Research on the Air Combat Countermeasure Generation Based on Improved TIMS Model

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Abstract. The real-time generation and auxiliary decision-making of air combat countermeasures are the main aspects of air combat countermeasures research. Aiming at the characteristics of Tactical Immune Maneuver System model that is easy to fall into local optimum and unstable convergence speed, this paper proposes an improved TIMS model, which combines sequential association data mining with TIMS model to generate air combat countermeasures, making the air combat countermeasures generate faster and the results more reliable. Finally, the validity of the improved model is verified by analysis of examples.

1. Introduction
In recent years, with the rise of intelligent technology, intelligent air combat has attracted more and more researchers’ attention. At present, great achievements have been made in the research of generating methods of air combat countermeasures at home and abroad. There are mainly: differential game method [1], influence graph method [2], machine game method [3] and artificial intelligence algorithms based on ‘IF-THEN’ rules, risk decision [4], genetic algorithm [5], etc. In document [6], Krishna Kumar K et al. applied biological immunity to air combat decision making and established a Tactical Immune Maneuver System (TIMS) model to improve the efficiency of air combat countermeasure generation. Moreover, the model can continuously carry out adaptive learning and enhance the accuracy of air combat countermeasure generation. However, when the situation and the actions in the gene pool cannot be matched, when the model is used for evolution, it is easy to fall into local optimum and the convergence speed is unstable. Based on this, this paper proposes an improved TIMS model, which combines sequential association rule data mining with TIMS model to effectively improve the efficiency and accuracy of air combat countermeasure evolution.

2. Tactical Immune Maneuver System Model
Immunology is a biological science that studies the immune response of objects to antigenic substances and their methods. Immune response is the response of organisms to the stimulation of antigenic substances, and it is also a biological process of identifying and excluding antigenic substances [7]. The biological immune system can be considered as a powerful adaptive system that can deal with external interference and uncertainties. When generating a new immune response, the system receives continuous feedback from the antigen-antibody and leads to more and more specific responses, which provides effective reference and help to establish a tactical immune maneuver system model.

2.1. Biological Immune System
In the process of long-term evolution, organisms can adaptively produce two immune systems: innate immunity and adaptive immunity. The functions of the immune system mainly include the following
four aspects [8]: immune defense, immune recognition, immune tolerance and immune response. Among them, the most complicated is the immune response mechanism. The immune response [9] refers to the whole process in which the immune cells of an organism recognize antigens, activate, differentiate and produce immune effects. In adaptive immunity, the first stage is recognition: T cells and B cells accurately recognize antigens through their respective antigen receptors; Then the activation and increment stage: lymphocytes after antigen recognition activate, proliferate and differentiate the cells with the participation of co-stimulatory molecules, and produce effector cells, effector molecules (such as antibodies) and memory cells; Finally, the effect phase: antigen is removed by the produced effector cells and molecules. The specific process is shown in figure 1.

Figure 1. Immune response process of biological immune system

2.2. Tactical Immune Maneuver System
John Kane shike and others modeled and simulated the biological immune system, applied the artificial immune system to mathematical modeling and solve the problem of air combat countermeasures, and established the Tactical Immune Maneuver System (TIMS). The system has good self-learning ability and real-time performance, can better overcome the uncertain factors that affect the decision-making of fighter planes in air combat, and thus has good adaptability to solve the real-time generation problem of air combat countermeasures.

TIMS imitates the biological immune system and evolutionary algorithm. Based on different air combat phases and air combat situations, according to the characteristics of the target machine, the weapon mounted by the target machine, the air combat method model and other influencing factors (antigens), tims automatically generates corresponding maneuver air combat countermeasures (antibodies) to deal with the threat caused by the antigens, stores the successful action sequences into memory cells, continuously updates the system, effectively improves the accuracy of air combat countermeasures, and has strong real-time and self-adaptability.

2.3 Generating Air Combat Countermeasures Based on TIMS
Firstly, we need to digitally edit and store the basic maneuver methods of our aircraft to form a complete maneuver gene bank and generate a bone marrow model (antibody) of air combat maneuver sequence of our aircraft. Secondly, according to the threat level of the target machine (antigen) to our machine, the situation between the enemy and our machine is evaluated and judged, the appropriate antibody is selected to generate air combat countermeasures, when the maneuver is successful, the maneuver and its corresponding air combat situation are programmed into the immune network maneuver database together, the tactical immune maneuver system will automatically memorize it,
and the maneuver sequence and its corresponding air combat situation are programmed into the bone marrow model to realize the self-evolution of the system. The specific process is shown in figure 2.

![Figure 2. Schematic diagram of air combat countermeasure generation process based on TIMS](image)

### 3. TIMS Model Based on Sequential Association Data Mining

When the posture (antigen) of enemy planes cannot match with the maneuver sequence (antibody) of our plane, our plane needs adaptive immunity. During this variation process, it is easy to make our plane’s air combat decision-making solution fall into local optimum and cannot get the optimal solution. Moreover, the immune evolution time is not fixed, which cannot meet the real-time requirement of air combat decision-making. Therefore, this paper proposes an improved TIMS model, which combines sequential association data mining with tactical immune maneuver system to solve our air combat countermeasures.

