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2019

Mathematical Contest in Modeling (MCM/ICM) Summary Sheet

Guardians Of The Sky: DroneGo Disaster Response System

Summary

Facing destructive disaster, effective management of the humanitarianism material delivered through the drone fleet is essential.The goal of our models is to develop a DroneGo disaster response system to support the Puerto Rico hurricane disaster scenario. There are four components of this response system, which are loading packages, gather point selection, medical supply delivery, and video reconnaissance. These four models, which are loading model, point-selection model, delivery model, and reconnaissance model, have been proposed to optimize the productivity of rescuing people.

The first problem is 3D container packing problem. Dimension reduction is implemented in simplification through Genetic Algorithm (GA). Additionally, in terms of the 3D simulation, by LoadMaster software, the percentage of final optimization could reach 98%. The second problem is optimization problem. Three classifications based on numbers of cargo locations are discussed. The the optimal proposal is determined through Lagrange Multipliers and K-means Clustering Algorithm. Thirdly, delivery model bases on the Analytic Hierarchy Process(AHP) to optimize the scheme. The fourth problem is a Traveling Salesman Problem (TSP) , GA is used to determine the shortest route for drones to be capable of doing two tasks in disaster areas.

We also run the sensitive test and analyze the strengths and weaknesses of our four models to make sure if this DroneGo disaster response system also works out in reality and could support potential future disaster scenario. Despite that there exist errors, the consequence chould be neglected if the samples are large enough. In summary, a suitable DroneGo disaster response system is designed considering all the constraints and is expected to be applied in reality.

Keywords: Disaster Response System. K-means Clustering Algorithm. Analytic Hierarchy Process (AHP). Genetic Algorithm (GA).

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1 Introduction

1.1 Background

Unmanned Aerial Drone is the aircraft without man operation. It is widely used in military application, commercial, product deliveries and many other areas[1]. The smaller value and faster speed of drones make that they are more handy compared with cargo aircraft. In 2017, hurricane Maria attacked Puerto Rico. Due to the damage of roads, some areas of Puerto Rico are totally isolated from outside. The blocked road and increase of injures will lead to the scarcity of medicine and medical equipment. In this case, drones are the first means of transport that one can choose to transport medicine supply.

However, in reality, there also exist many problems related to the drones' application in product delivery. In order to reduce the cost of transport and increase the efficiency of delivering to disaster areas, many factors should be considered. An aerial disaster relief response system is expected to be put forward to assist local healthcare system when disaster happens.

1.2 Problem Analysis

The optimal DroneGo disaster response system is expected to be determined in this paper. This system is not only to be used when disaster happens to satisfy anticipated medicine supply, it will also be used in other similar future disaster scrnario.

The first aim is to maximize the space utilization filling the cargo containers with three kinds of packages and eight types of drones. This is a 3D container packing problem, which is also an optimization searching problem. Genetic Algorithm (GA), an algorithm simulating nature evolution to find the best possible results, will be used to find the optimal solution inside containers.

The Second aim is to identify the best locations to place DroneGo disaster response system and design the optimal routes for drones delivering supply and reconnoitring main roads together. Five possible hospitals are viewed as stationing points, and main roads of Puerto Rico are found on the map. The optimal locations could be solved using Lagrange Multipliers and K-means Clustering.

The third aim is to find the best scheme of delivering and flight route. This is a Travelling Salesman Problem(TSP) problem. Considering all the constraints, the optimal road will be found by using Genetic Algorithm (GA).

2 Assumptions

- **Assumtion 1**
  Rotating and inverting drones and medicine will bot damage themselves.
- **Assumtion 2**
  Drones can take off noemally when flying in the air without being affected by airflow and weather factors.
- **Assumtion 3**
  Drones will not collide while flying in the air.
- **Assumtion 4**
  Time of taking off and landing is negligible.
- **Assumtion 5**
  Drones will not meet obstacles while flying in the air
- **Assumtion 6**
  The price of drones is the same.
- **Assumtion 7**
  The flight time of drones with loaded cargos is 70% of ones without cargos.
- **Assumtion 8**
  Drones always fly at the maximum velocity.

3 Symbols and Definitions

Symbol	Defnition
$k_i^j, (i = 1, 2, \cdots, k)$	clustering center
$\vec{x}$	sample vector
K_{ih}^{j+1}	adjusted clustering center
J	objective function iteration
λ	eigenvalue
λ_{max}	the maximum of eigenvalue
CI	consistency index
CR	consistency ratio
RI	average consistency index

4 Model 1: Solve Three-dimensional Container Packing Problem

Our purpose is to fill the cargo containers with drones and medicine package to minimize the remaining space in constraints of the dimensions of three items. Because one standard rectangular has three methods to put it in the container. Therefore, the combination of three ways of inputs makes packing problems even complicated. Here, we use software Load Master to find the optimal three-dimensional packing solution of cargo containers.

4.1 Dimension Reduction

Genetic Algorithm (GA) could be also applied in three-dimensional container packing problem. As using GA to solve 3D container packing problem is too complicated, thus we try dimensionality reduction. That is, reduce three dimensional problem to two dimensional one, and then solve packing question. The bottom area is viewed as the basic plane and use Matlab to analyze the possible outcomes. Figure 2 show the results.

