Searching the Lost Plane

Summary

We are discussing how to search the lost plane that may dropping in the ocean like Malaysia Airlines MH370. We divide our paper into three parts

First part, we will determine the circle of the possible crashed plane. By expansion and application of Markov Process, we will narrow the circle so that the searching power can be focused. It's the base of all searching works. Without predict the dropping position, searching work can't be started.

Second part, we will build an ocean current model to estimate the effects of ocean current to the black boxes or other plane parts. In this model we have two assumption and build two models. The first one is for the coastal sea and the other one is for the open sea. We are building this because the electronic devices like sonars have different searching area in these two situation. We will use the area find before and by connecting the Bayes Theorem and the area we get in the first part to create a grip map with possibility.

Third part, we have determined the area that need to be searched and by building a searching model based on the optimal search theory. We need to decide the arrangement and use of different search methods including planes, boats and radars. We will what is the most efficient combination of these methods to search in every small area is.

Searching Lost Plane

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Contents

1. Introduction

Even it has past one year, the question where is the missing Malaysia Airlines MH370 flight is still one of the topic that catching people's eyes. However, plane crash is not a new topic. Based on the statistics there are 33 plane crash in the 2014 year. Comparing to other transportations like train, vehicle or ship, plane has so many advantages like it won't be restrict by the type of the area like land or water, it's much faster that other transportations. However, these advantages will turn to huge inconveniences when the plane is lost and searching teams are searching it. If the plane is lost on sea, it's a much bigger area than land. Seawater will weaken the radio signal made the sensors of searching machine inefficient. Also, the high speed makes the distance that the plane may reach after its signal is lost is much bigger that other transportations.

Because of these reasons, searching a lost plane is so hard and making it harder when it's lost on sea. For example, it took two year to search Air France Flight 447's black boxes. How to determine the probably place to narrow the searching area and how to use the optimal search theory to decide the most efficient search plan is a worth discussed problem.

In this paper, we will discuss the finding lost plane problem in three parts. First part, we will determine the circle of the possible crashed plane. By expansion and application of Markov Process, we will narrow the circle so that the searching power can be focused. Second part, we will build an ocean current model to estimate the effects of ocean current to the black boxes or other plane parts. Based on that model, we can get a function D of t which D is the distance that we estimate the parts moved to the origin point. Third part, we have determined the area that need to be searched and by building a searching model based on the optimal search theory. By separating this parts into two, first we will cut the big possible area to multiple small area that is reasonable for the search team to search and build the model based on the Bayes theory to calculate the probability of the searching parts in that area. Then, we need to decide the arrangement and use of different search methods including planes, boats and radars. We will build a model to show what is the most efficient combination of these methods to search in every small area is.

2. Dropping Model

2.1 Introduction

We use this model to determine the distance the plane has flew after the last time the machine on the ground got its signal to the moment it dropped into sea. We divide this part into two piece and the key difference is whether the plane is flying normally. Here, we define “normally” as it follow the pre-set flying route but just lost connection to the ground.

2.2 Normal Moving Model

2.2.1 Introduction

In this part, we denoted A_1 as the coordinate of the plane where people on the ground got its signal; A_2 as the coordinate that the plane become incontrollable. We are aiming to find the possible area ofA_2.

2.2.2 Assumption

We assume that everything is working well in the last time's signal and the plane is flying on its pre-set route.

2.2.3 Variables

Symbols	**Descriptions**
T_r	T is the duration of two signals that should be reported.
t_1	$t_1$is the time since it took off to the last time ground received its signal.
t_m	t is the duration since last time that ground receive the signal to the plane that start being abnormal.

S(t)	S(t) is the map that contain all the flying coordinate which has an one-to-one relationship to the t.

2.2.4 Models

① Since we assume that plane is flying normally in this stage, we can say that A_2 is a point in map S.

② Meanwhile, time t is the time that the ground got a signal before t but do not received the one next to time t. So, we could say that $0 < t_m < T_r$.

With these two, we can get the possible area ofA_2.

2.2.5 Results and summary

By the model before, we can conclude that$A_2 \in \mathrm{S(t)}$. Since we can't determine the exact value of time t and there is no clue about that. We should say that the largest searching area is the circle that center at A_2 with radius of the distance of$A_2 - A_1$ and minus the area of land since we are discussing the maritime search and the area that radars can detected.

2.3 Abnormal Moving Model

2.3.1 Introduction

In this part, we use the point A_2 in 2.1 as a start point. We denoted A_3 as the coordinate of the plane where it hit the sea level. We need to figure out the area that the plane may hit the sea level so it can give a smaller area to apply the later models and easier to search.

2.3.2 Assumption

We assume that after time t which is the time of normal flying after the last signal was received the plane can't keep flying on the pre-set route which we determined as abnormal flying. We also assume that this abnormal flying is caused because there is parts like engine not working on the plane. There is no hijacking and pilots are very professional. Further, we assume that pilots on the plane are still trying to save the plane from off course.

2.3.3 Variables

Symbols	**Descriptions**
T_d	T_d is the total time it cost from the plane acting abnormal to it hit on the sea level.

D_{max}	D_{max} is the distance that the fuel in the plane can support it to fly. It will be changed due of different types of plane.
t	t is the time interval that decide by us. We get this number by divide T_d by n which is a constant that means the number of interval we want to cut from the time plane start flying abnormal to the time it hit the sea level.
t_n	t_n is the time that the plane has flew after it became abnormal. t_n has the property that $t_1 + t = t_2; t_2 + t = t_3; \dots; t_{n-1} + t = t_n$ and $t_n = T_d$.
S(t_n)	S(t_n) is the distance that it should fly as planned in time $t_n - t_{n-1}$.
$O(x_n, y_n, z_n)$	$O(x_n, y_n, z_n)$ is the estimate position of the lost plane at time t_n.
$O_1(x_n, y_n, 0)$	$O_1(x_n, y_n, 0)$ is the estimate position of the lost plane at time t_n in horizontal plane.
$O_2(0, y_n, z_n)$	$O_2(0, y_n, z_n)$ is the estimate position of the lost plane at time t_n in vertical plane.

θ_n	θ_n is the angle between the planes actually flying route to its pre-set route in time t_d in horizontal direction. This parameter has included the try made by the pilots. We set if the plane turn right as the positive angel and $-180° \leq \theta_n \leq 180°$
γ_n	γ_n is the angle between the planes actually flying route to its pre-set route in time t_d in vertical direction. This parameter has included the try made by the pilots. We set if the plane fly up as the positive angel and$-90° \leq \gamma_n \leq 90°$.
H_{max}	H_{max} is the highest height the plane is able to reach. It will be changed based on different types of plane.

2.3.4 Models

(i) We start building the model by determine the initial situation. We assume that the height of plane is H(A_2)

(ii) First, we take consideration of the horizontal direction. We build a set $\{\theta_1, \theta_2, \theta_3, \dots, \theta_n\}$ which is related to the set of t_n. All the elements in set $\{\theta_1, \theta_2, \theta_3, \dots, \theta_n\}$ are independent and domain is $-180° \leq \theta_n \leq 180°$. Since we don't have any signal of the plane, assuming that this set match the normal distribution. So the equation is:

$$f(\theta, \mu, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(\theta-\mu)^2}{2\sigma^2}}$$

Here, the parameter μ is the expectation of the distribution. Since we expect the plane to fly on its pre-set route, so μ is 0. We can simplify it to:

$$f(\theta, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\theta^2}{2\sigma^2}}$$

The parameter σ is its standard deviation.

Then, we can have the probability of the appearance of every off course angel. By using the Matlab code, we will have an imitate data. We can get the value of $\{\theta_1, \theta_2, \theta_3, \ldots, \theta_n\}$ related to set $\{t_1, t_2, t_3, \ldots, t_n\}$ after that.

Next, we can form a coordinate system which involves x and y. Set the direction of the pre-set route as y-axis and the point A_2 as the origin.

