Optical Reconnaissance Vehicle Simulation Model Research

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Abstract. Based on some definition, an optical reconnaissance vehicle simulation model is proposed in this paper, which includes initialization, discrete reconnaissance target simulation, continuous reconnaissance target simulation, target position and velocity simulation, and so on, the model is simple and feasible.

Introduction

Optical reconnaissance vehicles carry reconnaissance equipment, including visible light reconnaissance equipment, infrared reconnaissance equipment. Reconnaissance equipment occupies reconnaissance positions, and completes reconnaissance preparatory work, reconnaissance equipment reconnaissance range is assumed to be rectangular.

If the reconnaissance range is within the view coverage field of the reconnaissance equipment, the optical mirror does not move and the continuous reconnaissance target mode is used. If the reconnaissance range is greater than the view coverage field of the reconnaissance device. Optical mirror using discrete reconnaissance target mode and sector scanning, the reconnaissance sector (θ1, θ2) is calculated from the scout range, counterclockwise from θ1 to θ2, and then clockwise from θ2 to θ1, recurring. From θ1 to θ2 is defined as a reconnaissance, from θ2 to θ1 is also defined as a reconnaissance, if target is found, stop reconnaissance, intelligence processing (extraction of target location and speed), processing is complete, continue to reconnaissance.

Initialization

If TT≠-1, turn 2).

II=1, TT=t and FLAG10=1.

(X1, Y1), (X2, Y2), (X3, Y3) and (X4, Y4). The four vertexes coordinates of the reconnaissance range are calculated based on the coordinates of the search range center point (X0, Y0), the search direction β0, the search depth L and the search width W.

The four vertexes coordinates of reconnaissance range in the O1-X1Y1 coordinate system are(L/2, -W/2),(L/2, W/2),(-L/2, W/2)and(-L/2, -W/2), for example, the first vertex coordinates in the O-XY coordinate system are:

\[
\begin{bmatrix}
X1 \\
Y1
\end{bmatrix} =
\begin{bmatrix}
X0 \\
Y0
\end{bmatrix} +
\begin{bmatrix}
\cos \beta_0 & -\sin \beta_0 \\
\sin \beta_0 & \cos \beta_0
\end{bmatrix} \cdot \begin{bmatrix}
L/2 \\
-W/2
\end{bmatrix}
\]
(X1, Y1) are the coordinates of the reconnaissance equipment in the geodetic coordinate system. (X3, Y3) and (X4, Y4) are the coordinates of the two points near the boundary in the reconnaissance range. (X1, Y1), (X2, Y2), (X3, Y3), (X4, Y4) are coordinates of the far-near boundary points in the counterclockwise direction.

If $\theta_1 > \theta_2$, then $\theta_1$ in the fourth quadrant, and $\theta_2$ in the first quadrant, let $\theta_2' = \theta_2 + 2\pi$

If $\theta_1 < \theta_2$, let $\theta_2' = \theta_2$

If $\theta_2' - \theta_1 \leq \alpha$, let $\beta = 0.5 \cdot (\theta_1 + \theta_2')$

If $\beta > 2\pi$, $\beta = \beta - 2\pi$. $\alpha_1 = \theta_2' - \theta_1$

Set the time is $\tau_1$, which is human eye clearly identify the target in the view field, if $M \cdot \alpha_1 > 14^\circ$, the human eye needs to search, complete one search takes time: $\tau = \tau_1 \cdot \frac{M \cdot \alpha_1}{14}$

If $M \cdot \alpha_1 \leq 14^\circ$, the human eye does not need to search, the time of human eye clearly identify the target in the view field: $\tau = \tau_1$

M is the search equipment magnification, $\alpha$ is search equipment field angle.

**Discrete Reconnaissance Target Simulation Module**

If $\theta_2' - \theta_1 > \alpha$, the discrete reconnaissance target process is simulated.

If $t < TT$, turn AA.