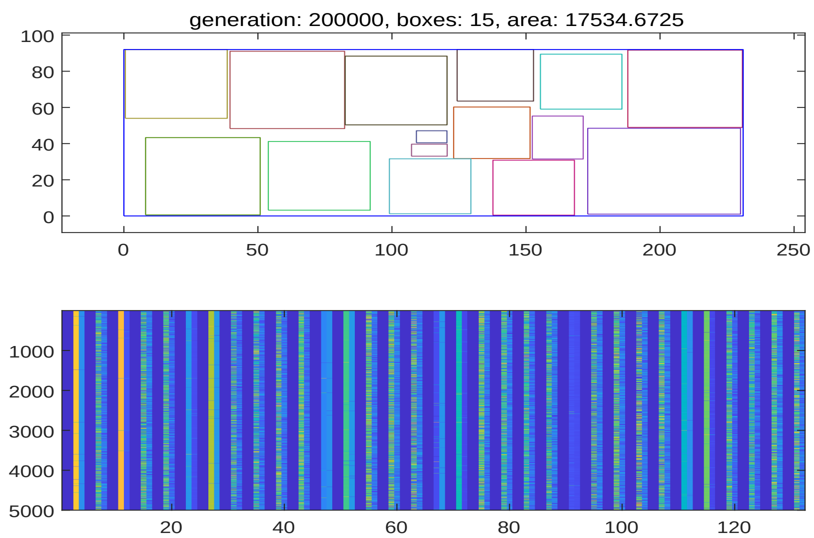

Figure 1: results of 2D container packing problem

However, after we work out the results of one area, the following work is too complex. Accumulating the same package or drones according to the bottom results fails, because there always exist interspace between packages that cannot be filled to maximize the utilization. Moreover, there are three areas could be viewed as basic areas, and it is difficult to calculate which circumstance is the optimal model.

4.2 3D Container Packing Model

In the types of drones provided, we notice that Drone H is a tethered drone[7] (see Appendix 1). It is a emergency communication system, and cannot shoot videos or carry medicine package.

We make **two asumptions** in this model:

- One, two, or three Drones H is needed in delivery, and each cargo container only contain one Drone H.

- The packing order is that drones first in, then the medical packages.

There are **three constraints** considered:

- Dimensions
  The dimension of Drones A to H, the dimension of three medical packages, and the dimension of standard ISO containers in the interior are used as one of the conditions. The dimension of exterior and door opening are ignored.
- Quantities of Medical Package Needed
  In overall, considering all quantities that five hospitals need, seven MED 1, three MED 2, and four MED 3 are required. Thus, the ratio of required quantities of MED 1: MED 2: MED 3 is 7 : 3 : 4, and packing model is done based on this requirement.

According to Load Master, the model is done in one cargo container with one Drone H, and the volume use rate is 98.15% which can be viewed as the ideal packing results. Packing method is illustrated in the Figure 1. The detail information see Table 1.

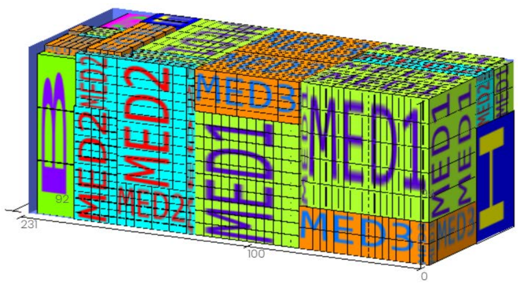

Figure 2: Packing Method With One Drone H

Table 1: Detail information of packing containers with One Drone H

Goods Name	A	B	C	D	E	F	G	H	MED1	MED2	MED3
Quantity	3	3	3	3	3	3	1	1	1384	593	791
Volume use rate(%)	98.15										
Goods Quantity(%)	2788										

5 Model 2 : Use K-means Clustering Algorithm to Solve Optimization Problems

To identify the best one, two or three stationing locations to allocate cargo containers, we have to minimize the distance between five delivery locations and stationing point (We define shortest distance as the selection criteria). In our second model, Lagrange Multipliers method is used to seek one optimal location, based on the conditions of two variables, latitude and longitude. Additionally, K-means clustering algorithm, an Iterative Clustering algorithm, is apllied to identify the best two or three locations. Lagrange Multipliers method is actually a principle of K-means clustering algorithm.

5.1 Use Lagrange Multipliers to find the optimal one location

Let x denotes the longitude and y denotes the latitude, then $(x_1, y_1), (x_2, y_2), (x_3, y_3), (x_4, y_4)$, (x_5, y_5) are the location of five different hospitals respectively. Let $f(x, y)$denotes the sum of the distance from each delivery location to stationing point. Then, according to the distance between two points,

$$f(x, y) = \sqrt[2]{(x - x_1)^2 + (x - x_2)^2 + \cdots + (x - x_5)^2 + (y - y_1)^2 + (y - y_2)^2 + \cdots + (y - y_5)^2}$$

We are going to calculate the minimum of $f(x)$. To simplify the mathematics operation, we set $g(x, y) = f^2(x, y)$, then,

$$\begin{aligned} g(x, y) =& (x - x_1)^2 + (x - x_2)^2 + \cdots + (x - x_5)^2 \\ &+ (y - y_1)^2 + (y - y_2)^2 + \cdots + (y - y_5)^2 \end{aligned} \tag{1}$$

The extreme valuve of two-variable function occurs at critical points of funtion. Since there are no boundary points and singular points, function $g(x, y)$ will attain extreme value at stationary point, where $\nabla g(\vec{p}_0) = \vec{0}, \vec{p} = (x, y)$, that is,

$$\nabla g(\vec{p}_0) = \begin{cases} g_x(x, y) = 2(x - x_1) + 2(x - x_2) + \cdots + 2(x - x_5) = 0 \\ g_y(x, y) = 2(y - y_1) + 2(y - y_2) + \cdots + 2(y - y_5) = 0 \end{cases} \tag{2}$$

After calculation, we can get the coordinate of extreme $(-66.128, 18.732)$. By doing the test of extreme value, we can konw that $g_{xx}(x, y) > 0$ and $g_{xy}^2 - g_{xx}g_{yy} < 0$. Thus it can be concluded that this point $(-66.128, 18.732)$ is the minimum point .

Figure 3 illustrates the graph of $g = (x, y)$, where we can see clearly that there exist the minimum point in this three dimensional graph.

Therefore, the best one location is at longtitude $-66.128°$ and lagtitude$18.732°$ and it is the optimal place to put cargo containers.

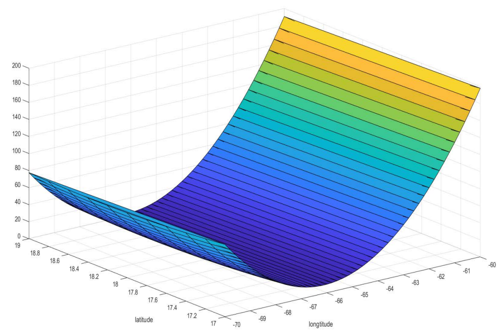

Figure 3: fuction of $g(x, y)$

5.2 Use K-means Clustering Algorithm to Find the Optimal Two or Three Locations

To identify the best locations, a classification of these five hospitals is needed. Clustering Analysis can effectively used for data clustering and analysis of known class number m.