Pick a point j that$1 \leq j \leq n, j \in$ Z. We can have the position of the plane in horizontal plane :

$$O_1(x_j, y_j, 0) = O_1(x_{j-1}, y_{j-1}, 0) + (\mathrm{S}(t_j) * \tan(\theta_j), \frac{\mathrm{S}(t_j)}{\cos(\theta_j)}, 0)$$

(iii) Then we consider the vertical situation. Similarly by using the normal distribution. We can have the equation about the probability of γ_n in vertical plane.

$$f(\gamma, \sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{\gamma^2}{2\sigma^2}}$$

Before moving to the direction calculation, we need to set a value γ_{max} which indicates the largest angel that a normal airlines can climb. If there is a γ_m which larger than γ_{max} appears, we call it stall. We assume that if a stall appear, the speed of plane will decrease to 0 and make a free fall movement. To let it calculable, we just define that

$$If\ \gamma_m > \gamma_{max}, the\ searching\ area\ will\ be\ O(x_m, y_m, z_m)$$

After discussing this situation, we now assume that $\gamma_j \le \gamma_{max}$. By setting up a coordinate system which involves y and z, set the direction of the pre-set route as y-axis, z-axis is about the height index. Also, set point A_2 as the origin. We still use point j that$1 \le j \le n, j \in$ Z. We can have the equation as follow:

$$O_2(0, y_j, z_j) = O_2(0, y_{j-1}, z_{j-1}) + (0, \mathrm{S}(t_j), \mathrm{S}(t_j) * \tan(\gamma_j))$$

(iv) Before getting to the last step, we need to make sure that the plane is flying in a reasonable area. First, we need to determine the highest height that different plans can reach. In order to simplified the model, similarly to the stall problem. We assume that if there is a point a that $1 \le a \le n, a \in$ Z . If point a match the following requirement:

$$In\ O_2,\ z_{a-1} + \mathrm{S}(t_a) * \tan(\gamma_a) > \ \ H_{max}$$

We say that the plane will stall and have a free fall movement and the searching area should be $O(x_a, y_a, z_a)$.

Also, it may have the problem that flying too low. We determine there is a point b that $1 \le a \le n, a \in$ Z . So, if:

$$In\ O_2,\ z_{b-1} + \mathrm{S}(t_b) * \tan(\gamma_b) \le 0$$

We say that the plane will hit the sea level at time b and the assumption should stop at here. The searching area then will be $O(x_b, y_b, z_b)$.

(v) Adding these two plane together to get the $O(x_n, y_n, z_n)$. Using the point j that$1 \leq j \leq n, j \in$ Z.

$$O(x_j, y_j, z_j) = \sqrt{(O_1(x_j, y_j, 0))^2 + (O_2(0, y_j, z_j))^2}$$

(vi) Finally, since we are talking about searching a lost plane, so the plane must dropped into the sea at last. As the same assumption before, we assume that the plane will drop as a free fall when the plane can't keep flying. So, the searching area will be:

$$O(x_n, y_n, 0)$$

Based on the variables we defined before, t_n is the last second before it hit the sea level.

2.3.5 Results and summary

In this first part, we discuss the possible area that the plane might first hit the sea based on several situations. Since there is nearly no detailed data, we must make a lot of assumptions to narrow the area. Otherwise, the possible area will be the circle that center at point A_2 and radius is the distance from A_2 to point B which is the destination. That range will be too big to predict and nearly impossible to search and save. After this step, we denoted the location that the plane hit the sea level as A_3.

3. Ocean Current Model

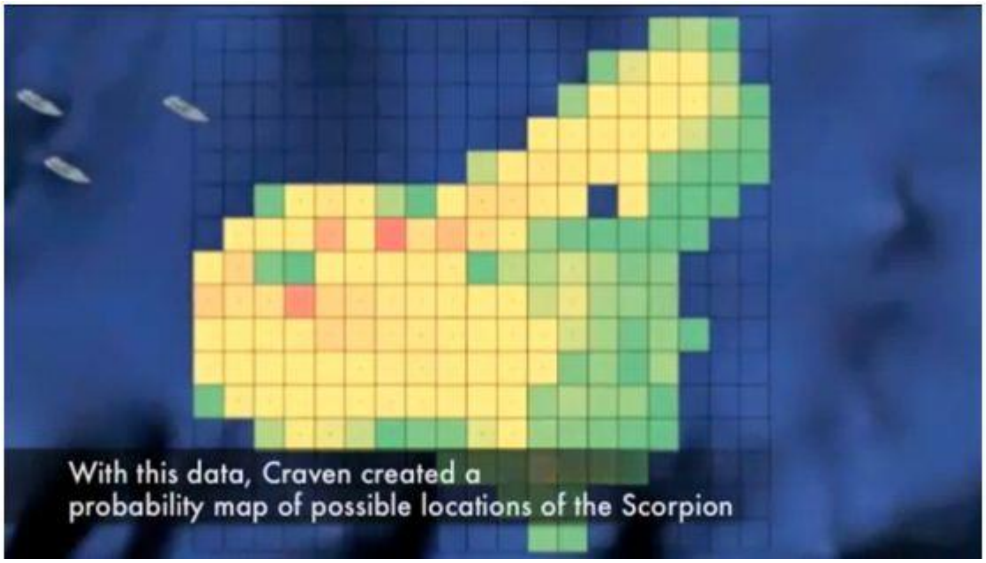
3.1 Introduction

Now we have the plane drop into the sea and we have the region of where the plane might drop. In this section, we are going to discuss the where the plane components are going and generate a map which we call “the Grid Map”.

When something drops into the sea, it either goes under the water or drift with the ocean current. If it goes under the deep water then there is almost no way to find them. Luckily, most components of the plane such as wings can float on the surface of the sea. Where the components will go? This depends on their transportation – ocean current.

3.1.1 Introducing the Grid Map

Before we start our analysis, we want to introduce “the Grid Map”. The Grid Map is what we want after we analysis the current. It’s a map that is divided into many small squares. We can obtain the possible area of dropping from part 2. And now we slice them into grids. Each grid has its general direction that where the current in it flow. Each grid has its own possibility of existence. Some has higher possibility and some has lower ones. One example of the Gird map is shown as below.

