Safety Assessment of Radar Software System based on Entropy Weight Method and Cloud Model

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Abstract— **The radar software system safety assessment indicators are mostly qualitative indicators, and the coupling, randomness and ambiguity are strong. Aiming at the problem of radar software system safety assessment, this paper proposes a method based on entropy weight method and cloud model theory assessment. Firstly, the entropy weight method is used to determine the index weight, and then the cloud model theory is used to combine the index weight with the cloud model to obtain a comprehensive cloud. Finally, the comprehensive cloud is compared with the standard clouds to obtain the safety assessment results of the software system. The feasibility and scientificity of the method are proved by comparison with other assessment methods.**

Keywords—Software system; Entropy weight method; Cloud model; Safety assessment

I. INTRODUCTION

The radar software system itself does not pose a direct threat to personnel and equipment safety. However, software safety problems may cause hardware malfunction or failure through software and hardware interfaces, or directly cause equipment to fail to operate normally, causing serious safety incidents and affecting normal conditions. At present, there are few researches on the safety of radar software systems. How to evaluate the safety of radar software systems is an urgent problem to be solved [1-9].

Commonly used safety assessment methods include fuzzy assessment method, Analytic Hierarchy Process (AHP), entropy weight method, Bayesian network assessment method, etc. For example, WANG [10] proposed a fuzzy model of software safety assessment, using the subjective assessment of objective dangerous failure in software testing process to carry out fuzzy reasoning, and realized the qualitative assessment of software safety; LIU [11] used AHP and entropy weight method to evaluate the safety of aviation tactical training airspace planning scheme, this method makes the subjectivity and objectivity of the assessment fully considered and has good practicability; TU [12] used the Bayesian network to describe the complex dependencies between safety influencing factors, and built a safety assessment model to make a reasonable assessment of machine safety. The above safety assessment method can not fully exploit the coupling and randomness factors of the software system in dealing with the safety assessment of software systems. When the qualitative indicators are converted to quantitative assessment, the information loss is too much.

Based on this, this paper proposes a method based on entropy weight method and cloud model to evaluate the safety of radar software system. The index weight can be determined more reasonably by the entropy weight method. The assessment by cloud model method can highlight the coupling, randomness and ambiguity of the assessment results, which provides a new idea for the radar software system to conduct more reasonable and scientific safety assessment.

II. RADAR SOFTWARE SYSTEM SAFETY ASSESSMENT INDEX SYSTEM

Through the search for data, military research, expert discussion, and the characteristics of the radar software system, this paper constructs the radar software system safety assessment index system according to three levels. The target layer is the safety of radar software system, recorded as U; the criterion layer is the safety of three subsystems of the radar software system, namely the safety of terminal subsystem, the safety of monitoring subsystem and the safety of signal processing subsystem. , recorded as U_1, U_2, U_3. The indicator layer includes the safety of 12 Computer Software Configuration Items (CSCI) under each subsystem, which are respectively recorded as $U_{11} \sim U_{33}$. The specific assessment index system is shown in Fig. 1.

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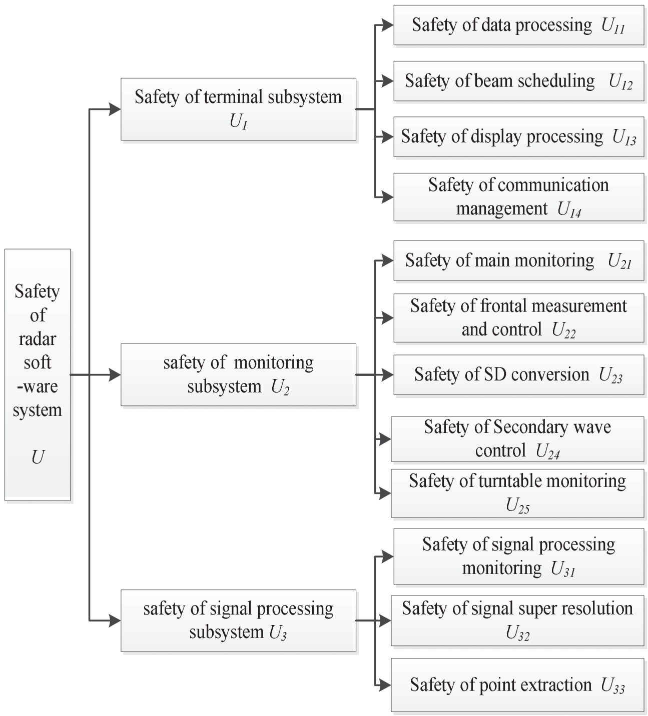

