Design of the Disaster Response System DroneGo

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Abstract: Under the ravages of disaster, drones, which own transport and shooting functions, can efficiently transport drugs and maximize the safety of surveyors. In order to optimize the post-disaster emergency system for such disasters, we started with the rescue by drones and studied to resolved various related problems. First, in order to make full use of containers, we maximize the filling of the container with linear planning and chosen the type of drone. Then, we number all the intersections of the roads and use cluster analysis to divide them into different areas. And based on the existing hospital location and the coordinates of the intersections obtained, the positioning of containers was obtained. When studying the UAV survey route, we try to make the total cruise distance close to the maximum range of the drone, and use the annealing algorithm to get the best path.

1. Introduction

The hurricane in 2017 caused a lot of damage to Puerto Rico, and HELP, Inc. is trying to design a disaster response system based on drones. We have obtained the relevant information for this system as follows: Selected drones should be able to perform these two missions – medical supply delivery and video reconnaissance – simultaneously or separately. HELP, Inc. is planning on three different medical packages referred to as MED1, MED2, and MED3. Drones will carry these medical packages within drone cargo bays for delivery to selected locations. HELP, Inc. will use International Standards Organization (ISO) standard dry cargo containers to quickly transport a complete DroneGo disaster response system to a particular disaster area.

Table 1. Potential Candidate Drones for DroneGo Fleet Consideration

	Shipping Container Dimensions			Performance Characteristics/Capabilities			Configurations Capabilities		
Drone	Length (in.)	Width (in.)	Height (in.)	Max Payload Capability (lbs.)	Speed (km/h)	Flight Time No Cargo (min)	Video Capable	Medical Package Capable	Drone Cargo Bay Type*
A	45	45	25	3.5	40	35	Y	Y	1
B	30	30	22	8	79	40	Y	Y	1
C	60	50	30	14	64	35	Y	Y	2
D	25	20	25	11	60	18	Y	Y	1
E	25	20	27	15	60	15	Y	Y	2
F	40	40	25	22	79	24	N	Y	2
G	32	32	17	20	64	16	Y	Y	2
H Tethered	65	75	41	N/A	N/A	Indefinite	N	N	N/A

*Note that cargo bays are affixed to the drone and that drone must be on the ground to offload cargo. See Attachment 3 for Drone Cargo Bay Type Configuration/Dimensions.

Table 2. Drone Cargo Bay Packing Configuration/Dimensions by Type

Drone Cargo Bay Type	Length (in)	Width (in)	Height (in)	
1	8	10	14	Top Loaded
2	24	20	20	Top Loaded

Table 3. Emergency Medical Package Configuration/Dimensions

Emergency Medical Package Configuration		
Package ID	Weight (lbs.)	Package Dimensions (in.) (L × W × H)
MED 1	2	14 × 7 × 5
MED 2	2	5 × 8 × 5
MED 3	3	12 × 7 × 4

We will propose our solution for the optimization of Puerto Rico emergency rescue system. And our optimization plan will mainly be researched and analyzed from three aspects including choice of drone and packaging configuration, determine the location of cargo container, reconnaissance evaluation route.

2. Process and Research

2.1 Choice of Drone and Packaging Configuration

2.1.1 Method and Process

Taking into account the tasks of patrolling and transporting, exclude drones F and H that cannot carry drugs and video reconnaissance, we choose the type B drone with the longest flight distance and the G-type aircraft with the largest load.

we assume that the product of the UAV's continuous flight time and the mass of the bearer is a constant. Set an amount O to be the product of mass and time, which represents the rated capacity carried by the drone, m is the mass carried, t is the number of hours of continuous flight, and the following formula is obtained.

$$O = m * t \tag{1}$$

Use t_o to express the continuous flight time, and use constant O to calculate t_o.