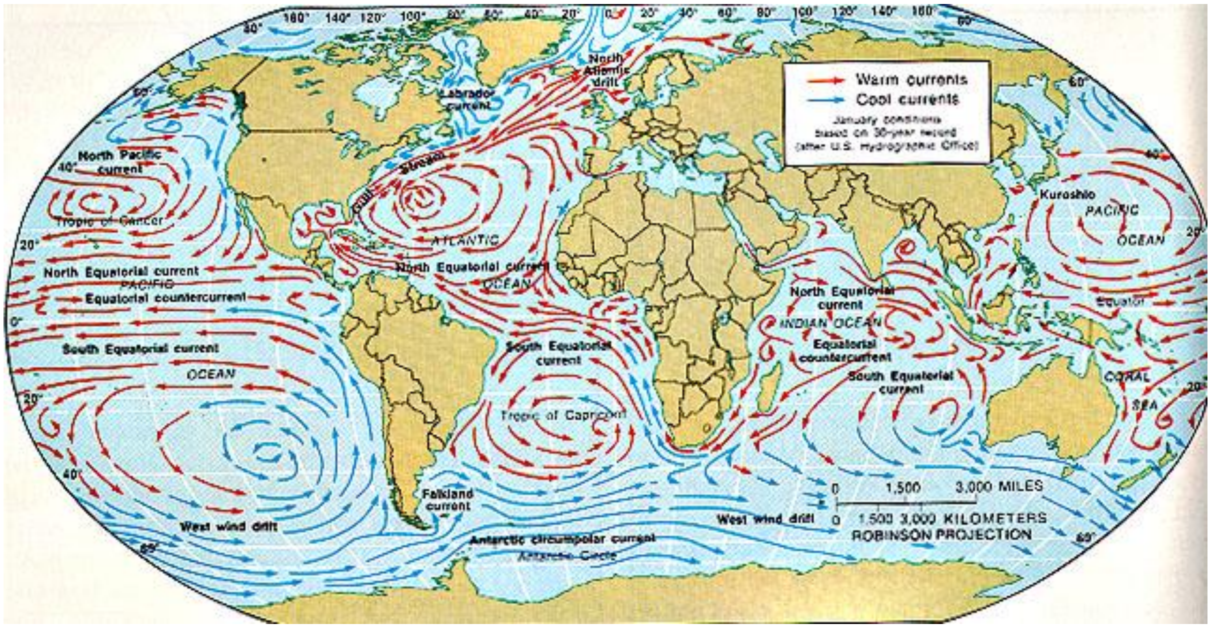


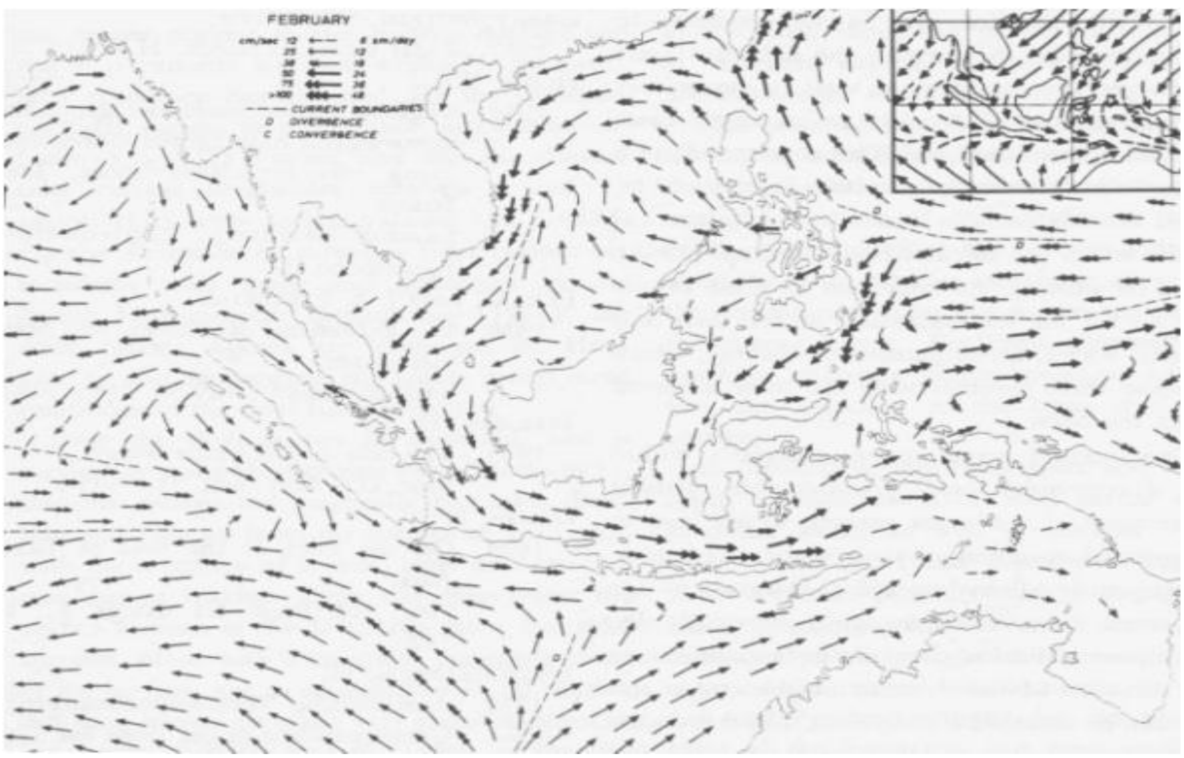
3.2 Assumption

The components of the plane are in the detective level in the water. That is, critical components such as black boxes are not going too deep into the sea that cannot be detected by the sensor.

3.3 Current in Open Sea

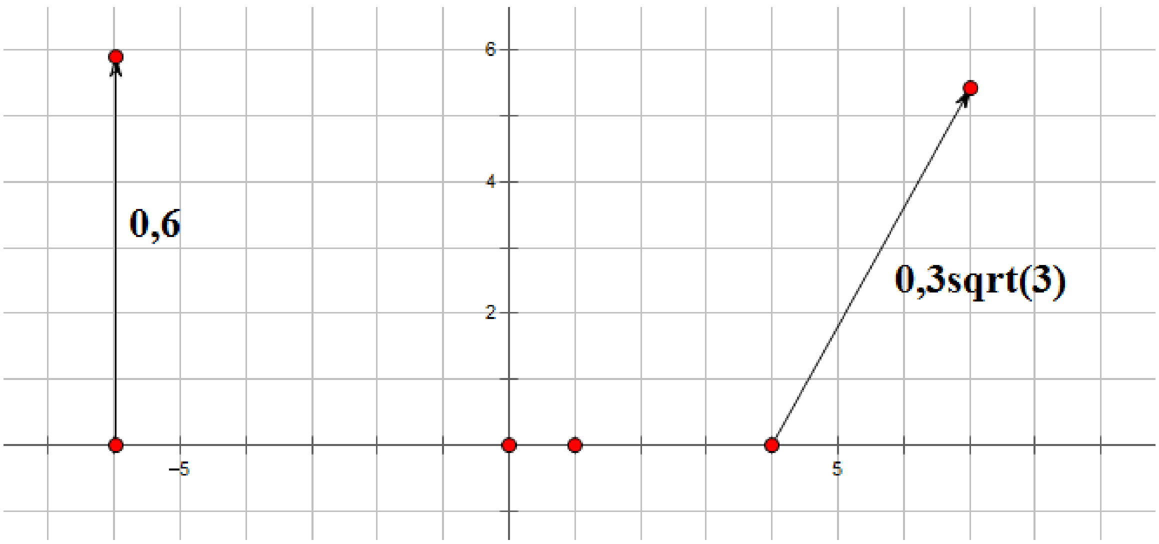
We first discuss the currents in the open sea. By saying open sea, we are talking about open water with no islands or reefs in it. We can grab the general global current direction from the existing data. The figure shown below is a map that shows a general pattern of the global ocean current and a report for Indonesia.





So now we have our general ocean currents. However, sometimes this is not enough. Although the second map is quite specific, but sometimes our grid is smaller than the spacing of the arrows and we want to know the current between them.

How are we going to do this? Pretty simple! You may find that the ocean currents on the maps are represents as arrows. We can easily associate this with vectors. Our model of getting the current direction between two currents is quite similar to vector calculation. First, we transform the surrounding factors into vector mode. For example, the following two vectors can be considered as $(0,6)$ and$(3,3\sqrt{3})$.



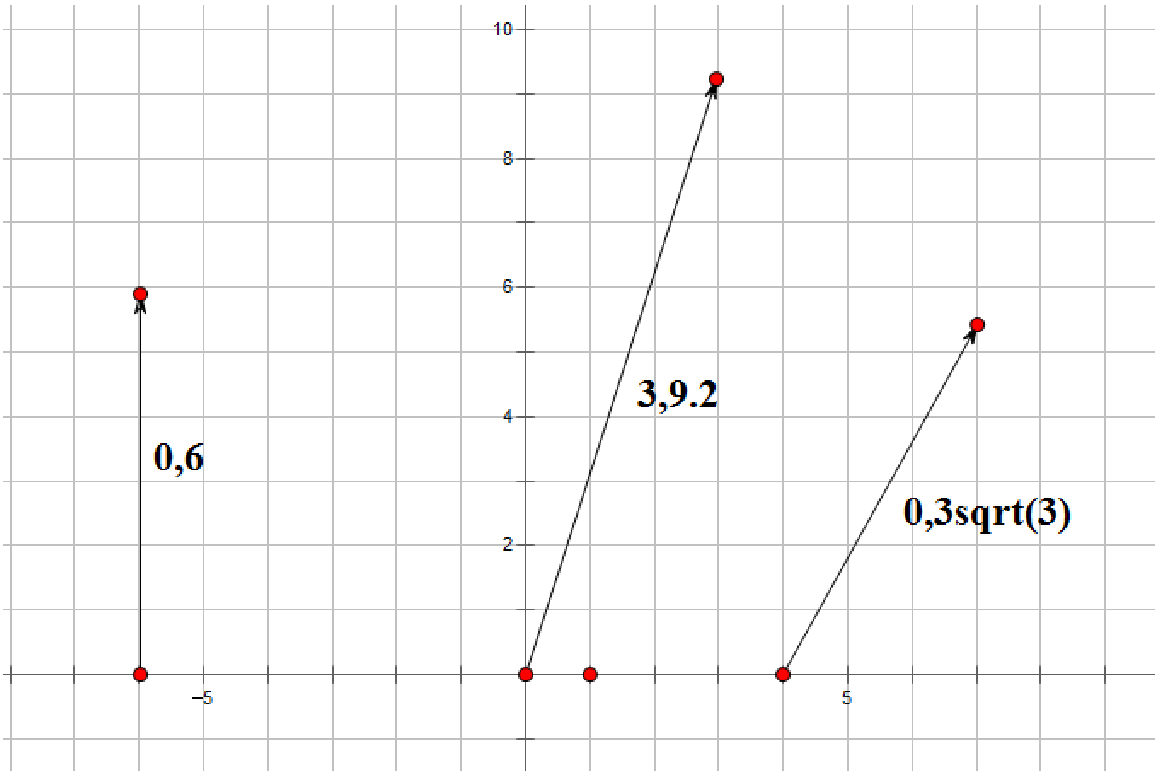
We only want to know where a current will flow, so we can neglect the speed of the current, which is the magnitude of the vector. Now we want to know the direction on the original point on the figure. The origin is 4 units away from the right current and 6 units away from the left one. So the ratio of the effect of the two surrounding current to the origin is 6:4 (right: left).Calculate this:

$$(0,6) * 0.4 + \left(3,3\sqrt{3}\right) * 0.6 = (1.8, 2.4 + 1.8\sqrt{3})$$

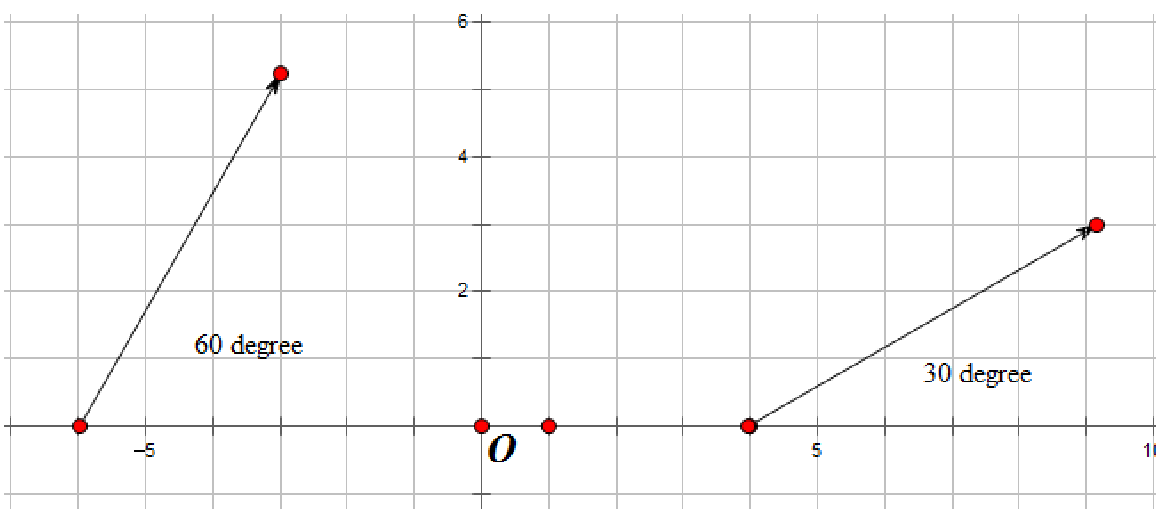
Since we just want to know the direction, we can transform this into:

$$\left(1.8, 2.4 + 1.8\sqrt{3}\right) = (3,4 + 3\sqrt{3}) \approx (3,9.2)$$

To make it looks simpler. Now we get the direction of the origin.



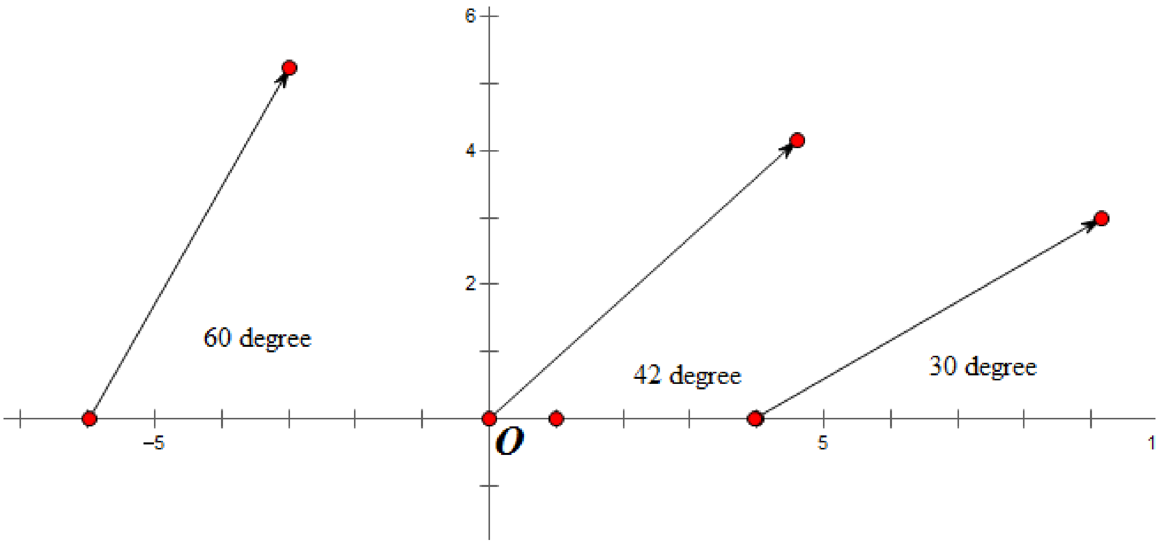
Another easier way to estimate the angle of one current between two is calculating the angle directly. In this way, we are going to assume that the angles changes linearly. This also works since we are in an open sea with no interference on it. So assume we have two currents A and B with A having an angle of 60 degrees from the X-axis and B having an angle of 30 degrees from the X-axis.



Again we want to know the direction of current at O. There are 10 units between A and B.O is 6 units right to A and 4 units left to B. So we get:

$$60 - \frac{60 - 30}{10} * 6 = 42$$

42 is the degree of the angle of the direction from the X-axis.



If we use the vector method, the result will be:

$$\left(3,3\sqrt{3}\right) * 0.6 + \left(3\sqrt{3},3\right) * 0.4 \approx (3.88,4.32)$$

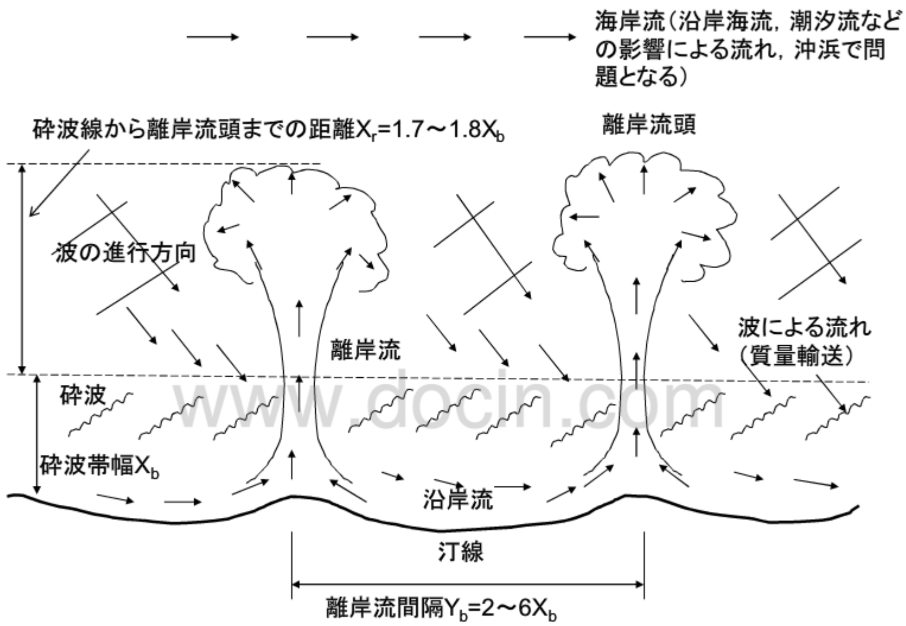
Compare this result to the vector method, we can find that:

$$\tan^{-1}(\frac{3.88}{4.32}) \approx 41.93degree$$

Which is quite close. In these ways, we can calculate the direction of a grid if there is no island or reef in it.

3.4 Current in the Offing Sea

When a wave reaches a land, it got blocked and changes its direction. We call this offshore current. The offshore current is parallel to the sea shore. The general idea and direction of the offshore current is like the figure shown below



And here is a real life example:

 (Both picture credit: Mr. Nishi Ryuichiro)

Our models can estimate the directions of the ocean current in each grid of the map. However, sometimes it's easier and better to use an ocean current meter to plot the accurate directions on the map since the general ocean current direction information we based on is not real time updated. And it takes usually less than 2 days to get the accurate real time report.

