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Study of Effective Rescue Based on Optimal Response System

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Abstract

After a worst hurricane, Puerto Rico experienced severe damage and a lack of electricity and medicine. We are required to expound a disaster relief response system called "DroneGo". Thus, we build models to solve the problems including the most medical packages, the optimal medical relief effect and the most comprehensive investigation information. We formulate a modified bin packing model and create an assessment system to seek the optimal configuration of medical packages for each kind of drones in order to meet the demand of medical packages. In the next step, we seek the configuration of drones in different ISO cargo containers to get the maximum of the medical packages supply period. Considering population density, traffic condition and medical relief effect which is given different weights by evaluation function in different areas, we could determine the specific locations of the three cargo containers based on analytic hierarchy method. Based on minimum time of delivering medical packages and maximum detection range of the disaster area, the optimal scheme is obtained by linear programming model. Besides, we design an investigation scheme which can improve our investigation efficiency greatly. In a word, we have almost given full consideration to feasibility, rationality and the actual situation of the island. We wish our solutions to the problem could make contributions to the disaster relief in the future.

Keywords

Natural disaster; Relief response system; Analytic hierarchy; Genetic algorithm.

1. INTRODUCTION

Nowadays, natural disasters still occur frequently and have a great impact on human society. In 2017, a worst hurricane called Maria hit Puerto Rico. It is regarded as the worst natural disaster on record to affect Puerto Rico. Widespread flooding blocked and damaged many highways and roads across the island, so it is nearly impossible for emergency services ground vehicles to plan and navigate their routes. People in Puerto Rico suffered from catastrophic damage and major humanitarian crises and most of the island's population was plagued by floods and lack of resources and medicine, because of a slow relief process. The hurricane also affected Puerto Rico's agriculture and caused great damage.

In Puerto Rico, the Central Mountain Range traverses the east and west, and the terrain stretches from the center to the periphery, from high to low. The coast of Puerto Rico is plain. It is a tropical rainforest climate and the rainfall is sufficient. This kind of geography makes it more vulnerable to hurricanes, especially in the middle of the island. The hurricane Maria's estimated rainfall is shown in Figure 1. After analyzing historic statistics in recent years. We find that most hurricane have similar path and impact to this island like the hurricane Maria. A Non-

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governmental organizations (NGOs) called HELP, Inc. tends to improve its response capabilities by creating a transportable disaster response system called "DroneGo". This response system tends to use rotor wing drones to deliver pre-packaged medical supplies and provide high-resolution aerial video reconnaissance.

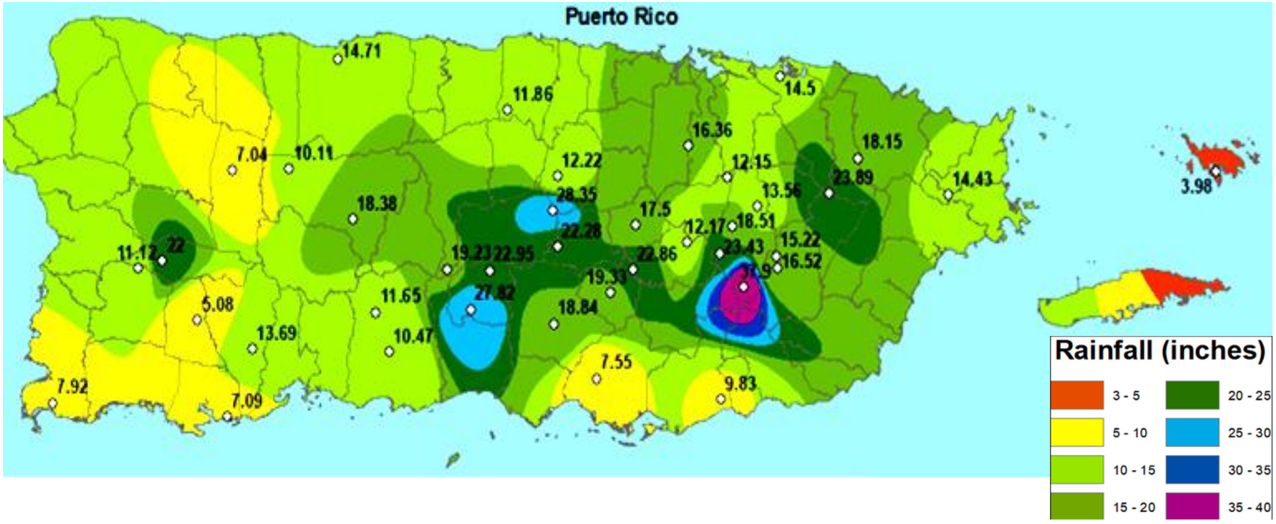

Figure 1. Hurricane Maria estimated rainfall

Our team is employed to design a DroneGo disaster response system based on the situation and the hurricane disaster scenario of Puerto Rico. The disaster response system will take on the mission of implementing anticipated medical supply delivery. At the same time, we will choose suitable drones to make video reconnaissance which is full of significance for further rescue and post-disaster reconstruction. We hope that this DroneGo disaster response system will work in any potential similar future disaster scenario in Puerto Rico.

In this paper, we propose to decompose this problem into three parts:

We build a modified bin packing model to design the medical package configuration plan, then we build a drone configuration model to find optimal packing configuration for each of three ISO cargo containers

We combine population density with traffic condition factors in order to determine the specific locations of the three cargo containers. We want to use some evaluation function to measure different weight of factors in our model.

We utilize constraint condition based on the optimal theory thus providing optimal configuration of the DroneGo fleet and specific delivery scheme of cargo containers. We want to realize the timely delivery and large investigation scope at the same time.

Finally, our team provide a memo to the CEO of HELP, Inc. which summarizes our modeling results and recommendations. We wish that our suggestion could make contributions to the disaster relief research in the future.

