Aerial Disaster Relief Response System Research

Hongyang He, Zhenlin Chen

Electronic and Information Engineering, Guangdong Normal University of Technology, Guangzhou, 51000, China

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Abstract: In order to solve the problem of medical supply in the affected areas, we designed a disaster response system to provide medical package transportation and related route detection for five regions. To solve the first problem, we built two optimization models for 3D boxing. By considering the size of the medical package and cargo bay, the first model of the number of medical packages required in the affected area was established. Solve the distribution plan of medical package by MATLAB. Then, by considering the size of ISO containers and shipping containers and the number of cargo containers, a three-dimensional packing optimization model is established. Solve in MATLAB to determine the type and number of drones needed. This resulted in a complete disaster response system consisting of a drone fleet and a medical packag To solve the second problem, we use cluster analysis. First, the five disaster areas were classified into three categories to determine the three best cluster centers as the best locations for the three ISO containers. Then, the Euclidean distance was taken as the similarity between the two points, and the three optimal positions were obtained by K-means clustering algorithm as x6=(18.45,-66.40),x7=(18.40,-66.16),x8=(18.27,-68.84)Finally, according to the demand characteristics of the disaster area and the video reconnaissance capability of the drone, the corresponding ISO container was allocated.

To solve the third problem, we solved the transportation path in two stages. In both stages, the 0-1 programming model was established with the shortest time as the objective function, and the transportation path, drone type and quantity of each aggregation center point to the disaster point were obtained by MATLAB. In the second stage, the remaining materials in the first-stage affected area were allocated to the affected areas that do not meet the demand. Thus, the delivery route and schedule of the cargo container payload package configuration were designed. After inspection, the flight path of the first problem covered all the railways and highways, that is, the flight path as the second problem.

1. Introduction

In 2017, the worst hurricane to ever hit the United States territory of Puerto Rico left the island with severe damage. The combined destructive power of the hurricane’s storm surge and wave action produced extensive damage to buildings,homes, and roads, particularly along the east and southeast coast of Puerto Rico. The full extent of the damage in Puerto Rico remained unclear for some time; dozens of areas were isolated and without communication. Demands for medical supplies, lifesaving equipment, and treatment strained health-care clinics, hospital emergency rooms, and non-governmental organizations’ (NGOs) relief operations. Demand for medical care continued to surge for some time as the chronically ill turned to hospitals and temporary shelters for care.

2. Restatement of the problem

Question one: Recommend a drone fleet and set of medical packages for the HELP, Inc. DroneGo disaster response system that will meet the requirements of the Puerto Rico hurricane scenario. Design the associated packing configuration for each of up to three ISO cargo containers

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to transport the system to Puerto Rico.

Question two: Identify the best location or locations on Puerto Rico to position one, two, or three cargo containers of the DroneGo disaster response system to be able to conduct both medical supply delivery and video reconnaissance of road networks.

a) Provide the drone payload packing configurations (i.e. the medical packages packed into the drone cargo bay), delivery routes and schedule to meet the identified emergency medical package requirements of the Puerto Rico hurricane scenario.

b) Provide a drone flight plan that will enable the DroneGo fleet to use onboard video cameras to assess the major highways and roads in support of the Help, Inc. mission.

3. Analysis of the problem

For the first problem: We assume the medical package required for 15 days, consider the size relationship between the medical package and the cargo bay, the number of medical packages required in each affected area. Try to load all the supplies with the small cargo harbor, thereby establishing an optimization model. According to the cargo bay model, load capacity, video function and altitude of the drone, we select the drone that can match the cargo bay. Then, by considering the size of ISO container and cargo container, and the number of cargo containers, a three-dimensional packing optimization model is established to obtain a distribution plan for drones and medical packages. Using the MATLAB to determine the type and number of drones you need.

For the second problem: Based on a comprehensive consideration of the distance between each affected area and the demand for materials, we take the five disaster points as samples. The latitude and longitude of the disaster site and the demand for the three types of drug packs are taken as five coordinate parameters, and the unit of the unified parameter is standardized by Z-score. Then take three of the five sample points as the initial aggregation center, and the Euclidean distance between the two points as the similarity. The K-means clustering algorithm is used to solve the best aggregation center, which is the optimal location of ISO container.

Finally, according to the demand for medical packages in each affected area and the configuration of ISO containers, select the appropriate ISO containers for the three locations.

