Drone Design for the Disaster Response System

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Abstract: After Puerto Rico was hit by a hurricane, medical supplies were scarce and roads were badly damaged. To solve these problems, we designed the DroneGo disaster response system. First, we found the data and combined the map to find Puerto Rico's eight ports. Considering the factors of transportation efficiency, transportation time, height, medical needs, area, etc., we have selected three ports and established three ports in Guashan, San Juan and Arecibo. However, considering road investigations, we eventually replaced Arecibo with Mayaquez. Through data analysis and model construction, we determined the packaging configuration and the location of the container.

1. Introduction

For the delivery of medical supplies, we hope that the delivery time is as short as possible to facilitate treatment. Under this premise, reduce the number of drones used to save costs. The order we solved the problem was to select the port, calculate the distance and configure the medical kit. In this process, we conducted a reasonable analysis, making the best use of space, approximate circle algorithm, simulated annealing algorithm, etc. Taking into account objective factors such as height, communication equipment, we finally gave a more reasonable solution.

2. Models

2.1 Data Collection

In the first step, we found 11 ports in Puerto Rico by querying the information (see Table 1).

Table 1. Main Ports of Puerto Rico

Port Code	Port Name	Country
PRAGU	AGUADILLA	Puerto Rico
PRARE	ARECIBO	Puerto Rico
PRFAJ	FAJARDO	Puerto Rico
PRGCA	GUANICA	Puerto Rico
PRGMA	GUAYAMA	Puerto Rico
PRGUA	GUAYANILLA	Puerto Rico
PRJOB	JOBOS	Puerto Rico
PRMAY	MAYAGUEZ	Puerto Rico
PRPON	PONCE	Puerto Rico
PRSJU	SAN JUAN	Puerto Rico
PRYAB	YABUCOA	Puerto Rico

Secondly, combined with the map, we found eight ports having drawn in purple circles.

In the third step, in order to calculate the distance between the two locations, we found the ports' (in blue) and populated places' latitude and longitude (see Table 2) through the network satellite map.

Table 2. Longitude and latitude of the populated places and ports

Name	Latitude	Longitude
Aguadilla	18.43	-67.15
Mayaguez	18.20	-67.14
Quebradillas	18.47	-66.94
San Sebastian	18.33	-66.99
San German	18.08	-67.04
Ensenada	17.96	-66.93
Arecibo	18.47	-66.73
Utuado	18.26	-66.70
Manati	18.42	-66.48
Dorado	18.45	-66.27
Bayamon	18.40	-66.16
Orocovis	18.22	-66.40
Santa Isabel	17.97	-66.39
Comerio	18.21	-66.23
Cayey	18.11	-66.16
Guayama	17.98	-66.11
San Juan	18.44	-66.07
Caguas	18.22	-66.03
Loiza	18.43	-65.87
Rio Grande	18.37	-65.84
Maguabo	18.21	-65.73
Humacao	18.15	-65.82
Maunabo	18.00	-65.89
Fajardo	18.33	-65.65
Ponce	18.00	-66.61
Guayama	17.98	-66.11
Yabucoa	18.05	-65.87
Aguadilla	18.43	-67.15
Mayaguez	18.20	-67.14
San Juan	18.44	-66.07
Fajardo	18.33	-65.65
Arecibo	18.47	-66.73

2.2 Data Analysis

First, we have determined the locations of the cargo containers. After that, we make choices for the number of H-type drones based on the communication conditions at the locations of the containers. Then, considering the distance between the five medical transportation destinations, the demand for medical supplies and the longest flight time of the drones, we initially determined the type and quantity of drones and medical packages that are loaded by every cargo container.

Figure 1 Five delivery locations of medical packages

Figure 1 shows five medical package destinations, which are Arecibo, Bayamon, Caguas, San Juan and Fajardo. In order to be able to deliver the medical packages to the destinations in the shortest time, and taking into account the geographical factors of Puerto Rico (mountain blockage, etc.), we distributed the cargo containers to three different ports, one in the west, one in the south and one in the north. The drones in the southern port were inconvenient to perform the delivery task because of the high terrain, so they will not be discussed here for the time being, and will be considered in detail in the subsequent road reconnaissance tasks.

When the northern port is selected, we choose San Juan as the port for the cargo container in the north because it is both a delivery destination and an important port, and it is in the center of the surrounding package destinations and the densely populated area in the north.

For the western region, there is only one delivery destination, Arecibo, and it is one of the important ports. We initially select it as the port of call for the container in the west.