Fig.1 Safety assessment index system of radar software system

III. CLOUD MODEL THEORY

Cloud model theory is a comprehensive assessment method based on the development of traditional probability statistics and fuzzy set theory. It can realize the mutual transformation between qualitative concepts and quantitative values, and effectively solve the quantitative treatment of fuzzy concepts [13-14].

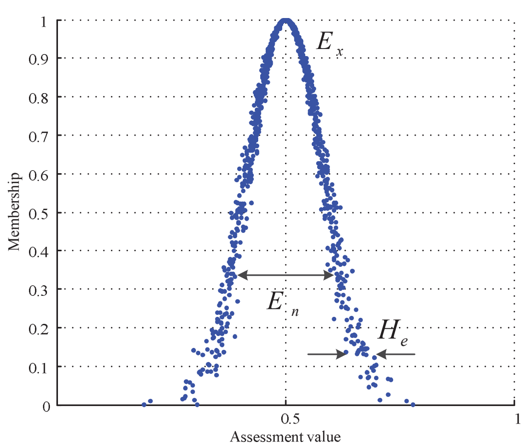

Fig.2 Digital indicator model of cloud center of gravity

The cloud model contains three numerical indicators, which are (E_x, E_n, H_e), as shown in Fig. 2. E_x is the expected value, which can best reflect the qualitative concept of an indicator, indicating that the corresponding fuzzy concept information is transformed into the central value of the quantitative assessment, which is expressed as the peak of the cloud in the cloud map. E_n is the entropy, which is a measure of the expected uncertainty, indicating the degree of ambiguity that can be accepted by the qualitative concept in the number field, expressed as the width of the cloud in the cloud map. H_e is super-entropy, which is a measure of the uncertainty of entropy, reveals the relationship between ambiguity and randomness, expressed as the thickness of the cloud in the cloud map.

The cloud model completes the conversion of qualitative concepts to quantitative values through CG changes, where CG is divided into positive CG and reverse CG^{-1}, and positive CG refers to conversion from qualitative to quantitative. Input the cloud value (E_x, E_n, H_e) and the number of cloud drops *N*, and output the results of *N* cloud drops, as shown in Fig.3.

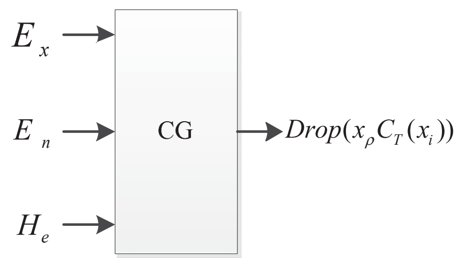

Fig.3 Positive CG

Reverse CG^{-1} refers to the conversion from quantitative to qualitative, input a number of cloud drops that meet the requirements, and output three values of the cloud model, as shown in Fig.4.

