Simulation Model of Target Exposure

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Abstract. This paper proposes a simulation model of target exposure, including simulation model of target exposure height, simulation model of the target exposure height relative to the observation line, simulation model of target exposure. The simulation model of target exposure height is used to calculate height of target exposure part. The simulation model of the target exposure height relative to the observation line is used to calculate height of the target exposed part relative to the observation line during the search. The simulation model of the target exposure is used to calculate the parameters and geometric center of the exposed part of the target of the vehicle or airplane relative to the observation line or the incident line. The model is simple and feasible.

Simulation Model of Target Exposure Height

Input Parameters
For the vehicle class object, the input parameters include Z coordinate Z1 at the bottom of the target under the vehicle body coordinate system, Z coordinate Z2 at the top of the vehicle body, Z coordinate Z3 at the top of the turret (for a target without a turret, Z3 = Z2), the above parameters are obtained from the combat unit integrated protection performance data file, the protection state of the target (obtained from the received entity status information).

Output Parameters
Target exposure part height hh2.

Simulation Model
For vehicles or aircraft class target, if the target is not within the fortifications, \( hh2 = Z3 - Z1 \).
For the vehicle class target, if the target in the fortifications, \( hh2 = Z3 - Z2 \).
For combat personnel, if the protection status is standing, the combatant height hh2 = 1.7m, if the protection status is not standing, the combatant height hh2 = 0.3m.

Simulation Model of the Target Exposure Height Relative to the Observation Line

Calculate the target exposure height relative to the observation line during the search.

Input Parameters
For the vehicle and aircraft class object, the input parameters include Z coordinate Z1 at the bottom of the target, Z coordinate Z2 at the top of the vehicle body, Z coordinate Z3 at the top of the turret (for a target without a turret, Z3 = Z2), the above parameters are obtained from the combat unit integrated protection performance data file, the target coordinates \((X2, Y2, Z2)\) (obtained from the received entity status information), the observation point coordinates \((X_i', Y_i', Z_i')\), the protection state of the target (obtained from the received entity status information), terrain data.
For the combatant class object, the input parameters include the coordinates of the target \((X_2, Y_2, Z_2)\), the target equivalent height, the observation point coordinates \((X'_1, Y'_1, Z'_1)\), and the terrain data.

**Output Parameters**

The output parameter is the target exposure height \(hh\) at the searching time.

**Simulation Model**

For vehicles that are not within fortifications, or for aircraft targets, make

\[
Z_{2\text{min}} = Z_2 + Z1 \\
Z_{2\text{max}} = Z_2 + Z3
\]

If the target is within the fortifications, make

\[
Z_{2\text{min}} = Z_2 + Z2 \\
Z_{2\text{max}} = Z_2 + Z3
\]

For combat personnel, make

\[
Z_{2\text{min}} = Z_2 \\
Z_{2\text{max}} = Z_2 + hh2
\]

\(Z_{2\text{min}}\) is the lowest point of the target observable part, \(Z_{2\text{max}}\) is the highest point of the target observable part, \(hh2\) is the combatant equivalent height.

Known \(AB\) is the observation equipment, \(B\) is the view point, \(CE\) is the goal, if the length \(OD\) is find from the terrain, the target exposure height \(DE\) could be find. Each point A, B, C, E geographical coordinates are \((l_A, b_A, h_A), (l_B, b_B, h_B), (l_C, b_C, h_C), (l_E, b_E, h_E)\).

Known latitude and longitude coordinates of the lower left corner of the map is \((l_0, b_0, h_0)\), the latitude and longitude coordinates of the top right is \((l_1, b_1, h_1)\), the map length and width are \(L\) and \(W\) respectively, each point A, B, C, E latitude and longitude coordinates are:

\[
\begin{align*}
I_A &= l_0 + \frac{X_1}{L}(l_1 - l_0) \\
b_A &= b_0 + \frac{Y_1}{W}(b_1 - b_0) \\
h_A &= Z_1 \\
I_B &= l_A \\
b_B &= b_A \\
h_B &= Z_1 \\
I_C &= l_0 + \frac{X_2}{L}(l_1 - l_0) \\
b_C &= b_0 + \frac{Y_2}{W}(b_1 - b_0) \\
h_C &= Z_{2\text{min}} \\
I_E &= l_C \\
b_E &= b_C \\
h_E &= Z_{2\text{max}}
\end{align*}
\]
The each point coordinates of the latitude and longitude into the geocentric coordinates of the
date.

C correspond to the geodetic coordinates are

\[(x_A, y_A, z_A), (x_C, y_C, z_C)\] .

Insert N equal points \(F_k(x_k, y_k, z_k)(k = 0, \ldots, N - 1)\) between AC:

\[
\begin{align*}
x_k &= x_A + \frac{x_B - x_A}{N+1}k \\
y_k &= y_A + \frac{y_B - y_A}{N+1}k \\
z_k &= f(x_k, y_k)
\end{align*}
\]

Into geocentric coordinates for \(F_k(X_k, Y_k, Z_k)\).

