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2019

MCM/ICM

Summary Sheet

Heuristic Algorithm Based Packing and LP Problems

Summary

The 2017 hurricane brought massive damage to Puerto Rico in the United States, including da mage to buildings, homes, power grids, roads andmore.In order to solve the problem of post-disaster rescue, we need to develop drone aerial rescue system.

First, based on the understanding of the distribution of ports and medical demands on the isla nd, we determined the optimal location and delivery route of the containers in the three ports of Fajardo,Arecibo and San Juan with the goal of the widest coverage of ports, the shortest tra nsportation distance of medical products and the constraint of the flight distance of the drone. Secondly, based on the heuristic algorithm of three dimensional packing , we consider the arr angement and combination of medical packages that can be accommodated in the cargo comp artment of the drone without exceeding the maximum payload of the drone.

Then, in order to better complete the two major tasks of medical package distribution and roa d survey, we defined the value output to measure the value of the drone, and used the improv ed heuristic algorithm under the greedy algorithm to obtain that the combination of the drone with the highest relative value in the container was 36 B and 12 D.

Finally, the combination of the drone in the container and the corresponding combination of t he medical bag were adjusted according to the requirements of the destination medical bag an d the number of main roads within the survey range of the drone in the port, and the payload packaging configuration, scheduling scheme and schedule of the drone were obtained.

Contents

目录

1 Introduction

1.1 Background

As is known to all, natural disasters have always been an important factor in the increase of human mortality. Thousands of people die in natural disasters every year, so it is inevitable to provide immediate relief to the disaster areas.1. In the context of the 2017 hurricane in Puerto Rico, please design a disaster response system to respond to the hurricane disaster situation in Puerto Rico.

1、 determine the packaging configuration of iso cargo boxes, that is, how many types of aircraft should be packed in a cargo box.

2、 determine the packaging configuration of each drone, that is, which kinds of medical bags should be packed in a drone cargo compartment.

3、determine the best location to place three cargo containers to enable delivery of medical supplies and video reconnaissance of the road network.

4、 combined with the drone's packaging configuration, delivery routes and schedules are given to meet the needs of all emergency hospitals in Puerto Rico's hurricane scenario.

5、provide unmanned as flight plans to complete surveys of major roads.

1.2 Our work

1、In order to solve this problem, we establish a comprehensive model. Model 1 is based on multi-objective linear programming, and given constraints are given to solve the packaging problem of drone. Model 3 establishes an algorithm inspired by greedy algorithm.Used to solve the packaging problem of freight containers.Model 2 combines the idea of minimum distance algorithm and the method of multi-objective programming to solve the establishment of the optimal location.

2、Solve the optimal solution set in model 1 to prepare for the next problem analysis.The optimal solution of model 3 is solved so that the sum of the total flying distance of the loaded aircraft can be maximized, which prepares for the next step of problem analysis.The optimal location was solved, and the aircraft model was selected according to the results of model 2, so as to verify whether the comprehensive survey of the main roads of the island could be achieved.

3、According to the results of model 2 and model 3, a complete packing configuration and drone configuration, as well as drone scheduling route and schedule are given based on the local population density, terrain and emergency conditions.

4、Calculate whether the space utilization analysis of complete packing configuration and drone configuration conforms to the actual situation.

5、Sensitivity analysis of models one, two and three was conducted respectively.

6、Analyze the advantages and disadvantages of the model, and improve and popularize it.

2 Preparation of the Models

2.1 Assumptions

Due to the practical conditions such as the complexity of Puerto Rico's terrain, the specific performance of the drone is unknown,etc.. It is difficult to study the problem of how to accomplish the task of medical resource transportation and road network exploration simultaneously by a drone flee. In order to simplify the problem and maintain the correctness of the results, after weighing the pros and cons , we made the following rationalized assumptions as follows:

1、The drone flies high enough.(It will not be affected by high obstacles.)

2、The cost of drones in the course of lifting up and down can be ignored.

3、The medical resources of the hospitals and the medical packages supplied by the drones were enouh until the roads are cleared and the medical packages can be transported on the ground.

4、The effect of medical packages on drones is negligible.

5、It does not take weather, disasters and other emergencies that have an impact on the drone's mission into account

2.2 Notations

The primary notations used in this paper are listed in Table 1. There can be some other notations to be described in other parts of the paper.

Table 1: Notations

Symbol	Definition
n_{ij}	The number of MED_i in cargo of type j drone
$m_{ij'}$	The number of MED_i required for destination j'
W_j	Maximum payload function of type j aircraft
J_i	Cargo Bay Packing Dimensions of drone j
M_i	Emergency Medical Package Dimensions
B_i、L_i^X、W_i^Y、H_i^Z、$C_{i,j}^p$	0-1 variables

3 Weight restricted Modified 3D-packing Model

3.1 The Construction of Solving Model

The model is established to solve the complex problems that how to make the discrete combination to be optimized.To solve the problem of medical package configuration in Task A, we built an improved Model based on the 3d-packing Model.First of all, we need to carry out a series of model preparation, unifying the data and simplifying the complex model.Then,with the goal of maximizing the total weight of the medical packages in the drone.Add the constraint condition that the total weight does not exceed the maximum payload for the first step screening.At last,solve all the solutions in line with the three-dimensional conditions with MATLAB.

