Air Combat Situation Assessment Based on Improved RS Theory

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Abstract. In order to improve the ability of the extraction and weight distribution of key air combat factors in air combat situation assessment, this paper improves the rough set theory and establishes an improved rough set theory air combat situation assessment model. Firstly, the air combat information is discretized and decoupled. Then, the improved rough set theory is used to reduce and assign the attributes, and the air combat situation is calculated and evaluated. Finally, the effectiveness of the model is verified by simulation.

1. Introduction
The air combat situation assessment is a process that quantifies and describes the air combat information of the enemy and our fighters, and evaluates the superiority of our aircraft according to the current status, aiming at quantifying the attack relationship between our fighters and targets. With the rapid development of information technology, the amount of data generated during the air combat is increasing. Therefore, the extraction of key air combat situation factors, the weight distribution and effective application to the air combat situation assessment are crucial. This paper proposes an improved RS theory, which organically integrates its factor reduction and weight distribution advantage with the air combat situation assessment, so as to evaluate the air combat situation more effectively.

2. Rough Set theory
At present, the fuzzy assessment method in air combat situation assessment mainly uses fuzzy algorithm reasoning to realize the processing and calculation of fuzzy information in air combat. Document [1] uses the Entropy-based TOPSIS improved algorithm to process the acquired air combat situation information; in the literature [2], based on the VBS Evidence Network as the main framework, a stand-alone air combat situation assessment model is built. However, in the evaluation of the air combat situation, the selection of air combat factors mostly depends on experience, and the weight of each influencing factor is obtained through expert scoring, which has a greater impact on the evaluation result of air combat situation.

Rough Set theory (RS) was founded by Polish scientist Z. Pawlak in 1982. It is a mathematical tool used to quantitatively analyze incomplete and fuzzy information and study its potential laws [3], [4]. The main principle of RS theory is to solve the fuzzy bound problem by setting the upper approximation set and the lower approximation set. The core field is the research on incomplete information processing, attribute knowledge reduction and the correlation and importance between attributes. Fig. 1 graphically depicts the related concepts of RS theory.
When using RS theory to deal with problems, the main steps are as follows:

1. Collecting Information and Building an Information Table

The RS theory usually uses a five-tuple $S = (U, C, D, V, f)$ as the information table to represent the knowledge system of the information to be processed. Where, $U$ represents the set of all research objects, $C$ is the conditional attribute, $D$ is the decision attribute, $V = \bigcup_{i=A}^{n} V_i$ represents the set of all attribute values, and $f$ represents the function mapping of the attribute value of each study object.

2. Preprocessing Information Data and Building a Decision Table

3. Calculating Attribute Dependency

$$\lambda_c (D) = \frac{|pos_c (D)|}{|U|} = \frac{\sum_{i=1}^{n} pos_c (x_i)}{|U|}$$

Where, $\lambda_c (D)$ is the dependency of attribute $D$ on attribute $C$.

4. Calculating Importance of a Single Attribute

$$\lambda_{c-C} (D) = \frac{|pos_{c-C} (D)|}{|U|} = \frac{\sum_{i=1}^{n} pos_{c-C} (x_i)}{|U|}$$

The importance of a single attribute $c_i$ can be expressed as:

$$\phi(c_i) = \lambda_c (D) - \lambda_{c-C} (D) \quad (i = 1, 2, ..., n)$$

5. Attribute Reduction

Setting the importance threshold $\psi$, when $\phi(c_i) < \psi$, the attribute $c_i$ can be considered as an unimportant attribute, and the condition attribute $C$ is reduced to $\bar{C}$.

6. Calculating Attribute Weight

$$\omega = \frac{\phi(c_i)}{\sum_{i=1}^{n} \phi(c_i)} = \frac{\lambda_c (D) - \lambda_{c-C} (D)}{\sum_{i=1}^{n} [\lambda_c (D) - \lambda_{c-C} (D)$$

3. Algorithm Improvement and Application in Air Combat Situation Assessment

RS theory has the advantages of attribute reduction and weight calculation. However, when calculating the weight, it cannot guarantee that the index weight of each factor is not 0 (Type A), or it may cause the phenomenon that the weight cannot be determined (Type B). Moreover, it has certain limitations when dealing with attribute factors with coupling relationship. Therefore, this paper proposes an improved rough set theory to solve the problem of air combat situation assessment.

3.1. Improvement of RS theory

Definition 1 [5]: In the information table $S = (U, C, D, V, f)$, the conditional entropy of the decision attribute $D(U/D = \{D_1, D_2, ..., D_n\})$ relative to the conditional attribute $C(U/C = \{C_1, C_2, ..., C_l\})$ is:
\[ I(D|C) = \sum_{j=1}^{k} \left[ \frac{1}{|C|} \sum_{i=1}^{n} \left| D_i \cap |C| \right| \left( 1 - \frac{|D_i \cap |C| |}{|C|} \right) \right] \]

Then the importance of attribute \( C_i \) is:

\[ \text{sig}(C_i) = I(D|C - \{C_i\}) - I(D|C) + \frac{\sum_{j=1}^{k} |C_h| - \sum_{j=1}^{k} |C_j|}{\sum_{j=1}^{k} |C_j|} \]

The weight of attribute A is as follows:

\[ \omega(C_i) = \frac{\text{sig}(C_i) + I(D|C)}{\sum_{j=1}^{k} \{ \text{sig}(C_j) + I(D|C_j) \}} \]

It has been proved that \( \omega(C_i) > 0 \), which gives practical meaning to each necessary factor. Attribute reduction based on it means that the necessary factor will not be deleted and the weight calculation is more reasonable.

