Mining Weights of the Combat Capability Evaluation Indexes Based on Cloud Theory and Correlation Analysis

Li Xiaoxi Chen Haoguang Li Daxi Chen Jiangping

***Abstract*—The veracity of combat capability evaluation is tightly related to the reasonable weights of combat capability evaluation indexes. By mapping qualitative linguistic words into a fine-changeable cloud drops and translating the uncertain index conditions into quantitative values with the uncertain illation based on cloud model[1], and then, integrating correlation analysis, a new way of figuring out the weight of combat capability evaluation indexes is proposed. It may solve the limitations of the conventional ways.**

***Index Terms*—cloud models, correlation analysis, combat capability evaluation, index, weight data mining**

I. Introduction

DETERMINATION of operational effectiveness evaluation index weight is one of the most important aspects in the performance assessment process, the accuracy of the index weight directly affects the accuracy of assessment, so how to scientifically determine the assessment index weight is the key to good assessment work. To determine the weight of the general method of set pair analysis, Delphi method, AHP, gray evaluation method, principal component analysis[2]. These methods requires strict data collection process, the last result calculated using mathematical methods. In the real world, however, is a non-linear, dynamic uncertain systems, contains a variety of parameters, and these parameters is uncertain, which makes traditional mathematical model to accurately describe the real world is very difficult. Cloud model[3] as a qualitative and quantitative conversion between model combines the traditional fuzzy mathematics and probability statistical knowledge, to achieve the transformation between the qualitative language to quantitative values.

In this paper, the characteristics of performance assessment, fuzzy and random knowledge of things and of human knowledge into the presence of pre-collected, the establishment of a transition model, and propose the use of cloud theory and related analysis phase a combination of methods[2] to determine the operational performance evaluation index weight.

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II. Based on the Description of the Cloud Model Assessment Index

A. Review Stage

In here to GADWS example, the description of the evaluation indicators. Ground air defense weapon system, select the response capacity, availability, reliability, inherent ability to control and viability as an indicator of the operational effectiveness evaluation[4], each indicator also includes some more detailed sub-indicators. Table 1 shows the evaluation criteria for each indicator.

Table 1 for each indicator evaluation criteria are given by expert knowledge. Qualitative and vague language to express a certain numerical range. For example, under the surface-to-air missile weapon system from finding the target time to launch the first missile from the frame instantaneous time intervals to assess the "reaction time"[5], the evaluation criteria for the "Shorter, Short, Common, Long, And Longer"; use per 100 fault system maintenance quantity evaluation index maintenance rate, and so on.

TABLE 1 EVALUATION STANDARD OF COMBAT CAPABILITY EVALUATION INDEXES

Index Layer	Sub-index Layer	Evaluation Criteria				
Ability to respond (U_1)	The reaction time (U_{11})	Shorter	Short	Common	Long	Longer
Availability (U_2)	Failure rate (U_{21})	Lower	Low	Common	High	Higher
	Repair rate (U_{22})	Higher	High	Common	Low	Lower
Trustworthiness (U_3)	Reliability (U_{31})	Higher	High	Common	Low	Lower
Inherent capacity (U_4)	Hit rate (U_{41})	Higher	High	Common	Low	Lower
	Damage rate (U_{42})	Higher	High	Common	Low	Lower
	Anti-jamming capability (U_{43})	Better	Good	Common	Bad	Worse
	Detection capability (U_{44})	Better	Good	Common	Bad	Worse
Ability to control (U_5)	Control rate (U_{51})	Better	Good	Common	Bad	Worse
Ability to survive (U_6)	Flexibility (U_{61})	Better	Good	Common	Bad	Worse
	Concealment (U_{62})	Better	Good	Common	Bad	Worse

"Reaction time" of the five evaluation criteria qualitative concept available cloud model is described as follows:

$$D_{A1} = \begin{cases} 1 & , \quad x \in [0,2] \\ D(2,4/3,0.005) & , \quad others \end{cases}$$

$$D_{A_2} = D(5,4/3,0.005) \; D_{A_3} = D(10,3/3,0.005)$$

$$D_{A_4} = D(15,4/3,0.005)$$

$$D_{A_1} = \begin{cases} D(18,4/3,0.005), & others \\ 1 & , x \in [18,\infty] \end{cases}$$

Figure1 shows the joint distribution of the cloud droplets and the qualitative evaluation criteria of the "reaction time" concept of degree of certainty.