For these three questions: on the basis of question two, it is carried out in two phases. The first phase first meets the material needs of the disaster site covered by the convergence center. Create a 0-1 programming model with the shortest time as the objective function; find the transportation route and the corresponding drone type and quantity. The program receives the remaining quantity and demand for three medical kits in each affected area. The second phase is based on the first phase, and the remaining materials are allocated to the disaster areas that do not meet the demand, and the optimal transportation path is obtained by establishing a linear programming model. Finally, the UAV's transportation route is obtained, matching the type and quantity of the cargo port, and the timetable. The second question needs to consider the video reconnaissance of the road. Since the flight path of the first problem drone has covered the route including the railway and the highway, the requirements are met, so the result is the same as the flight route of the first problem.

4. Assumptions

Assume that the medical packages are placed in parallel in the drone cargo bay and can change the orientation, the shipping containers are placed in parallel in the ISO container and the orientation can be changed.

Assume that the drone can be unloaded after landing.

Assume that the drone is flying straight in the air.

5. Description of the symbol

Symbol	Meaning
L	Length of ISO container
W	Length of ISO container
H	Length of ISO container
V	Length of ISO container
l_{xj}	a variable describing the relative position between the shipping harbor and the medical package
$u_{ij}1j2$	Describe the relative position of any two medical packages j1, j2 in the i-th cargo bay
d(x_i, x_j)	the distance between x_i and x_j
(x_{ij}, y_{ij}, z_{ij})	The coordinates of the position of the lower left rear corner of the jth medical package in the i-th cargo bay
k_m	Number of aircraft in the mth center

6. Question one: Optimization model for 3D packaging

Establishing a three-dimensional boxing problem optimization model, find the number of drone cargo bays required and the types and number of medical packages loaded in each drone cargo bay.

6.1 Description of the model

Assume that the medical package required for 15 days, as known in Annex 4 and Annex 5, requires a total of 195 medical packages. The ratio of the three medical packages MED1, MED2, and MED3 is approximately 7:2:4:

L_j,,H_j,M_j: The length, width, height and weight of the jth medical package.

L_j=14,=7,H_j=5,M_j=2,j=1,2,…,105;

L_j=5,=8,H_j=5,M_j=2,j=106,107,…,135;

L_j=12,W_j=7,H_j=4,M_j=3,j=136,137,…,195.

L_i,W_i,H_i,V_i: The length, width, height and volume of the i-th drone cargo bay.

L_i=14,W_i=7,H_i=5, V_i=1120, i=1,2,…,d;

Restrictions:

All medical packages must be loaded into the drone cargo bay:

$$\sum_{i=1}^{m} X_i = 195$$

Each medical package can only be loaded into one drone cargo bay:

$$\sum_{i=1}^{m} Y_{ij} = 1, \text{j} \in \text{n}$$

To save space, each side of the medical package is parallel to one side of the drone cargo bay:

l_{xj}+l_{yj}+l_{zj}=1, w_{xj}+w_{yj}+w_{zj}=1, h_{xj}+h_{yj}+h_{zj}=1

l_{xj}+w_{xj}+h_{xj}=1, l_{yj}+w_{yj}+h_{yj}=1, l_{zj}+w_{zj}+h_{zj}=1 Medical packages cannot exceed the drone cargo bay:

$$Y[x_{ij}+(L_j \cdot l_{xj} + W_j \cdot w_{xj} + H_j \cdot h_{xj})]+ f_{ijj1} \cdot (L_j \cdot l_{xj1} + W_j \cdot w_{xj1} + H_j \cdot h_{xj1}) \le L_i$$

$$Y[y_{ij}+(L_j \cdot l_{yj} + W_j \cdot w_{yj} + H_j \cdot h_{yj})]+ r_{ijj2} \cdot (L_j \cdot l_{yj2} + W_j \cdot w_{yj2} + H_j \cdot h_{yj2}) \le W_i$$

$$Y[z_{ij}+(L_j \cdot l_{zj} + W_j \cdot w_{zj} + H_j \cdot h_{zj})]+ f_{ijj3} \cdot (L_j \cdot l_{zj3} + W_j \cdot w_{zj3} + H_j \cdot h_{zj3}) \le H_i$$

To make the drone cargo bay volume as small as possible, the objective function is:

$$\min \sum_{i=1}^{m} Y_i V_i$$

6.2 Model solution

We need to allocate a total of 74 drone cargo bays, of which 66 type 1 drone cargo bays and 8 type 2 drone cargo bays. See Appendix 1 for the code.

Tab1: The types and quantities of medical packages loaded in each drone cargo bay

Serial Number	The Number of MED1 (a)	The Number of MED2 (a)	The Number of MED3 (a)	Weight (lbs.)	Drone Cargo Bay Type	Quantity of Demand (a)
1	1	2	0	6	1	15
2	1	0	1	5	1	42
3	0	0	2	6	1	5
4	2	0	0	4	1	4
5	5	0	1	13	2	8

Ignoring the weight of the drone cargo bay itself, the weight of the drone cargo bay is equal to the weight of the medical package loaded in it.