The optical mirror searching ground target simulation foundation model is called, the number of targets within the search range N, searching equipment center cross line and target intersection time $T_{ii}$, the time $\tau$ of human eye clearly identify the target in the view field, the eyepiece view $\theta_1$ of the target are calculated, $i=1—N$, II=II+1.
For i=1-N, the search device finding the target simulation model is called, calculate the target finding situation, if the i-th target is found, calculate the time required to locate the target:

\[ CC_i = m_i + \sigma_i \cdot r_i \]

In a search, suppose M targets are found, the corresponding Ti1, \( \theta_i \), CCi are Ti1j, \( \theta_j \), CCj respectively, j=1-M, the j-th target intelligence processing time is:

\[ TL_j = TL_j + \sum_{i=1}^{j} CC_i \]

The time of complete a search is:

\[ TT = t + \frac{\theta_i - \theta_j}{\omega} + \sum_{i=1}^{M} CC_i \]

AA:

For j=1-M, if \( t < TL_j \leq t + \Delta T \), the target position and velocity simulation model is called, the target position, velocity, etc are calculated. The data structure of the optical reconnaissance information is filled and published to the communication network evaluation module.

**Continuous Reconnaissance Target Simulation**

If \( \theta_1 - \theta_i \leq \alpha \), the continuous reconnaissance target process is simulated.

If \( t < TT \), this simulation module exit.

\[ D = \sqrt{(X1 - X_i)^2 + (Y1 - Y_i)^2} \]

Determine whether there is an enemy target within the angle range\((\beta-\alpha1/2, \beta+\alpha1/2)\) and distance range (0, D).

If L targets are received, for each target, finish the following steps:

If the tank and the target is the same side of the force, don’t search the target, determine the next target.

If the target is damaged, don’t search the target, determine the next target.

If \( D > X_2i - X_i \), the target is not within the search range, determine the next target.

If \( D > Y_2i - Y_i \), the target is not within the search range, determine the next target.

If \( D > \sqrt{(X_2i - X_i)^2 + (Y_2i - Y_i)^2} \), the target is not within the search range, determine the next target.

\[ \theta_1 = \beta - \alpha_1/2 \]

\[ \theta_2 = \beta + \alpha_1/2 \]

\[ \beta_i = \tan^{-1} \frac{Y_2i - Y_i}{X_2i - X_i} \]

If \( \theta_1 > \theta_2 \), then \( \theta_1 \) in the fourth quadrant, and \( \theta_2 \) in the first quadrant, let \( \text{exceptf} = 1 \) (initially 0), make transformation
$$\theta_2 = \theta_2 + 2\pi$$

If exceptf=1 and \(\beta_i < \pi/2\), let

$$\beta_i = \beta_i + 2\pi$$

If \(\beta_i < \theta_1\) or \(\beta_i > \theta_2\), the target is not within the search range, and determine the next target.

Determine exactly whether the target is in the quadrilateral \((X1, Y1), (X2, Y2), (X3, Y3)\) and \((X4, Y4)\) using functions in VC ++.

If there are \(N\) targets in the search range, complete the following simulation.

The coordinates of the observation point are:

\[
X_i' = X_i \\
Y_i' = Y_i \\
Z_i' = Z_i + \Delta h
\]

The target relative to the observation line exposure height simulation base model is called, and the search target exposed part height \(hh_1\) is calculated.

For the non-combatant target, the simulation base model of the target exposure body is called, and the outer surface parameters (vertex, center coordinate) and the geometric center of the exposed body are calculated.

For the non-combatant target, the target in the observation line visual range projection simulation model is called, the projection range \(S_i\) of the target observation surface in the observation line is calculated.

For the combatants target, \(S_i = hh_1 \cdot 0.3\).

The planar object with the diameter \(R_i\) is viewed with a search device of magnification \(M\). The angle of target view is:

$$\theta_i = 2 \cdot \tan^{-1} A$$

$$A = M \cdot \frac{R_i}{2L_i}$$

$$R_i = 2 \cdot \frac{S_i}{\pi}$$

$$L_i = \sqrt{(X_{2i} - X_1)^2 + (Y_{2i} - Y_1)^2}$$

Assume \(M1\) targets can be observed (view angle is greater than 0).

If \(M1=0\), there is no target in the search range, exit the simulation module.

If \(M1>0\), for \(i=1\) to \(M1\), invoke the simulation base model of the search device discovery target, and if it finds the \(i\)-th target, calculate the required time to locate the target:

$$CC_i = m_i + \sigma_i \cdot r_i$$

In a search, assume \(M\) targets are find, corresponding \(\theta_i\) and \(CC_i\) are \(\theta_j\) and \(CC_j\) respectively, \(j=1-M\), intelligence processing time of the \(j\)-th target is:

$$T'j = t + \tau + \sum_{i=1}^{j} CC_i$$

The time of complete a search is:
\[ TT = t + \tau + \sum_{i=1}^{M} CC_i \]

AE:

For \( j = 1 - M \), if \( T_{ij}^t < t \leq t + \Delta T \), the target position, velocity, etc are calculated. The corresponding optical reconnaissance information data structure is filled, and published to the communication network evaluation module.