3.1.1 General Preparations for Solving Model

1、 The pretreatment of the data

First, we visualized the data and combined the data corresponding to the size of medical packages, shipping container Dimension, maximum payload capacity of drone and weight of medical packages obtained from Attachment 2, Attachment 4 and Attachment 5 in the same table. Then,we unified the units of data.The data processing results are shown in the following table

	Type	Length (in.)	Width (in.)	Height (in.)	Max Payload Capability /Weight (lbs.)
Shipping Container Dimensions	A	45	45	25	3.5
	B	30	30	22	8
	C	60	50	30	14
	D	25	20	25	11
	E	25	20	27	15
	F	40	40	25	22
	G	32	32	17	20
	H	65	75	41	N/A
Drone Cargo Bay Packing Configuration/Dimensions	1	8	10	14	
	2	24	20	20	
Emergency Medical Package Configuration/Dimensions	1	14	7	5	2
	2	5	8	5	2
	3	12	7	4	3

2、Assumptions of the model

(1)Medicine in the medical packages have a stable placement (the placement will not affect the quality of medicine)

(2)The axis of the medical package in three directions keep parallel with three central axes of Drone's shipping container

3.1.2 The Description of model

To maximize the total weight of the medical packages loaded by the drone， the objective function we set is

$$\max(2n_1 + 2n_2 + 3n_3)$$

To satisfy the condition that the total weight of the medical packages combination in the drone does not exceed the maximum payload， the limitation we set is

$$\max\ (2n_1 + 2n_2 + 3n_3) \le W_j$$

The shipping container dimension is $J_j(L_j, W_j, H_j)$

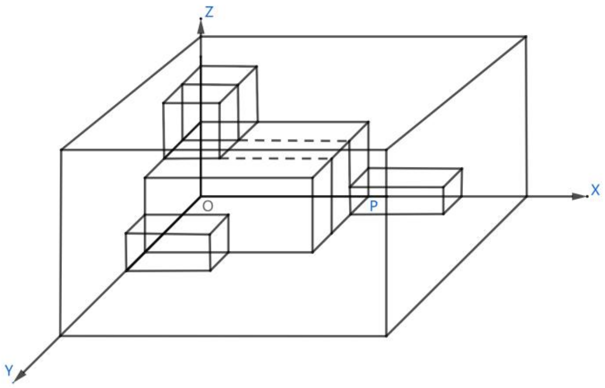
The medical package dimension is $M_i(l_i, w_i, h_i)$

B_i is a variable of 0-1. If MED_i is put into the shipping container, then $B_i = 1$; Otherwise 0.

L_i^X is a variable of 0-1. If MED_i is put into the shipping container and occupy l_i units along the X-axis， then $L_i^X = 1$; Otherwise 0.

W_i^Y is a variable of 0-1.If MED_i is put into the shipping container and occupy w_i units along the Y-axis,then $W_i^Y = 1$; Otherwise 0.

$H_i^Z$is a variable of 0-1. If MED_i is put into the shipping container and occupy h_i units along the Z-axis,then $H_i^Z = 1$； Otherwise 0.

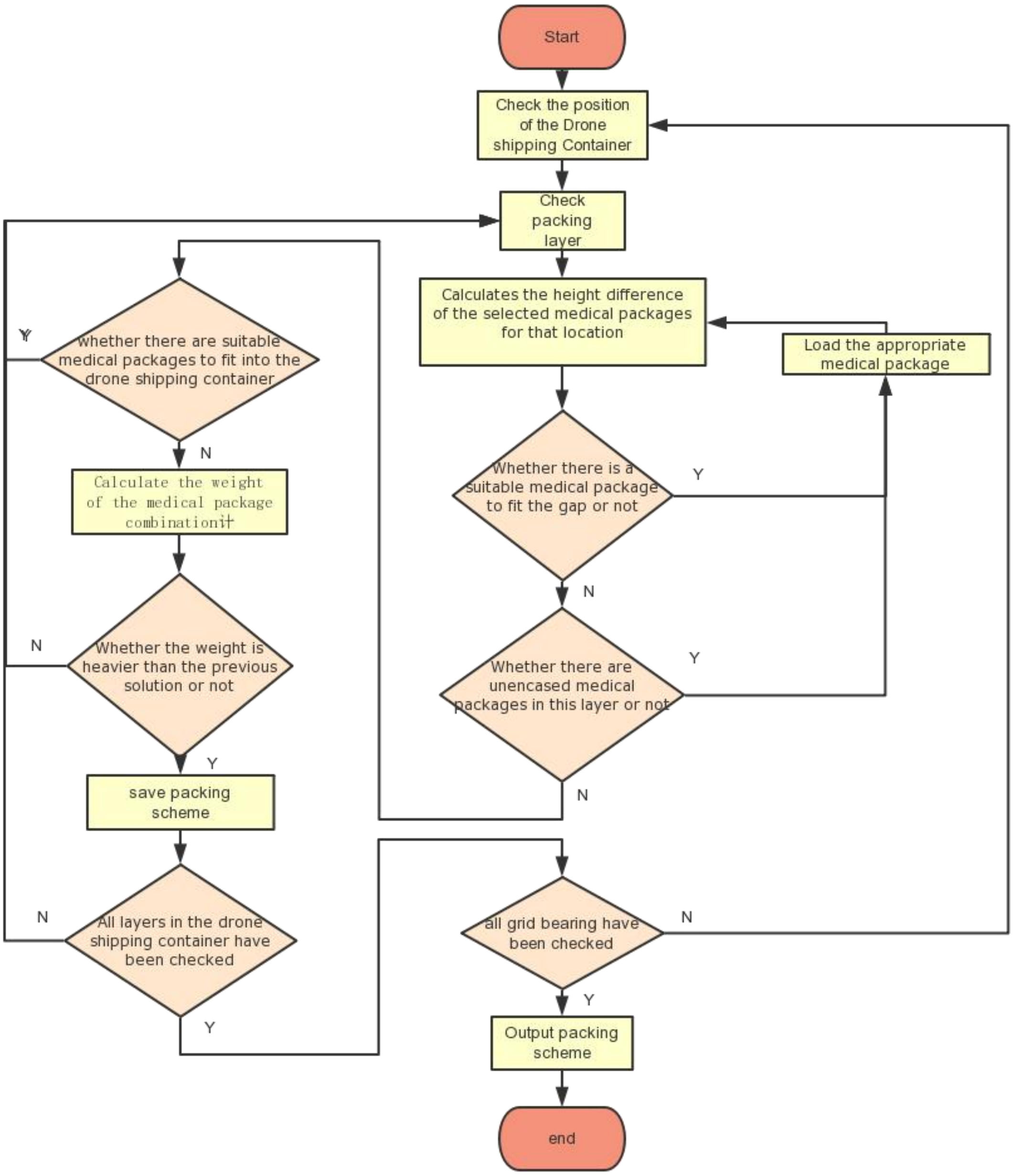


The vertex coordinate of the left posterior lower corner in the cargo compartment of medical packaging is p(x_p,y_p,z_p)（Orthogonal point）， then for drone j ， the followings have got to work：

$$\begin{cases} x_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le L_j \\ y_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le W_j \qquad (i = 1,2,3) \\ z_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le H_j \end{cases}$$