Next, we will configure the type and number of drones based on the selected port location.

Table 3. Flying Distance of All Drones

Drones	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Speed (km/h)	40	79	64	60	60	79	64
Flight Time No Cargo (min)	35	40	35	18	15	24	16
Distance (km)	23.3	52.6	37.3	18.0	15.0	31.6	17.0

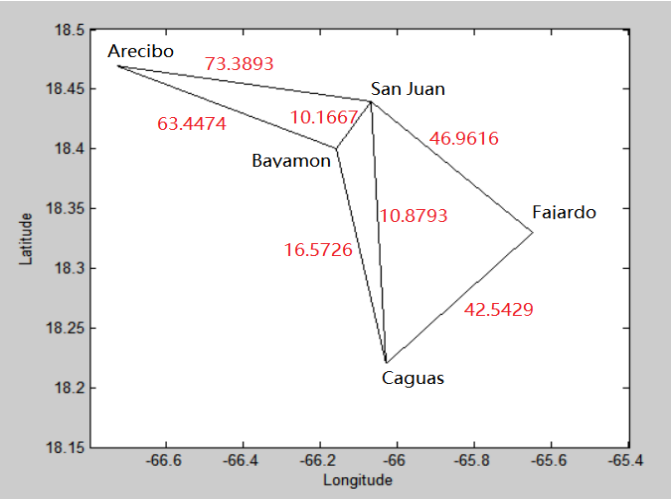

Figure 2. The distance of five delivery destinations

In the northern region, in addition to San Juan, there are another three delivery destinations-Bayamon, Faiardo and Caguas. We calculate the Flying Distance of All Drones (see Table 3) and the distance of five delivery destinations (see Figure 2).

For each of these, we have separate discussions. For the far right one, because it is 49.9616 kilometers away from San Juan, we found that only the B-type drone can meet the travel requirements. According to the data provided by the title, B-type drone can deliver the required medicines in the area at one time. For Bayamon, it requires a large number of medical packages. In order to minimize the delivery time, we choose an F-type drone that can complete the deliver task at one time. For Caguas, from the perspective of distance, A, B, C, F drones meet the requirements. But from the speed point of view, B and F drones are the fastest. Therefore, the delivery time is also the shortest. Because the B-type drone can't send the required packages at one time, we choose F as the final choice. At the same time, we have configured the corresponding medical packages that are consistent with the requirements. In short, the basic configuration of the container in San Juan port is as follows. (see Figure 3).

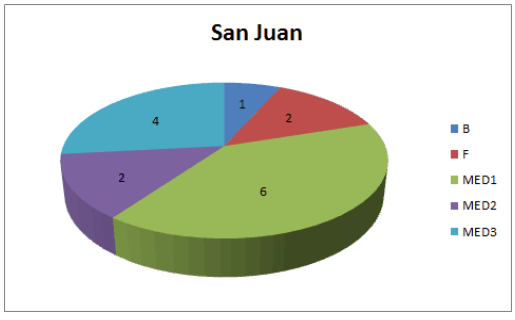

Figure 3 Container configuration

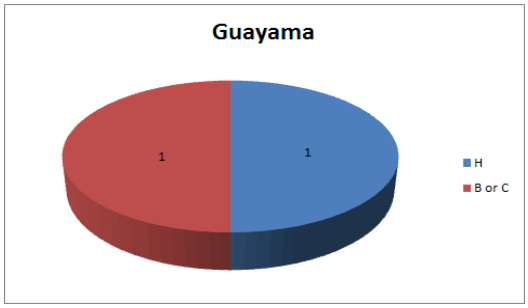

Figure 4 Container configuration

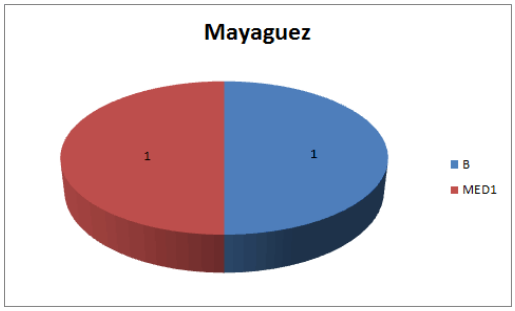

Figure 5 Container configuration

For Arecibo, the cargo container only contains medical packages-MED1.

Through the calculation of the port distance (see Figure 6), we find that no matter which one of the southern ports are chosen, there are always unreachable population gathering places for the drones from Arecibo.