2. GENERAL ASSUMPTIONS

The DroneGo disaster response system is ideal in reality and as a result the system include some uncertainty. In order to quantify the uncertainty in actual relief tasks, it is necessary to make some simplifying assumptions. Listed below are several of the general assumptions we make regarding how we meet requirements.

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The emergency medical package can be approximated as a standard cuboid. When we need to pull up several emergency medical package in drone cargo, we assume that those packages will not be damaged.

To simplify the mission, we assume that the loads of drones have no effect on the maximum flight distance. Because compared with the weight of medical packages, the weight of drones is far heavy than packages. At the same time, we assume all kinds of drones can fly at their highest speed all the time.

When we transport ISO cargo containers and the delivery of medical packages, we do not take the effect of weather conditions into consideration. We assume that all the drones can deliver medical packages to the destination and finish their video shooting mission without coincidence.

We assume that drones and medicine are easily transported within a given small area. Under this circumstance, when drones arrive at this area, we could conclude that the drones can be carried back by cargo containers.

Additional assumptions are made to simplify analysis for individual sections. These assumptions will be discussed at the appropriate locations.

3. BASIC MODELS FOR TASK A

In regard to the task A, we view the problem as a modified bin packing problem when we design the associated packing configuration for each of three ISO cargo containers. In the beginning, we use linear regression algorithm to equip the cargo of each drone with optimal configuration considering the requirement of specific disaster areas and the utility rate of drone cargo.

3.1. Symbols and Definitions

In our model, we use some symbols for constructing the model as shown in Table 1.

Table 1. Symbols for constructing the model

Symbol	Meaning
Loc.1	Caribbean Medical Center Jajardo
Loc.2	Hospital HIMA San Pablo
Loc.3	Hospital Pavia Santurce San Juan
Loc.4	Puerto Rico Children's Hospital Bayamon
Loc.5	Hospital Pavia Arecibo Arecibo
d_{ij}	Distance between Loc. i and Loc. j
x_i	The weight of medical package i
T	A benefits target function
n	The number of parcels per unit area
$\tilde{n}$	The unitized number of parcels per unit area
t	Flight time of drones
$\tilde{t}$	Unitized Flight time of drones
λ_i	Artificial coefficients
M_i	The max payload capability of type i

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3.2. Medical Package Configuration Model

After preprocessing the information of disaster situation and the requirement of medical packages of the five location, we mark the five locations on the map of Puerto Rico intuitively. We use histogram to indicate the different quantities of medical packages.

We find that the total proportion of medicine 1, medicine 2 and medicine 3 is:

3.5: 1: 2 (original value is 7: 2: 4)

Assumed that each emergency is a standard cuboid, we calculate the volume of three kind of packages. Their proportion is:

2.45: 1: 1.68 (original value is 490: 200: 336)

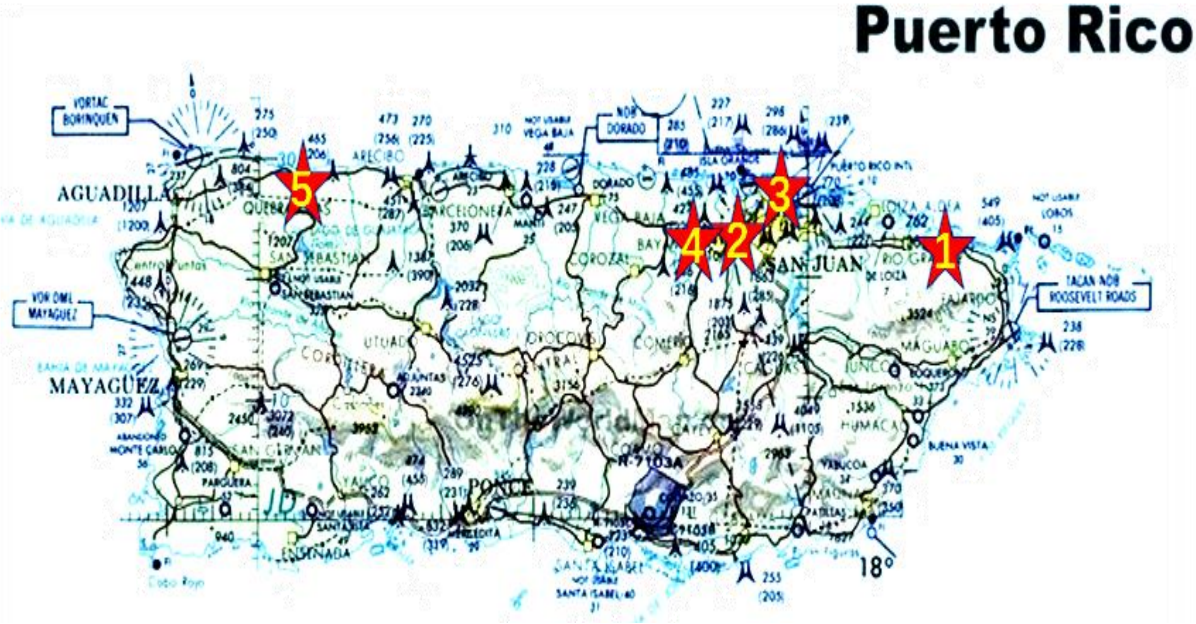

Figure 2. Location on the map of Puerto Rico

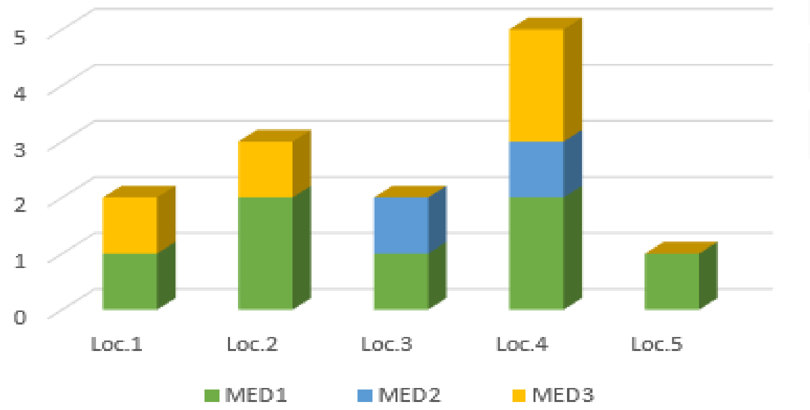

Figure 3. Medical packages' requirement

For drones A, B and D, their drone cargo bay type is No.1 (8 in*10 in*14 in). Considering that the volume of this type of drone cargo bay is close to medical packages. We try to list all the possibility of drone A, B and D's medical package configuration. In those possible cases, we measure the requirement and the utility rate of drone cargo with the aim of finding the optimal scheme of these three kinds of drones.