3.5 How to use the Grid Map

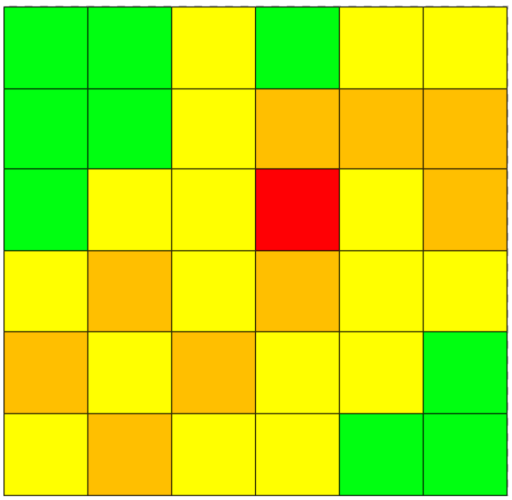
Now we have the sketch of the ocean current and have the idea of where the current brought our plane components to. By saying where we mean the possibility of the components go through each grid. In fact, we are going to put two possibility values into each grid, p and q. p is the possibility that there are components existing in the grid, and q is the possibility of the chance we can find it if the component is in the grid. According to experience, q is related to the depth of the water in the tile. The deeper the water is, the smaller the chance is. We are going to apply the Bayesian search theory to our searching method. If one tile has been searched and we don't find any components, we are going to lower the possibility of the tile:

$$p' = \frac{p(1-q)}{(1-p)+p(1-q)} = p\frac{1-q}{1-pq} < p$$

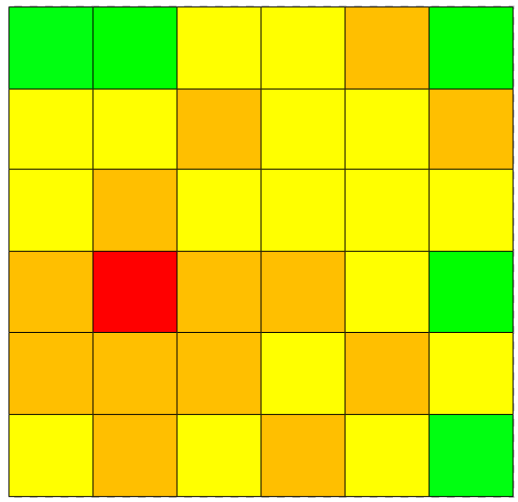
And increase the possibility of other tiles:

$$r' = r\frac{1}{1-pq} > r$$

Every time, we apply our deep search on the most possible tile (the red tile) and broad search in other tiles. If there is no finding, we update the map and apply our deep search on the new red tile. We keep going this method until we have the convincing result. The method is raised by Dr. John Piña Craven in the searching for the missing hydrogen bomb that had been lost in the Mediterranean Sea and the submarine USS Scorpion, which had disappeared in deep water in the Atlantic Ocean west of Portugal and Spain. The figure below shows the procedure of how the Grid Map works.



1st Trial



2nd Trial

4. Searching Model

4.1 Introduction

We have determined the most possible place by cutting the large area into pieces and the Bayes Theorem. In this part, we are discussing the model of how to search the lost plane most efficient under the fixed searching powers. We are going to discussing in multiple searching environment, searching equipment, searching methods and their advantages and disadvantages in this model.

4.2 Searching Methods

4.2.1 Searching by Eyes

Searching by eyes is one of the most traditional way. It has its own advantages like it won't be influence by the signal noise, it won't be cheated by the item that has the similar signal or radar detection. However, it's not that efficient because first eyes can only detected the items floated on the sea but can't sea the item drifting under the sea. Then, the range that human eye can see is much smaller that radar or other electronic equipment. Finally, by searching by eyes, people need a transportation like plane or ship. However, it's still used widely as a supporting searching way in searching on the ocean.

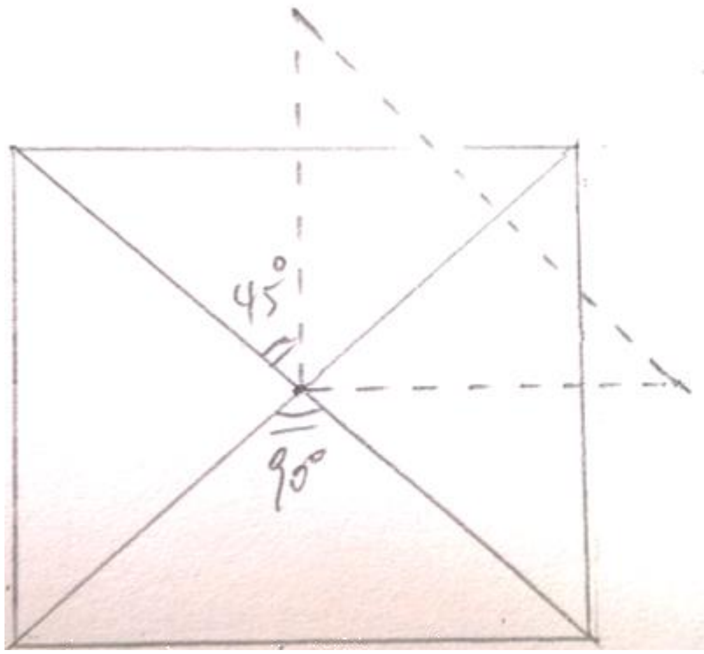
There are several models that can make searching by eyes more efficient.

4.2.1.1 Sector Search

Sector Search is the most efficient way for ship searching when the target searching area is small. The radius of the searching area is usually between 2-5 sea miles and 3 sections (with an angle of 120 degrees each) for ship searching. For aircraft searching, the radius is usually between 5-20 sea miles and the angle of each section is smaller.

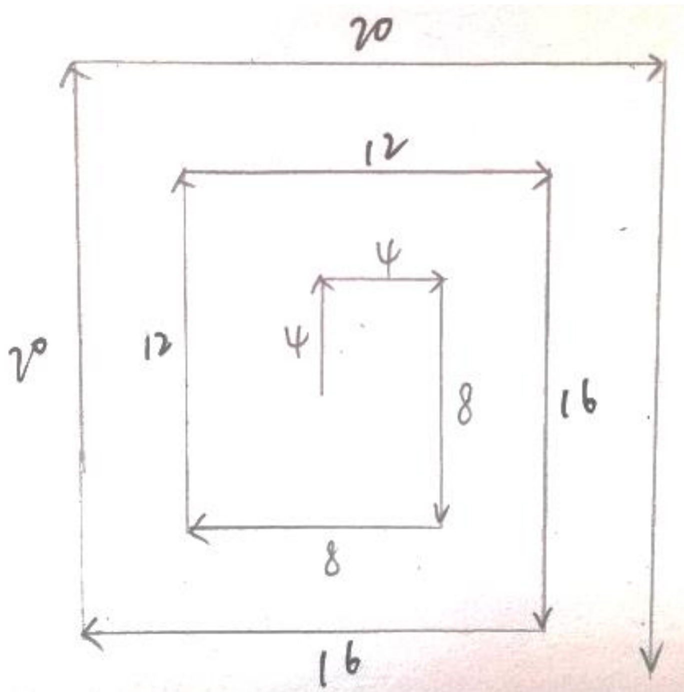
Applying the sector search method on the small grid, we first set the center of the grid as our origin. We then put a buoy at that point. The buoy position will change by the ocean current and update our searching area. This will help us getting the auto correction to the influence from the ocean current.

If the first search does not find the target, then we need a second search. We spin the sector for half of the interval angel and do the search again, as shown in the figure below by dash lines. (i.e. in Figure 4.x, the interval searching angle is 90 degrees, the second search will be in the triangle that is 45 degrees from the original triangle sector)



Since the searching area of sector search is rather small, considering the safety of navigation, there is a limit on the number of searching ship and aircrafts. In our model, we suggest to use one airplane and one ship in each sector search.

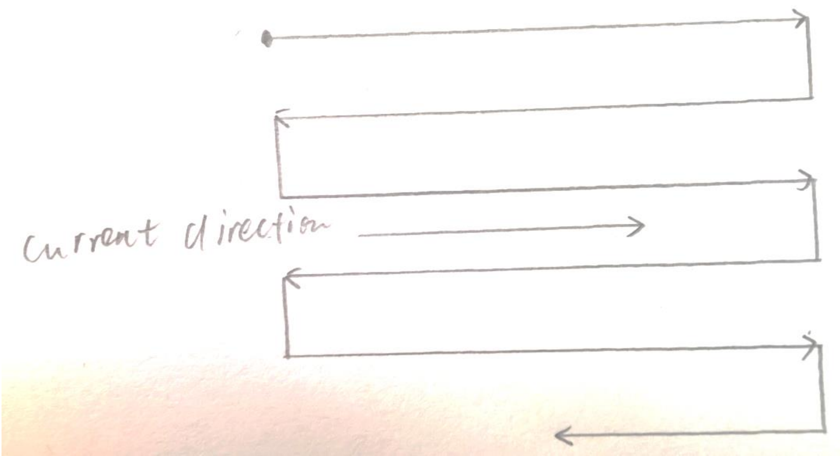
4.2.1.2 Extended Square Search



Extended Square Search is used for small-medium searching areas. The area of the searching area is usually around 100 square sea miles. Same as the Sector Search, we first put a buoy at the center of the grid to cancel the influence of ocean current. The search starts at the center of the grid, and then extends with a shape of concentric square.