3.2 The process of solving the model

3.2.1 The implementation of the algorithm



3.2.2 The solution result of the model

The final solution of the medical package combinations which can be put into the shipping container are shown in the table as follow：

Type	MED1	MED2	MED3	Type	MED1	MED2	MED3
A	1	0	0	E	0	0	5
	0	1	0		X	6-X	1
	0	0	1		X	3-X	3
B	0	4	0	F	X	11-X	0
	2	2	0		X	8-X	2
	1	0	2		X	5-X	4
	0	1	2		X	2-X	6
	1	3	0	G	X	10-X	0
C	X	7-X	0		X	7-X	2
	X	4-X	2		X	4-X	4
	X	1-X	4		X	1-X	6
D	2	2	1	Note: such as MED1=x ,MED2=6-x, indicates that the condition is satisfied as long as the sum of the two is equal to 6.			
	0	4	1				

3.3 Analysis and conclusion of the model result

As can be seen from the table, the medical package combination of each model is not unique.In particular, the combination of E, F and G drones is more diversified.The final destination of medical package combination is also affected by the design of drone fleet and route allocation, so there are multiple qualified medical package combinations of each drone model with authenticity and scientificity. Therefore, this model is reasonable.

4 Discrete object programming based LP model

4.1 Construction of Solving Model

The model is established to solve the problem of site selection for cargo containers installation in TaskB and route planning for drone fleet in TaskC. Based on the multi-source Weber problem, constraints that satisfy the maximum flight distance of drone were added to the objective with the minimum sum of distances.Finally, the delivery matrix was calculated by matlab, so as to obtain the results of installation address and drone flight path.

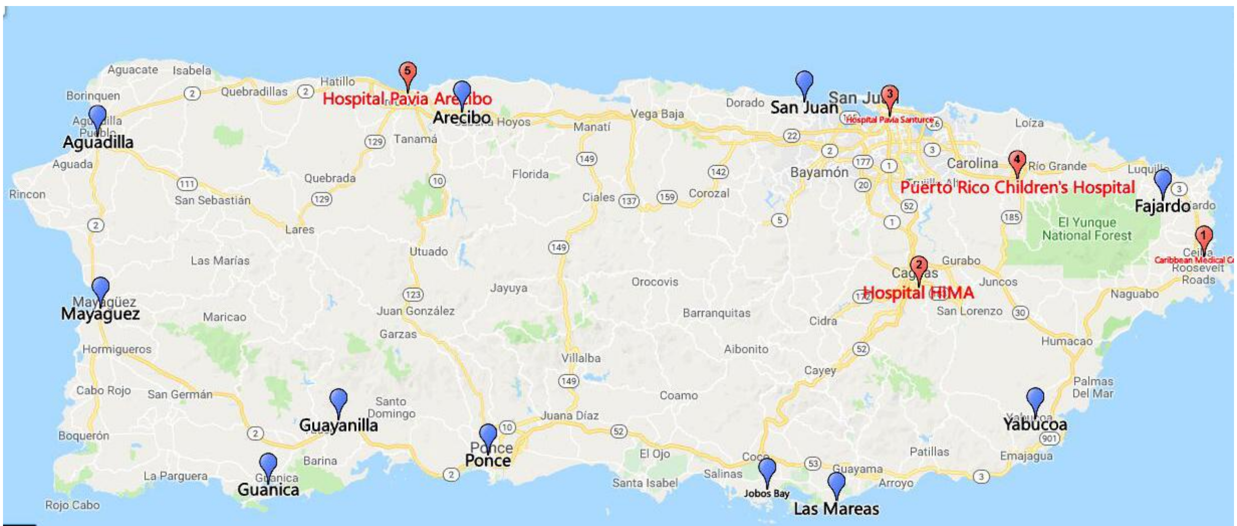
4.1.1 General Preparations for Solving Mode

1、The pretreatment of the data

By official channel, we have the latitude and longitude of all 11 ports available in Puerto Rico.

Shipping Point	latitude	longitude
Aguadilla	18.42	-67.15
Fajardo	18.32	-65.65
Guanica	17.97	-66.9
Guayanilla	18.03	-66.79
Jobos Bay	17.94	-66.19
Mayaguez	18.2	-67.14
Ponce	18.01	-66.61
San Juan	18.46	-66.1
Yabucoa	18.05	-65.88
Arecibo	18.44	-66.64
Las Mareas	17.98	-66.26

The distribution of ports and destinations is shown below:



2、Assumptions of the model

(1) The drone flies in a straight line from the Shipping Point to the Delivery Location.

3、Further processing of data

According to the longitude and latitude of Shipping Point and Delivery Location, we can calculate the linear distance between each Shipping Point and each Delivery Location.

The longitude and latitude coordinates of the shipping points are $G_i(x_{ig},y_{ig})$ .The longitude and latitude coordinates of Delivery Locations are $M_j(x_{jm},y_{jm})$

$$\begin{cases} \Delta x_{ij} = x_{ig} - x_{jm} \\ \Delta y_{ij} = y_{ig} - y_{jm} \\ a_{ij} = \sin^2(\Delta x_{ij}/2) + \cos(x_{jm}) * \cos(x_{ig}) * \sin^2(\Delta y_{ij}/2) \\ d_{ij} = 2R * \arcsin\sqrt{a_{ij}} \end{cases}$$