5.2.1 Modeling step

- Initialization
  Given the number of classification and set $j = 0$. Pick m vectors from sample vectors as $k_1^j, k_2^j, \cdots, k_m^j$, then considering them as the clustering center $k_i^j = [k_{i1}^j, k_{i2}^j, \cdots, k_{i3}^j], (i = 1, 2, \cdots, k)$[5].
- Classification of samples
  Include each sample vector $\vec{x} = [x_{l1}, x_{l2}, \cdots, x_{lm}]^T$ in the class which owns k_i^j as the center by this formular[5]:

$$\left\| x_l - k_i^j \right\| = \min_{1 \le h \le m} \left\| x_l - k_m^j \right\| \tag{3}$$

- Center adjustment
  Adjust the clustering center by

$$K_{ih}^{j+1} = \frac{\sum\limits_{x_{lih} \in k_i^j} x_{lih}}{N_i} \tag{4}$$

  Where N_i represents the number of vectors of the clustering block K_i^j[5].

- Condition judgment
  Construct the objective function iteration J as

$$J = \sum_{m=1}^{n} \sum_{x_m \in K_i} \|x_k - k_i\| \tag{5}$$

  Put the data which from the first step into the formula and judge the result. The iteration ends when the result does not have obvius change. Or $j = j + 1$ and turn to the first step[5].

5.2.2 Results and Analysis

We use the software SPSS to process data to get the optimal loactions, and get the following information.

First, to find the best two locations, five hospitals are classified into two levels. One is Arecibo, and the other is the rest places. The coordinate of two centers and the distance from hospitals inside cluster to the center could be seen from the Table 2. The coordinate of the best two locations are $(-65.98, 18.35)$ and $(-66.73, 18.74)$.

Table 2: Clusters and Best Locations of Two Classifications

Name	coordinate	Cluster	Center	distance
Fajardo	(-65.65, 18.33)	1	(-65.98, 18.35)	0.328
San Pablo	(-66.03, 18.22)	1	(-65.98, 18.35)	0.138
San Juan	(-66.07, 18.44)	1	(-65.98, 18.35)	0.131
Bayamon	(-66.16, 18.40)	1	(-65.98, 18.35)	0.190
Arecibo	(-66.73, 18.47)	2	(-66.73, 18.47)	0.000

Table 3, analysis of variance (ANOVA), is calculated from the data of Table 2 to analyze two clusters and five groups of location data, According to significant value in Table 3, $sig_x = 0.058\ 0.05$, which means H_0 can not be rejected. Moreover, $sig_y = 0.338\ 0.05$, thus H_0 can not be rejected. Therefore, it means that although the coordinates of two best locations satisfy the minimum distance, the difference is significant and the method of clustering is not optimal. Actually, our purpose is to calculate the minimun distance instead of clustering, thus there would exist errors when using K-means clustering.

Table 3: part of ANOVA of two classifications

	$sig.$
x	0.058
y	0.338

Similarly, the identification and analysis of three best locations is the seem as two ones above. The classification is Fajardo for cluster one , Arecibo for cluster two, and the rest for cluster three. According to Table 4, the optimal coordinates are $(-65.65, 18.33)$, $(-66.09, 18.35), (-66.73, 18.47)$. Additionally, $sig_x = 0.689 > 0.05$ and $sig_y = 0.015 < 0.05$ can be seen from Table 5, which also means that there exists errors when using K-means clustering to locate the optimal places where the distance could be minimized.

Table 4: Clusters and Best Locations of Three Classification

Name	coordinate	Cluster	Center	distance
Fajardo	(-65.65, 18.33)	1	(-65.65, 18.33)	0.000
San Pablo	(-66.03, 18.22)	2	(-66.09, 18.35)	0.145
San Juan	(-66.07, 18.44)	2	(-66.09, 18.35)	0.088
Bayamon	(-66.16, 18.40)	2	(-66.09, 18.35)	0.087
Arecibo	(-66.73, 18.47)	3	(-66.73, 18.47)	0.000

Table 5: part of ANOVA of three classifications

	$sig.$
x	0.689
y	0.015

6 Model 3: Medical Package Delivery Scheme

6.1 Use AHP to Rank the Influence Factor of Delivering Order

In order to find and rank the influence factors of delivering order, many factors are found in literatures, and three factors are considered: Quantity Demand, Diatance and Velocity. First, the hierarchical structure model is established (Figure 4)

When $\lambda = \lambda_{max}$, we can get the weight vector, $\vec{X} = (x_1, x_2, x_3)$. Where x_i is the $weight_i$. Consistency check of comparion matrix[6]:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

$$CR = \frac{CI}{RI} \tag{7}$$

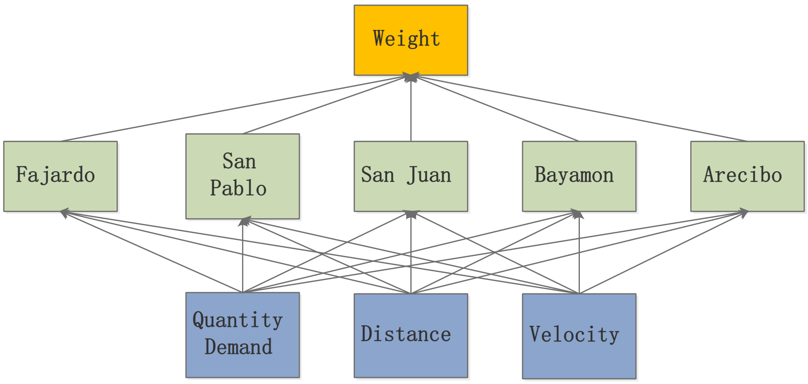

Figure 4: hierarchical structure model

Where CI is consistency index, CR is consistency ratio, RI is average consistency index. If CR< 0.1, the consistency of comparison matrix is acceptable.

