Simulation Realization of Aircraft Target and Multi-task Conversion Model in Ground Attack Mission

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Abstract—In response to the actual requirements of radar early warning simulation training for the integrity and flexibility of the combat behavior of the detected aircraft targets,5 models of multi-behavior transformation of aircraft targets based on bombing missions are given. In military training, it is necessary to convert aircraft targets from take-off to landing and various tactical tasks. Otherwise a single model cannot be applied to simulat training practice. The experimental results show that the model can simulate the operational behavior of the aircraft target in the radar warning simulation training target environment. It provides reference for the study of more mission types conversion of aircraft targets.

Keywords-Early warning simulation training; Task switching; Aircraft target motion model

1 INTRODUCTION

The radar early warning simulation training model center provides various target entity data for building the radar warning simulation training target environment. The overall system architecture is shown in Figure 1.

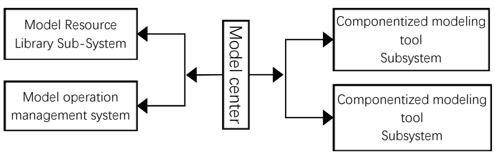

Figure 1 Model center structure

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The aircraft target behavior model is an important target model of the weapon equipment entity model library in the model resource library. It is a relatively complicated problem to simulate the behavior model of multi-aircraft targets that meets the requirements of actual combat and accurately reflect the air situation. Literature [1] and [2] conducted simulation research on aircraft target dive motion model and its combat application. Literature [8] and [9]showed research on typical motion models such as aircraft target runway line and figure-of-eight motion model. In general, the existing data just gives a typical motion model of aircraft targets, to meet the actual needs of radar warning simulation training. Based on the fighter bombing mission combined with the typical motion model of the aircraft target, this paper studies the multi-behavior conversion model of the radar warning simulation training aircraft target.

2 AIRCRAFT TARGET TACTICAL MISSION MODEL

In the practice of radar early warning detection, the combat tasks of aircraft targets mainly include air combat, attack aircraft and missiles etc. In actual combat, there are often multi-task alternates. Therefore, a single research and generation training scenario for a combat task is not in line with actual combat requirements. In order to research and apply these types of tasks in radar early warning simulation training, mathematical descriptions can be made based on the typical motion model of aircraft targets for conversion and connection that meets the requirements of actual combat. Based on the aircraft target-to-ground attack mission, this paper studies and analyzes the conversion and connection of aircraft target-to-ground attack missions, return missions, and guard inspection missions, and conducts simulations and experimental demonstrations.

3 ANALYSIS OF TYPICAL MOTION OF AIRCRAFT TARGET

3.1 Aircraft target particle model

In the research process, this article focuses on simulating the track characteristics of different behavior models of aircraft targets. Therefore, assuming that the aircraft is always in a state of moment balance, the 3DOF particle model is used here, and its dynamic equation is (1):

$$\begin{cases} \dot{v} = g(n_x - \sin\theta) \\ \dot{\theta} = \dfrac{g}{v}(n_y \cos\gamma_s - \cos\theta) \\ \dot{\varphi} = -\dfrac{g}{v\cos\theta} n_y \sin\gamma_s \end{cases} \tag{1}$$

The motion equation of the particle in the body coordinate system is (2):

$$\begin{cases} \dot{x} = v\cos\theta\cos\varphi \\ \dot{y} = v\sin\theta \\ \dot{z} = -v\cos\theta\sin\varphi \end{cases} \tag{2}$$

Where θ, φ, and γ are pitch angle, yaw angle and roll angle, respectively, v is the flight speed, n_x is the tangential overload, and n_y is the normal overload.