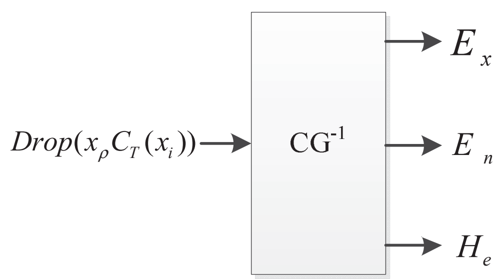

Fig.4 Reverse CG-1

IV. ASSESSMENT PROCESS

Before using the entropy weight method and cloud model theory for assessment, first determine the indicator set, weight set, and assessment set. The indicator set is shown in Fig. 1. The weight set is the weight corresponding to each level of indicators, for example, the weight of the criterion layer is $W = \{W_1, W_2, W_3\}$, where $\sum_{i=1}^{3} W_i = 1$.

The comment set is V={excellent, good, medium, general, poor}, and the comment set is placed on the cloud scale by Matlab simulation, and the cloud generator can be obtained, as shown in Fig. 5.

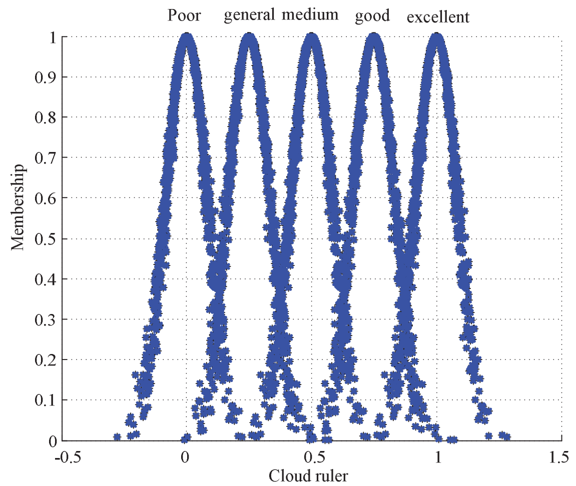

Fig.5 Cloud center of gravity assessment generator

The assessment process is shown in Fig. 6, and the specific steps are as follows.

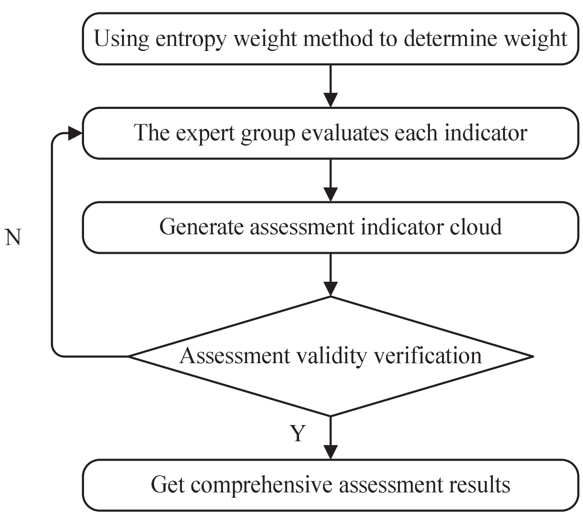

Fig.6 Assessment process

Step 1 Using entropy weight method to determine weight

The entropy weight method can be used to determine the weight of each indicator. There are *a* evaluation objects, *b* evaluation indicators, and the initial data matrix is $F=(f_{ij})_{a\times b}$, Where f_{ij} is the observed value of object i with respect to index j

1) Calculate the proportion p_{ij} of the i-th object under the j-th indicator:

$$p_{ij}=\frac{x_{ij}}{\sum_{j=1}^{b}x_{ij}} \tag{1}$$

2) Calculate the entropy value e_j of the index j:

$$e_j=-\frac{1}{\ln a}\sum_{i=1}^{a}p_{ij}\cdot\ln p_{ij} \tag{2}$$

3) Calculate the weight w_j of the indicator j:

$$w_j=\frac{1-e_j}{b-\sum_{i=1}^{b}e_j} \tag{3}$$

Step 2 Assessment of indicators

The expert group evaluates the assessment indicators according to the assessment set, and converts the assessment results into specific scores. The corresponding relationship is *V*={excellent, good, medium, general, poor} quantified as (1,0.75,0.5,0.25,0), to form an assessment matrix $X_i(x_{i1},x_{i2},\cdots,x_{im})$, $i=1,2,\cdots,n$, where n represents the number of experts, and m represents the number of indicators. Then, through the inverse CG^{-1} change of the cloud model, the numerical characteristics of each assessment index cloud are obtained. The specific steps are as follows.