#### 3.1. Sequential Association Data Mining

The concept of sequence association mining was first proposed by Agrawal and Sri Kant in 1995 and a classical algorithm Apriori all was also proposed to solve the model. In recent years, the research on sequence association mining has developed rapidly and has been widely used in many fields.

The common correlation analysis reflects the simple correlation between things, while the sequence correlation has a certain sequence, usually related to time. The research object of sequence association is the sequence of things, or sequence for short. The purpose of studying sequence association is to find out the relationship between things and generate sequence association rules from a large number of sequences. Sequence correlation can reflect the relationship between the developments of things and can be used to predict the development trend of things. There are two main algorithms to solve this model: one is based on Apriori all algorithm, the core of which is to find rules and patterns by mining frequent itemsets. Secondly, the algorithm based on pattern growth strategy proposed by J Han et al. This paper mainly deals with the second type of Prefixspan algorithm.

#### 3.2. TIMS Model Based on Sequential Association Data Mining

In daily exercise training, our pilots will carry out targeted training for a certain hometown situation, which will produce many successful maneuver sequences and form a maneuver database of combat methods. Among them, the basic maneuver of the fighter plane can be used as the item set in the sequence, and the optimized maneuver sequence can be obtained by using prefix span algorithm to mine association rule data. This group of action sequences has reliable selectivity in generating air combat countermeasures.

When generating air combat countermeasures, the TIMS model is first used to judge the current situation (antigen) of the enemy and the corresponding maneuver (antibody) generating countermeasures are selected. When the situation and maneuver cannot be matched, a certain calculation time limit is set for it. If the air combat strategy calculated by TIMS model tends to be
stable within this time limit, this strategy is evaluated and compared with the advantage of maneuver strategy obtained by Prefixspan algorithm, and the maneuver strategy with greater advantage is selected as the air combat decision for final decision. If no stable solution is obtained through TIMS model calculation within this time limit, the maneuver strategy obtained through Prefixspan algorithm will be taken as the final air combat decision. The specific flow is shown in figure 3.

Figure 3. Air combat countermeasure generation diagram base on improved TIMS model

4. Analysis of Examples
For data mining of sequence association rules, in document [10], scholars of the national aviation advisory Committee of the United States have designed seven basic maneuvers of fighter planes according to the control methods of aircrafts in air combat: acceleration, deceleration, left turn, right turn, stable flight, climb, and dive. They are numbered a, b, c, d, e, f, g respectively. Assuming that there are four sets of maneuver sequences as shown in table 1, the maneuver association results obtained after the sequence association data mining are shown in table 2.

Table 1. Four groups of simulated fighter action sequences

| Serial number | Action sequence          |
|---------------|--------------------------|
| 1             | <a(abc)(ac)d(cf)>        |
| 2             | <(ad)c(bc)(ae)>          |
| 3             | <(ef)(ab)(df)c>          |
| 4             | <eg(af)c>               |
Table 2. Simulation of aircraft movement sequence correlation results

| a | a | c | b | (ab) | f | c | d | c | b | e | f | b |
|---|---|---|---|------|---|---|---|---|---|---|---|---|
| a | a | c | c | b | c | a | e | c | b | a | e | f | c |
| a | b | a | d | b | c | b | e | a | f | c | b |
| a | b | a | c | b | a | c | e | a | b | f |
| a | b | c | a | f | b | d | d | e | a | c |
| a | (bc) | (ab) | b | d | c | d | e | a | b | f | b | c |
| a | (bc) | a | (ab) | c | b | f | e | b | e | c | f |
| a | c | (ab) | d | (bc) | e | b | c | e | c | b | f | c | b |
| a | c | a | (ab) | d | c | (bc) | a | d | e | f |

One hundred successful maneuver sequences from a troop training record were selected and brought into the improved TIMS model to carry out calculation training in one-to-one correspondence with its air combat situation. The air combat countermeasures at a key node are selected for separate calculation and analysis. The calculation time limit is set to 1s, the simulation step size is 0.1s, and numbers 1-7 respectively represent the maneuver among them. The results are shown in figure 4.

Figure 4. Air combat countermeasure calculation results

As can be seen from figure 4, at this point, through the tactical immune maneuver system model, it is concluded that our aircraft should make an accelerated left turn, through sequential association mining, it is concluded that our aircraft should make a reduced left turn, and the calculation result is within the set time limit. After evaluating the current situation of the two, it is concluded that our air combat strategy at this point is to slow down and turn left.

5. Conclusion
In this paper, an improved TIMS system is established by combining sequential association data mining with tactical immune maneuver system model, which effectively improves the stability and reliability of air combat countermeasure generation. The validity of this model is verified by simulation, which is of great significance to enhance the effectiveness of air combat countermeasure generation.

6. Reference
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