As conducted in [3],in order to conveniently reflect the aircraft attitude angle and facilitate the simulation calculation, the body coordinate system and the geographic coordinate system need to be converted during the simulation process. The conversion matrix is as (3):

$$B = \begin{bmatrix} \cos\beta\cos\alpha & \cos\beta\sin\alpha & \sin\beta \\ \sin\gamma\sin\beta\cos\alpha - \cos\gamma\sin\alpha & \cos\beta\cos\alpha + \sin\beta\sin\gamma\sin\alpha & -\cos\beta\sin\gamma \\ -\cos\gamma\sin\beta\cos\gamma & \cos\alpha\sin\gamma - \sin\alpha\sin\beta\cos\gamma & \cos\gamma\cos\beta \end{bmatrix} \tag{3}$$

3.2 Diving motion model

The dive movement is used in combat to quickly descend to the target height or strike the enemy's low-altitude targets. It consists of an entry phase, a dive phase, and a recovery phase. Since the aircraft cannot obtain a large centripetal force when entering a dive without a slope, the pilot usually establishes a 180° slope before entering the dive, so that the aircraft quickly enters the dive process.

Entry phase:

$$h_1 = \int_0^\theta v_1 t_1 sin\theta d\theta \tag{4}$$

Dive phase:

$$h_2 = h - h_1 - h_3 - h_t \tag{5}$$

Exit phase:

$$h_3 = \int_\theta^0 v_3 t_3 sin\theta d\theta \tag{6}$$

3.3 Climbing motion model

The movement process is mainly divided into three parts: the entering section, the straight section and the leveling phase.

Entry phase:

$$h_4 = \int_0^\theta v_4 t_4 sin\theta d\theta \tag{7}$$

Straight line stage:

$$h_5 = h - h_4 - h_6 - h_j \tag{8}$$

Flattening stage:

$$h_6 = \int_{\theta}^{0} v_6 t_6 sin\theta d\theta \tag{9}$$

3.4 Horizontal turning motion model

Before the airplane completes a horizontal turn, firstly, it should determine the yaw angle change Δφ between the current heading and the target heading, and then determine the gradient value that needs to be entered, that is, the roll angle γ. Then, increase the normal overload n_y, so that the aircraft obtains the corresponding centripetal force during the turn, and its component in the direction of gravity enables the aircraft to maintain or adjust the flight altitude. Finally, when the aircraft reaches the target heading, the roll angle γ is adjusted in the opposite direction to make the aircraft fly level.

According to the aforementioned aircraft dynamic equation with 3 degrees of freedom $\dot{\varphi} = -\frac{g}{v\cos\theta} n_y \sin\gamma$ It is not difficult to see that the roll angle γ and the normal overload n_y have a greater impact on the yaw angle of the aircraft when maintaining a small change in the flight speed of the aircraft. Therefore,according to [4],[5] and [6], the horizontal turning of the aircraft can be achieved by controlling the roll angle γ and the normal overload n_y.

$$n_y = \begin{cases} 1 & \theta = 0 \text{ or } \theta > \varphi \\ \text{set point} & 0 < \theta < \varphi \end{cases} \tag{10}$$

$$\gamma = \begin{cases} 0 & \theta = 0 \text{ or } \theta > \varphi \\ \text{set point} & 0 < \theta < \varphi \end{cases} \tag{11}$$

4 AIRCRAFT TARGET MULTI-BEHAVIOR CONVERSION MODEL AND SIMULATION REALIZATION

4.1 Return home conversion model after ground attack

Generally speaking, when an airplane dives into a ground attack, it should ensure its minimum safe altitude, that is, the maximum dive altitude. According to [7] and [10],the minimum safe altitude H_{min} for an airplane carrying different weapons to attack can be determined by consulting the data, and then the level that must be corrected can be obtained. Early warning height H_j.

$$H_j = H_{min} + r(1 - cos\theta) \tag{12}$$

r is the flattening radius, $r = \dfrac{v^2}{g(n - cos\theta)}$, we can get:

$$H_j = H_{min} + \frac{v^2(1 - cos\theta)}{g(n - cos\theta)} \tag{13}$$

The return-to-home conversion model after ground attack can be divided into the following three types of models according to the requirements of tactical missions and the degree of enemy threat:

In the three types of model simulations, the initial position of the aircraft is set to Nanjing LuKou Airport, the maximum flight altitude is set to 6500m, the flight speed in level flight is 350m/s, and the simulation step length is 0.4s.

