Safety Valuation of Military Aviation Control System Based on Cloud Model

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Abstract. At present, the flight training, army operation increase constantly, the army ATC faces rigorous challenges. The safety evaluation on ATC can enhance the control effect and guarantee fly safety. In this paper, an evaluation index system is established based on ‘human factor, machine factor, environment factor and management factor’. On the basis of AHP and cloud model, the safety evaluation model is built. To validate the model, an experiment is operated, the result is accord with the real situation, which proves the scientifically and feasibility of this model.

1. Introduction
Aviation control system is the general designation of the organization, personnel and technical equipment of aviation control. How to ensure the normal operation of the military air traffic control system becomes an important problem to be solved urgently when the system is attacked or abnormal. How to realize the coordinated operation of human, machine and environment elements in the air traffic control system through effective control is the key to ensure the safety and reliability of the system. The focus of safety assessment of air traffic control system is the assessment of control factors.

2. Formatting the Title, Authors and Affiliations
Cloud model is a mathematical model that uses language values to represent the transformation model between qualitative concepts and quantitative values. \( \mu(x) \) can form a cloud of trust \( drop(x, \mu(x)) \). The numerical eigenvalues expressed by the whole cloud, i.e. expected value( \( E_x \) ), entropy( \( En \) ) and hyperentropy ( \( He \) ). The relationship between the three eigenvalues is shown in Fig. 1.
Figure 1. Numerical characteristics of clouds

2.1. Standard Trust Cloud Generation Algorithm
Assuming that the system has set up a series of trust clouds in advance, each trust cloud is called a standard trust sub-cloud, and each standard trust sub-cloud has a definite concept that indicates the corresponding trust level. Assume that the trust value has \( n \) value taking intervals, where the trust value of the \( i \)-th interval is \([C_i^{\text{min}}, C_i^{\text{max}}]\).

2.2. Standard trust cloud generator
Enter \( n \) subintervals. Output standard trust cloud \( \text{STC}(E_x, E_n, H_e) \). According to the upper and lower limits of the interval, calculation:

\[
E_{xi} = \begin{cases} 
C_i^{\text{min}} & i = 1 \\
(C_i^{\text{min}} + C_i^{\text{max}})/2 & 1 < i < n \\
C_i^{\text{max}} & i = n 
\end{cases}
\]  

(1)

According to the calculation results of the previous step, calculate

\[
E_{ni} = (C_i^{\text{min}} + C_i^{\text{max}})/3
\]  

(2)

Calculation \( H_e = \eta \).
\( \eta \) reflects the randomness of the trust value and should not be too large. Otherwise, it will increase the randomness of the trust value and make the evaluation result uncertain. According to experience, \( H_e = E_n/10 \). The purpose of establishing a standard trust cloud is to divide trust levels and provide criteria for the final evaluation of trust levels.

2.3. Trust attribute cloud generation algorithm
The evaluated entity has \( m \) evaluation attributes, and obtains several evaluation values respectively. When each evaluation is taken as a cloud drop, the trust cloud generated by the reverse cloud generator is called trust attribute cloud.

Enter \( m \) Sample Points for Evaluation Attributes \( X_i(x_{i1}, x_{i2}, x_{i3}), i = 1, 2Lm \).

Outputting the digital characteristics of \( m \) trust clouds \( \text{STC}(E_x, E_n, H_e), i = 1, 2Lm \).

The specific steps of the algorithm are as follows:

\[
\overline{X} = \frac{1}{n} \sum_{i=1}^{n} x_i
\]  

(3)
The trust attribute cloud represents the trust level of each attribute, also reflects the trust characteristics of the evaluation object in a certain aspect, and is an independent factor that determines the final trust level.

2.4. Similarity of trust cloud Let be the comprehensive trust cloud and be the standard trust cloud. Generating cloud drops from the comprehensive trust cloud through a forward cloud generator. If ‘s membership in the standard trust cloud is . The similarity between comprehensive trust cloud and standard trust cloud is recorded as.

3. Evaluation Index System of Aviation Control Safety

The establishment of aviation control safety system must analyze the whole dynamic process of obtaining, transmitting, processing and applying aviation control information according to the functions of control subjects, control means and control objects in the information flow and control work cycle.

From the perspective of "controller", it includes the following sub-indicators and factors: (1) basic quality sub-indicators: including physical quality and psychological state. (2) sub-indicators of skills and attitudes: including knowledge and skills, on-the-job training time, implementation standard degree and engagement degree. (3) Competency sub-indicators, including coordination processing capability and decision-making capability, which can measure the transmission effect and integration effect of safety information within the organization.

From the perspective of "aircraft", it includes the following sub-indexes: (1) design and production, aircraft type, service life of aircraft and modification of aircraft system. (2) Navigation radar system, instrument operation system and engine system. (3) Maintenance.

From the perspective of "environment", it includes the following sub-indicators: (1) natural environment sub-indicators, including weather and terrain. (2) Sub-indicators of safeguarding the environment, including comprehensive air support capability and airport construction. (3) Sub-indicators of accidents, including bird strikes and terrorist incidents.

From the "management" point of view, it includes the following sub-indicators and factors: (1) sub-indicators of safety planning function: including comprehensive planning, safety rules and standards and improvement of safety system. (2) Sub-indicators of safety organization: including the setting of safety organization and the proportion of safety personnel. (3) Sub-indicators of enterprise safety culture, including the degree of leadership attention and safety incentive mechanism. (4) Sub-indicators of safety control, including safety training and safety inspection inspectors.