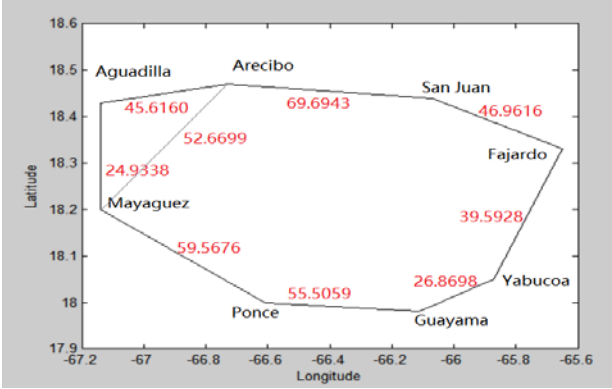

Figure 6. Distance among ports

To coordinate the two tasks, we select the western port Mayaguez. In order to complete the medical delivery task, we need to configure the drone B (see Figure 5).

Due to the characteristics of its population distribution in the southern region, we choose Guayama as the southern cargo container docking port. Located in the southeast coastal area severely affected by the hurricane disaster, the communication equipment is damaged. Then we must configure the H-type drone as the communication basis. It has to complete the road exploration mission simultaneously, and considering its distance from the exploration point, we can choose B or C drones to complete the task (see Figure 4). In combination with the location of the port, the flight capability of the drone, and the influence of the mountain range, we determine the population-intensive points that drones need to detect at each port (see Figure 7).

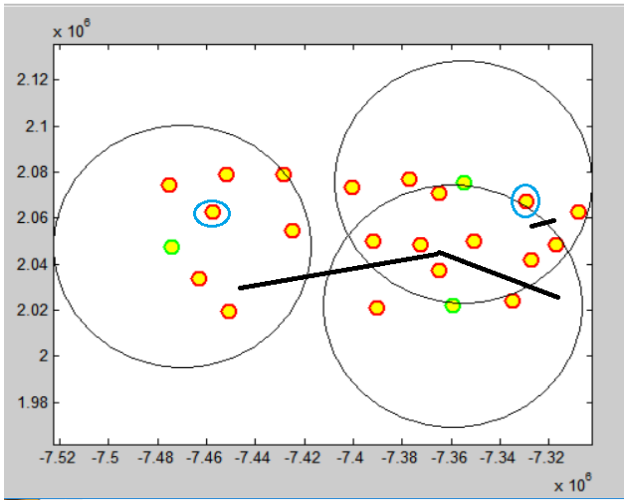

Figure 7. The population-intensive points

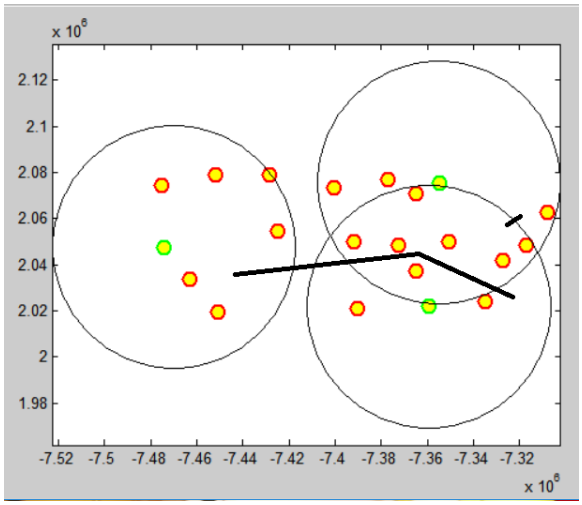

Figure 8. The population-intensive points

In Figure 6 and 7, the green circles represent three ports that cargo containers are located. represent the population-intensive points that are also the road reconnaissance points. The long straight black lines represent the mountain range. The black circles show the maximum of the area for drone flying.

We find there are two points that have been surveyed when the drone delivers medical packages. Then we cancel the two points that have been circled in blue to get final area. (see Figure 8)

At this point, the medical package and drone distribution problem have been resolved.