We find the optimal equipment scheme of drone A, B and D are:

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A: one medical package 1
B: two medical package 1
D: four medical package 2

For drones C, E, F and G, their drone cargo bay type is No.2 (24 in*20 in*20 in). In order to measure the optimal package configuration better, we weigh the utility rate of drone cargo and the medical package requirement of the five location. Combined with literature, we conclude that the utility rate just as importance as medicine requirement. Based on this theory, we give the same weight of utility rate medicine requirement. So we come to the target function T :

$$T = 5.95x_1 + 2x_2 + 3.68x_3 \tag{1}$$

For further discuss, the total weight of medicine packages in drone cargo should less than the max payload capability. At the same time, the total volume packages should also less than the volume of drone cargo of drone cargo bay type 2. Using the linear regression constraint method, we find the constraint of this model:

$$\begin{cases} 2x_1 + 2x_2 + 3x_3 \le m_i \\ 490x_1 + 200x_2 + 336x_3 \le 24 \times 20 \times 20 \\ x_1, x_2, x_3 \in N \end{cases}$$

We find the optimal configuration scheme of drone C, E, F and G are:

C : seven medical package 1
E : five medical package 3
F : eleven medical package 1
G : ten medical package 1

3.3. Drone Configuration Model

After finding the optimal allocation of medical package to each kind of drones, we set out to design optimal drone configuration for each of three ISO cargo containers.

In view of the situation of the Puerto Rico, we need to meet the daily requirement of five locations without interrupt. On the other hand, considering that the three ISO cargo containers need to be shipped to the island, we intend to make the transportation period as long as possible. We define the optimal Drone configuration Model is that the transportation period should long and the medical package carried in drones cargo should also meet the requirement of five locations.

With the aim of maintaining the constant supply of medical packages, we want to enable drones to cover areas as large as possible. After analyzing the distances between locations and the maximum flight distance of drones. We find that the distance between Loc.5 and Loc.4 is 60.6982 km. At the same time, the drone B owns the maximum flight distance of seven drones, which is 50.6km. In order to ensure drones could come back to the starting point, the valid flight distance is 25.3km. That is to say, if we set a ISO cargo container between Loc.5 and Loc.4, we can not cover the requirement of the two locations, which lower the transport benefits. Based on the analyses above, we determine to set three locations of three ISO cargo containers preliminarily: ①, ② and ③. We also specified the locations for drones in the ISO cargo containers, which is shown in picture 4.

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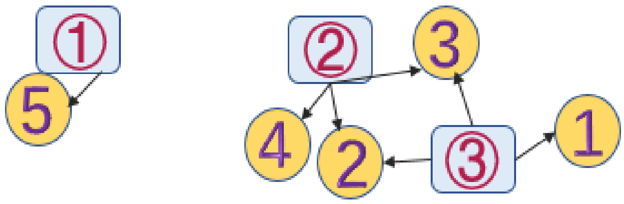

Figure 4. Coverage areas of ISO cargo containers

Next, We choose two performance of the seven kind of drones, one is the number of parcels per unit area (n), the other is flight time (t).

Considering the weight between the number of parcels per unit area and flight time, we assume that the flight time is more important than the number of parcels per unit area because the longer flight time is beneficial for the distribution of medical packages. The longer flight time also means the larger areas where drones can finish video mission which is also helpful for further relief process. We assume a ratio α .Thus, we determine the weight of the number of parcels per unit area is 0.4, and the weight of flight time is 0.6. In order to make the data comparable, we have unitized them. We use unitized data $\tilde{n}$ and $\tilde{t}$ to indicate the performance of the two indexes.

The evaluation function of drones is:

$$S = \alpha \times \tilde{n} + (1\text{-}\alpha) \times \tilde{t} \tag{2}$$

Thus, we use this method make an evaluation of all kinds of drones as shown in Table 2.

Table 2. Evaluation of drones

Drones	A	B	C	D	E	F	G
n	$\frac{1}{2025}$	$\frac{2}{900}$	$\frac{7}{3000}$	$\frac{4}{500}$	$\frac{5}{500}$	$\frac{11}{1600}$	$\frac{10}{1024}$
$\tilde{n}$	$\frac{100}{2025}$	$\frac{200}{900}$	$\frac{700}{3000}$	$\frac{400}{500}$	$\frac{500}{500}$	$\frac{1100}{1600}$	$\frac{1000}{1024}$
t	23.33	52.67	37.33	18	15	31.6	17.07
$\tilde{t}$	$\frac{23.33}{52.67}$	$\frac{52.67}{52.67}$	$\frac{37.33}{52.67}$.	$\frac{18}{52.67}$	$\frac{15}{52.67}$	$\frac{31.6}{52.67}$	$\frac{17.07}{52.67}$
S	0.2855	0.6889	0.5186	0.5251	0.5709	0.6350	0.5851

As is vividly shown in the table above, we find that drones B, D, E, F have better performance in the evaluation of the number of parcels per unit area and the flight time. Thus, we will give priority to these kinds of drones when we allocate drones for medical package delivery.

According to our definition of the optimal model, our basic rule is to ensure the total period of shipping three ISO cargo container as long as possible. Combined with the volume of ISO cargos, we divide the total quantities of every ISO cargo container into several small period P, which means the most efficient transporting plan. Our goal is to make a balance between the total shipping period and daily medical package requirement and find the maximum of the value of P.