1) After a ground attack, climb to a safe altitude and then return

After the aircraft has completed its attack on the target point T, when the given enemy threat is relatively high, the aircraft should first climb to a safe altitude (to reduce the amount of calculation, the aircraft can also be set to climb to the height before diving), and then return to the original airport or maneuver To the designated location. As shown in Figure 2, the aircraft first performs a dive jump to attack the ground, and then maneuver to the next target point or return to land according to the training scenario.

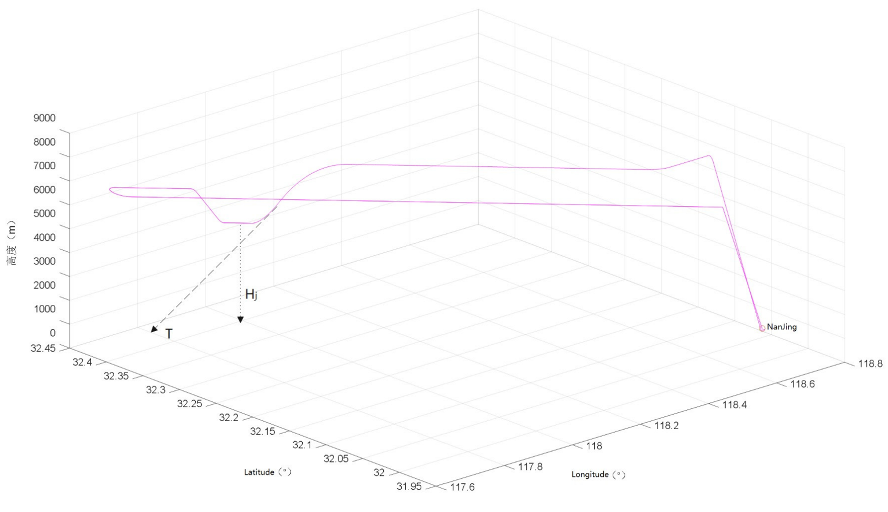


Figure 2 Return after bombing

2) Return based on the altitude after the dive after the ground attack

When the aircraft completes a ground attack and the given enemy threat is relatively small, the aircraft can return directly at the post-dive altitude, or climb to a safe altitude, and then return to the original airport or maneuver to a designated location. As shown in Figure 3:

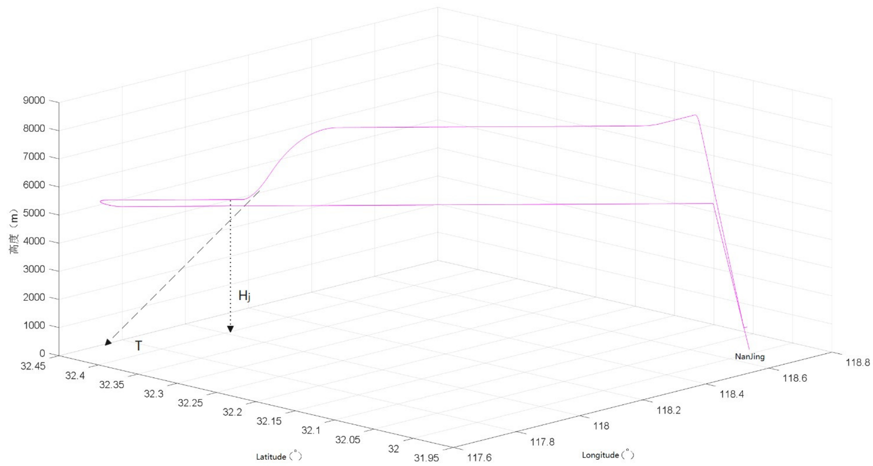


Figure 3 Return after bombing at original altitude

3) After a ground attack, maneuver to a designated location and land.

