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Send in the Drones Developing an Aerial Disaster Relief Response System

Qinhan Yao, Xinnan Yu

Changzhou Campus Of Hohai University   Changzhou   Jiangsu 213022

ABSTRACT. *Based on the locations of locations of ISO cargo containers and the drone fleet, we develop a shortest path model. The model provides a recommendation for flight plan of drones using Dijkstra's algorithm. By re-planning the flight path through the short- est path algorithm, it is possible to reduce the flight length of drones and increase the navigation time of drones. We reduce the length of the roads need to be photographed by 60.2% (282.8km) and 46.2%(365.24km) respectively in the western region and eastern region.*

KEYWORDS: *Disaster Relief; K-means Clustering; Shortest Path Algorithm*

1. Introduction

In 2017, the worst hurricane to ever hit the United States territory of Puerto Rico left the island with severe damage, killing more than 2,900 people. Widespread flooding has blocked and destroyed many highways and roads across the island, dozens of areas were isolated and there is no communication. Demands for medical supplies, lifesaving equip- ment, and treatment strained health-care clinics, hospital emergency rooms, and non-governmental organizations'(NGOs) relief operations. Demand for medical care con- tinued to surge for some time as the chronically ill turned to hospitals and temporary shel- ters for care.

However, non-governmental organizations (NGOs) are often challenged to provide ad- equate and timely response during or after natural disasters, such as the hurricane that struck the United States territory of Puerto Rico in 2017. One NGO in particular - HELP, Inc. - is attempting to improve its response capabilities by designing a transportable disas- ter response system called 'DroneGo' .Selected drones should be able to perform these two missions - medical supply delivery and video reconnaissance.We need to help the NGOs design the DroneGo System.

2. Preparation for modeling

From the background and the statement of the problem, we summarize the relationship between the Standard ISO Container, Shipping Container, Drone Cargo Bay and Emergency Medical Package, as shown in Figure1. The standard ISO

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Container has the largest size, and the Shipping Container, Drone Cargo Bay and Emergency Medical Package are installed in the Standard ISO Container to form a complete DroneGo disaster response system.When Drones are in the Shipping Containers they do not perform delivery and detecting tasks in the Shipping Container. When the drone performs the delivery task, it will carry medical packages within drone cargo bays for delivery to the areas which need medical supplies. Each drone land on the ground for the medical packages to be unloaded from the cargo bay at its destination.

3. Recommend a Drone Fleet

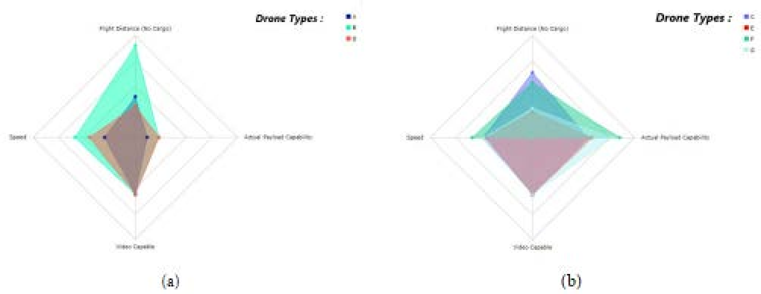

Figure 1 Performance of Low (left) and High(right) Payload Drones

From figure 1, It can be seen that droneB is superior to drone A and D in four aspects: Actual payload capability, Speed, Flight distance and Video capable. In view of the wide range of disaster in Puerto Rico, we prefer Drone B. Then we compare the performance of the drone with the cargo bay type 2. We can get drones with better performance as C,F ,G among them, Drone C in terms of flight distance; Drone F performs best in terms of Speed, Actual payload capability and Flight distance; Drone G has balanced performance. According to the above analysis, the following inferences can be obtained:

Western Hospital HIMA required fewer medical packages, and Drone B can be used to maximize the range of detection. The demand for medical packages in the eastern hospitals was large, thus at least 2 drones are needed. Therefore, we hope to select a drone fleet to meet the demands of the hospital and the number of drones included in the fleet was as small as possible.

In order to compare BCFG better , we draw the performance radar map of Drone BCFG. It can be seen from the figure that the combination of Drone B and F can reach the optimal performance. Therefore ,we chose the combination of Drone B and F .

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4. Identify the Number and the best locations of ISO cargo containers

We know that the ISO cargo container for the DroneGo disaster response system can be placed in up to three different locations if three cargo containers are used in the disaster area. We need to determine the number of the ISO cargo container required in the Puerto Rico region and the specific position. The classification is discussed as follows:

First, we consider the case where the DroneGo Disaster response System sets an ISO cargo container in the Puerto Rico area. The figure shows:

The distance between Hospital Pavia Arecibo and the other four delivery locations is at least 60.58*km*. There are no drones in the candidate drone that can fly so far. The distance between the remaining four delivery locations is 10.18 □ 54.45*km*. Among the candidate drones, there are drones whose flight distance can meet these distance range. Therefore, if the DroneGo Disaster Emergency System has only one ISO cargo container, it will need to give up transporting medical packages for Hospital Pavia Arecibo. We will use the k-means clustering algorithm to calculate the specific location of the ISO cargo container. In this case, the sum of the distances from the ISO cargo container to the four delivery locations is the smallest, and the time for transporting medical packages to each hospital is balanced. The specific algorithm implementation principle is as follows:

Considering the timeliness of medical supply delivery (the shortest flight distance and the shortest flight time), we need to find the centroid of the delivery locations, which has the shortest distance to all the delivery locations. We find the best location to position the cargo container needs to be as close as possible to the centroid.