The distance matrix D_{ij} is

Delivery Location / Shipping Point	Caribbean Medical Center	Hospital HIMA	Hospital Pavia Santurce	Puerto Rico Children's Hospital	Hospiyal Pavia Arecibo
Aguadilla	167.318	125.212	120.441	110.405	46.890
Fajardo	0.460	42.618	47.152	56.985	120.620
Guanica	140.323	97.655	94.894	84.706	29.023
Guayanilla	127.837	85.174	82.349	72.162	20.504
Jobos Bay	62.779	21.876	26.253	21.011	64.688
Mayaguez	166.256	123.786	119.795	109.644	47.224
Ponce	108.020	65.359	63.223	53.125	24.345
San Juan	50.527	13.382	3.466	7.219	70.255
Yabucoa	28.676	18.427	27.623	35.028	96.639
Arecibo	110.506	68.733	63.562	53.556	10.124
Las Mareas	69.857	27.842	29.656	21.956	56.771

The maximum distance the drone is

$$s_i = v_i * t_i$$

The final result is shown in the figure below::

Drone	Speed (km/h)	Flight Time No Cargo (min)	Maximum flight distance (km)
A	40	35	23.333
B	79	40	52.667
C	64	35	37.333
D	60	18	18.000
E	60	15	15.000
F	79	24	31.600
G	64	16	17.067

4.1.2 The process of solving model

According to the analysis of Task B, we first selected three ports to place the containers, and there were 165 possible combinations.

$C^{p}_{i,j}$ is a variable of 0-1. If the i port in the p combination has a drone to deliver the medical package to the j Delivery Location，then $C^{p}_{i,j}=1$;Otherwise 0。 (p=1,2,...165 ; i=1,2,3 ; j=1,2,...,5)

In order to minimize the distance sum of the selected three ports to the corresponding five delivery locations, the medical package can be delivered as soon as possible.We set the objective function is

$$m(p)=\min \sum C^{p}_{i,j} * d^{p}_{i,j}$$

constraints.:

Ⅰ Three ports must have five planes flying to each of the five target hospitals

$$\sum_{i=1}^{3} \sum_{j=1}^{5} C^{p}_{i,j}=5$$

Ⅱ The distance from the port to the target hospital is no more than that of the farthest flying drone

$$d^{p}_{i,j} \leqslant s \quad , (C^{p}_{i,j}=1)$$

The results are shown in the following table:

Shipping Point \ Delivery Location	Caribbean Medical Center	Hospital HIMA	Hospital Pavia Santurce	Puerto Rico Children's Hospital	Hospiyal Pavia Arecibo
Aguadilla	0.000	0.000	0.000	0.000	0.000
Fajardo	0.460	0.000	0.000	0.000	0.000
Guanica	0.000	0.000	0.000	0.000	0.000
Guayanilla	0.000	0.000	0.000	0.000	0.000
Jobos Bay	0.000	0.000	0.000	0.000	0.000
Mayaguez	0.000	0.000	0.000	0.000	0.000
Ponce	0.000	0.000	0.000	0.000	0.000
San Juan	0.000	13.382	3.466	7.219	0.000
Yabucoa	0.000	0.000	0.000	0.000	0.000
Arecibo	0.000	0.000	0.000	0.000	10.124
Las Mareas	0.000	0.000	0.000	0.000	0.000

Z_{ij} denotes the delivery matrix， z_{ij} denotes the distance from the port where the i container is placed to the J destination (If there is no drone flying from shipping port i to destination j,then $z_{ij}=0$）

$$Z_{ij}=\begin{pmatrix} 0.460 & 0 & 0 & 0 & 0 \\ 0 & 13.382 & 3.466 & 7.219 & 0 \\ 0 & 0 & 0 & 0 & 10.124 \end{pmatrix}$$

Thus, the optimal location of the three containers are as follows:

Fajardo、San Juan、Arecibo

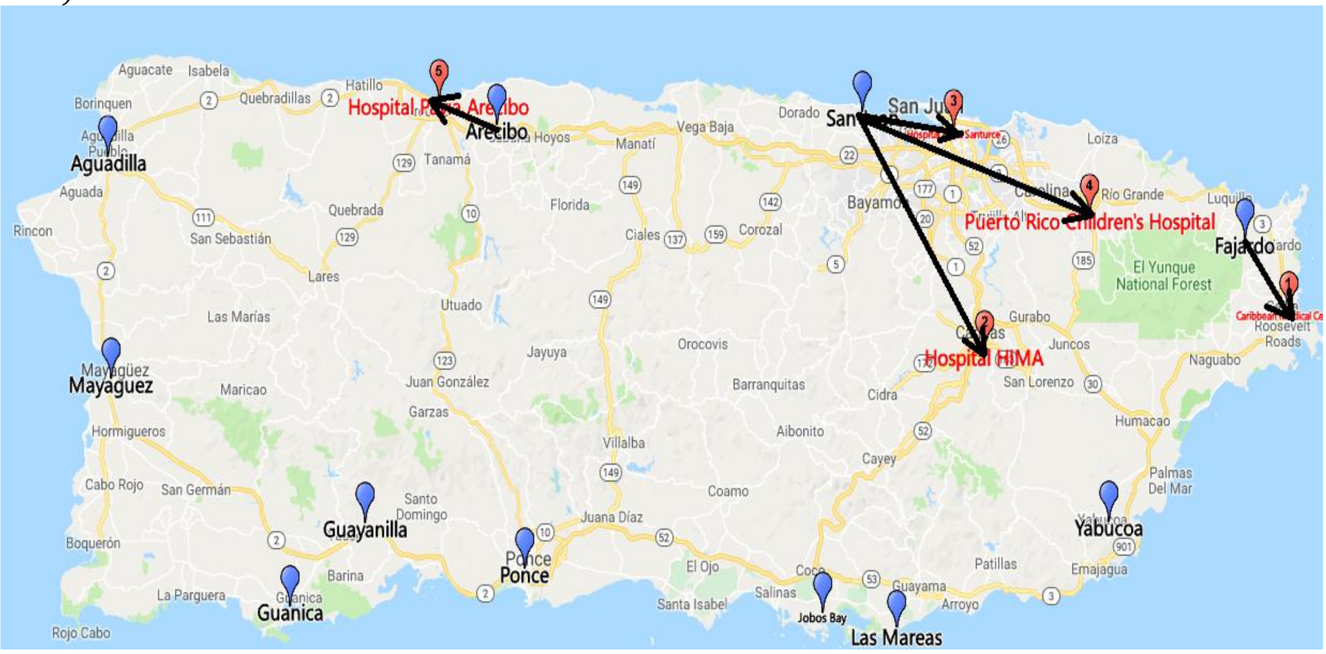
Delivery routes for medical supplies are as follows:

Fajardo→Caribbean Medical Center
San Juan→Hospital HIMA
San Juan→Hospital Pavia Santurce
San Juan→Puerto Rico Children's Hospital

Arecibo→Hospital Pavia Arecibo

4.2 Analysis and conclusion of the results

The location of the three containers and the delivery route of the medical package are shown as follows : (the starting point of the black arrow is the location of the container, the black arrow is the delivery route for medical supplies, and the yellow line is the main highway in Puerto Rico.)