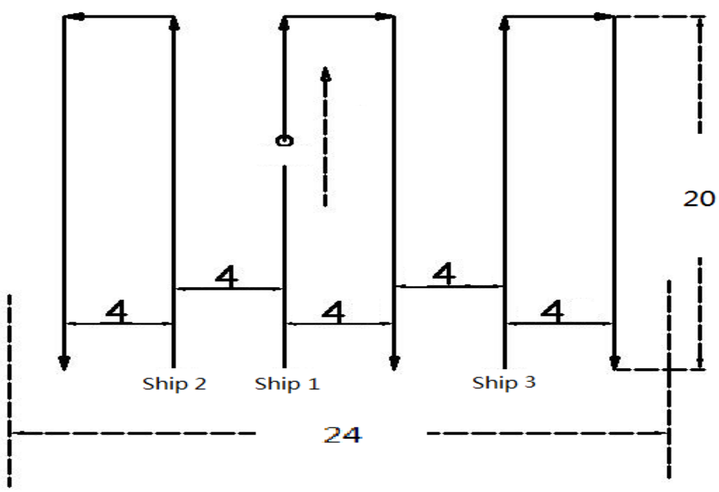
In order to execute the extended square search properly, the searching vehicle is required an accurate navigation to avoid gaps due the inconsistency of interval distance. Similar to the sector search, considering the safety of navigation, it is not suggested to use too many same-type vehicles in one searching area. In our model, we suggest to use one airplane ad one ship in each sector search.

4.2.1.3 Parallel Scan Search



Parallel Scan Search is good for large area searching. It scans the area uniformly. We start our Parallel Scan Search from one corner of our grid, and set an interval spacing of searching. We then search back and forth along the extension line of the ocean current with the interval spacing

Since we are applying the parallel scan search in a large area, we can use multiple vehicles in one parallel scan search. For example, Figure 4.x shows how 3 vehicles are going to parallel scan search a 24*20 area.



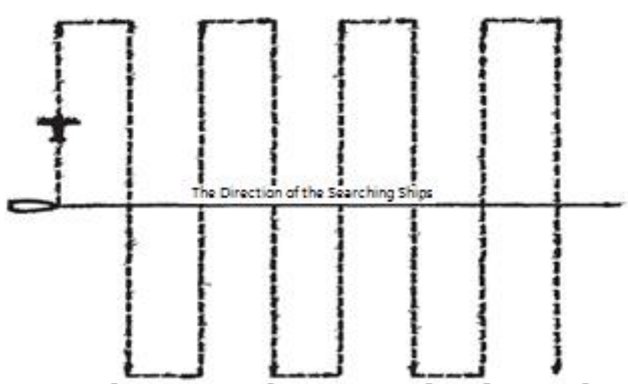
4.2.1.4 Parallel Scan Search

The Horizontal Parallel Scan Search is similar to the Parallel Scan Search. The difference between the two searching methods is rather than search back and forth along the extension line of the ocean current, the Horizontal Parallel Scan Search use the direction that is perpendicular to the current direction. The Horizontal Parallel Scan Search is also good for large areas. Usually, the Horizontal Parallel Scan Search method is not used alone, but to use with the Parallel Scan Search. For example, use the aircrafts to do Horizontal Parallel Scan Search and the ships to do the Parallel Scan Search.

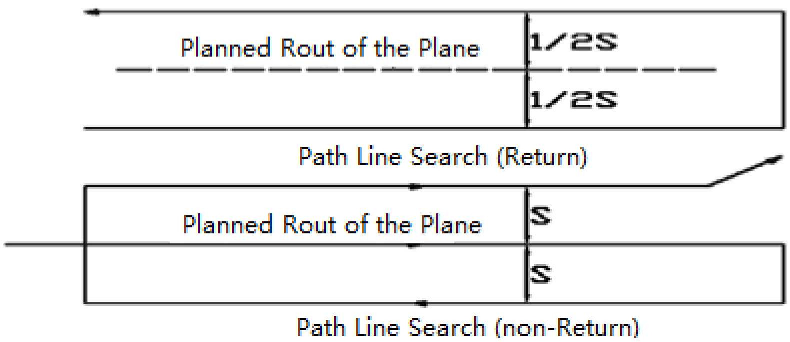
In this situation, we need to coordinate the ship speed, aircraft speed and spacing to make the horizontal displacement of the aircraft equal to the speed of the ships. The equation below shows the relationship:

$$V_s = \frac{S \times V_a}{L + S}$$

V_s is the speed of the ships; S is the spacing; V_a is the aircraft's speed; L is the length of the searching area. Because V_s, S, V_a for specific ships and aircrafts are fixed, we can get L using the equation and therefore get the size of the searching area.



4.2.1.5 Path Line Search



We use Path Line Search to search the area around the planned route of the airplane. If the pilot tried to perform an emergency landing on the ocean, the Path Line Search can achieve a good result.

To apply Path Line Search, we first set the planned route as the baseline of our searching route. Our search will concentrate the area near the baseline. We can either search one side of the baseline along the flight direction and then search the other side along the opposite direction or track along the baseline and then the both sides. The Path Line Search requires the vehicles to keep on the exact route or the close parallel routes.

The advantage of the Path Line Search is its efficiency. So aircraft is the most suitable vehicle to perform the search tasks and it is easier for aircraft to keep on the accurate route. When searching aircraft is doing Path Line Search, it maintains an altitude around 300m~600m during day time and 600m~900m during night time. The Searching can be divided into two kinds – return and non-return – according to the path. In return Path Line Search, the searching aircraft search along each side of the baseline once and then back to the departure port; in non-return Path Line Search, the searching aircraft search along the baseline first, then the sides of the baseline and leave the searching area after completing the task.

4.2.1.6 Shoreline Search

Shoreline search usually consists of small ships and low speed aircrafts that can fly safely in a low altitude. This search method doesn't depend on navigation information.

4.2.1.7 Dynamic Rectangular Search

The Dynamic Rectangular Search is found that is useful in critical environments with large waves, low visibility and night search. It is good at finding small, fast moving objects. In fact, the Dynamic Rectangular Search can be considered as an extension of the Extended Square Search. This searching method needs to estimate the drift direction C, drift velocity S, drift direction error ±C and drift velocity error ±S from the prevailing sea and weather conditions to determine the searching range. It also needs to get the effective distance D based on the properties of the wrecked aircraft and weather condition. We can calculate S with the equation:

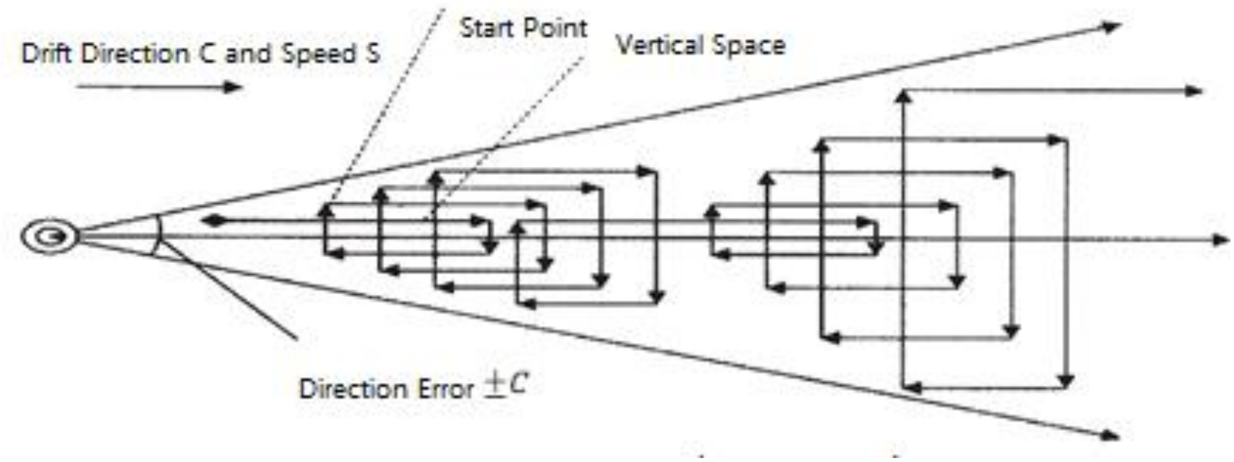
$$S = dt * S - dt * |\pm S|,$$

$$dt\ is\ the\ time\ between\ the\ accident\ time\ and\ the\ arrival\ time\ of\ the\ ships$$

We can calculate the vertical length (L) of the searching with the equation:

$$L = |\pm C| * 2 + k, where\ k\ is\ the\ progress\ coefficient$$

The progress coefficient k is judged by our searching progress. Usually, it's between 0.5 – 1.5 mile. The distance between the two adjacent vertical lines to the current direction is the transverse searching space, which is twice as large as the effective distance D. If the first trial of the search fails, we can recalculate the parameters and continue the 2^{nd}, 3^{rd} trials.



