Design of Air Combat Deduction System Based on UML Language

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Abstract. According to the characteristics of high cost and great difficulty in air combat exercise, relying on information equipment, this paper designs an air combat deduction model system. Firstly, the system is designed with the idea of ‘Human input, system deducts automatically’, and the key modules of the system are designed. Then the radar search model, missile motion model and the airborne fire control system model are established. Finally, the static model, dynamic model and data flow direction of the system are designed respectively by selecting system use case diagram, sequence diagram and coordination diagram, and the overall model of the system is built based on UML language.

1. Introduction
With the continuous development of modern science and technology, great changes have taken place in the form and theory of the combat operations, and the importance of joint operations has become more and more prominent [1]. In order to accurately judge the choice of air combat tactics under a certain situation, the most ideal method is to determine whether the choice of tactics under different situations is reasonable through actual military exercises [2]. However, the actual military exercises not only consume a lot of time and resources, but also cannot be completely simulated for some extreme battlefield situations. If the computer system is used for simulation deduction, it will not only consume less time and resources, but also greatly reduce the limitation on battlefield situation.

In view of the above problems, an air combat deduction system is designed in this paper, which uses computers to perform automatic deduction on the basis of given initial situation and input tactics, and uses the evaluation results given by the system as the basis for judging whether the tactics selection is reasonable. Under the premise of not consuming a lot of manpower and material resources, it is of great significance to improve the effectiveness of air combat and make the selection of tactics more accurate.

2. Theoretical Framework Design of the System
The air combat deduction system is mainly used to verify and evaluate the actual effects of the existing air combat methods, and to provide some basis for improvement in the development of new methods, thus enhancing the scientific and effectiveness of the research of warfare. Starting from the initial situation set by the user, maneuvering the fighter through the man-made tactics and the air combat situation is developed to the pre-conceived situation. Then the events in the air combat process are recorded with data and the collected data are used to evaluate the tactics and give the evaluation results. In addition, the entire air combat process can be analyzed in a comprehensive manner so as to
analyze the problems found in the evaluation results in a targeted way. If necessary, the tactics can be modified according to the actual situation, and then re-entered, deduced and evaluated, thus completing the training process of the tactics. It mainly has the functions of initial situation creation, time control, maneuver decision of air combat maneuver deduction, maneuver evaluation and deduction data recording.

2.1 Overall Design
The system design adopts a ‘semi-automatic’ deduction method. That is, the initial battlefield situation and the adopted tactics are manually entered before the deduction starts, and then the automatic deduction is carried out according to the entered information and the evaluation result is given. There are two main tasks: one is to verify the effectiveness of the existing tactics; the other is to provide a basis for the improvement of the new tactics. The processes are shown in Fig. 1

2.2 Key Module Design of the System
The first is to create an initial situation module. The air combat method deduction system starts from a certain initial situation, so the initial situation has a great influence on the whole deduction process and the results. The initial situation creation module provides users with functions such as creating new situations and modifying the initial situation, so that users can create different initial situations according to their own ideas. The main functions include creating new situations, modifying initial situations, deleting initial situations and saving initial situations. According to the UML unified modeling language [3], some partial use case diagrams of the module are given, as shown in Fig. 2.

Then it is the creation of tactical evaluation module. Considering the efficiency indexes of close and long range air combat, the overall evaluation index system of the system is given, as shown in Fig. 3.

Then it is the deduction rule module. The rules that must be followed in the deduction process mainly refer to the basis that our aircraft and target aircraft must follow in the process of search, discovery, maneuver and attack in air combat, which is necessary to make the system closer to reality. Generally speaking, the deduction rules involved in this system can be divided into two categories: constraint rules and operational rules. Finally is the time control module and the data recording module. The time management module mainly ‘reproduces’ the whole deduction process after the
deduction is completed, which is convenient to analyze the problems in the deduction results and find out the reasons. You can also pause, rewind and fast forward at any time during the deduction process, which is convenient to view the situation at any time during the deduction process. The main functions of this module include playback and deduction process control.

Figure 2. Part use case diagram of initial situation creation module

Figure 3. Air combat effectiveness evaluation index system

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3. Key Function Parts of the System

According to the system requirement analysis, the system is designed in detail. In this section, the key functional parts of the system—radar search module, missile attack area, airborne fire control system module are studied and modeled.

3.1 Radar Search Model

The radar search model [4] is an important part of this system. It is mainly used to judge whether our fighters can find and intercept targets. Its specific functions include: calculation of radar beam angle, calculation of enemy plane's line-of-sight angle, RCS calculation and judgment of whether targets can be intercepted.

(1) Calculation of Radar Beam Angle

For the horizontal system of radar, the time for scanning the field of view back and forth for one cycle is:

\[
T_{\text{radar}} = 2 \times (\text{numy} \times \text{numz} - 1) \times A_{\text{radar}} / V_s
\]

where, \text{numy} is the number of scanning horizontal lines and \text{numz} is the number of scanning vertical lines.

Introducing the equivalent parameter \( t_s \) of a certain time \( t \), and \( 0 < t_s < 2 \times (\text{numy} \times \text{numz} - 1) \)

\[
t_s = \frac{(t \mod T_{\text{radar}}) \times V_s}{A_{\text{radar}}}
\]

According to the value of \( t_s \), the coordinates of the central beam of the radar field of view at time \( t \) can be determined, and then the radar beam angle can be determined.