The drone fleet we designed starts from the position of three containers to complete both the transportation of medical packages and reconnaissancing the road network. As shown in the figure, San Juan is located at the convergence of several major highways, and the route roughly coincides with the medical bag delivery route, so the drone in the container located in this port is best to can both delivering the medical packages and the video function. Arecibo is in the northwest part of Puerto Rico and is also home to several major roads, so most of the drones in the container port are used for road exploration in the west.Fajardo, in the eastern part of Puerto Rico, is the safest of several ports closer to the hard-hit southeast.The drones in the container at the port will be used for real-time monitoring of the delivery of Medical packages from the Caribbean Medical Center and the worst-hit areas across Puerto Rico.Therefore, this model has certain rationality and practicability.

5 Maximun relative value Based New Packing Model

5.1 Construction and Solution of The Model

The model is established to solve the problem of new three-dimensional packing which ensures the highest relative value of the combination inside the box.Relative value is an index of how well an aircraft can perform two tasks.Design the configuration of drone formation in container in Task A and the Task requirements of drone formation in Task C.Based on the general 3d boxing model, we define value variables to sort the drone, and give priority to the drone with large loading value when the 3d conditions are satisfied.Finally, we use the heuristic iterative algorithm based on greedy algorithm to calculate the packing strategy with the highest relative value by MATLAB software.

5.1.1 General Preparations for Solving Model

1、The pretreatment of the data

We unified the flying speed and endurance time units of the drone, and calculated the maximum flying distance of the drone with the formula in Excel. The results are shown in the following table.

Drone	Speed (km/h)	Flight Time No Cargo (min)	Maximum flight distance (km)
A	40	35	23.33333333
B	79	40	52.66666667
C	64	35	37.33333333
D	60	18	18
E	60	15	15
F	79	24	31.6
G	64	16	17.06666667

2、Assumptions of model

(1) The effect of medical bag loading on the speed and endurance of the drone is negligible.

5.1.2 The Description of model

First, we discuss the problem of choosing several ports to place three containers in:

(1) Three containers are placed in the same port

At least one of the 11 ports is close enough to five target hospitals to cover the distance flown by the farthest drone ($s = \max s_i$)

$$\exists i_0 \in N_+ \text{ , s.t. , } D_{i_0 j} \le s \quad (i_0 \in [1,11], j = 1,2,\ldots,5)$$

Through calculation, we cannot find any port that meets the conditions, so we exclude the situation that three containers are placed in the same port.

(2)Three containers in two ports or three ports

Through calculation, we find that there are plans to choose two ports and three ports to deliver the medical package to the destination. Considering that the scope of three ports is theoretically wider than that of two ports, we only consider the situation of three ports.

At this time, we set a value variable, and define $r_i = s_i/V_i$ (V_i is the volume of type i drone delivery container), which is used to represent the distance that can be flown within the unit volume of type i drone

$$V_i = l_i' * w_i' * h_i', \quad i = 1,2,\ldots,7$$

(When packing drones, we give priority to drones with high value.)

v_i, t_i ,denotes the flight speed and flight time of type i drone

Since the height of all type of drone does not exceed the height of the container door, the only way to load the drone into the container is to ensure that the size of the drone transport container does not exceed the internal size of the container.

Q(L,W,H) denotes Inside dimensions of container, $F_i(l_i', w_i', h_i')$ denotes outside dimensions of container. Similar to the packing problem in model 1, first satisfies

$$\begin{cases} x_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le L_j \\ y_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le W_j \\ z_p + B_i(L_i^x l_i + W_i^y w_i + H_i^z h_i) \le H_j \end{cases} \quad (i = 1,2,\ldots,7)$$

Secondly, the drone in the container is to complete the task of road survey and medical package distribution. The location and delivery route of the container have been solved in the previous model.

The last step is to solve the problem of medical package distribution. In model 1, an optimal combination of medical packages that can be assembled into the drone has been listed, combining with the medical package requirements of the destination.The variety of medical packages in the drone flying to the destination should be no less than the number required at the destination:

$$n_{ij} \geq m_{ij'}, \quad i = 1,2,3, j = 1,2,,,7, j' = 1,2,,,5$$

The delivery route has been given in model 2. The flight distance of the drone flying out of the port cannot exceed the straight-line distance from the port to the destination:

$$\begin{cases} d_{i1} \leq z_{11} \\ d_{i2} \leq z_{22} \\ d_{i3} \leq z_{23} \\ d_{i4} \leq z_{24} \\ d_{i5} \leq z_{35} \end{cases}$$

5.2 The process of solving the model

5.2.1 The implementation of the algorithm

Step1：initialization

Vector $l(x, y, z)$ denotes three dimensions of a large box. (x,y, and z represent length, width, and height). $v = \{s_i(x_i, y_i, z_i)\}$ $i \in \{1\,2\,...n\}$,v denotes the type sites of small box ,includes n types.(x_i , y_i , z_i denotes three dimensions of a small box.Then the corresponding vector components of each large and small boxes are sorted in descending order .According to the size of value variable, the small box model set is sorted from large to small, so as to get the initial value。

Step2：Prioritize boxes with the highest value variable

$$\begin{cases} k_1 = floor(x / x_{i1}) \\ k_2 = floor(y / y_{i2}) \\ k_3 = floor(z / z_{i3}) \end{cases}$$

（k_i denotes the proportionality constant， $floor$ denotes the integral function downward）

Then， we can know the Number of i box $count_i = k_1 \times k_2 \times k_3$.

