The Determination of Search Pattern after an Air Crash Based on the Bayesian Analysis

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Abstract. We divide the whole search region aimed to get the two smaller semicircle regions and the bigger central rectangle region. As to the smaller semicircle regions, we adopt a spiral search path. Namely, use two search planes parallel to the ocean along the concentric semicircle to go round till finish searching the specified region. To the central region, we focus on confirming a rational search mode. So we firstly divide it into several cells and number them. Then, we synthesize the random probability of the landing point and the success probability impacted by the depth there and then determine the region with maximum probability.

Introduction

We divide the search region as Figure 1.

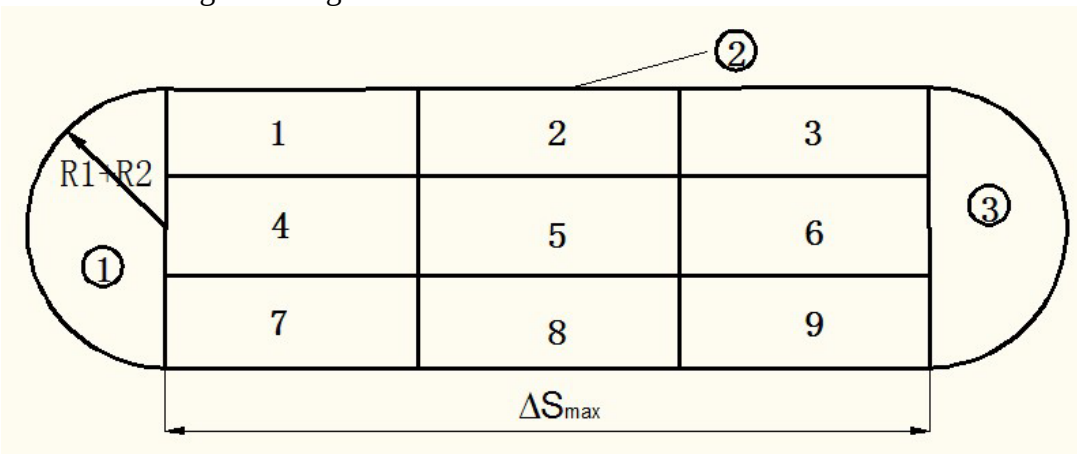

Figure 1. The division of search region

The Determination of the Prior Probability

We perform a random experiment to simulate the plane crash. Specifically, we use particle to stand for plane and then have multiple trials by randomly scatters experiment to count the particles dropped in each region separately. Moreover, we define the number we counted before as the primary existence probability pi.

On the other hand, we define the success probability as *qi*, which is related to the water depth. Evidently, the shallower of the water, the greater the success probability will be. Namely, the depth(*h*) have a negative correlation with the success probability. To simplify our model, we set *h* to 3000m,4000m,5000m in turn. And then, we calculate $h^{-\frac{1}{2}}, h^{-\frac{1}{3}}, h^{-\frac{1}{4}}, h^{-\frac{1}{5}}$. Finally, we found the optimum function to describe q_i is $h^{-\frac{1}{4}}$. The Figure 2 is used to describe *pi* and *qi*.