Next, Comparison Matrix Pairs in rule hierachy is made.

$$A = \begin{pmatrix} 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & 3 \\ 3 & 1 & 1 & \frac{1}{3} & 3 \\ 3 & 1 & 1 & \frac{1}{3} & 3 \\ 5 & 3 & 3 & 1 & 5 \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} & \frac{1}{5} & 1 \end{pmatrix} \tag{8}$$

CR=0.0461<0.1. Thus consistency check passed. Then, Comparison Matrix Pairs in indicator hierachy is made.

$$B_1 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} B_2 = \begin{pmatrix} 1 & 3 & 2 \\ \frac{1}{3} & 1 & 1 \\ \frac{1}{2} & 1 & 1 \end{pmatrix} B_3 = \begin{pmatrix} 1 & 3 & 2 \\ \frac{1}{3} & 1 & 1 \\ \frac{1}{2} & 1 & 1 \end{pmatrix} B_4 = \begin{pmatrix} 1 & 1 & \frac{1}{2} \\ 1 & 1 & \frac{1}{2} \\ 2 & 3 & 1 \end{pmatrix} B_5 = \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix} \tag{9}$$

The consistency check of B_1 is 0.0000<0.1, of B_2 is 0.0176<0.1, of B_3 is 0.0176<0.1, of B_4 is 0.0176<0.1, of B_5 is 0.0000<0.1.

After calculation, the weight of velocity is 0.2407; the weight of distance is 0.2429; the weight of need is 0.5164. Therefore, according to AHP, Quantity Demanded will be first considered, next is the Distance, and then is the Velocity of Drones. That is to say, distribution order of five delivery hospitals will be decided based on numbers of quantity needed. Next, the delivering distance will decide whether Drone H is required. Since the limitation of flight time of some types of drones, they will run out of battery wirelessly while flying. Thus, Drone H is necessary to prelong the flight time of other drones. Finally, Velocity of drones is considered to choose which types of drones are demanded to perform delivery tasks.

6.2 Delivery Preparation

In the previous model, the packing method which maximize space utilization is shown. That is, in every cargo container, three A, three B, three C, three D, three E, three F, three G and three H are loaded. 1384 MED1, 593 MED2, and 791 MED3 are also loaded. Furthermore, the quantity needed ratio of three medicine packages is integral multiple of daily medicine packages requirements. Thus the supply of one cargo containers could satisfy 197 days demand.

Drone H is a tethered drone, which combiens drones and mooring rope. This rope allows drones not restricted to the power and stay in the air for a long time. Also, tethered drone is capable of charging other drones. Therefore, it is assumed in this scheme that the rope of drones is infinitely long. This allows Drone H can go anywhere within Puerto Rico and charge other drones wirelessly at any time, which means that if a drone is flying while drone H flying, the problem that drones will run out of battery will not be considered.

Accoring to the dimension of drone cargo bay and dimension of medicine packages, the number of drones in one cargo container, and the max payload capacity, the possible ways to loading medicine package on the drones are shown in Table 6. In this table, if one drone bay only load one kind of package, it will take one MED1, or three MED2, or two MED3. If one drone bay load two kinds of packages, it will take one MED1 and one MED2, or one MED1 and one MED3, or two MED2 and one MED3. Two types of drone cargo bay do not considered here. Additionally, every cargo could be filled with one medical package, and this packing method will not be influence by max payload capacity of drones as they always mathch conditions.

Table 6: The Maximum quantities loaded in drones bay under two circumstances

	MED1	MED2	MED3
Load one kind of packages	1	3	2
Load two kinds of packages	1	1	0
	1	0	1
	0	2	1

6.3 Selection Process and Results

Based on delivering order decided in the last two section, Quantity Demand will be considered first, next is Distance, final is Velocity. Addittionally, the packing method which shown in the last table will also be considered all the time. Number of drones only in one cargo container will be considered in delivering, which could ruduce the cost and satisfy daily demand. We take the circumstance of one best location as the example to see how this order works.

- Quantity Demand
  Hospital which needs medical packages most will be delivered first. In overall, Bayamon needs five packages, San Juan and San Pablo need three packages, and Arecibo and Farjardo need one package. In this level, Bayamon will be delivered first, next are San Juan and San Pablo, and Arecibo and Farjardo are the last.

- Distance
  Since we just confirm the first delivering order is Bayamon, then Distance should be considered next. The distance of best location to San Juan is 10.4km, to San Pablo is 19km, to Farjardo is 51.3km, to Arecibo is 65.87km. According to the data given, the longest fight distance is 36.9km. Thus, there will be a Drone H needed when drones flying to Farjardo and Arecibo, which means that drones to these two places can go at the same time. Additionally, the second delivering order is San Juan, the third is San Pablo, and the last is Fajardo and Arecibo.

- Velocity
  In the condition of For drones flying to Bayamon, based on the medicine packages needed and payload capacity of drones, C, D, E, F could do delivery job. However, F is the fastest drone among those four. Thus, F will be selected to deliver supply to Bayamon. According to the supply needed, three F will be used.

Table 7: drone payload packing configurations for one best location

Places	Delivery order	Drones used	Deliver Duration(h)
Bayamon	1	F+MED1, MED2 F+MED1,MED3 F+MED3,MED3	0.12
San Juan	2	C+MED1, MED2 C+MED2,MED2	0.16
San Pablo	3	C+MED1, MED3 D,H+MED1,MED1	0.32
Farardo	3	H,D+MED1, MED3	0.86
Arecibo	3	H,B+MED1	0.04
Total			1.5

Similarly, two C will be used to deliver goods to San Juan. Then, one C and one D will be used to deliver supply to San Pablo. As there only three C in one cargo container, thus one D will be needed. However, the maximum flight distance of D is shorter than delivering distance. Thus, a H is needed to fly to San Pablo, which means San Pablo will be delivered in thid place with Fajardo and Arecibo.