$$t_o = \frac{O}{m} \tag{2}$$

Introduce n as the number of times a drone can fly continuously. According to $O = m * t$, it can be concluded that m is inversely proportional to t, η is introduced as the efficiency of each flight operation, and t_1 is the time of no-load continuous flight. So, we can get:

$$\eta = \frac{m}{t} \tag{3}$$

The actual number of consecutive flights is necessarily less than its ideal value. The ideal continuous flight times can be multiplied by the efficiency, and $n'$is used as the actual number of consecutive flights. It can be known that:

$$n' = n * \eta \tag{4}$$

Then, using the calculated number to multiply the number of first-aid kits that the drone can carry, the number of such first-aid kits in the container can be obtained. After the actual ratio is obtained, according to the limitation of the container, we take type B drone, a cargo holds and a MED2 as a combination 1, a G-type drone and a cargo hold and MED1, MED3 as combination 2. We use linear programming with lingo to solve the actual answer of the problem, and find the best combination. The inequality is as follows:

$$\begin{cases} x1*30*20*35+x2*98*32*32<231*92*94 \\ x1*30*20+x2*98*32<231*92*3 \\ x1*20*35+x2*32*32<92*94*8 \\ x1*30*35+x2*98*32<231*94*5 \\ \frac{x2}{x1}>0.48 \\ \frac{x2}{x1}<0.52 \end{cases} \tag{5}$$

2.1.2 Results

Aircraft B: MED2= 1:45, Aircraft G: MED1: MED3=1:89:53. And the packaging configuration is as follows.

Table 4. Parameters of the B-type aircraft

Parameter	Numerical value	Unit
O	320	kg*h
t	80	h
m	4	kg
n	225	times
η	10%	
n'	22.5	times

Table 5. Parameters of the G-type aircraft

Parameter	Numerical value	Unit
O	320	kg*h
t	16.842	h
m	19	kg
n	17.8	times
η	100%	
n'	17.8	times

Table 6. Configuration parameter

Material	Numerical value
x_1	28
x_2	14
Aircraft B	28
Drone cargo bay 1	28
MED2	1200
Aircraft G	14
Drone cargo bay 2	14
MED1	1246
MED3	742

2.2 Determine the Location of the Cargo Container.

2.2.1 Method and Process

First of all, we have to meet the delivery of the medical box. To this end, we marked five hospitals and found that the hospital 5 is far away from other hospitals. The other four hospitals are relatively close, so we put a cargo container which is responsible for the medical supply of these four hospitals. We decide to take one point to place the container 1, and its position satisfies the shortest distance to the first four hospitals. Then we mark all road intersections with numbers, a total of 44, cluster analysis of them to find out areas with dense roads. Points that are close to each other are grouped into four categories, which are divided into four categories, each of which is yellow, red, black, and blue, each as an observation

The blue area includes four hospitals, so the observation task can be realized during the process of distributing medical kits. The sum of the distances found in the yellow area to the intersections is the smallest, knowing latitude and longitude, we use *Euclidean distance formula*, and program to find an ideal point. For the red area, we use the same method, when studying the black area, we find that using the hospital 5 to charge the drone can radiate all the black areas. Similarly, we found an ideal point. which is minimizing the following S_i.

$$S_i = \sum_{j=2}^{3} \sqrt{(a_i - e_m)^2 + (b_i - f_m)^2} \tag{6}$$

$$\begin{cases} \text{When } i = 2;\ j = 1,2,3,8,9,10,11,12,13,14,15,16,17,19,20,21,23,24,29; \\ \text{When } i = 3;\ j = 25,26,27,28,32,33,34,35,36,37,38,42,43,44; \end{cases}$$

Fig.1 The representation of the cluster analysis results on the map

Fig.2 Containers' specific location

2.2.2 Results

After precise positioning, we obtained the latitude and longitude coordinates of three containers.