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First, for the Loc.5, we have expounded the reason why we set an independent ISO cargo container for the supply of the location. We call the independent ISO cargo container as cargo 1 in short. At the same time, Loc.5 only need one MED1 package daily, which means that the supply period for Loc.5 hardly have impact on the general configuration case.

Then, we optimize the cargo 2 and cargo 3. In view of the distance between Loc.2, 3 and 4, we think that the cargo 2 and cargo 3 both can provide the medical packages for the two locations. At the same time, cargo 2 provides the medical packages for the Loc.4 and cargo 3 provide the medical packages for the Loc.1. In addition, we also should take the quantity and the requirement of medical packages into consideration. When it comes to the medical package configuration of drones, we will use the schemes we have calculated in the Medical package configuration Model above.

We also use the linear regression constraint method to find the optimal drones configuration for the two cargos.

We should ensure the transported quantities of MED3 more than the requirement of Loc.2 and 4 during a period:

$$2\lambda_1 \times 5 + 10\lambda_3 - P \geq 3P$$

We should ensure the transported quantities of MED1 more than the requirement of Loc.2, 3 and 4 during a period:

$$26 + 11\lambda_2 - P \geq 5P$$

We should ensure the transported quantities of MED2 more than the requirement of Loc. 3 and 4 during a period:

$$2\lambda_4 \times 4 \geq 2P$$

Thus, we expect to use the constraint to calculate the maximum value of P, we conclude all the inequations above:

$$\begin{cases} 2\lambda_1 \times 5 + 10\lambda_3 - P \geq 3P \\ 26 + 11\lambda_2 - P \geq 5P \\ 2\lambda_4 \times 4 \geq 2P \\ \lambda_i \in N \end{cases} \tag{3}$$

After simplifying and rearranging the inequations above, the problem can be transformed into:

$$\max\left\{\min\left[\frac{10(\lambda_1+\lambda_3)}{4}, \frac{11\lambda_2+26}{6}, 4\lambda_4\right]\right\} \tag{4}$$

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3.4. Solution and Result

Using the mathematical software MATLAB, we can conclude the value of days that a suit of medicine and drones packing configuration can maintain for the five disaster locations daily:

$$P = 4$$

It's worth noting that P only indicate the longest time that a suit of our packing configuration can provide necessary medical packages for the five locations.

In view of the volume of ISO cargo containers, we want to make full use of the volume of cargoes to maximize the function and find a optimal shipping plane for the disaster island.

Using Genetic algorithm, we calculate the cargo 2 can accommodate 8 suits of our medicine and drones packing configuration. Every suit of our packing configuration can satisfy daily requirement of the five location. In view of the cargo 2 in our model taking on the most mission of distributing medicine to disaster areas, we can conclude that if we make full use of the volume of cargo 2 and put into more suit of our medicine and drones packing configuration as possible, we will achieve our optimal solution to the configuration. After using the Genetic algorithm and linear regression constraint method we calculate the maximum value of day that the three ISO cargo containers can satisfy daily requirement of the five location:

$$P_{\max} = 32$$

The result indicates that our ISO cargo containers' packing configuration can satisfy thirty-two days' requirement for the five locations, which means a suit of drones can provide thirty-two days' medical packages requirement. In addition, our result also takes time, benefits and efficiency into consideration.

Under this condition, we can allocate suitable drones and medical package configuration based on our result in basic model for task A. Our ISO cargo containers' packing configuration results is shown in Table 3.

Table 3. ISO cargo containers' packing configuration

ISO Cargo container	Cargo ①	Cargo②	Cargo③
packing configuration	1*B (2MED1) 1*F (11MED1)	1*B (2MED1) 2*D (2*4MED2) 2*E (2*5MED3) 2*F (2*11MED1)	1*B (2MED1) 2*E (2*5MED3) 1*F (11MED1)

4. MODEL FOR TASK B

4.1. Preparation for the Model

In regard to the task B, we need to identify the best locations on Puerto Rico to position the three cargo containers that we have discussed in the former of the paper. We also expect the DroneGo disaster response system can be able to conduct both medical supply delivery and video reconnaissance of road networks at the same time as effectively as possible

In order to make the problem more intuitive to explain, we set the Loc.5 as the origin of coordinates. We change the provided latitude and longitude data into distance with the function of distance in MATLAB (Figure 5).

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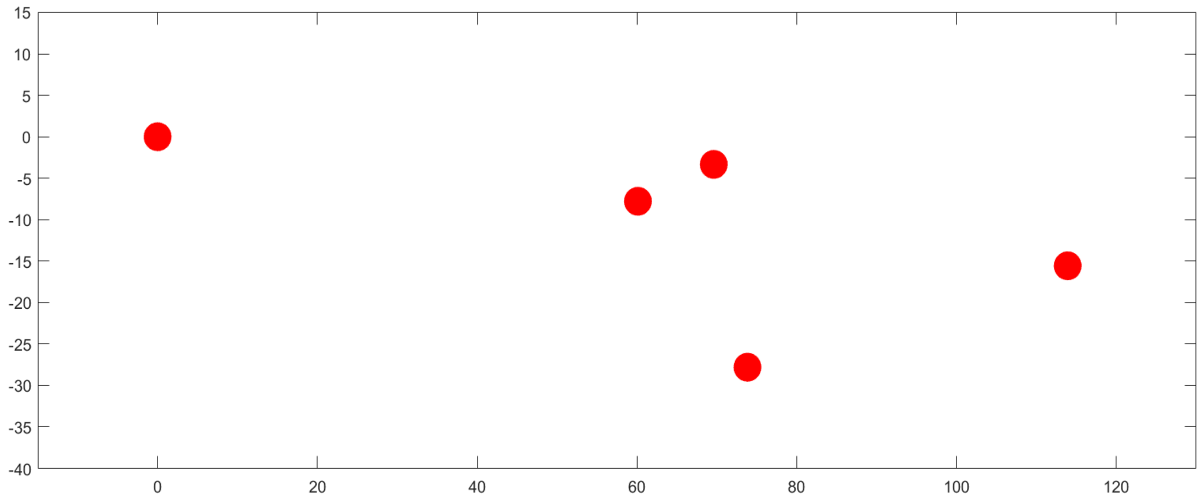

$$(x_1, y_1) = (113.90, -15.56)$$
$$(x_2, y_2) = (73.83, -27.80)$$
$$(x_3, y_3) = (69.61, -3.34)$$
$$(x_4, y_4) = (60.12, -7.78)$$
$$(x_5, y_5) = (0, 0)$$