In this case, after the aircraft completes its attack on the target point T, it will determine the heading according to the input destination location information,as in (14),and judge to pull up or directly maneuver to the designated target point according to the given threat of the enemy situation, where the threat to the enemy situation is small. The situation is simulated,

$$\theta = \mathrm{atan}[(x_1 - x_0)/(y_1 - y_0)\ ] \tag{14}$$

Among them,“a”is the common acceleration corresponding to the set model aircraft at the altitude, and the equation of motion of the aircraft target particle is brought into the simulation to get the simulation result as shown in Figure 4. The plane landed at the designated location Z.

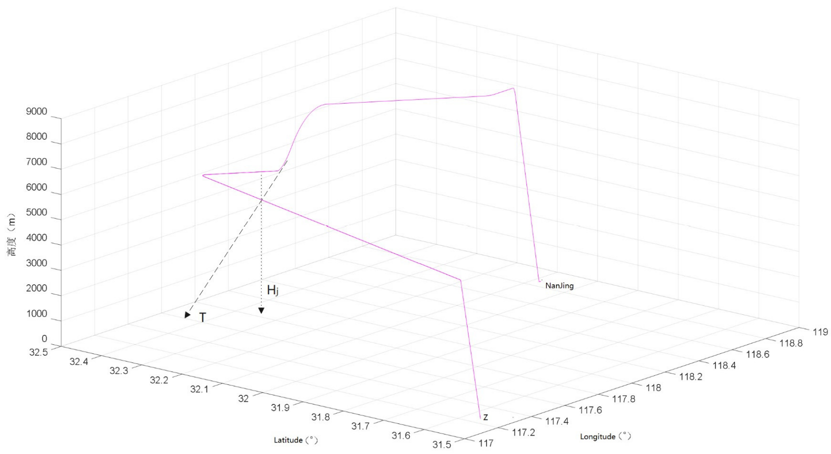


Figure 4 Go to next target after bombing

4.2 Ground attack and guard inspection conversion model

1) Runway line patrol after ground attack

As shown in Figure 5, on the basis of the aforementioned model, after the aircraft hits the target point T, the aircraft is pulled up. After inputting the coordinate of the center point O, the aircraft flies towards point O. When the distance is less than or equal to the patrol radius, it starts at O Patrol the area around the point, and the patrol range is set in the algorithm.

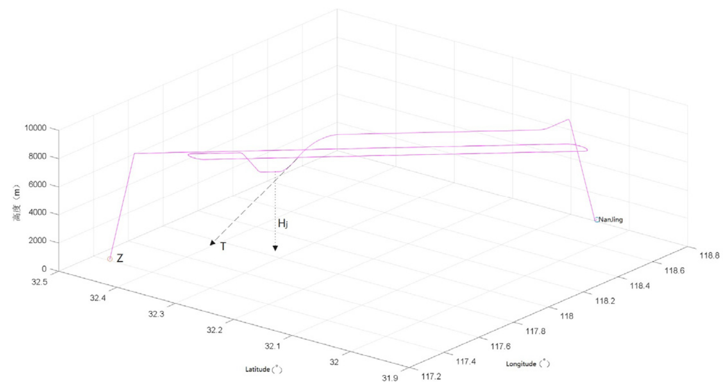


Figure 5 Patrol after bombing

2) 8-character patrol task conversion model

As shown in Figure 6, it is assumed that the threat of the enemy is relatively high. After the aircraft completes the attack on the target point T, it is pulled up to a safe height (given by the weapon performance parameters). The aircraft determines its heading according to the coordinates of the center point of the patrol area entered in the software interface. Fly to the area near point O for figure-eight patrols. The number of patrol laps can be set according to the training plan. After completing the mission, land at the designated location.