Table 7. the position of container

Container	Latitude	Longitude
Container1	18.39	-66.06
Container2	18.19	-66.70
Container3	18.05	-66.39

2.3 Reconnaissance Evaluation Route

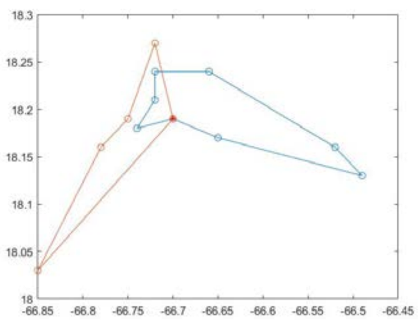
2.3.1 Method and Process

The reconnaissance mission has high requirements for the drone's battery life, so we choose the qualified G-type drone. Because of the wide distribution of road intersections, so we have chosen to exclude some intersections which drones can reach. That is, centering on containers and hospitals, draw a circle with a radius of half the farthest distance of the drone (the drone needs to return to the container location), and exclude the points outside the circle. The distance formula is as follows.

$$d = R\arccos[\cos(x_1 - x_2)\cos y_1 \cos y_2 + \sin y_1 \sin y_2] \tag{7}$$

x1 is the Longitude of hospital or container, x2 is the Longitude of the intersection, y1 is the latitude of hospital or container and y2 is the latitude of the intersection, d is the distance.

Because the number of remaining points is still very large, we use the selected points for cluster analysis, divide them into different areas. Then we need to develop a specific reconnaissance route. That is, in each region, the Simulated annealing is used to find the shortest path that passes through all the points and returns. Cluster analysis divides the points into three regions. The points in the first region can be reached by the drones in the other two regions, so only the second and thire regions need to be annealed. Generate the following picture:



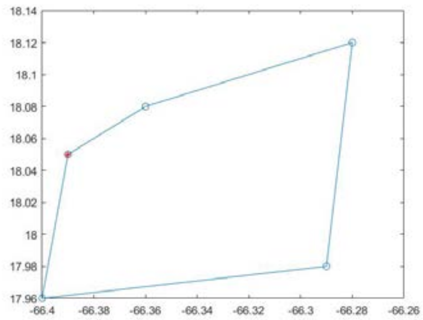


Fig.3 UAV route based on container 2   Fig.4 UAV route based on container3

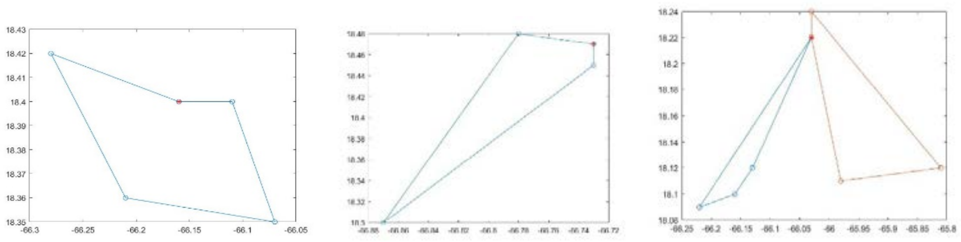


Fig.5 UAV route based on hospital

The results are basically in line with our expectations. The length of the journey is basically longer than the cruising range, and it reaches the maximum utilization of the drone.

2.3.2 Results

After calculation, we got a reasonable survey route for the drone, as shown in the table.

Table 8. Planned flight route

Drone base	Planned flight route
Container2	Route 1: 14——15 ——16——19——21——20——17 Route 2: Route 18——9——10——11
Container3	25——26——27——28
Hospital1	42
Hospital2	Route 1:33——32——34 Route 2: 38——43——37
Hospital4	30——31——40——39
Hospital5	6——7——18

3. Summary

This paper introduces a strategy for optimizing the resource allocation of emergency rescue system. In the analysis process, the clustering algorithm is used to classify the location coordinates. Linear programming is used to find the optimal container packing method under multi-constraint conditions. The annealing algorithm finds the shortest path for drone cruising. This paper innovatively integrates multiple algorithms to analyze how to optimize emergency rescue systems, and finally achieves the goal of optimizing the configuration of emergency rescue system.

References

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