (60-65.9)***	***Fail (below 60)***	
Chinese	1	[87, 95]/9	[75, 84.5]/12	[66, 74]/16	[65, 62]/4	[59, 50]/4	75.03
	2	[85, 96]/17	[75.5, 85]/9	[66, 71]/7	[65, 63]/3	[59, 46]/9	75.03
English	1	[85, 95]/12	[75, 84]/21	[67, 74]/7	[65, 61]/3	[58, 56]/2	80.00
	2	[85, 98]/31	[78, 84]/10	[74, 73]/2	[64, 64]/1	[58, 58]/1	85.00
Mathematics	1	[85, 98]/32	[78, 84]/8	[66, 74]/2	[63, 62]/2	[54, 54]/1	85.00
	2	[85, 98]/16	[76, 82]/17	[68, 74]/6	[61, 64]/4	[55, 59]/2	80.00

TABLE II. STUDENTS' ACHIEVEMENT IN THE FORM OF CONNECTION PROBABILITY

Courses	Classes	Excellent(85-100)	Good (75-84.9)	Medium (65-74.9)	Pass (60-65.9)	Fail (below 60)
Chinese	1	0.20+0.27i+0.53j	0.27+0.56i+0.18j	0.36+0.36i+0.29j	0.09+0.44i+0.47j	0.09+0.09i+0.82j
	2	0.38+0.20i+0.42j	0.20+0.53i+0.27j	0.16+0.27i+0.58j	0.07+0.36i+0.58j	0.20+0.07i+0.73j
English	1	0.27+0.47i+0.27j	0.47+0.42i+0.11j	0.16+0.53i+0.31j	0.07+0.20i+0.73j	0.04+0.07i+0.89j
	2	0.69+0.22i+0.09j	0.22+0.73i+0.04j	0.04+0.24i+0.71j	0.02+0.07i+0.91j	0.02+0.02i+0.96j
Mathematics	1	0.71+0.18i+0.11j	0.18+0.76i+0.07j	0.04+0.22i+0.73j	0.04+0.07i+0.89j	0.02+0.04i+0.83j
	2	0.36+0.38i+0.27j	0.38+0.49i+0.13j	0.13+0.47i+0.40j	0.09+0.18i+0.73j	0.04+0.09i+0.87j

TABLE III. ANALYSES ON THE CONNECTION POTENTIAL

Courses	Classes	Integrated values of score	Connection potential tending to identity	Connection potential tending to discrepancy	Connection potential tending to contrary
Chinese	1	69.20+73.94i+68.76j	0.485	0.536	0.480
	2	70.89+73.19i+67.50j	0.504	0.529	0.468
English	1	74.87+76.99i+65.73j	0.525	0.548	0.433
	2	85.59+80.11i+65.56j	0.588	0.530	0.396
Mathematics	1	83.78+74.88i+63.24j	0.607	0.509	0.399
	2	74.38+76.56i+66.07j	0.521	0.545	0.438
Integrated values	1	75.95+75.27i+65.91j	0.538	0.531	0.436
	2	76.95+76.62i+66.38j	0.538	0.535	0.432

TABLE IV. ANALYSES ON THE TRANSFORMATION TENDENCY OF SCORES

Courses	Classes	Forward biased potential	Reverse biased potential
Chinese	1	0.483+0.518i	0.517+0.482i
	2	0.492+0.520i	0.508+0.480i
English	1	0.493+0.539i	0.507+0.461i
	2	0.517+0.550i	0.483+0.450i
Mathematics	1	0.528+0.542i	0.472+0.458i
	2	0.493+0.537i	0.507+0.463i
Integrated values	1	0.502+0.533i	0.498+0.467i
	2	0.501+0.536i	0.499+0.464i

As mentioned above, evaluation of students' achievement is the process of determining the performance levels of individual students in relation to educational objectives, the assessment method proposed using connection probability is set up on the actual samples retaining all the known information and achieving maximum faith to the given data, so it can effectively depict the distribution of students' achievement and the discrepancy of learning skills among students. Compared to previous methods it has an advantage of a clear analysis process and can objectively predict the transformation tendency and the actual level of students' achievement. And the result of the model proposed is suitable, fair, impartial beneficial to all students, and it also can objectively assess the ability of students. Moreover, the proposed method enables to forecast trends of students' achievement as a whole.

V. CONCLUSIONS

The situation assessment of the sophisticated problem inevitably involves various uncertainty factors. Herein, a novel model built on the connection probability and connection potential, which can uniformly depict the probabilities of certainty and uncertainty, was held to discuss the transformation tendency. The results from the case study of students' achievement indicate that this proposed model can be understood as a promising alternative for the comprehensive analysis of students' achievement, which is also beneficial to express the actual distribution, improve the objective and rationality in the process of transformation tendency and make up for the defects in previous methods for the evaluation of students' achievement. Moreover, it provides a useful way to identify effectively the relation of unity and opposites of certainty and uncertainty system such as the randomness of dynamic transformation of complex problem, the certainty of "either-or", and the fuzziness of "both a and b", which enables to depict the merits and defaults and the corresponding transformation tendency of uncertainty problem.

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