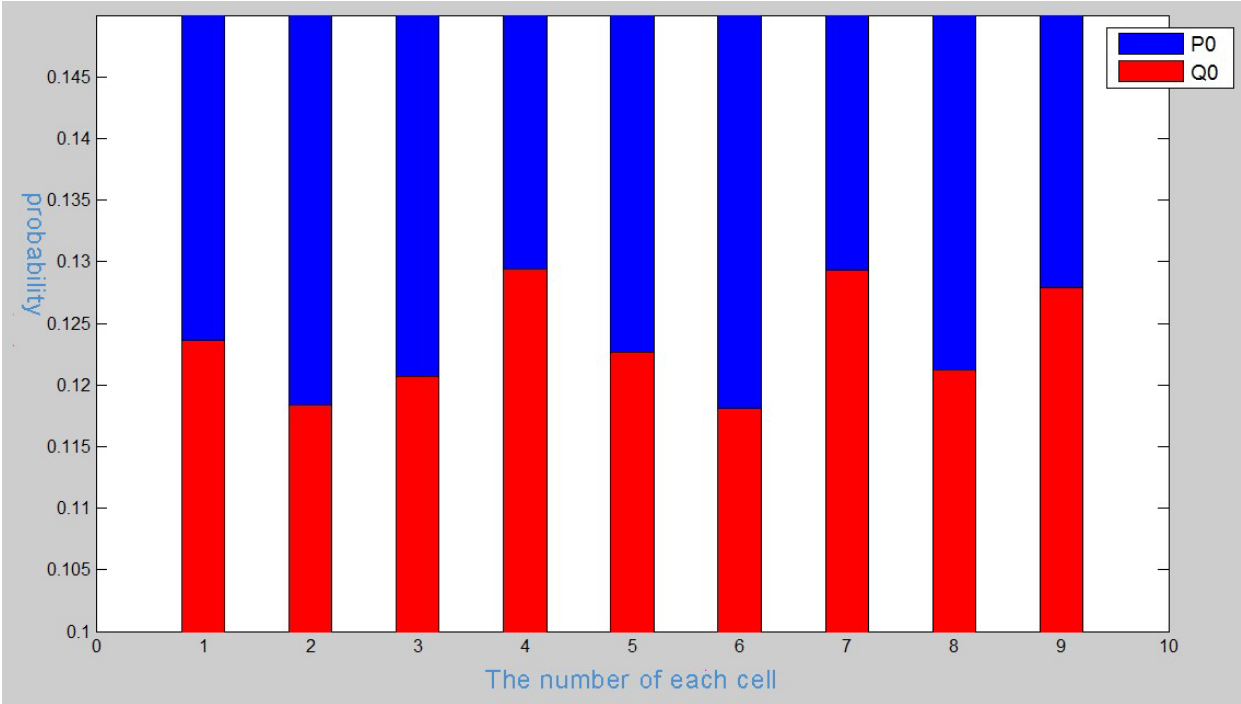

Figure 2. The numerical value of *pi* and *qi*

The Determination of the Search Path

Since there are many types of planes, we shall adopt corresponding electronics or sensors [2][3]. Therefore, in order to guarantee the validity of our search, we decide to adopt 2 kinds of search plane. They are laser sensor search plane used to explore the floating object and sonar sensor search plane used to explore the underwater target.

Because sonar search is difficult, we first apply laser search aimed to have an extensive search for clues of the missing flight [1]. After collecting the related clues in the target search region, we apply sonar search to improve the accuracy of our work. Now we divide the search work into 2 steps.

Step 1: the Scope Searching Principle. We define the product of primary *pi* and *qi* which are derived from prior probability as the exist probability *pi* of each optimized cell. Then, we compare *pi* and regard the corresponding cell of the largest *pi* as the next search area. Apparently, there exist 2 results: one is harvest new clues (including discover oil stains, floating wreckage and so on) and the other is no gains. Now we will update *pi* and *qi* in different conditions.

Harvest New Clues. At first, we adjust the exist probability to zero and sign the searching region. And then, we consider that the update of *pi* and *qi* is controlled by the searching results. Moreover, when the search plane moves from the current area to the next area we should strive to shorten the transfer distance. Therefore, to conduct a comprehensive and multifactorial update to *pi*, we combine bayes formula and introduce the weight function.

First, since we have discovered new clues in this cell, it is obviously that the exist probability *pi* of its ambient cells raises. Based on bayes formula, we update the ambient *pi* as follows.

$$p' = pi\frac{1 - piqi}{1 - qi} > pi \tag{1}$$

And *pi* of other cell will decrease and we update it to:

$$p' = pi\frac{1 - qi}{1 - piqi} < pi \tag{2}$$

Second, we consider the transfer distance. In order to simplify our model, we compare and $D_{max}^{-\frac{1}{4}}, D_{max}^{-\frac{1}{5}}, D_{max}^{-\frac{1}{6}}, D_{min}^{-\frac{1}{4}}, D_{min}^{-\frac{1}{5}}, D_{min}^{-\frac{1}{6}}$ (D_{max} and D_{min} represent the farthest and the nearest distance of the cells) and finally conclude $D_{min}^{-\frac{1}{5}}$ is the ideal. Third, weight. We set the weight of search

result and transfer distance to update *pi* are all 0.5. So, the final update formula is:

$$p'' = c_1 p' + c_2 \frac{1}{\sqrt[5]{D}} \tag{3}$$

No Gains. Just as the method of (1), we consider the weight of each cell and then combine bayes formula and transfer distance to update.

