

# Establishment of the Comprehensive Searching Plan

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**Abstract.** Use infinitesimal method to gain the horizontal displacement about black-box based on features of crash plane. Then use “law of marginal” to calculate the circle  $P_i$  that cover the searching area. Define the possibility weight  $K$ , the edge weight for point  $i$  and  $j$ , use Ant colony algorithm to evaluate the optimum patrol path holding the greatest finding possibility with shortest time.

Model one addresses the patrol path that has the greatest possibility with shortest time for several same planes. Particularly, assume every plane travel through the center  $P$  to acquire the extreme optimum time. Model two addresses sending how many planes is effective and economic if the number of each type is same. use “added method” to find the unique sector with maximum searching time. define  $E_n$  to balance the time and cost.

## Introduction

In 2014, Boeing 777-200ER aircraft is regarded as "the most bizarre" aircraft lost case. Black-box is special equipment in the airplane. it can record the flight altitude, speed, heading, rate of climb, descent rate, acceleration, fuel consumption, landing gear retraction, Greenwich time, aircraft system working conditions.

I establish a universal model to assist the "searcher" find black-box taking care of the various types of searched plane and the electronic equipments.

## Assumption

1. Assume before the plane touch the water it remain intact,
2. Assume there is no influence from the sea animals or the Ocean currents during the sinking.
3. Assume the closer it leave the airline, the bigger possibility to find the black-box
4. Assume all the planes fly through the center  $P$  in all the models to consider the extreme situation

## Parameter

Parameter	Definition	[Unit]
$r_i (i=1,2,3)$	Radius of the range of the searching plane.	<i>n mile</i>
$v_i (i=1,2,3)$	Velocity of each type	<i>mile / h</i>
$\$ _i (i=1,2,3)$	Cost of searching plane per hour.	<i>dollar / h</i>
$c_i (i=1,2,3)$	Number of one type	
$a_i (i=1,2,3)$	Length of square of each plane.	<i>n mile</i>

**Model one. One type one plane model:** find the optimum path for one type plane

1 Using infinitesimal method, According to reference [1],

choose the gravity of crashed plane as 3556175 N, the direction as 22 degrees south latitude with Longitude 88 degrees, the wing area as 75m<sup>2</sup>, h(0)=10000m, the depth of the sea as 4200m. v<sub>2</sub>(0)=222.2m/s, v<sub>1</sub>(0)=0m/s, S(0)=0m, black-box mass as 50 kg, volume as 50cm\*20cm\*15cm.

The horizontal displacement of the plane dropping down in the sky

$$s(i+1) = s(i) + 0.5 * t * (v_2(i+1) + v_2(i)) \quad (1)$$

The horizontal displacement of the black box under water.

$$s'(i+1) = s'(i) + 0.5 * t * (v_2'(i+1) + v_2'(i)) \quad (2)$$

Note that. v<sub>1</sub> is the vertical velocity. v<sub>2</sub> is the horizontal velocity. H is the height

So the radius of the most likely searching area

$$R = S(t) + S'(t) = 13 \text{ n mile} \quad (3)$$

2 “Law of marginal”

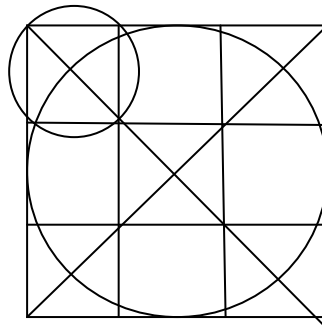


Figure 1. The basic explanation for the Law of marginal

$$(D - R) / 2r < 1 \quad (4)$$

Note that. R is the radius of big circle. r is the radius of small circle. D is half the diagonal of the Tangent Square of the big circle

If this formula holds, then I take all the point as the center point as the little circle, or I need to countdown the four corner points and take the rest point as the center.