Step3:Then divide the remaining space into three boxes.For the three small boxes respectively turn to step two.

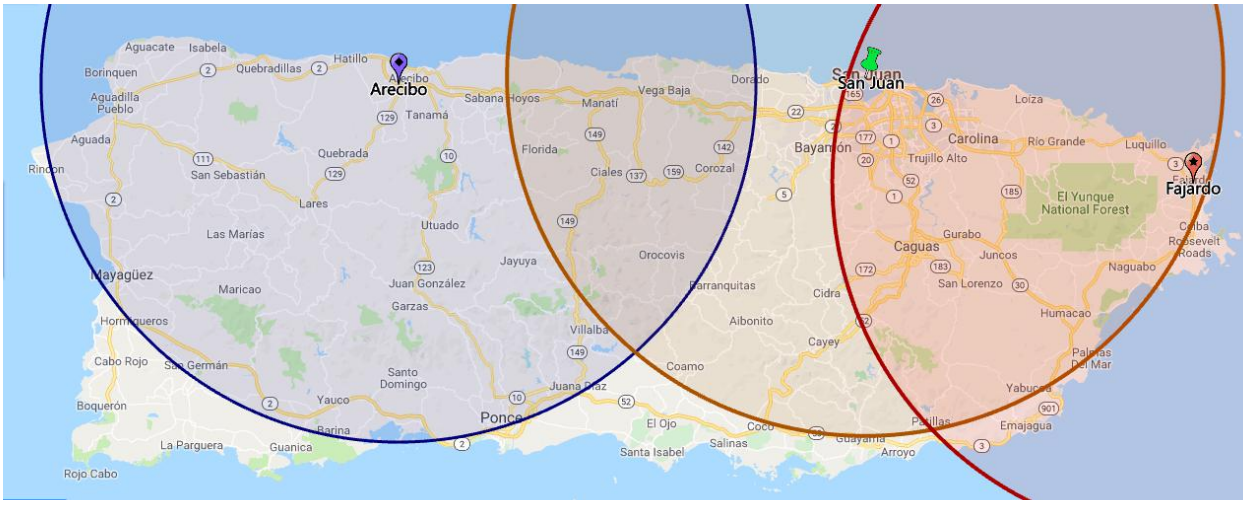
Step4:Until there is no more room for any boxes,count=0.

5.2.2 The solution result of the model

The combination of drones available in containers at each port and medical packages in the drone's cargo hold is shown in the table below

Route	Qualified Drones	MED1	MED2	MED3	Route	Qualified Drones	MED1	MED2	MED3
Fajardo→ Caribbean Medical Center	B	1	0	2	San Juan→ Hospital Pavia Santurce	B	1	3	0
	C	4	0	2			2	2	0
		1	0	4		C	X (≥1)	(7-X) (≥1)	0
	E	6	0	1		D	2	2	0
		3	0	3		E	X (≥1)	(6-X) (≥1)	0
	F	8	0	2		F	X (≥1)	(11-X) (≥1)	0
		5	0	4		G	X (≥1)	(10-X) (≥1)	0
		2	0	6	San Juan→ Puerto Rico Children's Hospital	C	2	2	2
	G	7	0	2			3	1	2
		5	0	4		E	2	1	3
		1	0	6		F	X (≥2)	(8-X) (≥1)	2
San Juan→ Hospital HIMA	C	4	0	2			X (≥2)	(5-X) (≥1)	4
	E	6	0	1		G	X (≥2)	(7-X) (≥1)	2
		3	0	3			X (≥2)	(5-X) (≥1)	4
	F	8	0	2	Arecibo→ Hospital Pavia Arecibo	A	1	0	0
		5	0	4		B	2	0	0
		2	0	6		C	7	0	0
	G	7	0	2		D	2	0	0
		5	0	4		E	6	0	0
						F	11	0	0
						G	10	0	0

According to the above algorithm and Matlab programming, the optimal packing plan of the drone is to load 36 B-type drones and 12 D-type drones into the container.
The maximum coverage of drones routes from three ports is shown in the figure below:



The optimal configuration in the container is 36 B and 12 D (the flight distance of B is greater than D).

(1)Arecibo port: There are drones A, B, C, D, E, F and G (B, D are all in them) to meet the distribution needs. There are about 7 long main highways in the coverage area, so 36 B and 12 D should be loaded into the container, and 7 B are used for video survey (no medical package is loaded), and 29 B are loaded with 2 each,It takes about 10.124÷60×60=10.124 minutes。 A total of 82 days' medical

demand was supplied to the destination. And the space utilization rate was（36×30×30×22+12×25×20×25）÷117÷92÷94×100%=85.272%

(2)Fajardo port：
The drones to meet the distribution needs include B, C, E, F and G (B is included). There are about 10 long main highways in the coverage area, so 36 B and 12 D should be loaded into the container. Among them, 10 B and 12 D are used for video survey (no medical package is loaded), and 26 B are loaded with 1 and 2 each.A total of 26 days' medical demand was supplied, and the space utilization was the same as that of Arecibo port, which was 85.272%

(3)San Juan port： Since the coverage of the drone in this port overlaps with Arecibo and Fajardo for the most part, and the drone in San Juan needs to deliver medical packages to the three destinations (medical packages are in great demand), the containers in San Juan port are mostly used for the delivery of medical packages. The road in the overlapping part is surveyed by the drone in Arecibo and Fajardo.
There are about 3 main highways close to each other and 1 main highway far from each other in the unoverlapped area, so 3 D and 1 B should be arranged for video survey.

Ⅰ、San Juan→Hospital HIMA： There are C, E, F, G (B, D are not among them) to meet the distribution needs. The size of E is similar to that of the transport container of b. therefore, it is considered to replace the distribution medical package of B with E (35 B can be replaced 4×3×4－2=46 E）。
Ⅱ、San Juan→Hospital Pavia Santurce ： The drones to meet the distribution needs include B, C, D, E, F, G (B, D are included), and D is the choice to distribute medical packages (B has a large demand, while D has a surplus).
Ⅲ、San Juan→Puerto Rico Children's Hospital： The same as Ⅰ

Recommendation：
San Juan→Hospital HIMA： Each of the 20 E is loaded with 3, 3， It takes about13.882÷60×60=13.882 minutes。It can supply medical needs of the destination for 30 days.

