Study on the possible position of the aircraft debris at sea

Fuzhi Xiong *

North China Electric Power University (Baoding), Hebei071028, China.

* Corresponding author email: 591835795@qq.com

Abstract. This paper is based on a simplified ocean current model to estimate the possible area of aircraft debris in the ocean, and then further optimize the simplified ocean current model by current velocity distribution. The aircraft debris will be further driven by the ocean current, so the calculated area of possible damage will also change. Two different ocean currents are considered in this model to estimate the possible location of the aircraft debris.

Key words: aircraft debris, ocean current, area.

1. Background

With the rapid development of the economy and society, airplanes now has become a more and more popular choice for modern people, especially for travelers and businessmen, due to its convenience and efficiency. However, recently, news about air crashes has been reported from time to time, making people’s heart up and down. Typically, the Malaysian flight MH370, which crashed together with all of the staff and passengers on board, has still not yet been found. It seriously reminds people once again of the significance of searching the lost plane.

2. Analysis on the Debris Drifting Process

Upon falling into the waters, the plane usually will suffer a destructive damage, for example, a total decomposition with debris distributes in a circular ring domain. Since the hole in the circular is too small to be taken into account, I suppose that the shape of the initial domain is a circle.

Under the effect of the factors such as the ocean currents, the ocean winds, and the Coriolis Effect, the debris will move from place to place. Therefore, to track the debris, the Ocean Surface Current Model must be considered [1]. Eq. (1) shows the abstract relation of the Surface Current Model.

\[ A = F(O, W, C) \]  

Where \( A \) represents the searching area, \( O \) represents the ocean current, \( W \) represents the ocean winds, and \( C \) represents the Coriolis Effect.

Due to the relatively small effect of the ocean winds and the Coriolis Effect in a short period, the Ocean Surface Current Model can be simplified, with only the ocean current considered [2]. Eq. (2) shows the abstract relation of the Simplified Ocean Surface Current Model.

\[ A = F(O) \]
Usually, an ocean current has a certain width. The center of the current have the fastest velocity while the edge of the current have a relatively slow velocity due to the drag of the water beyond the current. Therefore, I established a simplified ocean surface current model and then improve it by considering the velocity-distribution of the ocean current which can be described as Eq. (3).

\[
V_{\text{current}} = \begin{cases} 
V_{\text{center}}, & 0 < L < L_C \\
\frac{V_{\text{center}}}{\alpha_{\text{out}}(L-L_C)}, & L_C < L < L_E(x) \\
\frac{V_{\text{center}}}{\alpha_{\text{in}}(L_E-L_C)}, & L < L_E
\end{cases}
\]

where \( V_{\text{current}} \) is the velocity of the ocean current, \( V_{\text{center}} \) is the center velocity of the ocean current, \( L \) is the distance between the sampling location and the center, \( L_C \) is the radius of the center region, \( L_E \) is the radius of the current, \( \alpha_{\text{in}} \) and \( \alpha_{\text{out}} \) are the drag coefficients of the in-current case and the out-current case, respectively. Fig. 1 indicates the domain of the velocity distribution.

![Figure 1. The domain of the velocity distribution](image)

According to Fig. 1, the current can be divided to three parts: the one \( a \) which is in the center domain, the one \( b \) which is between the center domain and the edge, the one \( c \) which is beyond the edge.

3. Quantitative Analysis

3.1. Simulation Strategy

According to the Simplified Ocean Current Model established, I simulate the change of the area which possibly contains the debris with two kinds of different ocean currents. For the sake of simplicity, during the simulation, I transform the continuous ocean current domain to discrete ones by dividing the domain into a 1000*1000 mesh, which contains 1,000,000 grids. Each grid represents a 1 square kilometer area. Then, I define the possible grids of the debris by Eq. (4):

\[
\text{Grid}[i][j] = \begin{cases} 
1, & \text{possible} \\
0, & \text{impossible}
\end{cases}
\]
Before I begin the simulation, the mesh is initialized by the equation below:

$$Grid[i][j] = \begin{cases} 
1, & d < 1 \text{41} \\
0., & d > 1 \text{41} 
\end{cases} \quad (5)$$

Where $b$ is the distance from $Grid[i][j]$ to the center of the original circle.

The updating time of the simulation is one hour during which the values in the mesh are updating by Eq. (6):

$$Grid[i][j] = Grid[i][j - V_{\text{current}}] \quad (6)$$

In all simulations I assume that the width of the current is 100 km, and the velocity of the current center is 3 kilometers per hour [3].

3.2. Situation I
I take the current which goes through the center of the original circle domain into account. Then, the distribution of the current velocities is defined by the equations established in this model. The five-day dynamic possible debris domains in this situation are simulated and indicated by Fig. 2, in which the black domain is the possible debris domain.

3.3. Situation II
I consider the current, which goes through the upper section of the original circle domain. Then, I use the same method to simulate the five-day dynamic possible debris domain under situation II. The results are indicated by Fig. 3, in which the black domain is the possible debris domain.
4. Extended Model: Search for the Main Body

Evidently, searching for the debris is just a part of the search mission. Considering the information generally stored in the black box, I need to find the main body if I desire the black box and the other components and parts.

Based on the model hereinbefore, the debris can be found in the downstream position of the ocean current. And then I are able to estimate the crashed location according to the found debris which I suppose has the same velocity as the ocean current. Since the common search and rescue mission is based on the longitude and latitude, I decompose the velocity of the ocean into two component velocities in the longitude direction and latitude direction, respectively. Then I can track the location of the main body via Eq. (7):

\[
\begin{align*}
L_{a1} &= L_{an} - \int_{1}^{n} V_{la} \, dt \\
L_{o1} &= L_{on} - \int_{1}^{n} V_{lo} \, dt
\end{align*}
\]

Where \( n \) is the total days of our search mission, \( L_{an} \) and \( L_{on} \) are the latitude and the longitude of the debris on the first day of our search mission, \( L_{an} \) and \( L_{on} \) are the latitude and the longitude of the debris on the \( n^{th} \) day of our search mission, \( V_{la} \) and \( V_{lo} \) are the component velocities of the current in the longitude direction and latitude direction, respectively. This part is relatively simple, so I won’t explain in detail.

5. Conclusion

In this model, the direction and velocity of the ocean current in the crashed location will directly influence the boundary shape of the possible crashed domain. Take five samples of the velocity of the
ocean currents and the corresponding farthest drifting distances. The relationship between the two is shown in Fig. 4.

![Graph showing the sensitivity analysis on this model](image)

**Figure 4.** The sensitivity analysis on this model

It is shown that the proposed models are feasible and robust. Moreover, the efficiency is better than the common methods such as the normal distribution.

**References**

[1] J. Bian, “Studies on planes crashed in a sea and the motion trail of the black box,” China High Technology Enterprise, No.202014, pp.39-40 (In Chinese).

[2] T. Furukawa, F. Bourgault, B. Lavis, and H.F. Durrant, “Recursive Bayesian Search-and-Tracking Using Coordinated UAVs for Lost Targets,” 2006 IEEE International Conference on Robotics and Automation, Orlando, Florida, May 2006.

[3] Q.W. Huang, “Cooperative Searching Strategy for Multiple Unmanned Aerial Vehicles Based on Modified Probability Map,” National University of Defense Technology, Changsha, Wuhan, China. Nov.2012