(2) Calculation of Enemy Fighter's Sight Angle

Under the ground coordinate system, the relative quantities of enemy and friend positions are:

\[
\begin{align*}
R_x &= x_e - x = R \cos \psi \cos \gamma \\
R_y &= y_e - y = R \sin \psi \\
R_z &= z - z_e = -R \cos \psi \sin \gamma
\end{align*}
\]

The conversion matrix between the ground coordinate system and the target line-of-sight coordinate system is:

\[
A(\psi, \theta, \gamma) = \begin{bmatrix}
\cos \theta \cos \psi & -\sin \theta \cos \psi \cos \gamma + \sin \psi \sin \gamma & \sin \theta \cos \psi \sin \gamma + \sin \psi \cos \gamma \\
\sin \theta & \cos \theta \cos \gamma & -\cos \theta \sin \gamma \\
-\cos \theta \sin \psi & \sin \theta \sin \psi \cos \gamma + \cos \psi \sin \gamma & -\sin \theta \sin \psi \sin \gamma + \cos \psi \cos \gamma
\end{bmatrix}
\]

Then the relative amount of friend or foe position \((R_x, R_y, R_z)\) in the ground coordinate system is converted to the target line-of-sight coordinate system as follows:

\[
(R_{x'}, R_{y'}, R_{z'})^T = A(\psi, \theta, \gamma)^T (R_x, R_y, R_z)^T
\]

Under the target line-of-sight coordinate system, the line-of-sight angle and the line-of-sight angle are:

\[
q_{\alpha} = t_{\psi^{-1}} \left( \frac{R_x}{\sqrt{R_x^2 + R_z^2}} \right)
\]

\[
\epsilon_{\alpha} = t_{\psi^{-1}} \left( \frac{R_z}{R_x} \right)
\]

If the difference between the enemy's line of sight angle and the radar beam angle is within the radar's field of view in the target line of sight coordinate system, the radar is considered to be able to detect the enemy.
(3) Target capture condition
The distance between the enemy and the aircraft is:
\[ R = \sqrt{R_x^2 + R_y^2 + R_z^2} \]  

(8)

Targets within the radar beam can be considered intercepted if the following conditions are met:
\[ R < R_{\text{max}} \frac{\sqrt{\text{RCS}}}{4} \]  

(9)

where, RCS is the radar cross section.

3.2 Missile Model
The equation of tangential and normal overload [4] are:
\[ n_x = \frac{-c_s q_s p(t)}{mg} \]
\[ n_y = \frac{c_s q_s}{mg} \]  

(10)

where \( p(t) \) is the thrust of the missile engine.

Aerodynamic characteristics of missiles:
\[ c_i \leq c_{\text{max}} \]  
\[ c_i = c_{i0} + c_{i1} + \Delta c_{i0} \]  

(11)

3.3 Airborne Fire Control System Model
The rules for the use of airborne weapons [5] are as follows:
1. Our fighters can only use one airborne weapon at a time.
2. For a variety of airborne weapons, the first priority is to meet the launch conditions.
3. When long-range and short-range missiles can be used, short-range missiles are preferred.
4. Ignore the preparation time for launching airborne weapons.
5. The number of weapons used is less than or equal to the maximum number of airborne weapons.

4. UML Model Design of Air Combat Warfare Deduction System
UML is a modeling language used for description and visualization. In engineering practice, it has been proved to be very effective in modeling large-scale complex systems, especially at the software architecture level [6]. Its main modules include system use case diagram, system sequence diagram and system cooperation diagram.

4.1 System Use Case Diagram
Use case diagram is an important diagram in UML language. It describes the system from the user's point of view. It is a static model of the system according to what functions the user wants the system to achieve and what information needs to be provided to design the composition and describe the relationship between system users and use cases. As shown in Fig. 4.

4.2 System Sequence Diagram
According to the system functions, the system objects can be roughly divided into six parts: user, login interface, initial information, deduction information, situation information and management information. Firstly, the ‘user’ object interacts with the ‘login interface’ object by entering an account password, and the ‘login interface’ object reaches the ‘management information’ object by matching whether the account password is correct or not, and returns the matching information. Secondly, the user reaches the ‘initial information’ object twice by entering the initial situation and entering the tactics, then records the information by accessing the ‘management information’ object, and at the same time reaches the ‘deduction information’ object by transferring instructions to make deduction decision and record the information, and transfers the result to the ‘situation information’ object for
display and record through situation display. Users can access ‘situation display’ objects and ‘management information’ objects to complete observation and deduction and playback analysis.

4.3 System Collaboration Diagram
System collaboration diagram is also one kind of interaction diagram, but its emphasis is different from that described by system sequence diagram. Sequence diagram mainly highlights the time sequence of interaction among system objects, while collaboration diagram mainly illustrates the flow of system data, so it is also called ‘communication diagram’. As shown in Fig. 5:

**Figure 4.** System use case diagram

**Figure 5.** System collaboration diagram

5. Conclusion
According to the characteristics of air combat, the overall framework and key modules of the system are designed, and the models of key functional modules such as radar search, missile flight and
airborne fire control system are established. Finally, using UML language, the system use case, system sequence and system cooperation mode are analyzed, and the UML model of air combat war method deduction system is designed.

6. References

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