2.3 Simulated Annealing algorithm

Now that we have chosen the concrete ports. For three ports, the application of the SA algorithm is similar. It is merely different in the number of sites drones flying away. We take San Juan as an example to describe the algorithm.

a) The solution space S can be expressed as a circular permutation set of all fixed Starting points and ending points.

$$S=\{(\pi_1,\cdots,\pi_{11})\,|\,\pi_1=1,(\pi_2,\cdots,\pi_{10}) \text{ is the circulating of } \{2,3,\cdots,10\},\pi_{11}=11\}$$

b) The objective function is to detect the path length of all targets. It demands:

$$\min f(\pi_1,\pi_2,\cdots\pi_{11})=\sum_{i=1}^{10} d_{\pi_i\pi_{i+1}}$$

c) Through iteration, we can see the solution:

$$\pi_1\cdots\pi_{u-1}\pi_u\pi_{u+1}\cdots\pi_{v-1}\pi_v\pi_{v+1}\cdots\pi_{w-1}\pi_w\pi_{w+1}\cdots\pi_{11}$$

d) We select serial number u and v and exchange their order to make it reverse. The new Path is $\pi_1\cdots\pi_{u-1}\pi_v\pi_{v-1}\cdots\pi_{u+1}\pi_u\pi_{v+1}\cdots\pi_{11}$.

e) The path difference is

$$\triangle f=(d_{\pi_{u-1}\pi_v}+d_{\pi_u\pi_{v+1}})-(d_{\pi_{u-1}\pi_u}+d_{\pi_v\pi_{v+1}})$$

f) The reception principle is that

$$P=\begin{cases}1, & \triangle f<0,\\ \exp(-\triangle f/T), & \triangle f\geq 0.\end{cases}$$

g) In general, we think of α=0.999 to lower the temperature. Then, we stop it by ordered breaking temperature $e=10^{-30}$.

3. Results

3.1 Cargo Container Packaging Configuration

We can know about the configuration in Figure 9, Figure 10 and Figure 11.

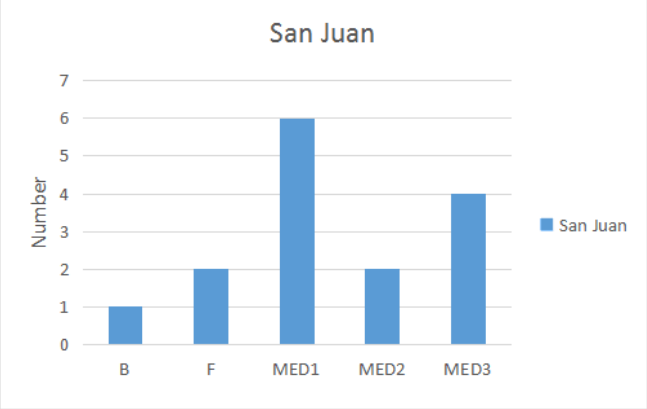

Figure 9 Cargo Container Packaging Configuration in San Juan

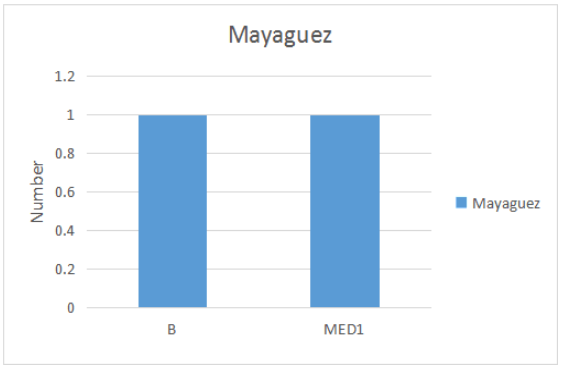

Figure 10 Cargo Container Packaging Configuration in Mayaquez

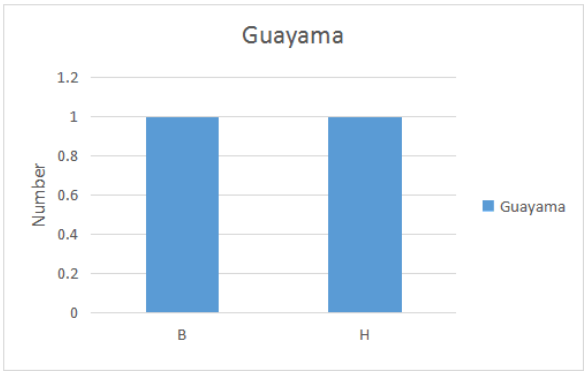

Figure 11 Cargo Container Packaging Configuration in Guayama

3.2 Locations of Cargo Containers

We set the Cargo Containers separately in San Juan, Mayaquez and Guayama.

4. Conclusion

Using algorithms and models, we solved the problem cleverly.Through the calculation of the distance between different ports, and using the simulated annealing algorithm and the establishment of the model, we completed the design of the disaster response system for the drone. This will facilitate post-disaster reconstruction in Puerto Rico.

5. Acknowledgements

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