Figure 5. The location of five hospitals

4.2. Contents of Our Model

We define the spy information efficiency function as SIE. The function has strong relationship between the people around the area and the traffic condition of the area. Even if we can not find the clear relationship, we are confident that the outside wants to know the condition of resident areas which is beneficial to carry out latter rescue activity. In addition, the drones should also spy the roads condition, which contributes to the recovery of disaster areas. Based on the theory above, we come to the function:

$$SIE = f_1(people) + f_2(road) \tag{5}$$

According to the basic model for task A, we have discussed the reason why we set the cargo 1 only providing medical packages for Loc.5. When we choose the suitable location of cargo 1, we also want that the drones can shot more situation of main roads and living areas. With the aim of finding the optimal location of cargo 1, we use the graph above based on distance. Considering the maximum flight distance is 52.66km, we need to ensure the drones have enough electricity to return. Thus, the maximum of the radius of the coverage area is 26.33km (Figure 6).

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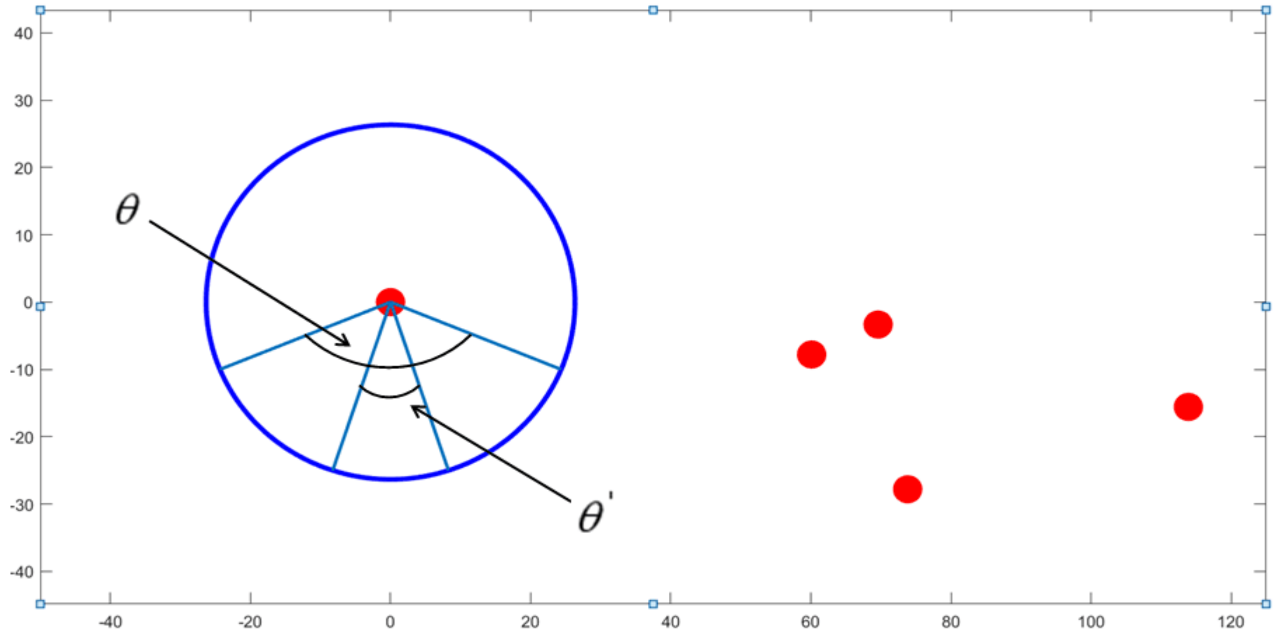

Figure 6. Investigation scope picture

We assume the spot of cargo 1 as (a_1, b_1).We are confident that the optimal location of cargo 1 is on the A circle centered at the Loc.5. The equation of the circle is:

$$a_1^{\ 2} + b_1^{\ 2} = 26.33^2$$

In order to find the spot, we assume the angle of the drones' view is θ, and the angle of expected spying area is θ', we can use limited time $\frac{\theta'}{\theta}$ to locate the best spot of the cargo 1. Combined with the function SIE, we should choose the location that have population center and main road. From the map of Puerto Rico, we choose a main road near Loc.5. Then we choose five typical spots on the road (Figure 7).