Then we use k-means clustering to determine the centroid of the delivery locations we want to send pre-packaged medical supplies to.

K-Means Clustering build steps:

(1) Constructing a sample set $L = x_1, x_2, x_3, ...x_n$, where $i = 1, 2...n$, and $x_i = (a_i, b_i)$, a_i and b_i are the abscissa and ordinate of the ith delivery location

(2) Determining the number of categories k of clusters;

(3) Selecting k samples randomly from the sample set L as the initial k centroids: $C_1, C_2, ...C_k$, and initializing the categorization $U = \mu_1, \mu_2, ..., \mu_k, j = 1...k$,;

(4) For $i = 1,2...n$, we calculate the distance between the sample x_i and each centroid vector C_j ($j = 1, 2, ...k$): $d_{ij} = ''''x_{ij}{}^{2}$,and mark x_i as the category λ_j corresponding to the smallest d_{ij}. In this case, we update $\mu_{\lambda_j} = \mu_{\lambda_j}$ S x_i;

(5) For $j = 1,2,...,k$, we recalculate the new centroid for all sample points in μ_j:

(6) If k centroids have not changed, go to step 7; otherwise go to step4;

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(7) Outputing the categorization $U = \mu_1, \mu_2, ..., \mu_k, j = 1...k$ and centroids of each category

$C_1, C_2, ... C_k$;

According to the above steps, and the horizontal and vertical coordinates of the five delivery locations in table 4, we can calculate the location information of the ISO container C1 is as shown in Table 1.

Table 1 Location information of ISO Container C1

ISO container location	Latitude(°)	Longitude(°)	x(km)	y(km)
C1	18.33	-66.01	104.21	36.1

We mark the ISO cargo container C1 on the map of Puerto Rico,as is shown in figure 2.

In the figure 8, the orange shadow is the overlapping area of four blue circles, indicating that, the drone can deliver medical packages to four nearby hospitals from the ISO cargo container C1 in a 'half-load state'. In order to calculate the maximum video reconnaissance coverage of the drone fleet, we assume that the Drone B with the longest flight distance is selected as part of the drone fleet. Then, the center of the red circle is C1, and the radius

$d = 52.67 \times 50\% = 23.7km$. The red circle indicates that the coverage of video reconnaissance

by the drone is in the state of no load from the ISO cargo container C1.

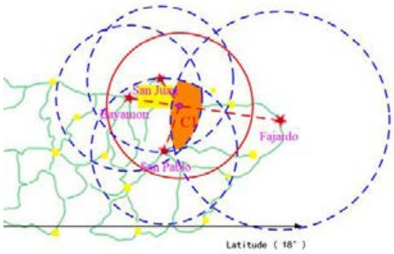

Figure 2 Location of ISO Container C1

5. Results

The drone fleet chooses the combination of B and F drones, which has the best perfor- mance in four aspects, so it can complete a small number of long-distance and short- distance transportation tasks. It can adapt to the wide range of disaster locations in Puerto Rico and the five delivery locations with large differences.

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Considering the widespread disaster situation in Puerto Rico and the number of lo- cations where medical packages need to be provided, it is unreasonable to set up an ISO cargo container in the region for the DroneGo disaster emergency system, which cannot meet the medical package requirements of all delivery locations; Two ISO con- tainers can meet the medical package requirements of all delivery locations, but the materials allocation of these two ISO containers is not balanced; three ISO container- s are set up to meet the medical package requirements of all delivery locations, and these three ISO containers The packaging configuration is relatively balanced. At the same time, drones have the largest coverage of video surveillance, covering the largest number of densely populated areas.

According to calculations, even if the ISO cargo container is loaded with the medical package demand of the corresponding hospital for one month, and the corresponding drone and warehouse are loaded, the space utilization rate of ISO cargo container is only 1.67% ~9.11%.

By planning the flight path through the shortest path algorithm, it is possible to reduce the flight mileage of the drone and increase the flight time of the drone while satisfying the path between all populated places and hospitals within the maximum detection range. For the western region, the detection of the route using the shortest path algo- rithm can reduce the length of the road to be photographed by 60.2%(282.8*km*)compared to each road. Re-planning the detection route using the shortest path algorithm inthe

eastern region can reduce the road length required to be photographed by 46.2%(365.24*km*).

6. Recommendations

In the DroneGo disaster emergency system, the B model drone has only reached half of its maximum load capacity due to the volume limit of the warehouse. We can try to improve the size of the bins of the B model drones and improve the long-distance mass transport.

For the disaster situation in Puerto Rico, it is reasonable to choose to install 3 the ISO cargo containers in the area. If more serious disasters occur in Puerto Rico in the future, in order to meet the needs of aid, it can be divided into two aspects:

If it is necessary to transport the medical kit to the hospital in the shortest time, it is necessary to increase the number of drones of each ISO cargo container and realize the simultaneous transportation tasks of multipledrones;

If we need to make the video surveillance major roads larger, we need to increase the number of ISO cargo containers. In the case of the Puerto Rico region, when five ISO cargo containers are used, the main roads in the area can be completely covered.

It is more reasonable to reduce the size of the ISO cargo container to 20% of the size of the given ISO cargo container. It can carry up to double the demand for

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medical kits in Puerto Rico and reduce costs. The effect of increasing the number of ISO cargo containers is far greater than increasing the size and material configuration of ISO cargo containers.

Before dispatching the drone to perform the task of shooting the road condition, it is recommended to use the shortest path algorithm to plan the flight route, which can effectively reduce the total length of the road to be photographed, thus completing the detection task of the road network faster.

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