Table 8: drone payload packing configurations for two best locations

Places	Delivery order	Drones used	Delivery Duration(h)
Arecibo	*	MED1	0
Bayamon	1	F+MED1, MED2 F+MED1,MED3 F+MED3,MED3	0.51
San Juan	2	C+MED1, MED2 C+MED2,MED2	0.23
San Pablo	3	C+MED1, MED3 D+MED1,MED1	0.24
Farardo	4	B+MED1 B+MED3	0.44
Total			1.42

Table 9: drone payload packing configurations for three best locations

Places	Delivery order	Drones used	Delivery Duration(h)
Arecibo	*	MED1	0
Farardo	*	MED1, MED3	0
Bayamon	1	F+MED1, MED2 F+MED1,MED3 F+MED3,MED3	0.25
San Juan	2	C+MED1, MED2 C+MED2,MED2	0.18
San Pablo	3	C+MED1, MED3 D+MED1,MED1	0.24
Total			0.67

Finally, D and H deliver goods to Farjardo, and B and H are used to sent goods to Arecibo. The same selecting procedure will also be applied to Two and Three best locations, the drone payload packing configurations and schedule.

The total time of delivery is respectively 1.5, 1.42 and 0.67 hours. This delivery period could be repeated for several times in a day. For working time 8am to 5pm, the repetition times is 7, 7 and 14.

The packing routes is shown in the Figure 5.

Notes: * means the best location is right at that hospital, thus this hospital could take nedical package without drones.

Figure 5: packing routes

7 Model 4: Best Routes for Video Reconnaissance

7.1 Use GA to Solve Travelling Salesman Problem

The purpose here is to reconnoitre roads net works. The goal of paths selection is to obtain the minimum path distance, and satisify the limitation that each hospital should only be passed once. Travelling Salesman Problem (TSP), a classic NP-problem and classic combinational optimization problem, will be used as the model here to find the best routes to detect all roads. For n points, there will be $(n-1)!$ possible routes. However, the roads could be seen as continuous function, furthermore, the roads could be viewed as infinite points. Therefore, there will be infinite solutions and the exhaustive is imprative [2].

In this case, GA could be applied. It is a search technique to find the approximate solutions to combinatorial optimization problems. According to the accessment of finding the optimal routes, GA allows the solution to be optimized generation after generation and approximates the best solution [3]. Moreover, the error between the approximate optimal solution and the optimal solution is acceptable.

In this model, Monte Carlo Method (MC) is also simulated. MC is a statistical simulation problem that solving computational problems using necessarily large random numbers. According to this, we take points along the roads as many as possible. 129 points are selected along the main roads manually to get the optimal route for video reconnaissance using GA.

7.1.1 Modeling Step

- **Encoding**
  A suitable encoding is found for the solution to our problem so that each possible solution has unique encoding and the encoding is some form of a string[3].
- **Evaluation**
  The initial population is then selected, usually at random though alternative techniques using heuristics have also been proposed. The fitness of each individual in the population is then computed that is, how well the individual fits the problem and whether it is near the optimum compared to the other individuals in the population[3].
- **Crossover**
  The fitness is used to find the individuals probability of crossover. Crossover is where the two individuals are recombined to create new individuals which are copied into the new generation[3].
- **Mutation**
  Next mutation occurs. Some individuals are chosen randomly to be mutated and then a mutation point is randomly chosen. The character in the corresponding position of the string is changed[3].
- **Decoding**
  Once this is done, a new generation has been formed and the process is repeated until some stopping criteria has been reached. At this point the individuals which is closest to the optimum is decoded and the process is complete[3].

7.1.2 Result and Analysis

We use Matlab and get the optimal routes for video reconnaissance (Figure 6). This outcome is the best solution using fitness criteria. The graph on the top left illustrate the points that we select manually, and the graph in the bottom left is the best rout that be chosen. However, it is just an approximation but not an optimal solution. In general circumstance, if the sample is large enough, the random error can be ignored. In this problem, we select 129 points along the roads manually, but the sample is not large enough. Therefore, this result exsits errors to a certain extent.

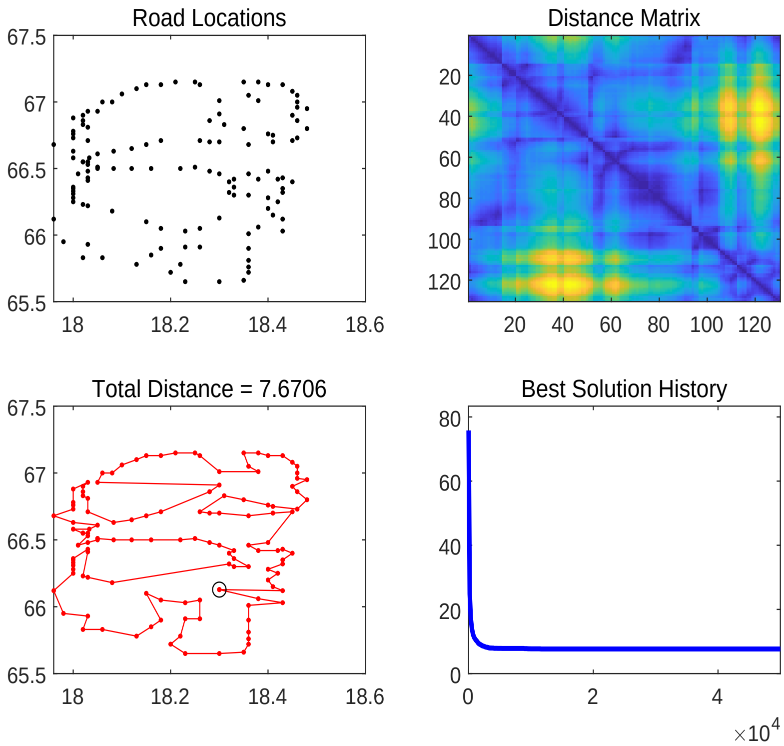

Figure 6: Best Routs for video Reconnaissance

8 Sensitivity Analysis

8.1 Enough Points For Map Simulation

In this model, there are 129 manually entered pairs of coordinates in simulating the major highways and roads, where we implement the TSP algorithm in solution. However, whether the number of points is sufficient for the simulation should be clarified. Therefore, verification with more points should be provided. In this verification, 891 points are selected from the Google Earth in order to full fill the simulation exhaustively. The output is presented as follows (Figure 7). Based on the simulation result. The total distance for this accurate explanation is 9.2418 units. Compared with the manually entered results mentioned in model section, which is 7.6706, the accurate rate is calculated through $1-((9.2418-7.6706)/9.2418)\times 100\% = 83.3\%$, which is relative acceptable.