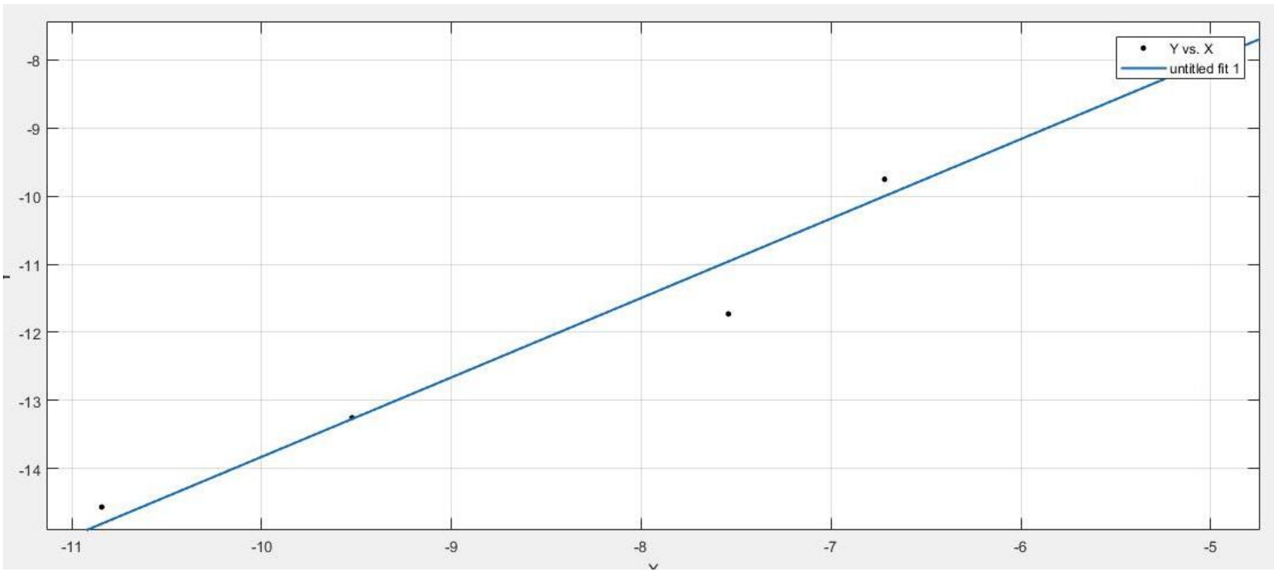

Figure 7. Liner fitting result

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Using liner fitting method, we draw the equation of a_1 and b_1:

$$b_1 = 1.167a_1 - 2.159$$

Solving the two simultaneous equations:

$$\begin{cases} a_1^{\ 2} + b_1^{\ 2} = 26.33^2 \\ b_1 = 1.167a_1 - 2.159 \end{cases} \tag{6}$$

We find the optimal spot of cargo 1 on the coordinate based on distance:

$$\left(a_1^{'}, b_1^{'}\right) = \left(-16.04, -20.07\right)$$

We convert the coordinate of the cargo 1 into latitude and longitude. The standard coordinate of ISO cargo container 1 on the map is:

$$\left(a_1, b_1\right) = \left(18.29, -66.88\right)$$

When it comes to the specific location of ISO cargo container 2 and 3, we need to set up an evaluation mechanism to measure the requirement and the benefits of different medical packages. For the medical packages, they have two measurable performance: weight (W) and package dimensions (D). We assume a ratio β, In this model, the ratio is 0.5. In order to make the data comparable, we have unitized them. We use unitized data $\tilde{W}$ and to $\tilde{D}$ indicate the performance of the two index. The evaluation standard function (G) is:

$$G = \beta\tilde{W} + \left(1\text{-}\beta\right)\tilde{D} \tag{7}$$

Thus, we use this method make an evaluation of all kinds of medical packages as shown in Table 4.

Table 4. Evaluation of medical packages

Package ID	MED1	MED2	MED3
W	2	2	3
$\tilde{W}$	$\frac{2}{3}$	$\frac{2}{3}$	1
D	490	200	336
$\tilde{D}$	1	$\frac{200}{490}$	$\frac{336}{490}$
G	0.8333	0.5374	0.8429
$\tilde{G}$	0.3764	0.2438	0.3808

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After analyzing the performance and the weight of medical packages, we should take the different requirement of different locations into consideration, especially for the Loc.1, 2, 3 and 4.Based on the medical package evaluation function G above, we unitize the value of three kinds of packages and calculate their value. Then we combine the requirement of different locations.

We build an area requirement evaluation function E :

$$E=\sum_{i=1}^{3}\tilde{G}\times n_i \tag{8}$$

Table 5. Area requirement evaluation

	Loc.1	Loc.2	Loc.3	Loc.4
MED1(0.3764)	1	2	1	2
MED2(0.2438)	0	0	1	1
MED3(0.3808)	1	1	0	2
E	0.7572	1.1336	0.6202	1.7582

As is shown in the area requirement evaluation function, the higher value the function is, the more urgent the medical packages are needed. That is to say, we should give priority to the locations where medicine is need urgently such as Loc.2. In order to deliver medical packages to the worse disaster areas.

Because the quantities of medical packages for specific locations are fixed, the only thing we can change is the distance between specific location and ISO cargo containers that will deliver medical packages for the location.

Thus, we build a deliver damage evaluation function g :

$$g=E\times d \tag{9}$$

In this function, d means the distance between specific location and expected supply ISO cargo containers. The deliver damage evaluation function indicates the degree of ineffective delivery when we transport drones to specific locations. Considering the cargo 2 and cargo 3 need to cover three locations separately, we summarize the deliver damage evaluation function. Our goal is to decrease the ineffective delivery that is to say, we intend to find the minimum value of Z . Based on the result we calculated, we can locate the specific location of the two cargo containers

$$Z=\sum_{i=1}^{n}g_i \tag{10}$$

For the cargo2:

$$Z=1.1336\sqrt{\left(x_2-a_2\right)^2+\left(y_2-b_2\right)^2}+0.6202\sqrt{\left(x_3-a_2\right)^2+\left(y_3-b_2\right)^2}+1.7582\sqrt{\left(x_4-a_2\right)^2+\left(y_4-b_2\right)^2}$$

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Using mathematic software, we find the optimal spot of cargo 2 on the coordinate based on distance:

$$\left(a_2^{'}, b_2^{'}\right) = \left(60.12, -7.78\right)$$

We convert the coordinate of the cargo 1 into latitude and longitude. The standard coordinate of ISO cargo container 1 on the map is:

$$\left(a_2, b_2\right) = \left(18.40, -66.16\right)$$

For the cargo3:

$$Z = 0.7572\sqrt{\left(x_1 - a_3\right)^2 + \left(y_1 - b_3\right)^2} + 1.1336\sqrt{\left(x_2 - a_3\right)^2 + \left(y_2 - b_3\right)^2} + 0.6202\sqrt{\left(x_3 - a_3\right)^2 + \left(y_3 - b_3\right)^2}$$

Using mathematic software, we find the optimal spot of cargo 3 on the coordinate based on distance:

$$\left(a_3^{'}, b_3^{'}\right) = \left(87.84, 19.09\right)$$

We convert the coordinate of the cargo 3 into latitude and longitude. The standard coordinate of ISO cargo container 1 on the map is:

$$\left(a_3, b_3\right) = \left(18.30, -65.90\right)$$

So far, we have determined the three optimal locations we choose for the three different cargo containers (Table 6).