The advantage of this searching method is that the searching area is updated every time we start over a new trial. This avoids the waste of time of searching impossible areas due to the current. The Dynamic Rectangular Search keeps the searching area in the areas with the highest possibility and increase the chance to success.

However, using the Dynamic Rectangular Search should remain cautious. The most likely area doesn't guarantee the target to be in the region. Using this method alone means we abandoned rest possible regions. As mentioned before, the method is good at critical environments. So we should use this when we have limit resources. But as a systematic searching plane, it shouldn't be considered as the only searching method.

4.2.2 Night Time Search

4.2.2.1 Introduction

When the searching mission starts, every second is very valuable to the possible survival and the black boxes information. So, even there is a lot of limits on searching in the night like the darkness, the coldness and the unpredictable ocean wave, the searching process can't be stopped.

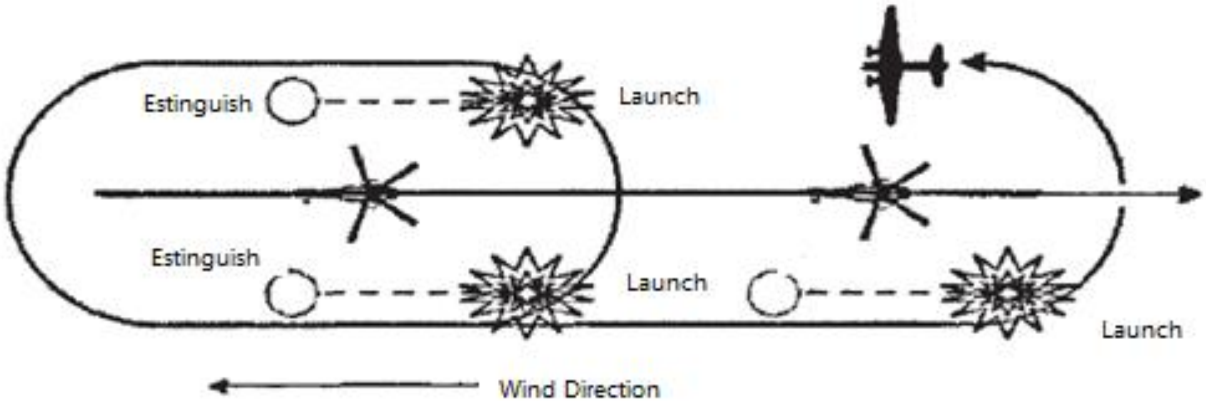
So, people has discovering an efficient night searching model is very important. Generally, night time search includes flash signal search, using infrared night equipment and using night vision equipment. Compared with the normal way of visual search, night search is more difficult, shorter in search distance and has a lower possibility of success. If searching without the aid of electronic equipment, searching capabilities are extremely limited at night.

We can use parachute flares to search during night time, but the search results are generally not ideal. It can only be used to search for large targets such as plane wing or body. In addition, shadows and reflective lights of other objects like rocks in the ocean can interfere the searching as well. When doing night search, we usually helicopters or ship rather than normal fixed-wing aircrafts for fixed-wing aircrafts' flying altitude and speed is too high for night search. However, we do use fixed-wing aircrafts to launch the flash shell.

4.2.2.2 Models

4.2.2.2.1 Helicopter night searching

Searching helicopters usually fly at a height of 150m. Fixed-wing aircrafts hover over the helicopter and launch the flash shell in the front left and right over the helicopter. The fixed-wing aircrafts need to choose their altitude and speed carefully to ensure the flares burn off below the helicopters and launch another shell before the previous one extinguished.



4.2.2.2.2 Ships night searching

When it is using ships as the searching equipment, we need to combine a plane flying above it to throw the flash shell. We need to keep the flash shell one at one side and another one on the other side so that they won’t influence each other and have dark zone.

4.2.2.2.3 Other night searching

Besides the searching ways before, there are a lot of other searching ways in night time like the Infrared camera or Infrared radar. We can also use night vision glasses to search.

4.2.3 Electronic searching ways

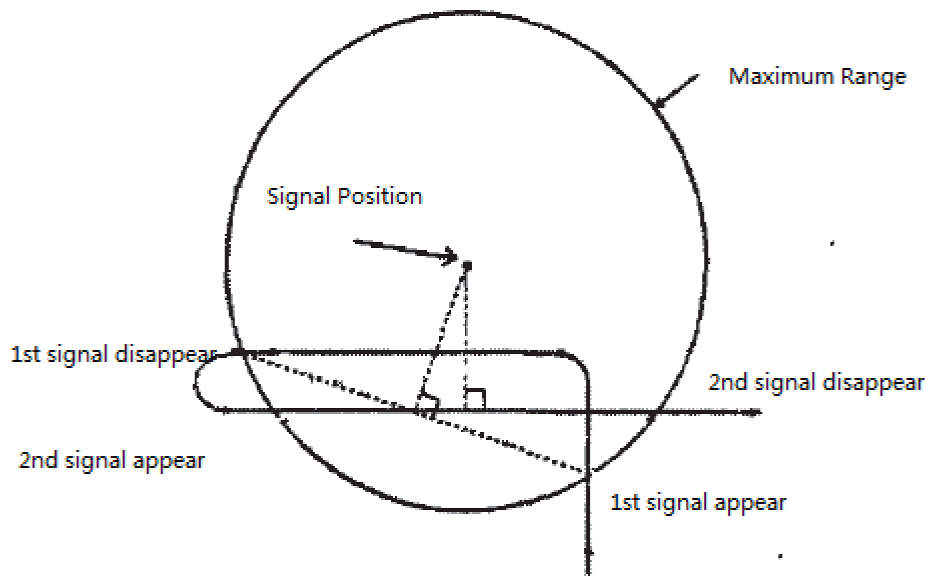
4.2.3.1 Introduction

No doubt, with the development of the modern technology, the electronic searching ways are becoming more and more efficient and reliable. The electronic searching way is to use the equipment like EPIRB, ELT, SART. The working principle of this method can be divided to two parts. First, receiving the radio signals from the items of the lost plane. Normally this way is used to detect the radio signal produced by the black boxes. The other way is to produce a radio signal and if there is anything like metal under this area water, the signal will be reflected and let the equipment know. The disadvantage of the first method is that it can't detect the item like the parts of the plane that can't produce a radio signal. However, the second method also has its disadvantage, the radio signal may be reflected not by the item you want to search but the other thing under the sea or the boat miles away. That may cause a false. Further, Radar searching is a very important way to support searching. Sometimes, the parts can be discovered by the radar. However, radar signals may be influenced by some other nonrelative items.