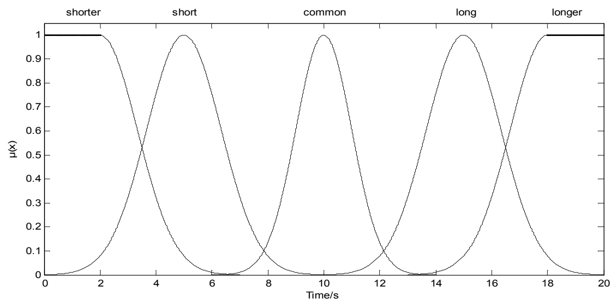

Fig.1 Cloud model of time

III. Based on Cloud Model Uncertainty Reasoning and Correlation Analysis

A. Based on cloud model uncertainty reasoning

A formalization of qualitative rules described as: If A then B, where A, B the language value indicates the object. The cloud generator uncertainty reasoning based cloud model [3][4][7]. We use with X Conditions cloud objects and with Y Conditions cloud object to construct a single qualitative rules. Figure 2 is a schematic diagram of the single rule cloud generator, in figure, CG_A indicates that the corresponding input value A flat-screen language with X. Conditions cloud Object, CG_B indicates that the corresponding output graphic language value B with Y Conditions cloud object. The point of view of the single rule generator single run, when the input plane of a specific input x_0 Stimulate CG_A, when CG_A randomly generate a μ_i, this value reflects the activation of the corresponding qualitative rules strength, the value of the control output plane CG_B generates a random cloud droplets output. However, in general, when the input plane of a particular input value x_0 Stimulate CG_A, when CG_A generating a set of random μ_i values. These values reflect the activation intensity corresponding qualitative rules, which group μ_i And control the output plane CG_B Quantitative generate a random set of cloud droplets $drop_i(y_i,\mu_i)$. From the diagram of a single rule can be found inherent uncertainty. Corresponding to a fixed input x_0, First CG_A Generate a random set of output values μ_i, the uncertainty of the input variable is passed to the output variable space. Under the control of the same μ_i, CG_B output a random set of cloud droplets $drop_i(y_i,\mu_i)$. Corresponding to a fixed input value, the output space y_i. Uncertain, this reasoning system to achieve a good inheritance and transitivity of uncertainty. Visible cloud model constructed qualitative rules to solve the problem of uncertainty propagation and update.

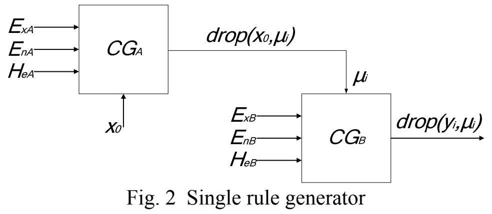

Fig. 2 Single rule generator

B. Correlation Analysis

First standardized reference data table which compares the data columns, according to the formula (2-1) and (2-2) evaluation index weight.

$$\gamma_i\left(x_0(k),x_i(k)\right)=\frac{\min_i\min_k\Delta_{0i}(k)+\zeta\max\max\Delta_{0i}(k)}{\Delta_{0i}(k)+\zeta\max\max\Delta_{0i}(k)} \quad (2\text{-}1)$$

$$\Delta_{0i}(k)=\left|x_0(k)-x_i(k)\right|,\quad \gamma_i=\frac{1}{N}\sum_{k=1}^{N}\gamma_i(k),$$

$$w_i=\frac{\gamma_i}{\sum_{i=1}^{n}\gamma_i}\times 100 \quad (2\text{-}2)$$

Where in, x_i is affect the value; $\gamma_i(k)$ is the correlation coefficient of x_i And x_0 of k-time Be; ζ is distinguishing coefficient, usually in the [0,1]; γ_i is the correlation of each index; w_i is the weight of each index.

C. weights mining process

Weights mining process shown in Figure3.