Step 3 Generate assessment indicator cloud

1) Calculate the mean value of each assessment indicator.

$$\overline{x_j}=\frac{1}{n}\sum_{i=1}^{n}x_{ij},\ j=1,2,\cdots,m \tag{4}$$

2) Calculate the expected value.

$$(E_{x_1},E_{x_2},\cdots,E_{x_m})=(\overline{x_1},\overline{x_2},\cdots,\overline{x_m}) \tag{5}$$

3) Calculate the first-order absolute center distance of the assessment.

$$d_j=\frac{1}{n}\sum_{i=1}^{n}\left|x_{ij}-E_{x_j}\right| \tag{6}$$

4) Calculate the entropy

$$E_{n_j}=\sqrt{\frac{\pi}{2}}d_j \tag{7}$$

5) Calculate the assessment variance

$$S_j^2=\frac{1}{n-1}\sum_{i=1}^{n}\left(x_{ij}-E_{x_j}\right)^2 \tag{8}$$

6) Calculate the superentropy

$$H_{e_j}=\sqrt{\left|S_j^2-E_{n_j}^2\right|} \tag{9}$$

Step 4 Assessment value validity verification

According to the atomization property of the cloud model and the 3δ principle of the normal function. When $H_e < E_n/3$, 99.8% of the cloud drops are between the minimum boundary curve $y = \exp[-\frac{(x - Ex)^2}{2(E_n - 3H_e)^2}]$ and the maximum boundary curve $y = \exp[-\frac{(x - Ex)^2}{2(E_n + 3H_e)^2}]$, and the cloud model is in a good state. When $H_e > E_n/3$, the cloud model is more atomized and needs to be remodeled. Therefore, $E_n/3$ is the assessment standard of the atomization point of the cloud model, and the cloud model that does not satisfy the condition is to be evaluated again by the expert group.

Step 5 Comprehensive assessment of cloud result

By calculating the weights obtained by the improved FAHP and the cloud digital features obtained by the cloud model, a comprehensive assessment cloud can be obtained, and the calculation formula is as follows.

$$\begin{cases} E_x = \sum_{i=1}^{m} E_{x_i} \omega_i \\ E_n = \sqrt{\sum_{i=1}^{m} E_{n_i}^2 \omega_i} \\ H_e = \sum_{i=1}^{m} H_{e_i} \omega_i \end{cases} \tag{10}$$

In equation (10), m is the number of indicators, ω_i is the index weight, and the obtained integrated cloud is $C(E_x, E_n, H_e)$. The comprehensive cloud is added to the cloud model assessment generator, and compared with each standard cloud, the assessment standard corresponding to the highest similarity assessment level. This is the final assessment result.

V. Instance Calculation

Step 1 Using entropy weight method to determine weight

Firstly, according to the entropy weight method, the index weights of each level are determined. According to the formulas (1)~(4), the index weights of each level can be obtained, as shown in TABLE I .

TABLE I INDEX WEIGHT AT EACH LEVEL

Criteria layer	Weight	Indicator layer	Weight
U_1	0.2870	U_{11}	0.4354
		U_{12}	0.1509
		U_{13}	0.2528
		U_{14}	0.1609
U_2	0.5296	U_{21}	0.2525
		U_{22}	0.1699
		U_{23}	0.0718
		U_{24}	0.3985
		U_{25}	0.1073
U_3	0.1834	U_{31}	0.5096
		U_{32}	0.3070
		U_{33}	0.1834

Step 2 Assessment of indicator

Inviting 10 experts from the military, colleges and manufacturers to evaluate the indicator layer. After summarizing the assessment form, each assessment is quantified into corresponding score, and the assessment matrix of the indicator layer is obtained.