Table 6. Locations of ISO cargo containers

ISO Cargo Container	Latitude	Longitude
Cargo 1	18.29	-66.88
Cargo 2	18.40	-66.16
Cargo 3	18.30	-65.90

To make our conclusion more intuitive, we spot the specific location of three ISO cargo containers on the graph based on latitude and longitude. The five red spot symbolize five locations and three blue spot symbolize three locations of ISO cargo containers (Figure 8).

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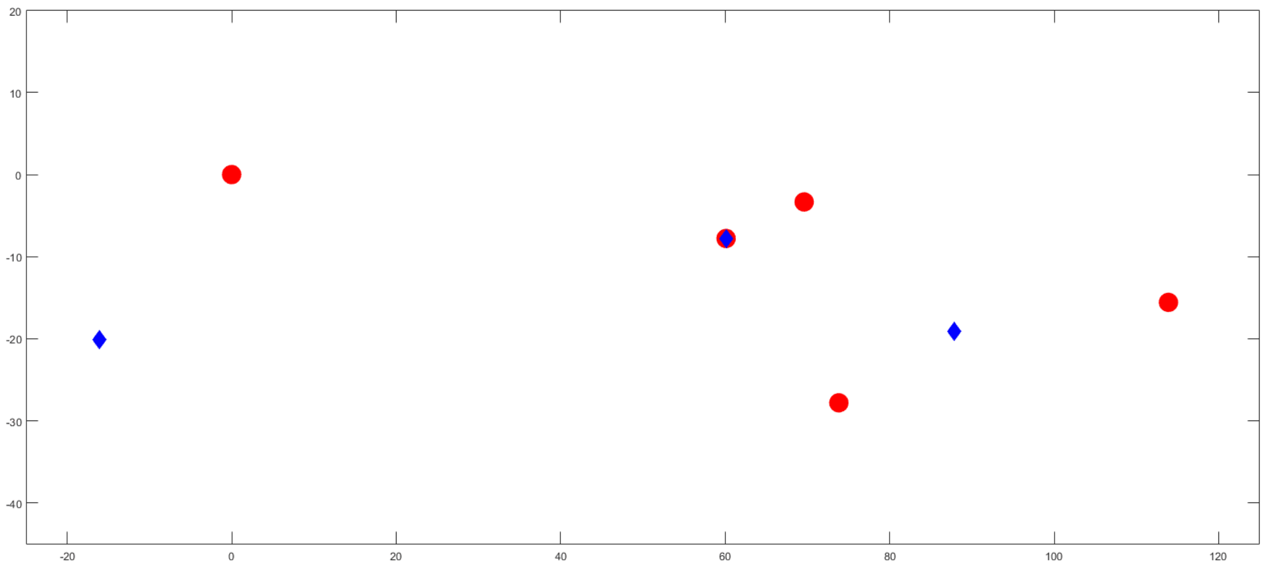

Figure 8. Locations of hospitals and ISO cargo containers

5. MODEL FOR TASK C

5.1. Scheme of Delivery Configurations

As for task C, we plan to provide the drone payload packing configurations and the delivery routes for each type of drone included in the DroneGo fleet. Generally, after measuring the weight of medicine requirement and the video shooting mission, we consider that meeting the requirement of medical packages is more important. For the disaster areas, we should deliver the necessary medicine as quick as possible. In the next step, we can take video shooting mission into consideration.

In view of the maximum flight distance of drones, we can conclude that drone B have advantages over other types of drones. In addition, drone B have the highest speed among these drones. Based on the principle that we satisfy the requirement of medical packages first, we give great priority to the drone B. We also take the max payload capability into consideration. The farthest distance in our initial model is from cargo 3 to Loc.1 which is within the maximum flight distance of drone B. We find drone B can finish all the delivery mission from a cargo to a specific location. Thus, we determine that we will use drone B to finish the delivery mission all the time.

On the other hand, we also want to allocate the specific mission for each of three cargo containers. After combining the distance and the capability of drones, we verify our thought proposed in the basic model for task A. Based on the specific location of three cargo containers and five locations, we draw a graph of their location and their mission in the disaster response system (Figure 9).

According to the model for task B, we have set the specific location of the three cargo containers. For the cargo container 1, the cargo only needs to meet the requirement of Loc.5.We noticed that cargo 2 have the same location with Loc.4, which means that we need not take the medical package configuration for Loc.4 into consideration. That is to say, we only need to arrange the drones plan of cargo 2 for Loc.2 and Loc.3. In a word, cargo 1 need to serve Loc.5; cargo 2 need to serve Loc.2,3 and 4 but we need not distribute drones delivering medicine for Loc.4, and cargo 3 need to serve Loc.1, 2, and 3.