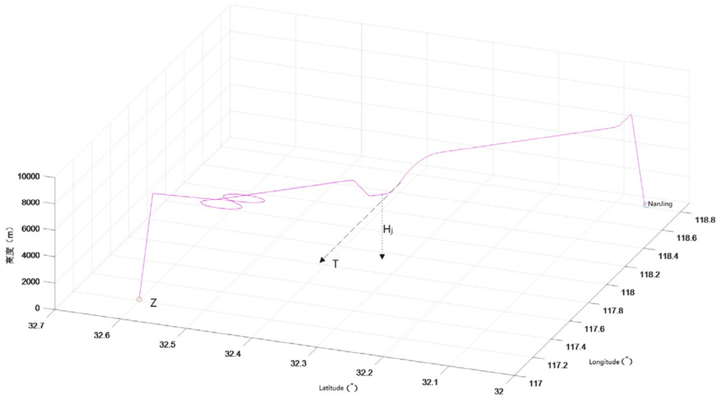
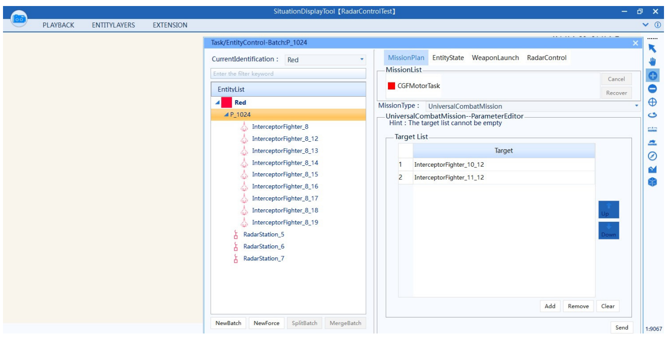


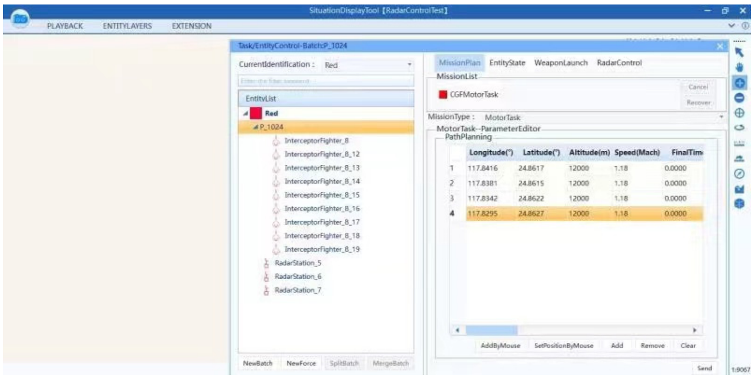
Figure 6 2)8-character patrol after bombing

5 SOFTWARE APPLICATION

The process of software calling the model to generate the flight trajectory can be summarized as four steps: starting simulation, scenario editing, model solving, and ending simulation.In order to obtain more reliable route data, it is assumed that the automatic generation software can automatically set the appropriate step length according to the script information. Figure 7 shows a screenshot of the software. Enter the corresponding parameters in the software interface to obtain the simulation results shown in section 3.



(1)



(2)

Figure 7 Scenario generated

6 CONCLUDING REMARKS

In response to the practical needs of radar early warning simulation training, this paper proposes 5 complete mission conversion models based on the aircraft target's ground attack mission, which can be used to simulate the aircraft target's ground attack, return home, maneuver to a designated location, guard inspection or continue The conversion process of common tasks such as attacking the next target point is closer to the actual tactical behavior of combat aircraft, meeting simulation training needs, and improving training efficiency. It will also provide fast and effective data support. Based on the research results of this article, we will have a reference for the further study of more mission types conversion of aircraft targets.

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