The topographic data (l, b) are arranged in a grid, the sides of the grid are \(\Delta l\) and \(\Delta b\), and \(\Delta d = \max(\Delta l, \Delta b)\). N is obtained as follows:

\[N = \max(\frac{(l_b - l_i)}{\Delta l} - 1, \frac{(b_b - b_i)}{\Delta b} - 1)\]

hk according to the following method:

An adjacent four points in the terrain data form a rectangle (as shown in the figure below).

\[
\begin{array}{c|c}
(i, j) & (i+1, j+1) \\
\hline
(i+1, j) & (i+1, j+1) \\
 \end{array}
\]

First, according to \((l_k, b_k)\) determine the value of i, j, and obtain the latitude and longitude coordinates:

\[
\begin{align*}
i &= \left\lfloor \frac{(b_k - b_i)}{\Delta b} \right\rfloor \\
j &= \left\lfloor \frac{(l_k - l_i)}{\Delta l} \right\rfloor \\
l_j &= j\Delta l \\
b_j &= i\Delta b
\end{align*}
\]

According to the terrain file, read the elevation values at the four vertices:

\[
\begin{align*}
h_1 &= f(l_j, b_i) \\
h_2 &= f(l_{j+1}, b_i) \\
h_3 &= f(l_j, b_{i+1}) \\
h_4 &= f(l_{j+1}, b_{i+1})
\end{align*}
\]

According to the elevation values h1, h2, h3, h4 at the four vertices, the elevation hk corresponding
to the inner (lk,bk) of the rectangle is obtained by linear interpolation method.

\[
\begin{align*}
h^* &= h_1 + (h_2 - h_1) \frac{l_k - l_j}{\Delta l} \\
h^* &= h_3 + (h_4 - h_3) \frac{l_k - l_j}{\Delta l} \\
h_k &= h^* + (h^* - h^*) \frac{b_k - b_j}{\Delta b}
\end{align*}
\]
For \( k = 0, \ldots, N - 1, B, F_k \) the point where the extension of the two-point line intersects the \( OE \) is \( D \), calculate the length \(|OD|\) of \( OD \) respectively:

\[
\begin{align*}
\overrightarrow{OB} &= (X_B, Y_B, Z_B) \\
\overrightarrow{OE} &= (X_E, Y_E, Z_E) \\
\overrightarrow{BE}_k &= (X_k - X_B, Y_k - Y_B, Z_k - Z_B) = (\Delta X_k, \Delta Y_k, \Delta Z_k) \\
\angle BOE &= \cos^{-1} \left( \frac{X_k X_E + Y_k Y_E + Z_k Z_E}{\sqrt{X^2_B + Y^2_B + Z^2_B} \sqrt{X^2_E + Y^2_E + Z^2_E}} \right) \\
\angle OBD &= \cos^{-1} \left( \frac{-X_k \Delta Y_k + Y_k \Delta X_k + Z_k \Delta Z_k}{\sqrt{X^2_B + Y^2_B + Z^2_B} \sqrt{\Delta X^2_k + \Delta Y^2_k + \Delta Z^2_k}} \right) \\
|OD| &= \frac{|\overrightarrow{OB}| \sin \angle OBD}{\sin \angle OBD} \\
\end{align*}
\]

Thus corresponding to each \( F_k \), D point elevation \( h_{id} = |OD| - r \)

Where \( r = \sqrt{X^2_E + Y^2_E + Z^2_E} \) is earth radius at point \( C \), set \( \max h = \max \{ h_{id} \} \), and if \( \max h \geq h_E \), then the target is not visible, \( hh = 0 \), and if \( \max h \leq h_C \), the target is completely transparent, \( hh = Z^2_{max} - Z^2_{min} \), and if \( h_C < \max h < h_E \), and if \( h_C < \max h < h_E \), the target is partially visible and the exposure height is \( hh = h_E - \max h \).

**Target Exposure Body Simulation Model**

The model is used to calculate the vehicle type or aircraft type target relative to the observation line or the exposure line of the exposed surface parameters and geometric center.

**Input Parameters**

Enter the target exposure height \( hh \) (relative to the observation line or incident line), the target outline size (obtained from the combat unit integrated protection performance data file), the coordinates of the target in the geodetic coordinate system \( (X_2, Y_2, Z_2) \) and the attitude (obtained from the received entity status information), the top of the target \( Z \) coordinate \( Z_3 \).

**Output Parameters**

Output parameters of the outer surface of the exposed body in the geodetic system (vertex, center coordinates), geometric center of the exposed body.