3.2. Air Combat Situation Assessment Based on Improved RS Theory.

During the aerial confrontation of the fighter, the situation information data of both sides will be transmitted to the ground equipment in real time and provided to the commander and pilot for maneuver decision after comprehensive processing. In order to improve the speed and accuracy of decision-making, the applicability of data processing methods, the effectiveness and reliability of results are of vital importance. This paper proposes an air combat situation assessment method based on the improved rough set theory, and the specific process is as follows:

(1) Data Discretization and Formatting

Collecting and sorting air combat situation information data and formatting information tables; the agreement rule discretizes the data in the table, defines the condition attribute and decision attribute, and constructs the air combat situation assessment decision table.

(2) Coupling Relation Processing of Air Combat Situation Information Factors

Air combat situation information factors include static factors and dynamic factors. Static factors mainly include weather, geographical environment, equipment performance, fighter performance, etc. The dynamic factors mainly include the height, speed, heading and distance between fighters. When calculating the comprehensive air combat situation of fighter planes, the factors are not independent, and some factors are coupled, so this paper adopts hierarchical calculation method. The first layer is an independent comprehensive factor, and the second layer is a specific air combat situation information factor corresponding to the first layer factor, as shown in figure 2:

![Figure 2. Air combat situation factor layering diagram](image_url)
3 Weight Calculation of Air Combat Situation Factors

Firstly, according to the specific air combat factors in the second layer, the corresponding decision table is established for the natural condition \( A_1 \) and fighter performance \( A_2 \). After the attribute reduction, the weight of each factor is calculated by using equations (5)-(7), and the specific parameters of \( A_1 \) and \( A_2 \) are obtained. Then use the formula in the literature [6], [7] to calculate the advantage value of \( A_3 - A_6 \), according to the decision table corresponding to the first layer factor, the corresponding factor weight is obtained.

4 Air Combat Situation Assessment Calculation

According to the key air combat situation factors and their weights determined in the above steps, the air combat situation is evaluated and calculated.

4. Instance Verification.

In order to verify the validity and reliability of the model established in this paper in the application of air combat situation assessment, six typical air combat training data are taken as the object, and the improved rough set theory is used to evaluate the current air combat situation.

The six typical air combat situation parameter values selected in this paper are shown in Table 1, and the first three groups are taken as evaluation data, while the last three groups are taken as test data.

| NO. | Fighter attributes | Natural conditions | Fighter performance | Dist. | Alt. | Spe. | Ang. |
|-----|-------------------|--------------------|---------------------|-------|------|------|------|
|     |                   | Weather           | Terrain             | Visibility | Radar | Flexibility | Weaponry | Stealth | Electronic warfare |       |
| 1   | Our fighter       | I I I I I I I I  | I I I I I I I I  | I I I I I I | I I I I | II II II II | II II II II | II II II II |       |
|     | Target            |                   |                     |             |       |       |       |       |                     |       |
| 2   | Our fighter       | I II I I II I I  | I II I I II I I  | I I I I I I | I I I I | II II II II | II II II II | II II II II |       |
|     | Target            |                   |                     |             |       |       |       |       |                     |       |
| 3   | Our fighter       | II I I II II I I  | I I I I II I I  | I I I I I I | I I I I | II II II II | II II II II | II II II II |       |
|     | Target            | II I I II II I I  |                     |             |       |       |       |       |                     |       |
| 4   | Our fighter       | I II I II III I I  | I II I II III I I  | I I I I I I | I I I I | II II II III | II II II III | II II II III |       |
|     | Target            | I III I II III I I  |                     |             |       |       |       |       |                     |       |
| 5   | Our fighter       | III II III III I I  | I II I II III I I  | I I I I I I | I I I I | III III III III | III III III III | II II II III |       |
|     | Target            | III II III III I I  |                     |             |       |       |       |       |                     |       |
| 6   | Our fighter       | II I III I II I I  | I II I II III I I  | I I I I I I | I I I I | II II II II | II II II II | II II II II |       |
|     | Target            | II I III I II I I  |                     |             |       |       |       |       |                     |       |

According to the three sets of evaluation data in Table 1, the attributes are reduced by using the improved RS theory, and the importance and weight of attributes are calculated. When establishing the decision table of air combat situation assessment for our aircraft, the natural conditions and the performance of the aircraft take the ratio of the two aircraft as the conditional attributes respectively. Finally, according to the calculated weight, the current air combat situation of our aircraft is evaluated. The results are shown in Table 2.

| NO. | 1 | 2 | 3 | 4 | 5 | 6 |
|-----|---|---|---|---|---|---|
| Air combat situation | I | II | III | V | IV | III |

From the result in Table 2, it can be seen that the evaluation results of the improved RS theory model for our air combat situation are in line with the actual air combat situation, which proves the effectiveness of the model.
5. Conclusion
In this paper, a small number of samples are selected in case verification, which has a certain impact on the accuracy of the results. In the later period, more data will be introduced for analysis, and combined with reinforcement learning algorithm, the information base will be updated regularly to improve the accuracy of calculation. But the rough set theory is improved, and the improved rough set theory model is applied to the air combat situation assessment. Through the example verification, the calculation results of the model accord with the actual air combat and prove the reliability of the model.

6. References
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