San Juan→Hospital Pavia Santurce: Each of the 9 D is loaded with 2, 2.It takes about 3.466÷60×60=3.466 minutes.It can supply medical needs of the destination for 18 days.

San Juan→Puerto Rico Children's Hospital： Each of the 26 E is loaded with 2,1,3， It takes about 7.219÷60×60=7.219 minutes.It can supply medical needs of the destination for 26 days.

Therefore, 1 B, 46 E and 12 D should be loaded into the container of San Juan port, among which 1 B and 3 D are used for video survey, and the rest are used to distribute medical packages.The total space utilization is(30×30×22+46×25×20×27+12×25×20×25)÷117÷92÷94×100%=78.157%

Delivery route	The type of drone	The number of drone	MED1	MED2	MED3	the delivery time(min)	Days of medical packages can supply	space utilizatio
Fajardo→Caribbean Medical Center	B	7	/	/	/	/	82	85.27%
	B	29	2	0	0	7.689		
	D	12	2	0	0	10.124		
San Juan→ Hospital HIMA	E	20	3	0	3	13.882	30	78.16%
San Juan→Hospital Pavia Santurce	D	9	2	2	0	3.466	18	
San Juan→Puerto Rico Children's Hospital	E	26	2	1	3	7.219	28	
	D	3	/	/	/	/	/	
	B	1	/	/	/	/	/	
Arecibo→Hospital Pavia Arecibo	B	10	/	/	/	/	/	85.27%
	D	12	/	/	/	/	/	
	B	26	1	0	2	0.349	26	

6 Sensitivity Analysis

6.1 Sensitivity Analysis

6.1.1 Sensitivity Analysis of Model One

This model is established on the premise of nonlinear programming to solve a set of solutions close to the optimal solution, so from the perspective of variable change, the slight change of each variable does not have obvious disturbance to the whole model, and the model is stable.

6.1.2 Sensitivity Analysis of Model Two

In the boxing model, we use the greedy idea to construct a nearly similar solution from the locally optimal idea, so as to achieve the solution of the problem.
Univariate analysis was adopted:
The range fluctuation of each aircraft by 10% yields the following ranking results:

Relative value	Order 1	Relative value	Order 2	Relative value	Order 3
4.61	6	5.07	6	3.69	6
26.6	1	29.26	1	21.28	1
4.15	7	4.56	7	3.32	7
14.4	2	15.84	2	11.52	2
11.11	3	12.22	3	8.89	3
7.9	5	8.69	5	6.32	5
9.8	4	10.78	4	7.84	4

According to our algorithm, when the flight distance of the aircraft changes, the solution of the whole model will remain unchanged as long as the first sorting result of small and medium-sized boxes in the algorithm is not changed.So our model is stable.

6.1.3 Sensitivity Analysis of Model Three

Model 3 is a discrete nonlinear programming solution model. Since we use the longitude and latitude to calculate the distance, a small change in the longitude and latitude will cause a large change in the distance, so we do not plan to measure the sensitivity of the model with the change in the longitude and latitude, but use the solution distance comparison method for analysis.

First, the optimal solution:

Shopping point / Delivery Location	Jajardo	San Pablo	San Juan	Bayamon	Arecibo	min
Aguadilla	0	0	0	0	0	34.6499
Fajardo	0.4603	0	0	0	0	
Guanica	0	0	0	0	0	
Guayanilla	0	0	0	0	0	
Jobos Bay	0	0	0	0	0	
Mayaguez	0	0	0	0	0	
Ponce	0	0	0	0	0	
San Juan	0	13.3817	3.4655	7.2187	0	
Yabucoa	0	0	0	0	0	
Arecibo	0	0	0	0	10.1237	
Las Mareas	0	0	0	0	0	

near-optimum solution：

Shopping point / Delivery Location	Jajardo	San Pablo	San Juan	Bayamon	Arecibo	min
Aguadilla	0	0	0	0	0	45.0303
Fajardo	0.4603	0	0	0	0	
Guanica	0	0	0	0	0	
Guayanilla	0	0	0	0	20.5042	
Jobos Bay	0	0	0	0	0	
Mayaguez	0	0	0	0	0	
Ponce	0	0	0	0	0	
San Juan	0	13.3817	3.4655	7.2187	0	
Yabucoa	0	0	0	0	0	
Arecibo	0	0	0	0	0	
Las Mareas	0	0	0	0	0	

We know our model, each parameter of the slight disturbance, the solution of the impact is not big, so that we can according to the optimal solution of the optimal solution and relative error to estimate sensitivity, kinds of optimal solution and optimal solution of the relative error is large, and our model can be obtained by combination of the solution, is a relatively discrete model, comprehensive the above knowable tiny changes in the other data next time optimal solution or optimal solution.So model 3 is stable.

7 Evaluation and Promotion of Model

7.1 Strength and Weakness

7.1.1 Strength

1、The established model can be closely related to the actual situation, and the proposed problem can be solved according to the actual situation, so that the model is more close to the actual situation, with strong universality and generalization.All our models are solved under the optimal planning conditions based on the main indicators, and then fine-tuned based on the actual situation, and finally an optimal scheduling that conforms to the actual situation is given.
2、By analyzing the actual data, the model not only solves the problem to a certain extent, but also quickly grasps the characteristics of the data and provides reference experience for the establishment of a more reasonable model.
3、The model has no strict restrictions on data distribution, sample size and index, and is suitable for both small sample data and large system with multiple evaluation units and indexes, which is more flexible and convenient.
4、Model 1 has strong operability and wide application range.Model 2 is more accurate based on the shortest path model, and the obtained factor weight is more reliable.Based on the single objective optimal solution, a more detailed scheme is proposed.Model 1, 2 and 3 put forward some general indexes, which can be widely used in other fields.
5、The model is reliable and the research method adopted is portable, but the estimated value may have some deviation.However, the three models have carried out local optimal treatment of the problem respectively, and finally modified the results by integrating various practical factors.In particular, the idea of model three pairs of problems has some originality, which introduces the idea of greed and provides a solution to the three-dimensional packing problem to a certain extent.