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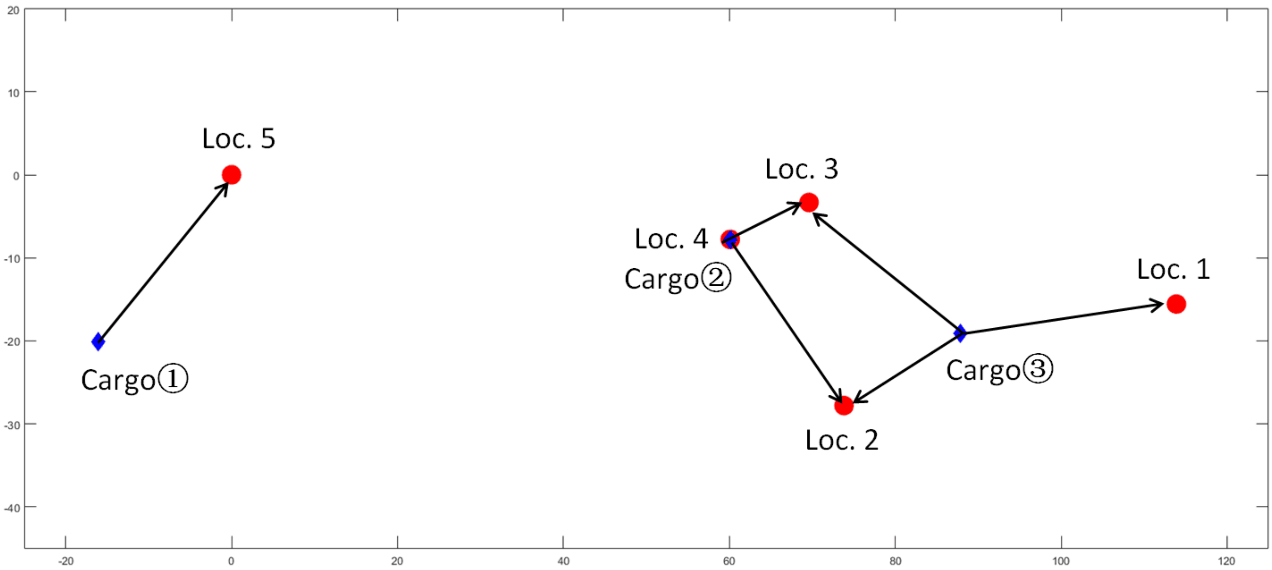

Figure 9. Specific delivery scheme of cargo containers

In order to determine the final number of drones delivering necessary medical packages, we expect to find an optimal scheme that will deliver medical packages as quickly as possible and investigate large area of disaster areas.

Considering the urgency of medicine, we assumed that the drones will fly to the destination in a straight line. When those drones come back to the cargo containers after finishing their deliver mission, they will fly in a broken line with the aim of shooting larger scale of disaster areas. On account of we want to make full use of the flight distance, every flight will reach their maximum flying distance when they come back to the cargo container. Based on this thought, we can view the video shooting area as an ellipse. In order to obtain the optimal configuration scheme of drones, we define the meaning of optimal model. We will use the liner constraint method build the model.

As is stated above, we have several flight route from a cargo container, we call these routes as i, and $i = 1 or 2 or 3$. Thus, we assume the distance between cargo containers and locations as d_i. This distance should less than the maximum flight distance of drone B. We can conclude:

$$d_i \leq \frac{1}{2} \max F_b$$

Next, we create a function h about the time of medicine package delivery of different routes. We expect to calculate the minimum value of function:

$$\min \sum_{i=1}^{i} h(t_i)$$

Then we start to take the factor of investigation scalp into consideration, when the drones come back to the cargo containers, we hope the drones could shoot larger scale of disaster area for us. We create a function b about the scale that a crane can shoot. This function indicates the efficiency of the shooting mission of drones. Thus, we expect to calculate the max value of function:

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$$\max \sum_{i=1}^{i} b(s_i)$$

Finally, we solve the three liner restrict condition below with MATLAB:

$$\begin{cases} \min \sum_{i=1}^{i} h(t_i) \\ \max \sum_{i=1}^{i} b(s_i) \\ d_i \leq \frac{1}{2} \max F_b \end{cases} \tag{11}$$

Our conclusion of the final drone payload packing configurations and delivery routes are shown in Table 7.

Table 7. Drone payload packing configurations and delivery routes

Location	Cargo ①	Cargo②	Cargo③
Loc.1			1*B (1MED1&1MED3)
Loc.2		1*B (1MED1&1MED3)	1*B (1MED1)
Loc.3		1*B (1MED2)	1*B (1MED1)
Loc.4		2MED1&1MED2 &2MED3	
Loc.5	1*B (1MED1)		

5.2. Optimal Video Shooting Scheme

When it comes to the video shooting scheme, we determine the max scope of video shooting based on the former model. We draw three circles centered with the location of three cargo containers. The drones can fly to the edge of these circles (Figure10).

Figure 10. The scope of video shooting

We have three rules when conduct video shooting mission (Figure 11):

Use drones as less as possible on the condition that we can deliver enough packages.

When we deliver medical packages to the five locations, we want to use least time.

We want catch video shooting information as much as possible.

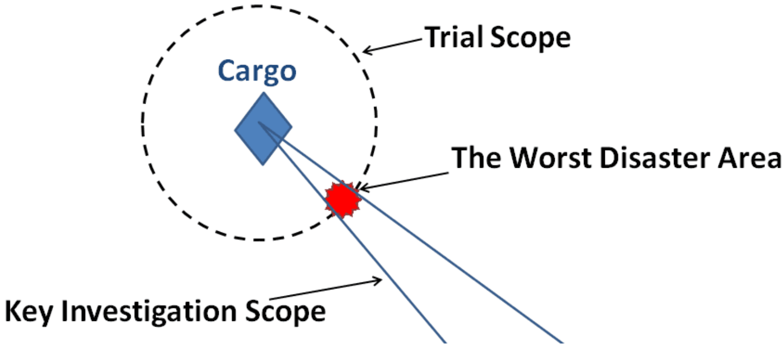

Figure 11. The video shooting scope

6. CONCLUSION

Based on the principle above, we work out our scheme of drone video shooting. We expect that we can dispatch a reconnaissance drone in the first time. The crane will fly in a small circle within its max flight distance. We call this circle as the trial scope. After the process, we will find a key investigation scope and the worst disaster area is in this scope. Then, a next reconnaissance drone will fly to the worst disaster area directly. After that, we dispatch another reconnaissance drone. This drone will fly in a bigger circle than the former one. This drone will expand the trail scope for the next reconnaissance drone, and our video scope will get bigger. Thus, we can get much valuable video information.

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