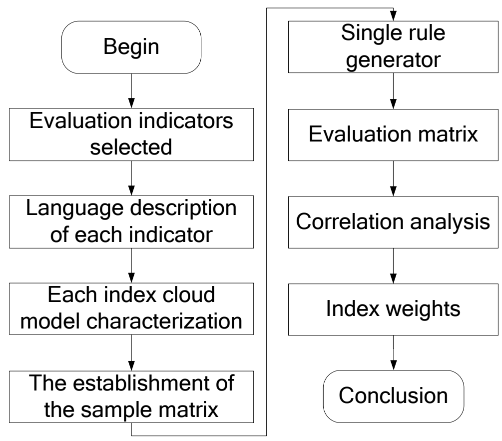

Fig. 3 Weight mining process

IV. Mining Models and Algorithms

First, according to the expert knowledge and experience with a given cloud model description to indicate the evaluation criteria of the evaluation index. Cloud model based on uncertainty reasoning can be indicators of uncertainty into quantitative form values[6]

"Reaction time", for example, according to the following expert knowledge to determine the criteria of uncertainty reasoning:

1) If the reaction time is "shorter", the value is "higher";

2) If the reaction time for the "Short" value "high";

3) If the reaction time is not a "common", affect the value of the "Common";

4) If the response time for the "long", the impact value is "low";

5) If the reaction time is longer affect the value of the "lower".

he five qualitative concept affect the value of the cloud model are as follows:

$$D_{B_1}=D(90,15/3,0.05) \quad D_{B_2}=D(70,15/3,0.05)$$

$$D_{B_3}=D(50,15/3,0.05) \quad D_{B_4}=D(30,15/3,0.05)$$

$$D_{B_5}=D(10,15/3,0.05)$$

Use the cloud rules to drive forward cloud generator, a set of performance data can be obtained as the average value there of X condition cloud generator input, and calculated the five qualitative concept certainty, to identify the maximum μ_i.

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In other words, the first rule set *i*-rule is activated. Single rule generator to produce the output, and the output as the indicators of value. When using the *Y* conditions cloud generator to calculate the output value, according to the size of the input to select the plus or minus. If $x<E_{xA}$, Select the Less, if $x>E_{xA}$, Select Add. The uncertainty reasoning can also be other indicators of value.

V. APPLICATION EXAMPLES

A. Data Preparation

According to the operational effectiveness evaluation index system and sample data space distribution, we characterize the performance of the weapon system with a 0-100 number. We collect a set of operational performance of a typical sample data, sample grade rating and specific index value, as shown in Table 2.

TABLE 2 SAMPLE DATA OF FORCE EFFECTIVENESS

Sample Class	95	81	73	59	47	33	19
The reaction time (U_{11})	Shorter	Shorter	Short	Short	Common	Long	Longer
Failure rate (U_{21})	Lower	Low	Low	Common	High	High	High
Repair rate (U_{22})	Higher	High	High	Common	Common	Low	Low
Reliability (U_{31})	Higher	Higher	High	Common	Common	Low	Low
Hit rate (U_{41})	Higher	High	High	High	Common	Low	Lower
Damage rate (U_{42})	Higher	High	High	Common	Low	Low	Lower
Anti-jamming capability (U_{43})	Better	Better	Good	Common	Common	Bad	Bad
Detection capability (U_{44})	Better	Good	Good	Common	Common	Common	Bad
Control rate (U_{51})	Better	Good	Good	Common	Common	Bad	Bad
Flexibility (U_{61})	Better	Better	Good	Good	Common	Bad	Bad
Concealment (U_{62})	Better	Better	Good	Good	Common	Common	Bad

B. sample cloud model description and uncertainty reasoning

Grade rating of the weapon system can be used to map the operational effectiveness is a positive relationship between combat effectiveness and impact indicators. Analysis of operational performance and evaluation indicators, the use of the cloud model can be uncertain indicators into a number of forms of value.

Indicators affect the value and sample grade rating of the reference data table which compares the data columns. As shown in Table 3.