7.1.2 Weakness

1、The operation process of the prediction model based on model 1 is rather troublesome, with a large amount of data and a huge operation process, and there are a lot of permutation and combination results of the scheme, which requires manual rationality analysis.
2、There are many random factors in the route making process, such as population density and disaster area emergency, which make the model unable to accurately reflect them.
3、There are many complex factors in the model, so it is impossible to establish a unified goal for programming and solving, resulting in some inconsistencies with the reality.

7.2 Promotion

Model 1 considers that the model is a multi-objective programming based on the problem, which is related to the problem requiring solution in the following part. We cannot carry out the rationality analysis manually, but we should give a reasonable evaluation plan, select the optimal solution in combination with the actual situation based on the solution set close to the optimal solution.Model 2 determines the optimal placement location. We make reasonable assumptions when we do not know the inland traffic. The location can only be selected at the port, which may not be consistent with the reality.The greedy algorithm of model 3 for 3d packing problem is limited to a good solution of this problem, which cannot be generalized for irregular packing problem.

In this paper, a comprehensive model of resource allocation and transportation scheduling is established based on the detailed analysis of hurricane rico.In the model, we combine the actual situation to adjust, and apply the method of local greed and hierarchical programming to solve the problem, and give a relatively good solution.It provides a good reference value for the response of large natural disasters such as earthquakes, hurricanes and so on in the future. The methods and algorithms used in this model can also be extended, such as the multi-target processing method and how to deal with problems in layers.Can be promoted in various fields and aspects.

The memo to the CEO of HELP, Inc.

Dear the CEO of HELP,Inc,

I heard that your company has been asking for the drone scheduling plan in the disaster response system, so we designed a model of the hurricane disaster response system for the hurricane in Puerto Rico, mainly considering the comprehensive survey of roads and meeting the needs of hospitals.In order to solve this problem concretly, we establish a comprehensive model. Model 1 is based on the multi-objective linear programming, and the given constraints are given to solve the packaging problem of the drone. Model 3 establishes an algorithm inspired by the greedy algorithm.Used to solve the packaging problem of freight containers.Model 2 combines the idea of minimum distance algorithm and the method of multi-objective programming to solve the establishment of the optimal location.

The solution results are as follows:
Three ports, Arecibo, Fajardo and San Juan, were selected to place containers, and drones of B, D and E were used for post-disaster rescue.

(1) Arecibo port: 36 pieces of B and 12 pieces of D were loaded in the container, and 7 pieces of B were used for video survey. 29 pieces of B were loaded with 2 pieces each and sent to Hospital Pavia Arecibo, which took about 7.689 minutes to deliver.Twelve Pavia D were delivered to Arecibo Hospital with two Pavia per aircraft, which took about 10.124 minutes to arrive.A total of 82 days' medical demand was supplied to the destination, and the space utilization rate was 85.272%.
(2) Fajardo port container loaded 36 B and 12 D, and 10 B and 12 D for video survey, 26 B perTwo were sent to the Caribbean Medical Center, and the delivery time was about 0.349 minutes.A total of 26 days' medical demand was supplied to the destination, and the space utilization rate was 85.272%.
(3) San Juan port: 1 B, 46 E and 12 D are loaded into the container, among which 1 B and 3 D are used for video survey.Each of the 20 E planes was loaded with 3, and 3 of them were sent to Hospital HIMA, which took about 3.882 minutes to deliver, providing a total of 30 days' medical demand for the destination.Nine Pavia D planes were each loaded with two Pavia, two of which were sent to Hospital Pavia Santurce. They were delivered in about 3.466 minutes, providing a total of 18 days' medical demand at the destination.Each of the 26 E aircraft was loaded with two, one and three to Puerto Rico Children's Hospital, which took approximately 7.219 minutes to arrive, providing a total of 17 days' medical needs at the destination.The total space utilization was 78.157%.

Conclusion:
We analyzed the aircraft flight distance, found through existing aircraft types can meet the survey on the island, so we in order to better implement transport vehicle supplies, make rescue operation smoothly, we will not pay attention to consider the recycling of the plane, but for the higher population density areas and the trunk road survey as the main target model.That's what we got.On the one hand, we found that if we mainly consider the cost, only two containers can meet the demand of the problem. On the other hand, for three containers, some ports have surplus.However, we found that the repeated areas are mostly the southeast coastal areas, where the hurricane disaster is critical.Therefore, we give priority to the comprehensive road survey, the scheduling plan is in line with the reality.

Advice:
In order to achieve the optimal multi-objective of the model, that is, on the premise of meeting the needs of road all-around survey and hospitals, and to save economic costs to a certain extent, I suggest providing more aircraft types with better performance for people to choose.First, the rough real-time route is planned through the satellite map, so as to facilitate the control of vehicles and drones in various aspects, so as to achieve the best support effect.Combined with the terrain and natural conditions at that time, such as must be the main wind direction, try not to fly against the wind, increase resistance.And so on.Finally, I hope our model can be helpful to you. I wish you all the best and every success in your work.

References

[1] Heuristic algorithm for three dimensional packing problem.2014.03.06.
https://wenku.baidu.com/view/31b3ff96195f312b3169a5ea.html

[2] Mathematical modeling algorithm and application. Shoukui Si,China,2015.04

[3] MATLAB and mathematical modeling.Ren Mu,Jianjun Wu,China.2018

[4] The formula for calculating the distance between two points according to latitude and longitude .2017.06.05

http://blog.csdn.net/xiejm2333/article/details/73297004

[5] Decision building of drone online path planning based on IMM.2018.04

www.doc88.com/p-6476486431684.html

[6] Multi-unmanned cooperative task planning research..2017.08.19

https://wenku.baidu.com/view/437b94cc4da50e2524de518964bcf84b9d52d2e.h