8.2 Minimum Requirement For Tethered Drone

The model mentioned above has covered the assumption that the tethered drone H has the infinite long tether, which could supply the corresponding drone to fulfill the mission on every area of the Puerto Rico since there are not any limitations

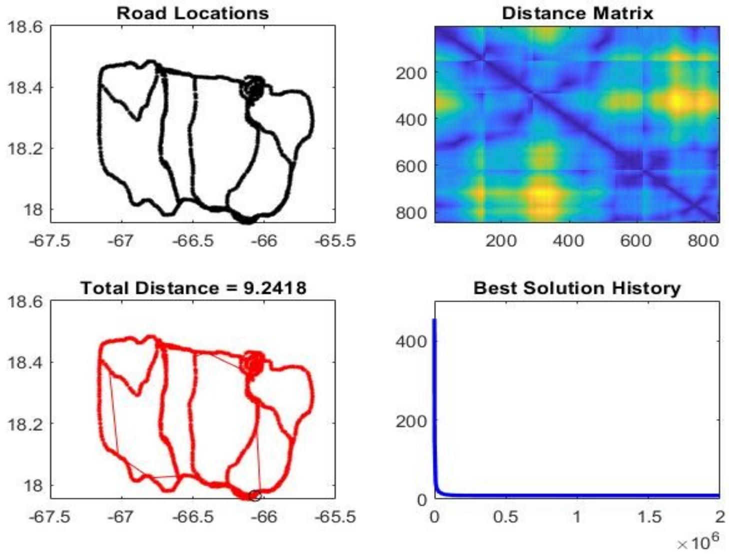

Figure 7: Accurate Route of One Location

about the drone H. However, the tether should have the minimum length in order to reduce the cost of the project, while accomplishing the missions. The minimum tether requirement for medical supply delivery should cover the farthest hospital while the requirement for the video reconnaissance should cover the farthest main road. Since there have been cargo locations along with Hospital Parvia and Carribbean Medical Center, the hospitals would receive cargos instantaneously. Meanwhile, the farthest location would be hospital HIMA, and the corresponding distance would be 15.71 Km, which is available for even the drone with the least flight ability. Thus, no H is needed for supporting the energy.

When it comes to the video reconnaissance mission, the plane should cover the main road of this island, which is highlighted as yellow. Based on the measurement of the Google Earth, minimum requirement for tether should be 59.33km, which is presented in appendix. The one or two cargo locations is illustrated in the appendix. (see appendix)

9 Strengths and Weaknesses

9.1 Strengths

A very high level of container utilization is enabled in the first model, and the quantity of drugs is enough to meet the needs of the region, which be able to deliver medicine to the hospital within the prescribed time.

The idea of categorization is used to find the short distance points which are the cluster centers in our second model.

AHP method is used to determine the weight of the speed, need and distance in the third model. Therefore, we can use the weights to figure out how do we assign planes.

In the fourth model genetic algorithm approaches the optimal solution very quickly instead of using the complicit graph theory algorithm.

9.2 Weaknesses

The quantity of medicine is too much in our 3-D binning model, the premise that can satisfy a demand actually falls again a few aircraft.

In the second model we only consider the distance factor, not the cost factor, so the consideration is not very comprehensive.

Subjectivity is a major factor in AHP model, therefore, this model does not consider the influence of objective factors, and there may be some errors.

As for the fourth model, there are no infinite points to choose from, so the TSP problem solved by genetic algorithm has some limitations.

10 Conclusions

In order to solve the Drones Disaster Response System Problem, we build four models to solve this problem. In the first problem, we find it difficult if we convert this three-dimensional problem to a two-dimensional problem. Therefore, we use Loadmaster to solve this problem. For the second problem, we use Lagrange Multiplier method and K-means Clustering Algorithm to put some points together to find the best location of medical supply delivery and video reconnaissance of road networks. For the third problem, we first use AHP algorithm to find out which one is the priority in the demand distance velocity, and then determine the various states of which aircraft charge, and finally determine the configurations, delivery routes and schedule constraint conditions.

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A Letter to CEO of the HELP, Inc

Dear CEO of the HELP, Inc

DroneGo disaster response system is required to design to support disaster scenario. In this problem, four models are proposed and corresponding assumptions are made. Our purpose is to find the optimal packaging method, delivery scheme, and video reconnaissance.

Loading model

Based on the ideology of dimension reduction and the support from the loadmaster software, loading model could maximize the utilization rate of the container up to 98%, which is efficient high, with three up to 20 drones and 2769 medicine packages. The suggestions disasters similar to the Puerto Rico hurricane, a 10% float of the magnitude of the responding plan should be considered. Furthermore, if the system faces scenarios of different dimensions, the computer aid software, load-master, is highly recommended in solving the package loading problem with high optimization rate.

Point-selection model

Based on the Lagrange Multipliers and K-means Clustering Algorithm, the point selection has optimized the point where the summed distance is the minimum for reaching the other locations. Point-selection model offers the best location and locations for three scenarios one, two and three cargo containers. For one location, the best location is the in the north of the Guaynabo City. If two locations are applied, the suggested locations are in the east of the Trujillo Alto City and the other is in the Hospital Pavia. Eventually, the three cities scenarios should be located on the Hospital Pavia, Caribbean Medical Center, and the west of cupey city.

Delivery model

Based on the analytic hierarchy process and patient first principle, the delivery model serves to ascertain the best drone medicine distribution plan for different hospitals. The main conclusion is that the daily requirements for medicines could be met within one hour for one location, half an hour for two, and less than fifteen minutes for three. The main suggestion is the requirements from the hospital with the highest demand of medicine should be met first for the emergency for rescuing and the drones should be divided depending on the loading capacities allocated with different loading capacities.