TABLE 3 REFERENCE DATA AND COMPARING DATA

Sample Class	95	81	73	59	47	33	19
The reaction time (U_{11})	96.67	93.41	75.91	72.49	52.03	30.65	8.17
Failure rate (U_{21})	95.75	74.23	72.56	50.55	33.45	30.84	25.81
Repair rate (U_{22})	98.12	78.42	72.03	52.85	53.68	30.21	26.45
Reliability (U_{31})	92.64	88.25	70.82	52.32	54.87	32.68	28.92
Hit rate (U_{41})	89.26	70.91	71.63	64.48	50.61	31.36	15.14
Damage rate (U_{42})	87.62	71.53	69.34	51.82	36.45	32.66	14.84
Anti-jamming capability (U_{43})	95.64	95.10	74.26	67.59	49.64	31.87	24.63
Detection capability (U_{44})	91.56	75.68	74.26	55.69	51.42	48.82	31.08
Control rate (U_{51})	88.94	72.93	70.43	48.72	51.81	25.47	30.61
Flexibility (U_{61})	90.23	88.61	75.64	71.92	54.08	32.67	27.59
Concealment (U_{62})	85.68	92.59	74.68	78.28	52.67	55.31	29.42

C. 5.3 relational analysis to calculate the weight

Operational Effectiveness Criteria 2.2 formula given in Table 3, the weight, as shown in Table 4.

TABLE 4 WEIGHT OF COMBAT CAPABILITY EVALUATION INDEXES

Index layer	Sub-index layer	Weights
Ability to respond (U_1)	The reaction time (U_{11})	0.096
Availability (U_2)	Failure rate (U_{21})	0.098
	Repair rate (U_{22})	0.090
Trustworthiness (U_3)	Reliability (U_{31})	0.081
Inherent capacity (U_4)	Hit rate (U_{41})	0.100
	Damage rate (U_{42})	0.076
	Anti-jamming capability (U_{43})	0.101
	Detection capability (U_{44})	0.097
Ability to control (U_5)	Control rate (U_{51})	0.092
Ability to survive (U_6)	Flexibility (U_{61})	0.082
	Concealment (U_{62})	0.086

D. 5.4 Comparative analysis and conclusions

Table 5 shows the use of correlation analysis method, the Delphi method and cloud model and associated analysis combined method calculated index weights.

As can be seen from Table5, the indicators calculated by the three methods, the weight distribution is basically the same, evaluation indicators the Combat Effectiveness strength can based on objective data analysis by the expert system to achieve. Assess the operational effectiveness of the index system, the indicators of “anti-interference ability” weight. Second, the indicators “hit rate”.

The experiments show that it is feasible to use the cloud model to describe the combat effectiveness. With a quantitative analysis method based on cloud model uncertainty reasoning and associated reflects the combat strength of the performance assessment indicators, the weight and get results more in line with the actual situation. And some traditional methods, such as the Delphi method, correlation analysis method compared to its salient features [2] as follows: ① heavy weights by objective data, eliminating subjective factors on the assessment of the impact. ② sample data no longer needs to be the exact value, but rather a natural language description. Fully take into account the fuzziness and randomness of the real world, a more accurate description of the real world. In line with the laws of the objective world of human knowledge. ③ easier than other methods of data and processing of the data.

The method is applicable to determine the multi-attribute evaluation index weight, especially those with qualitative language to describe the situation. The accuracy of the results is determined by the standard model of the evaluation index.

TABLE 5 COMPARISON BETWEEN RESULTS OF CLOUD MODEL AND OTHER WAYS

Method	U_{11}	U_{21}	U_{22}	U_{31}	U_{41}	U_{42}	U_{43}	U_{44}	U_{51}	U_{61}	U_{62}
Cloud Model and Correlation analysis	0.096	0.098	0.090	0.081	0.100	0.076	0.101	0.097	0.092	0.083	0.086
	0.096	0.188		0.081		0.374			0.092	0.168	
	U_1	U_2		U_3		U_4			U_5	U_6	
Correlative Degree Analysis	0.095	0.097	0.089	0.082	0.101	0.076	0.102	0.097	0.091	0.084	0.086
	0.095	0.186		0.082		0.376			0.091	0.170	
	U_1	U_2		U_3		U_4			U_5	U_6	
Delphi	0.095	0.098	0.091	0.081	0.100	0.075	0.102	0.098	0.090	0.083	0.087
	0.095	0.189		0.081		0.375			0.090	0.170	
	U_1	U_2		U_3		U_4			U_5	U_6	

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