4.2.3.2 Models

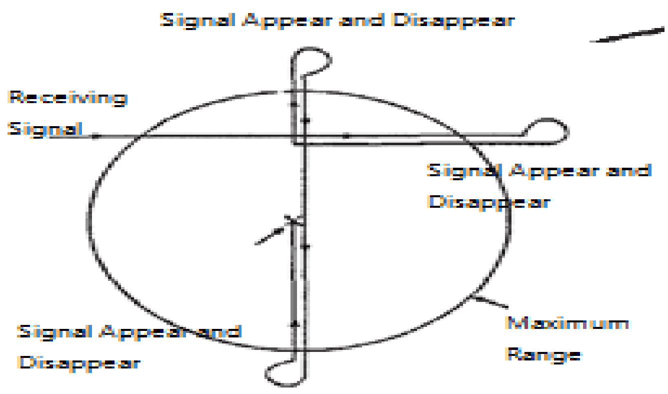
4.2.3.2.1 Searching model 1

We assume that we have already got a signal from the searching item. First we need to locate the position of the searching equipment which receive the signal on the map then turn left or right for 90° and driving until the signal disappear. Then, we point this place on the map again. Next, we turn 180° keep driving and record the position of the signal appear again and disappear again. We connect the point that first and second times' signal appearance and disappearance so that we can get two chords on circle. We draw the Perpendicular bisector construction of a quadrilateral of these two lines and the intersection points is the parts position.



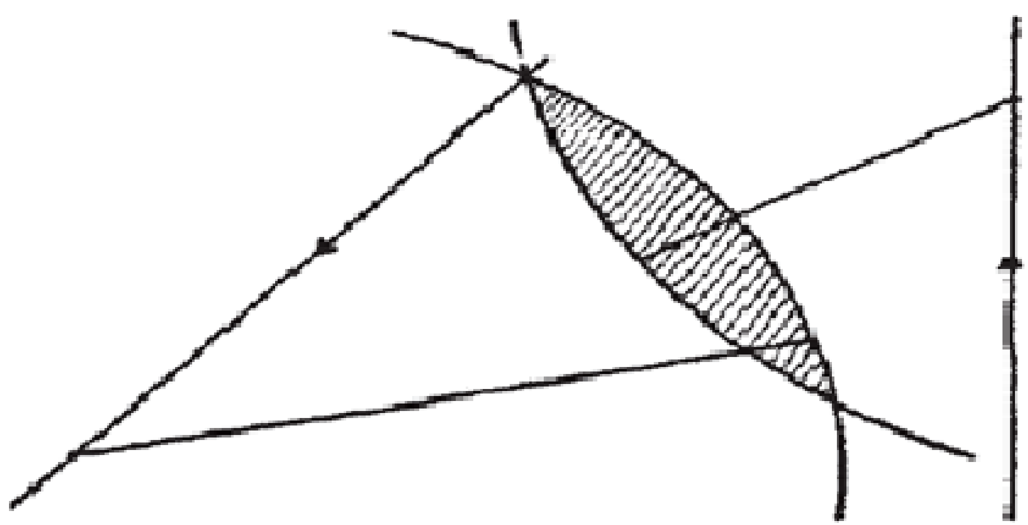
4.2.3.2.2 Searching model 2

First, Searching equipment record the time they receive the first signal and keep driving until the signal disappear and then turn 180°. Then, driving along the route before with the half time of the first time's signal appear and disappear. Then, turn left or right until the signal disappear. Next, turn 180° until the signal appear again and record the time. Keep driving and record the time that signal appear again. Finally, turn 180° and drive the time that is half of the last time's signal appear and disappear. The reaching point is the signal's location.



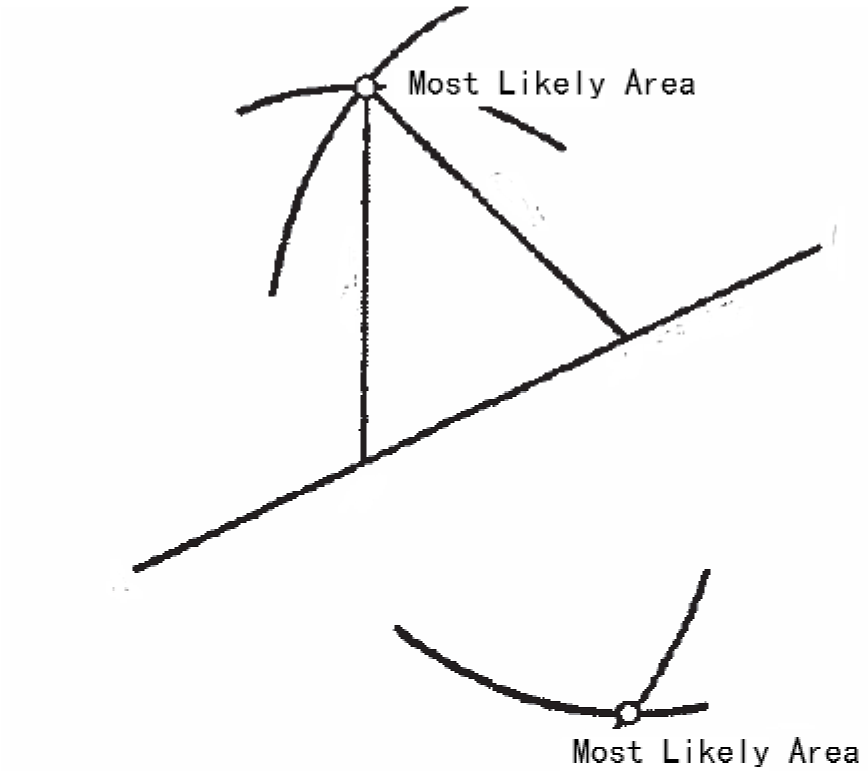
4.2.3.2.3 Searching model 3

Two planes fly on the targeting sea. If they all receive the signal, then use the place location that they received the signal as the center and draw a circle with the radius is the theoretical largest distance that the plane can received the signal. The overlapping arear is the place that the searching item should be.



4.2.3.2.4 Searching model 4

A plane flies a straight line and records the location it receive the radio signal as X and disappearing location as Y. Taking X and Y as the center draw two circles that radius is the theoretical largest distance that the signal can be received by the equipment. The point that these two circles interception may be the place of the searching item.



5. Conclusion

In the first part, we build a normal that can predict the plane's possible dropping place by first considering two situation when the plane's signal is lost. Then, we discussed each situation with a mathematical model. Here, since we don't have any data from the lost plane, we have to make a lot of assumptions to narrow the possible dropping area. After, this step, we got a function of t that can predict the dropping area with the dropping time t.

In the second part, we discuss the effects of the ocean current to the plan parts and the black boxes. In this part, we considered two situation which is the near-sea and far-sea. Since these two situations have quite different searching ways. After building the ocean current model, we still can only get a range instead of an exactly result of the searching item. This is caused because of the uncertain of the ocean current and the dropping place. So, we cut the large searching area into pieces and use the Bayes Theorem to calculate the probability that the searching item is in each piece.

In the third part, we need to figure out how to start the search job in every small area. We discussed the model for the human' eyes searching, electronic devices searching and other supporting searching ways.

6. Non-technology Letter

6.1 Searching Considerations

Searching work is a very complex thing which need to be changed from the current situation from time to time, normally there are these consideration:

A. The uncertainty of the searching item.
B. The type of searching equipment is using.
C. The type of searching item
D. The ability of different kinds of searching equipment.
E. The status of the ocean
F. The searching progress that has already made
G. The longer of the searching time that planning will last
H. Other small possibility things like the searching item was eat by fish n the ocean

6.2 Choosing searching method.

It may looks obviously that the fastest searching way is to use the electronic devices like radars or sonars. Its advantage is that it can search large areas in very short times and has very high rate of success. However, if the status on the ocean is good and there is enough light, searching by eyes is efficient too. The rate of success is only one rule to judge whether it’s an efficient searching method or not. There is some ways that can improve that rate:

A. The ability in area searching.

Here you need to consider the area that can be searched in unit time and the accurate together. How to make the searching area as large as possible but not missing anything may matters is the problem.

B. The speed of searching

Time is very precise in the searching job. There may be survivals if they can be find fast. The black boxes batteries may run out if the searching is not fast enough and if its batteries run out, if it can't produce radio signals anymore which will make the searching work more difficult.

C. Safety

The status of the ocean may sometimes limit the searching job. For example, if there is huge waves and wind, it will be very dangerous and inefficient to search by eyes.

D. Operability

How can the searching ways be really used in the searching work is a problem. Some searching methods may looks good but it may be very hard to apply in real.

Taking the searching methods we mentioned before, we made a table that can be a reference in determining the use of them.

	Searching Range	Searching item number	Searching work's initial place
Sector Search	Small	Single item	Origin of the searching area
Extended Square Search	Small	Single item	Origin of the searching area

Parallel Scan Search in length	Big	Single or Multiple item	One side of the searching area
Parallel Scan Search in width	Big and narrow	Single or Multiple item	One side of the searching area
Dynamic Rectangular Search	Small	Single item	Origin of the searching area

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