4. Examples of Safety Assessments

Taking the safety assessment of an airport control system as an example, the actual utility of cloud model method in safety assessment is verified, and whether safety assessment is of practical significance in improving the efficiency of aviation control system is verified.

The safety assessment steps are as follows:
Step1: Analyze the hierarchical structure of the military aviation control system and determine the key indicators for safety assessment;
Step2: Determine the index weight through consulting experts;
Step3: Collecting expert evaluation scoring data;
Step4: Multiplying the scoring data and the corresponding weight, and generating a comprehensive cloud by using the obtained data;
Step5: Comparing the similarity between the comprehensive cloud and the standard cloud;
Step6: Obtain the safety level and safety value.

4.1. Generate Standard Cloud
The index set up in this paper adopts a ten-point system, that is, the evaluation values of all attributes are in, and the score interval is divided into several sub-intervals according to the actual situation, and corresponding to different evaluation levels. According to expert advice, the final set of safety comments is { very low, low, average, high, very high, very high }. The corresponding value ranges are " very low" [0,1], " low" [1,2], " average" [2,4], " high" [4,6], " very high" [6,8], " extremely high" [8,10]. The numerical characteristics of the identified security level standard trust cloud are very low (0,0.3,0.05), low (1.5,0.15,0.05), average (3,0.3,0.05), high (5,0.3,0.05), very high (7,0.3,0.05), very high (9,0.3,0.05), and the corresponding cloud model is shown in Fig.2.

![Figure 2. Standard cloud model for safety evaluation set of military aviation control system](image)

4.2. Set Weight
This paper takes an airport safety evaluation index as an example, and through consulting experts' suggestions, obtains its index weight as follows: B=[0.42,0.28,0.17,0.13]
- Sub-index Weight of Indicator Controller: [0.15,0.15,0.10,0.08,0.16,0.14,0.10,0.12]
- Sub-index weight of index aircraft: [0.15,0.08,0.10,0.13,0.16,0.14,0.10,0.07,0.07]
- Sub-index weight of index environment: [0.15,0.15,0.17,0.23,0.16,0.14]
- Sub-index weight of index management: [0.16,0.07,0.10,0.13,0.15,0.14,0.10,0.08,0.07]

4.3. Expert Scoring
Through consulting experts, score each index in the score range of 0 ~ 10. Some data are shown in Table 1.

Multiply the scores in Table 1 with the weights to obtain the evaluation scores of B1, B2, B3 and B4 as shown in Table 2.

| Table 1. Grade B assessment score |
|----------------------------------|
| Score | Expert 1 | Expert 2 | Expert 3 | Expert 99 | Expert 100 |
|-------|----------|----------|----------|-----------|------------|
| C1    | 5        | 7        | 4        | 6         | 7          |
| C2    | 5        | 4        | 5        | 7         | 5          |
| C3    | 7        | 6        | 8        | 6         | 8          |
| C4    | 6        | 6        | 4        | 7         | 7          |
| ...... | ......    | ......    | ......    | ......     | ......      |
| C28   | 6        | 6        | 4        | 7         | 7          |
| C29   | 7        | 7        | 7        | 6         | 9          |
Table 2. Grade B assessment score

| Score | Expert 1 | Expert 2 | Expert 3 | ………… | Expert 99 | Expert 100 |
|-------|----------|----------|----------|---------|-----------|------------|
| B1    | 6.12     | 7.22     | 7.65     |         | 4.55      | 5.47       |
| B2    | 7.23     | 6.26     | 4.45     |         | 6.45      | 7.36       |
| B3    | 6.36     | 5.45     | 7.47     |         | 5.23      | 5.45       |
| B4    | 4.45     | 4.78     | 6.23     |         | 4.15      | 6.12       |

Table 3. Assessment score of air traffic control system

| Score        | Expert 1 | Expert 2 | Expert 3 | ………… | Expert 99 | Expert 100 |
|--------------|----------|----------|----------|---------|-----------|------------|
| Air traffic  | 5.22     | 6.14     | 7.47     |         | 5.36      | 6.17       |
| control      |          |          |          |         |           |            |
| system       |          |          |          |         |           |            |

Multiply the scores in Table 1 and Table 2 with the weight to obtain the evaluation score of the aviation control system as shown in Table 3.

4.4. Generate Integrated Cloud

According to the obtained data, the expected value \( \text{Ex} = 5.9 \), entropy \( \text{En} = 0.7 \) and super entropy \( \text{He} = 0.5 \) of the trust attribute cloud can be obtained by adopting a reverse cloud generation algorithm. The similarity of the obtained cloud model and the standard cloud is compared. The comparison results are shown in fig. 3.

![Figure 3. Comparison of integrated trust cloud and standard trust cloud](image)

Through comprehensive comparison of trust cloud and standard cloud, it can be seen that the trust value is concentrated between 4 and 7, and the corresponding evaluation level is high. It can be concluded that the safety evaluation level of the airport aviation control system is high, which is basically consistent with the actual situation of the airport. This method is feasible.

5. Concluding Remarks

As one of the pillars of military aviation safety flight, it is very necessary to evaluate the risks in the air traffic control system with reasonable and scientific methods. Safety assessment of control system can effectively improve control efficiency and ensure flight safety. This paper constructs the
evaluation index system of aviation control system from four aspects of "human, machine, environment and management", and uses AHP to evaluate. The safety risk assessment of military aviation control depends to a large extent on the empirical data given by experts, and the uncertainty of such data will reduce the reliability of the assessment results. Therefore, this paper uses cloud model theory to evaluate the military air traffic control system based on the actual situation of the operation of the military air traffic control system, and gives an example calculation.

6. References
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