Reconnaissance model

Based on the genetic algorithm, the reconnaissance model provides an approximation solution where the drone could prospect the major road network, without redundant efforts. The model outcome of the simulation meets the requirement of 83% of the real situation. Additionally, since the maximum cruising radius has exceeded drone capacities, the tethered drone H is considered essential not only for maintaining through communication but also a sufficient time of endurance.

In conclusion, loading model, point-selection model, delivery model and reconnaissance model could be of essential tools optimize the performance of the DroneGo disaster response system.

Yours

Sincerely

Team 1916920

Appendices

Figure 8: Thethered Drone

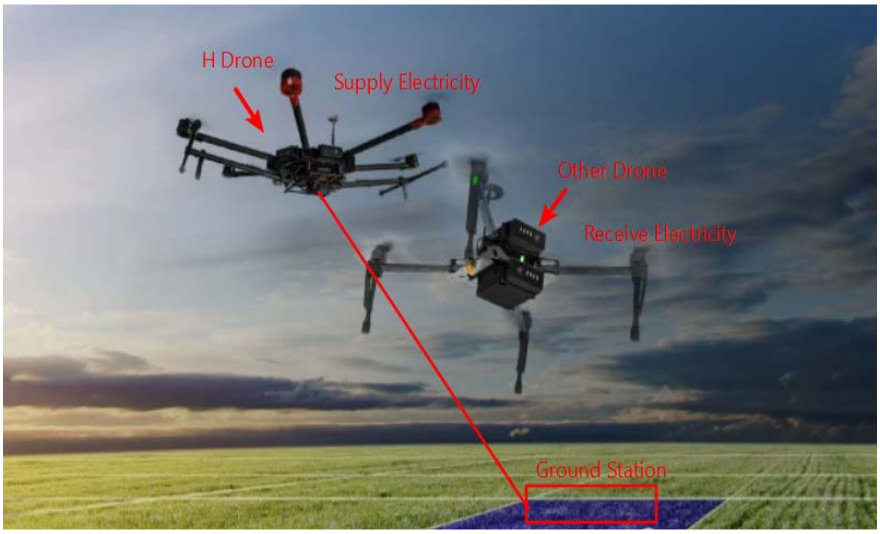

Figure 9: Thethered Drone

Figure 10: Thethered Drone

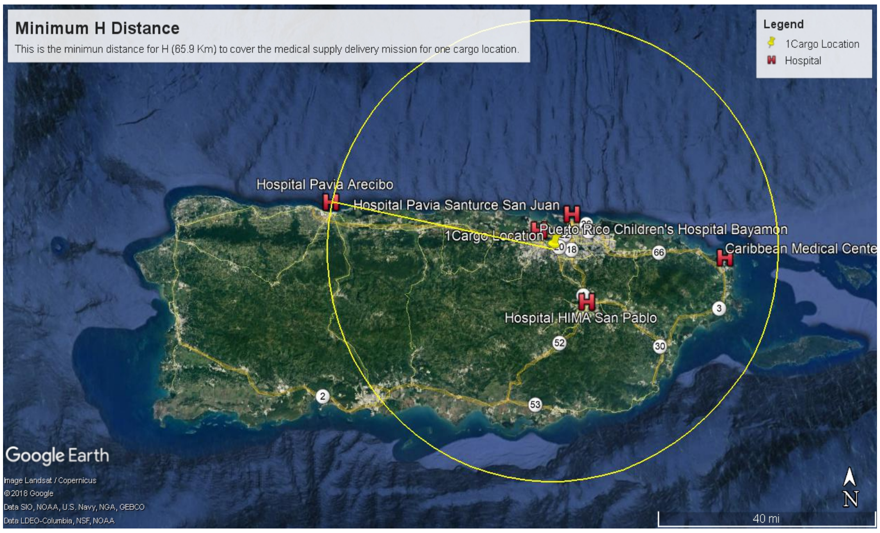

Figure 11: minimum H distance for one best location Mission 1

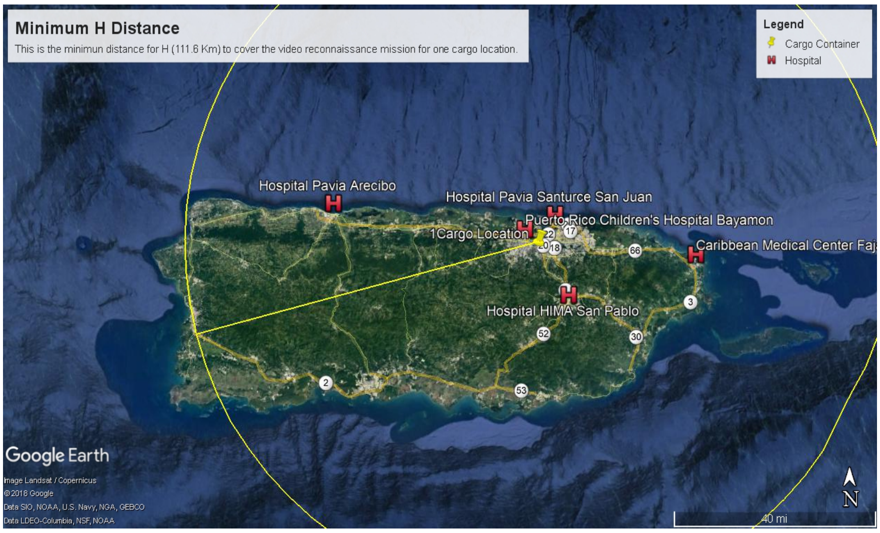

Figure 12: minimum H distance for one best location Mission 2

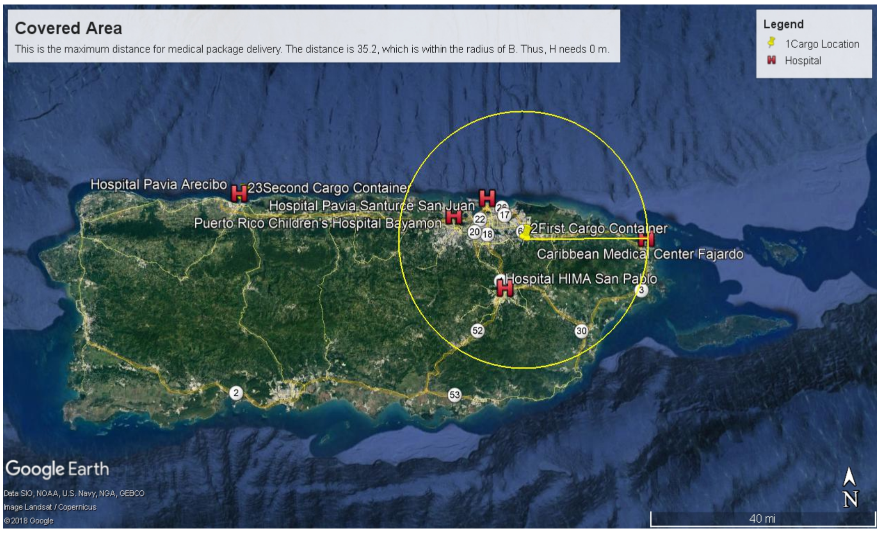

Figure 13: minimum H distance for two best locations Mission 1

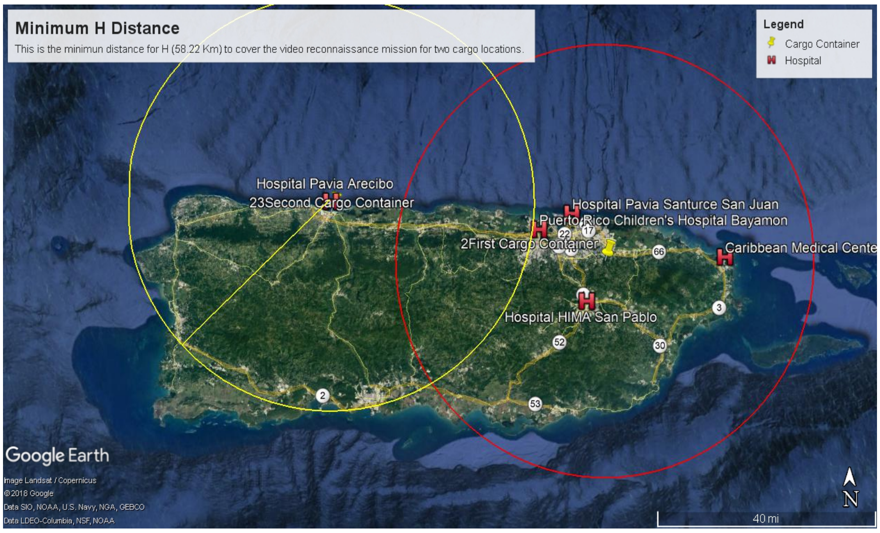

Figure 14: minimum H distance for two best locations Mission 2

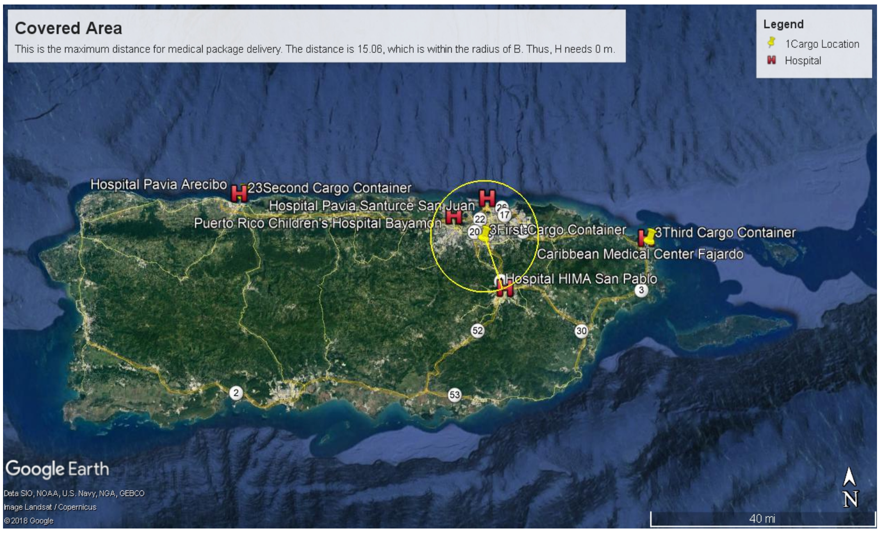

Figure 15: minimum H distance for three best locations Mission 1

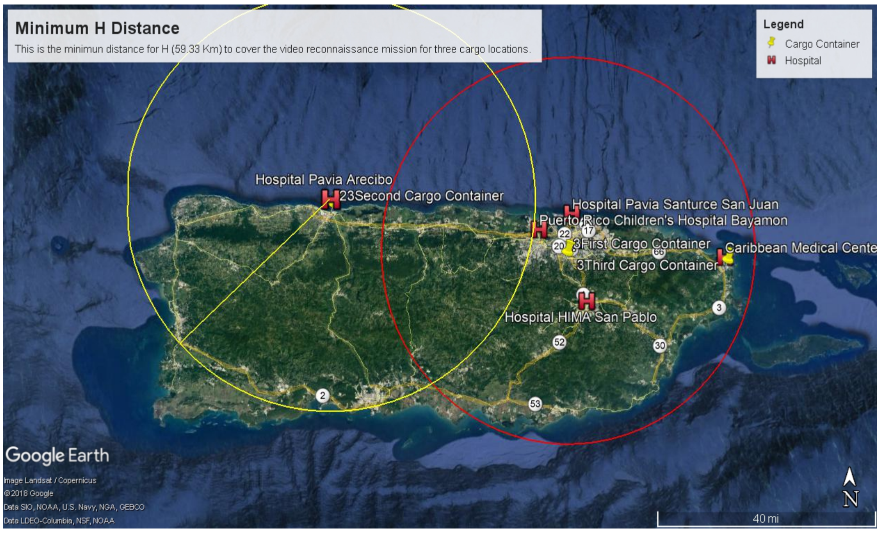

Figure 16: minimum H distance for three best locations Mission 2