$$p'' = c_1 pi \frac{1 - qi}{1 - piqi} + c_2 \frac{1}{\sqrt[5]{D}} \tag{4}$$

Then, we conduct the updated as the final exist probability to begin the search loop: every time after finding the largest *pi*, we set its corresponding cell to be the new search area. Repeat the process until search out all cells.

Step 2: Refine Search. In this step, according to the flag sequence, we conduct an accurate search to the cells where we find clues to find the fuselage. If can't find, we need to search the cells that aren't signed by the order of the scope searching principle. Based on the former searching method, we construct a harvest matrix to simulate the search process and then validate the reasonability of our search path.

Conclusion-The Determination of the Search Pattern

The Determination of the Semicircular Region's Search. Considering the fact that the region is rather small comparing with the central rectangle region and have special geometrical characteristic—semicircle, we design two search paths in view of its characteristic as Figure 3. Note: the red portion is the search track; I_1 *to* I_{14} are the starting points of the 28 planes; the center of the circle represents the end of search; neglect the turnings.

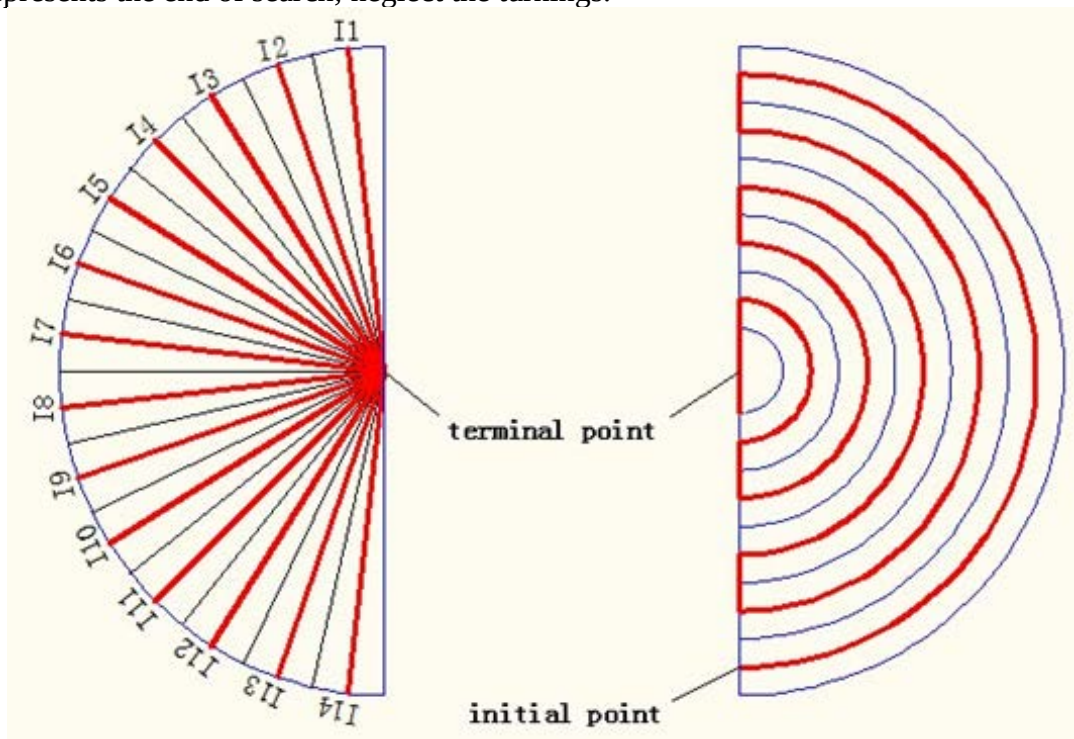

Figure 3. The Search pattern of semicircular region

Now we can intuitively get: in the left figure of 3, though the search time is short, there still exist many overlapping regions which increases the number of search planes which is unsuitable for searching. So considering the general condition, we adopt the scheme namely the right figure whose needed search planes is less and also avoid the overlapping problem.