Constrained by the height of the shipping container: because the drone must unload the cargo on the ground, the height of the shipping container is greater than the height of the drone cargo bay, and the drone G does not meet the requirements, that is, the drone cargo bay of type 1 can be equipped with the drone B, D, type 2 drone cargo bays can be used with drones C, E, F.

Once again, an optimization model for the three-dimensional packing problem is established, and the number of required ISO containers and the type and number of drones in each container are obtained.

7. Question two: K-means clustering algorithm

7.1 Description of the model

This problem uses K-means clustering algorithm. K-means clustering algorithm takes k as a parameter and divides it into k clusters. Using the algorithm, the final result is k cluster centers. The data set in the same cluster has a higher similarity, otherwise it is lower.

K-means clustering algorithm:

Step 1: Randomly select 3 initial points from the data set as the initial cluster center, let I=1,(I) , j = 1, 2, 3

C_i is the ith cluster, n_i is the number of samples contained in C_i, and x is the sample in C_i.

First select $Z_1(1)$ as the disaster point 5, $Z_2(1)$ as the disaster point 4, and $Z_3(1)$ as the disaster point 1 as the initial three cluster centers.

Step 2: Calculate the distance d(x_i,x_j) of the remaining data to the cluster center, and find the shortest distance from the data point to each cluster center, which indicates that the data point is the point with the highest similarity to the cluster center. Finally, the data is attributed to this cluster.

d(x_i,x_j)is the distance between any two points, using the Euclidean distance formula: aggregation center 5, 4, 1 respectively.

d_{21} = 4.41 ; d_{24} = 5.76 ; d_{25} = 8.22 d_{31} = 4.80 ; d_{34} = 4.43 ; d_{35} = 5.29

Therefore, the disaster point 2 is classified as $Z_1(1)$, and the disaster point 3 is classified as $Z_2(1)$. That is: $Z_1(1)$:{2,5} ,$Z_2(1)$ = {3,4},$Z_3(1)$ = {1}.

Step 3: Calculate the average of each cluster as a new cluster center based on the divided data set points.

The new cluster center is:

$Z_1(2) = \{0.315, 0.18, 0.21, -0.82, -0.4\}$
$Z_2(2) = \{0.535, -0.04, 0.21, 1.25, 0.76\}$
$Z_3(2) = \{-0.47, -1.37, -0.83, -0.82, 0.26\}$

Combining the types and quantities of medical packages required for the affected sites covered by different aggregation centers, three ISO containers are distributed to three aggregation centers, and the analysis is:

x_6 Place ISO container One, x_7 place ISO container Two,
x_8 place ISO container Three.

7.2 Model of topic b

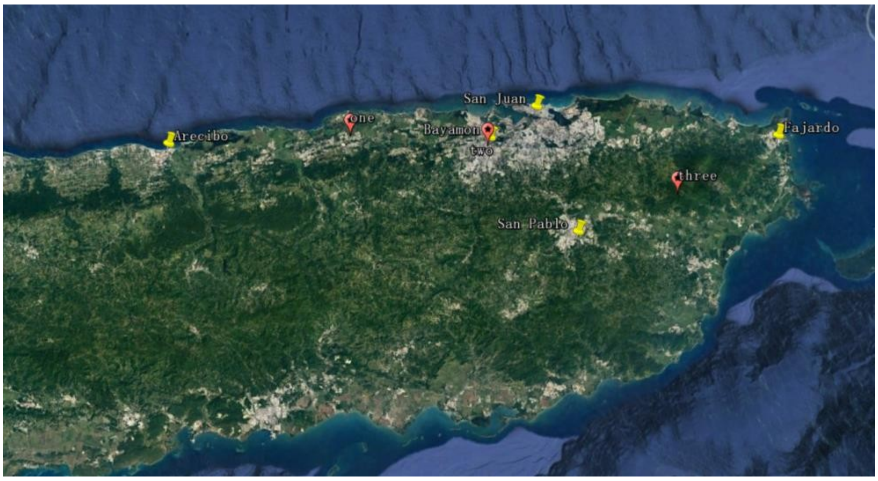

Fig2:Major road and rail maps between three cluster centers and five disaster sites(The purple line in the picture is the path of five disaster-affected points and three aggregation centers with roads or railways)

Since the flight path of the first question has covered all the railways or highways that the UAV can pass, the flight plan of the UAV is the same as the result of the previous question.

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