**Calculate the Vertex and Center Coordinates of the Exposed Body**

Let the target have \( n \) outer surfaces \( p_1 \ldots p_n \), and there are rectangular, The center of each surface is \( E_1 \ldots E_n \), let a outer surface center \( E_i \) coordinates is \( (X_{iE}, Y_{iE}, Z_{iE}) \) under the vehicle system, the four vertices are respectively \( A_i, B_i, C_i, D_i \), the vertices coordinates are \( (X_{ia}, Y_{ia}, Z_{ia}), (X_{ib}, Y_{ib}, Z_{ib}), (X_{ic}, Y_{ic}, Z_{ic}), (X_{id}, Y_{id}, Z_{id}) \) under car body coordinate system

The equivalent shading height in the body (target) coordinate system is:

\( h = Z_3 - hh \)
If \( Z_{iA}, Z_{iB}, Z_{iC}, Z_{iD} \) are all greater than or equal to \( h \), the outer surface is unobstructed; if \( Z_{iA}, Z_{iB}, Z_{iC}, Z_{iD} \) are all less than \( h \), the outer surface is completely obscured, eliminating the surface; if there are two greater than \( h \) in \( Z_{iA}, Z_{iB}, Z_{iC}, Z_{iD} \), the outer surface is partly obscured.

Suppose there is \( k_1 \) partly obscured outer surface, set \( Z_{iA}, Z_{iD} \) is greater than \( h \), then the area covered by the total area of the ratio is:

\[
K_i = \frac{h - Z_{ib}}{Z_{ia} - Z_{ib}}
\]

Calculate the vertices and center coordinates of the unobstructed rectangles in the body coordinate system:

\[
(x'_{iA}, y'_{iA}, z'_{iA}) = (X_{iA}, Y_{iA}, Z_{iA})
\]

\[
(x'_{iD}, y'_{iD}, z'_{iD}) = (X_{iD}, Y_{iD}, Z_{iD})
\]

\[
(x''_{iB}, y''_{iB}, z''_{iB}) = (X_{iB}, Y_{iB}, Z_{iB}) + K_i \cdot (X_{iA} - X_{iB}, Y_{iA} - Y_{iB}, Z_{iA} - Z_{iB})
\]

\[
(x''_{iC}, y''_{iC}, z''_{iC}) = (X_{iC}, Y_{iC}, Z_{iC}) + K_i \cdot (X_{iD} - X_{iC}, Y_{iD} - Y_{iC}, Z_{iD} - Z_{iC})
\]

\[
(x''_{iE}, y''_{iE}, z''_{iE}) = \left( x'_{iA} + x'_{iB} + x'_{iC} + x'_{iD}, y'_{iA} + y'_{iB} + y'_{iC} + y'_{iD}, z'_{iA} + z'_{iB} + z'_{iC} + z'_{iD} \right) / 4
\]

Suppose there is \( k_2 \) unobstructed outer surface, calculate the rectangular vertex and center coordinates under the car body coordinate system:

\[
(x'_{iA}, y'_{iA}, z'_{iA}) = (X_{iA}, Y_{iA}, Z_{iA})
\]

\[
(x'_{iD}, y'_{iD}, z'_{iD}) = (X_{iD}, Y_{iD}, Z_{iD})
\]

\[
(x''_{iB}, y''_{iB}, z''_{iB}) = (X_{iB}, Y_{iB}, Z_{iB})
\]

\[
(x''_{iC}, y''_{iC}, z''_{iC}) = (X_{iC}, Y_{iC}, Z_{iC})
\]

\[
(x''_{iE}, y''_{iE}, z''_{iE}) = \left( x'_{iA} + x'_{iB} + x'_{iC} + x'_{iD}, y'_{iA} + y'_{iB} + y'_{iC} + y'_{iD}, z'_{iA} + z'_{iB} + z'_{iC} + z'_{iD} \right) / 4
\]

The rectangular vertex and center coordinates of the unobstructed rectangles under the geodetic coordinate system:

\[
(x'_{iA}, y'_{iA}, z'_{iA}) = (X_{iA}, Y_{iA}, Z_{iA}) + C_{iA} (x'_{iA}, y'_{iA}, z'_{iA})
\]

\[
(x'_{iD}, y'_{iD}, z'_{iD}) = (X_{iD}, Y_{iD}, Z_{iD}) + C_{iD} (x'_{iD}, y'_{iD}, z'_{iD})
\]

\[
(x''_{iB}, y''_{iB}, z''_{iB}) = (X_{iB}, Y_{iB}, Z_{iB}) + C_{iB} (x''_{iB}, y''_{iB}, z''_{iB})
\]

\[
(x''_{iC}, y''_{iC}, z''_{iC}) = (X_{iC}, Y_{iC}, Z_{iC}) + C_{iC} (x''_{iC}, y''_{iC}, z''_{iC})
\]

\[
(x''_{iE}, y''_{iE}, z''_{iE}) = (X_{iE}, Y_{iE}, Z_{iE}) + C_{iE} (x''_{iE}, y''_{iE}, z''_{iE})
\]

**Calculate the Geometric Center of the Exposed Body**

Target exposure part height hh2.

\((x''_{iE}, y''_{iE}, z''_{iE})\) is the exposed body outer surface coordinates in the geodetic system, and the geometric center of the exposed body is \((X_2', Y_2', Z_2')\), according to the exposed body surface \(p_1… p_k \), \((k=k1+k2)\), we can get:

\[
\begin{align*}
\begin{bmatrix} X_2' \\ Y_2' \\ Z_2' \
\end{bmatrix} &= \frac{1}{k} \left[ \sum_{i=1}^{k_1} Y_{iE} \right] \\
\end{align*}
\]
References