**Target Position and Velocity Simulation**

For a radar or optical reconnaissance system, the oblique distance, azimuth and elevation angles of the target can be measured. The coordinates of the reconnaissance system in the geodetic coordinate system are \((X_1 + x_b, Y_1 + y_b, Z_1 + z_b)\)

This coordinate is also the coordinates of the reconnaissance system in the terrain coordinate system. Coordinate \((X'_1, Y'_1, Z'_1)\) of the reconnaissance system in the geocentric coordinate system are calculated (using the functions provided by the development tools).

The coordinates \((X''_i, Y''_i, Z''_i)\) of the \(i\)-th target corresponding to the geocentric coordinate system is calculated. The conversion formula the geocentric coordinate system to the terrain coordinate system is called. The coordinates \((\Delta X_i, \Delta Y_i, \Delta Z_i)\) of the target in the terrain coordinate system is calculated.

Distance, azimuth, high and low angles of target relative to the reconnaissance system are:

\[
D_i = \sqrt{\Delta X_i^2 + \Delta Y_i^2 + \Delta Z_i^2} \\
\beta_i = \tan^{-1} \frac{\Delta Y_i}{\Delta X_i} \\
\epsilon_i = \tan^{-1} \frac{\Delta Z_i}{\sqrt{\Delta X_i^2 + \Delta Y_i^2}}
\]

Target oblique distance, azimuth, high and low angles of reconnaissance system output are:

\[
D'_i = D_i + m_D + \sigma_D \cdot \text{gauss} \\
\beta'_i = \beta_i + m_\beta + \sigma_\beta \cdot \text{gauss} \quad 1 \\
\epsilon'_i = \epsilon_i + m_\epsilon + \sigma_\epsilon \cdot \text{gauss} \quad 2
\]

\( m_D, \sigma_D, m_\beta, \sigma_\beta, m_\epsilon, \sigma_\epsilon \) are the mean and mean square error of distance measurement error, the mean and mean square error of the azimuth measurement error, the mean and mean square error of the high and low measurement errors, gauss to gauss2 are Gaussian white noise sample with mean 0 and mean square error of 1.

Set reconnaissance system horizontal orientation positioning circular probability error is \( m_a \), mean square error of orientation error in height direction is \( \sigma_H \), the reconnaissance position of target in the terrain coordinate system:

\[
\Delta X'_i = m_a / 1.1774 \cdot r_i \cdot \cos r_3 + D'_i \cdot \cos \beta'_i \cdot \cos \epsilon'_i \\
\Delta Y'_i = m_a / 1.1774 \cdot r_i \cdot \sin r_3 + D'_i \cdot \sin \beta'_i \cdot \cos \epsilon'_i \\
\Delta Z'_i + \sigma_H \cdot r_2 + D'_i \cdot \sin \epsilon'_i
\]

\( r_1 \) and \( r_2 \) is a Gaussian white noise sample with mean is 0 and mean square error is 1, and \( r_3 \) is a uniformly distributed random number between 0 and \( 2\pi \).
The target reconnaissance location in the terrain coordinate system transform to the geographic coordinate system, then the geographic coordinate system transform to the geodetic coordinate system.

For the moving target, the mean square error of the target motion direction estimation error of is $\sigma_\beta$, the mean square error of the target horizontal velocity estimation error is $\sigma_\nu$, the actual velocity of the target is $(VX_{2i}, VY_{2i}, VZ_{2i})$, and the estimated target velocity is $(VX_{1z}, VY_{1z}, VZ_{1z})$.

$$V_i = \sqrt{VX_{2i}^2 + VY_{2i}^2 + \sigma_\nu \cdot gauss}$$
$$\beta V_i = \tan^{-1} \frac{VY_{2i}}{VX_{2i}} + \sigma_\beta \cdot gauss$$
$$VX_{1z} = V_i \cdot \cos \beta V_i$$
$$VY_{1z} = V_i \cdot \sin \beta V_i$$
$$VZ_{1z} = VZ_{2i}$$

References