In calculation, I assume r is 4n mile,. And R is 13 n mile. and I need 49 circles

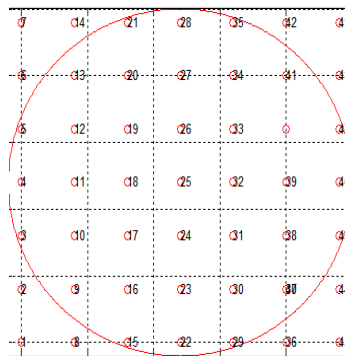


Figure 2. The final distribution of p with one plane

3 using the method of Ant colony algorithm

First, I divide the distribution into four levels, if the point lies in the circle whose radius is  $r_{25-26}$ , I classify it as the first level. If the point lies in the circle whose radius is  $r_{25-27}$  but not in the first

level, I classify it as the second level. If the point lies in the circle whose radius is  $r_{25-28}$ , but not in the first and second level, I classify it as the third level. If the point lies in the other part, I classify it as the fourth level.

Secondly, I identify the weight for each path between point  $P_i$  (at the I level) and  $P_j$  (at the J level)

If  $I=J$  then  $K=1$ ;

If  $I>J$  then  $K=1/(I-J)$ ;

If  $I<J$  then  $K=(J-I)$

(5)

$$W_{ij} = K_{ij} * d_{ij}$$

$$\min \sum d_{ij} * k_{ij}$$

(6)

Note that.  $d_{ij}$  is the distance between points,

Then use Ant colony algorithm to find the optimum path for one plane.

4 select n to evaluate the path

$n=4$

Use 4 planes find the best searching path, as there has points in the diversion line, when  $n=4$ , each of the sector need to consider the points in one diversion line

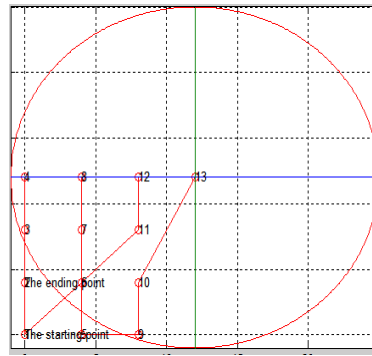


Figure 3. The optimum path in one sector

The point order is 1- 6- 11- 12- 13- 10- 9- 5- 7- 8- 4- 3- 2- 1. As  $n=4$ , the length of the path that one plane should travel is 64.2580 n mile, and the total time for this whole searching is 12 min

$n=4$

There is another separation for  $n=4$ , each sector include one diversion line, so there has same points in sectors.

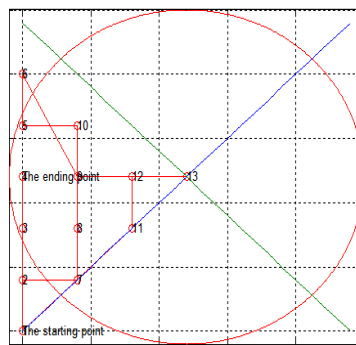


Figure 4. The optimum path in one sector, as  $n=4$

The point order is 1- 11- 12- 13- 9- 6- 5- 10- 8- 7- 2- 3- 4- 1. As  $n=4$ , the length of the path that one plane should travel is 80.2580 n mile, and the total time for this whole searching is 15 min.

**Model two. Multiple of type and number model:** find the best sending plan and searching path

Table1. The feature of three type planes

	$x_1$	$x_2$	$x_3$
a(n mile)	4	6	3
V(n mile/h)	321	490	450
\$(dollar)	7952	13603	11993

I assume the three type of plane has the same number in this model, which means  $n=3m$ .

*Note that.* Added method.