$$\mathbf{X} = \begin{bmatrix} 1 & 0.75 & 0.75 & 0.5 & 1 & 1 & 0.75 & 0.5 & 0.75 & 1 & 0.75 & 1 \\ 0.75 & 1 & 0.5 & 0.75 & 0.75 & 0.75 & 0.75 & 1 & 0.75 & 0.5 & 0.5 & 0.75 \\ 0.75 & 0.5 & 1 & 0.75 & 0.5 & 0.5 & 1 & 0.75 & 0.5 & 1 & 0.25 & 0.75 \\ 0.5 & 0.25 & 0.5 & 0.75 & 0.25 & 0.75 & 0.75 & 1 & 0.75 & 0.5 & 0.5 & 0.5 \\ 1 & 0.5 & 0.75 & 0.5 & 1 & 0.25 & 0.5 & 0.5 & 1 & 0.75 & 1 & 1 \\ 0.75 & 1 & 0.5 & 0.75 & 0.5 & 0.75 & 1 & 1 & 0.75 & 0.5 & 0.5 & 0.75 \\ 0.25 & 0.75 & 0.25 & 0.75 & 1 & 1 & 1 & 0.75 & 0.5 & 1 & 0.75 & 0.25 \\ 0.75 & 0.25 & 0.25 & 0.5 & 0.75 & 1 & 0.5 & 0.5 & 1 & 0.75 & 0.75 & 1 \\ 0.25 & 0.5 & 0.5 & 0.75 & 0.5 & 0.75 & 0.25 & 1 & 0.75 & 0.5 & 0.5 & 0.75 \\ 0.5 & 0.25 & 1 & 0.75 & 0.75 & 0.5 & 1 & 0.75 & 0.5 & 1 & 0.25 & 0.75 \end{bmatrix}$$

Step 5 Generate assessment indicator cloud

According to (4) to (9), the assessment index cloud of the criterion layer is solved, and the results are $U_1(0.76,0.14,0.05)$, $U_2(0.84,0.15,0.02)$, $U_3(0.82,0.13,0.01)$.

Step 6 Assessment value validity verification

Through the verification of the cloud results of the assessment indicators in the criterion layer, it is found that U_1 does not satisfy the $H_e < E_n/3$ condition. The cloud model of U_1 is as shown in Fig. 7, and the atomization state can be seen obviously.

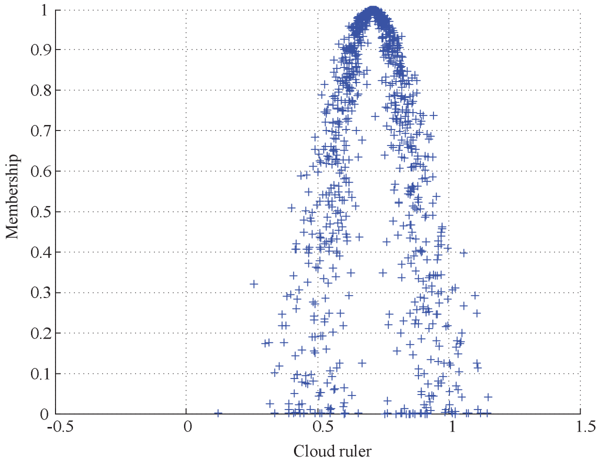

Fig.7 Cloud model of indicator U_1

The reason for this situation is that there is a big difference in the assessment of this indicator by experts. The assessment results are fed back to the expert group, and then the assessment is repeated by the expert group. The new assessment index cloud of U_1 can be obtained, which is (0.76,0.15,0.01), as shown in Fig. 8.