The Determination of Each Cell Region's Search Mode. To each cell region, we set the sweep width as the side length and divide it into several squire regions in order to avoid the overlapping of search area efficiently [4] [5]. What's more, to the length and width that are not integral multiple of the sweep width, we shall all round up the results and then plus 1 aimed to guarantee the

comprehensiveness of our search scheme. Finally, we devise four different search methods as Figure 4 and have a comparison among them.

It is obviously that the four schemes have the same path length. However, considering the fact that it is a waste of time when the plane enters or leaves the region, we set the starting and end point on the edge of the region. So the scheme (b) and (c) are more reasonable. Furthermore, if we consider the turning time, the scheme (b) is apparently superior to (a). To sum up, the scheme (b) is the optimum search mode of cell.

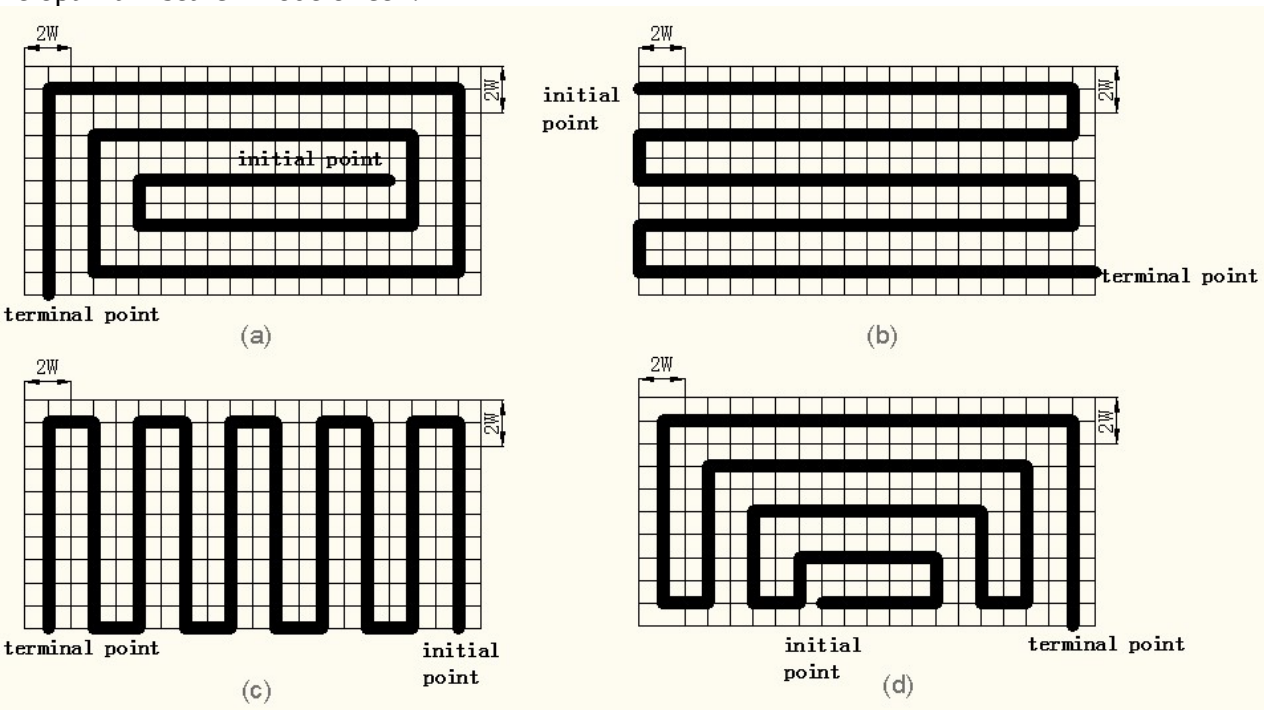

Figure 4. The search pattern of cell

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