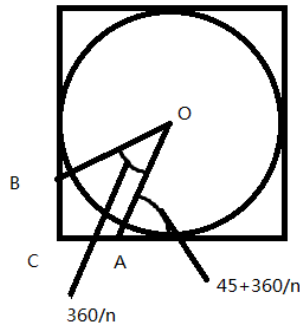


Figure 5. The explanation of extreme sector

I want to find the sector which contains the largest points. if I use tangent square to stand for the circle, then the area is the biggest area, and the points in the circle is regularly distributed based on model one, if  $BC=CA$ , this is the unique sector I am looking for that has the largest optimum patrol path and time

1 determine the superior limit of n

Ensuring that every sector has one point, which means n has superior limit,

$$\frac{360}{n} \geq \arctan \frac{a_3}{2a_3} = \arctan \frac{1}{2} \quad (7)$$

Which means  $n < 13$ , as  $n=3m$ , so the value of n is 3, 6, 9, 12.

2 get the distribution of searching points for each type of plane in model one.

3 find the  $t_{n(\max)}$  for each n

$$t_{n(\max)} = \max(t_{n1}, t_{n2}, t_{n3}) \quad (8)$$

This equation means that for each given n varying as 3, 6, 9, 12, according to the added method finding the unique sector, I can calculate the optimum time  $t_{n(\max)}$  in this sector, and the total searching time is  $t_{n(\max)}$ .

Take  $n=6$ ,  $x_2=6$  n mile as an example.

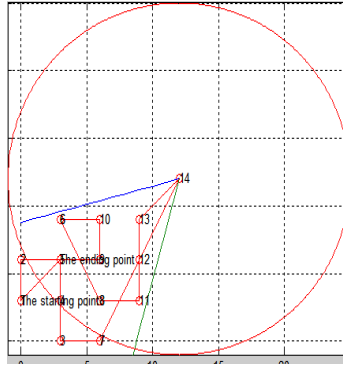


Figure 6. The optimum patrol path in the unique sector for  $n=6$  and  $a=6$  n mile.

Its travel along the point 1- 2- 9- 10- 6- 8- 11- 12- 13- 14- 7- 3- 4- 5- 1, and  $t_{62}=7.5$  min.

Follow the same step, I can get the time  $t_{ni}$  for all  $n$  (3, 6, 9, 12) that I need

4 substitute the information in  $E$  as the judgment function,

$$E_n = At_{n(\max)} + m \sum_{i=1}^3 \$_i t_{ni} \quad (9)$$

I choose  $A=20000$  to make sure that time and cost has the same influence on  $E$ , so I can get the most suitable  $n$  with low cost and short time whose  $E$  is smallest

Table 2. The corresponding  $E$  for any given  $n$

	$t_{n1}(h)$	$t_{n2}(h)$	$t_{n3}(h)$	$t_{n(\max)}(h)$	$E$
$n=3$	0.30821869	0.11527612	0.24239	0.30821869	13028.2619
$n=6$	0.17303862	0.08143204	0.13691088	0.17303862	11624.3420
$n=9$	0.14081713	0.08143204	0.10289311	0.14081713	13069.0725
$n=12$	0.13296012	0.06926755	0.10500622	0.13296012	15545.3278

## Conclusion

So it can be seen from table 2 that, when  $n=6$ ,  $E$  is smallest.and the total cost is 8163.569 dollar, the total searching time is decided by the maximum time which is 0.173038629h

## Future application

Our models are suitable for the airline company to search for the black-box. I can build different searching plans based on the type and the number of the planes that the company can offer. Above all, I can make the most effective and economic plans varying with the type and number,

## Strength

1. Consider the different type of the crashed plane. And the electronic application
2. Our model mainly focus on the extreme situation, such as the largest time among the optimum patrol time,
3. Define the judgment function  $E$ , which can consider both time and cost, making our final decision much more reasonable.

4. Define a new parameter *weight k*, thanks to it, the optimum searching path is not only the shortest time path, but also the path has the greatest possibility to find the black-box.

## References

- [1]<http://Inku.baidu.com/view/31023a5ce2bd960591c6775a.html> accessed on 2.6. 2015
- [2] Li Jun, Cai Zhiyong, Xie Hui “Design of large scale amphibious aircraft maritime search level navigation requirements” <Science and Technology>, 2014
- [3]Sun Yingde, Zheng Lizhi, “Talking about military blind based on searching for MH370”<China’s National Defense>2014-04-08