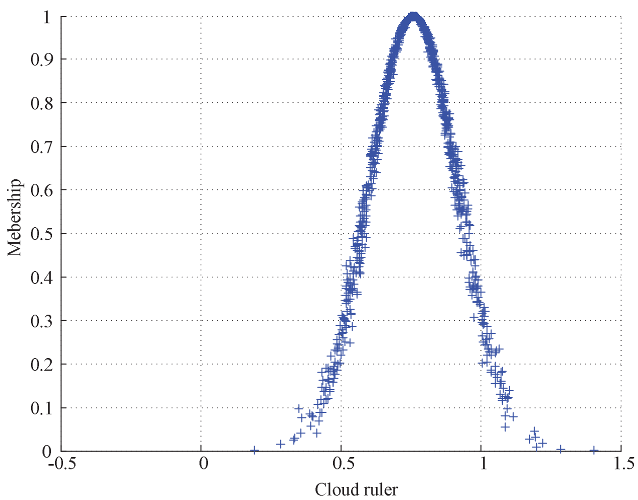

Fig.8 Improved Cloud model of indicator U_1

Step 7 Comprehensive assessment of cloud result

According to (10), the comprehensive assessment cloud result can be obtained as C (0.81,0.14,0.01), which is substituted into the cloud model assessment generator. The cloud image is shown in Fig. 9.

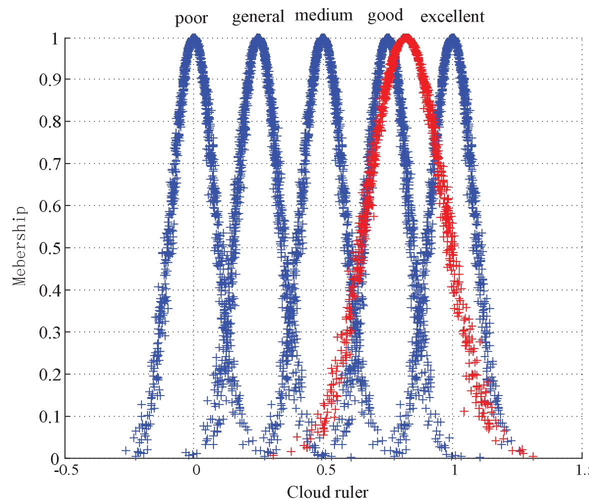

Fig.9 Comprehensive cloud assessment result

According to Fig.9, the comprehensive cloud assessment result of this paper is between the standard cloud "good" and "excellent". According to the principle of maximum similarity, this paper considers that the radar software safety assessment result is good.

VI. Comparative Analysis

Compare the method of this paper with the cloud center of gravity method, mainly compare the differences of the evaluation methods, as shown below.

Using the cloud center of gravity assessment method determined in [15] to evaluate the safety of the radar software system, the total weighted deviation of the cloud center of gravity is A, which is substituted into the cloud center of gravity assessment generator, and the assessment result is good. The result obtained by this method is consistent with the result of this paper.

Comparing the two assessment methods, we can find that the assessment result obtained by using the cloud model is more intuitive and convincing. Because the result obtained by the cloud model is $C(E_x, E_n, H_e)$, it contains three values of the cloud model, not only the assessment result (expectation), but also the entropy (width) and super entropy (thickness) of the cloud model are also visually displayed. To make people at a glance and persuasive. In addition, the cloud model also has a discriminating power for the result of serious atomization. When the result does not meet the test condition $H_e < E_n / 3$ of the cloud model, it can be re-evaluated. In summary, the cloud model assessment method is more intuitive, rational and scientific than the cloud center of gravity assessment method.

VII. Conclusion

This paper has done the following work through the research on the safety assessment of radar software system.

(1) The radar software system safety assessment system was determined, which laid the foundation for subsequent assessment.

(2) The entropy weight method is used to determine the weight of each level of indicators, avoiding excessive loss of original information..

(3) Using the cloud model assessment method to evaluate the safety of the radar software system, fully compiling the coupling and randomness of the assessment indicators, the assessment results are more intuitive and persuasive.

The assessment method proposed in this paper is also useful for the assessment of other weapons and equipment.

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