AHP and Cluster Analysis Method for Drone Classification

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Abstract

In 2017, Puerto Rico, the United States, suffered the worst hurricane in history. It caused serious damage and casualties. In order to take effective measures to deal with disasters, a disaster response system called DroneGo needs to be designed. In our paper, a series of methods are implemented to help us to Choose the appropriate type from the given types of drones and use it, So that the selected drone is more suitable for disaster situations.

Keywords

Drone, Classification, Disaster situations.

1. Introduction

Puerto Rico is a unique island located in the northeastern Caribbean Sea. In late September, 2017, Hurricane Maria landed in Puerto Rico, causing devastating damage. As a category four storm, it caused serious damage to infrastructure and buildings. The death toll reached 2975 according to authority [1].

The tempest cut off the cellular communication network which made rescue difficult to implement. The destruction of transmission line resulted in the loss of almost all electricity for months. Widespread flooding blocked roads and highways across the island, making it impossible for rescue. Besides, heavy casualties make medical service fall short of demand. The demand for medical supplies and equipment is quite severe.

When transportation and communication are blocked but medical needs are intense, the concept of a transportable disaster response system was proposed. Through drone fleet, we can achieve the two goals of dispatching medical products and video surveillance of road conditions. This article gives some types of drones, and chooses a more suitable one

Figure 1: A drone with the cargo bay

2. Organization of the Text

2.1 Nomenclature

Table 1: Nomenclature

Symbol	Definition
X_i	the i th drone model
v_i	the speed of the the i th drone model
t_i	the flight time of the the i th drone model
V_i	the volume of the i th drone model
Z_i	the i th ISO container
Y_i	The i th drone cargo bay model

2.2 Cluster Analysis Method for Drone Classification

Considering H-type drone has neither loading capacity nor video capacity, we do not take it into the alternative drone models. We consider that the drone fleet needs to carry out two tasks: medical supply delivery and video reconnaissance. The monitoring area on the island is broad and the road condition is complex. Moreover, the number of hospitals is relatively large and the demand for medical care is strong. Thus, we classify the seven types of drones into three categories according to their flight distance. Video reconnaissance is mainly performed by drones with long flight. Drones flying in short and medium distance should have better loading capability while the flight distance is not too long.

We define the drone model as. Their flight time is described by a two-dimensional variable. We use Absolute Distance Method to measure the distance between points, and we use the Shortest Distance Method to measure the distance between classes. Thus, we get the following formula [2].

$$\begin{cases} d\left(X_i, X_j\right) = \sum_{k=1}^{2} \left|v_{ik} - t_{ik}\right| \\ D\left(G_p, G_q\right) = \min_{\substack{X_i \in G_p \\ X_j \in G_q}} \left\{ d\left(X_i, X_j\right) \right\}. \end{cases} \tag{1}$$

where are the categories of samples.

We calculate the Distance Matrix from the Distance Formula

$$\begin{array}{c} \\ X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \\ X_6 \\ X_7 \end{array} \begin{array}{c} \begin{array}{ccccccc} X_1 & X_2 & X_3 & X_4 & X_5 & X_6 & X_7 \end{array} \\ \begin{bmatrix} 0 & 44 & 24 & 37 & 40 & 50 & 43 \\ & 0 & 20 & 41 & 44 & 16 & 37 \\ & & 0 & 21 & 24 & 26 & 39 \\ & & & 0 & 3 & 25 & 6 \\ & & & & 0 & 28 & 5 \\ & & & & & 0 & 23 \\ & & & & & & 0 \end{bmatrix} \end{array} \tag{2}$$

Then, we input the data into MATLAB and get the following figure.

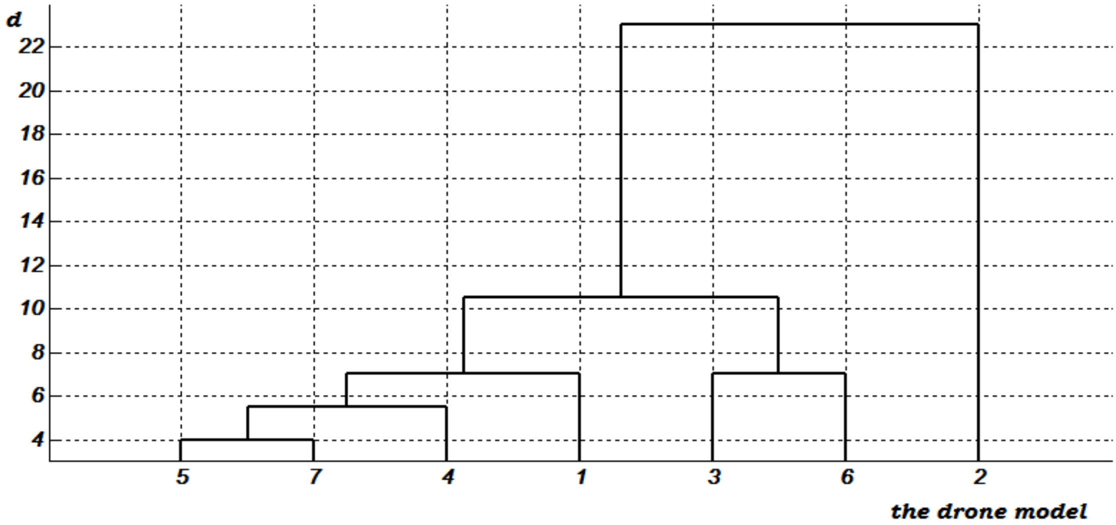

Figure 3: Classification result of Cluster Analysis

According to the observation of the figure, we divide the drones into three categories.

Table 2: Classification of drones by flight distance

long-distance class	X_2
intermediate range-distance class	X_3 , X_6
short-distance class	X_1, X_4, X_5, X_7

2.3 Optimal Selection of Drones with the Same Flight by AHP

After Clustering Analysis, we get the model of drone under each category. Since there's only one type of long-distance drone, we don't think about this class anymore. As for the medium-distance drones, doesn't have video capability while the loading capability of is poor. So we decide to use both drones as medium-distance transport drone.

Therefore, we select the drones with highest comprehensive ability in short-distance using Analytic Hierarchy Process [3]. We take five factors as evaluation indicators considering all aspects of drones.

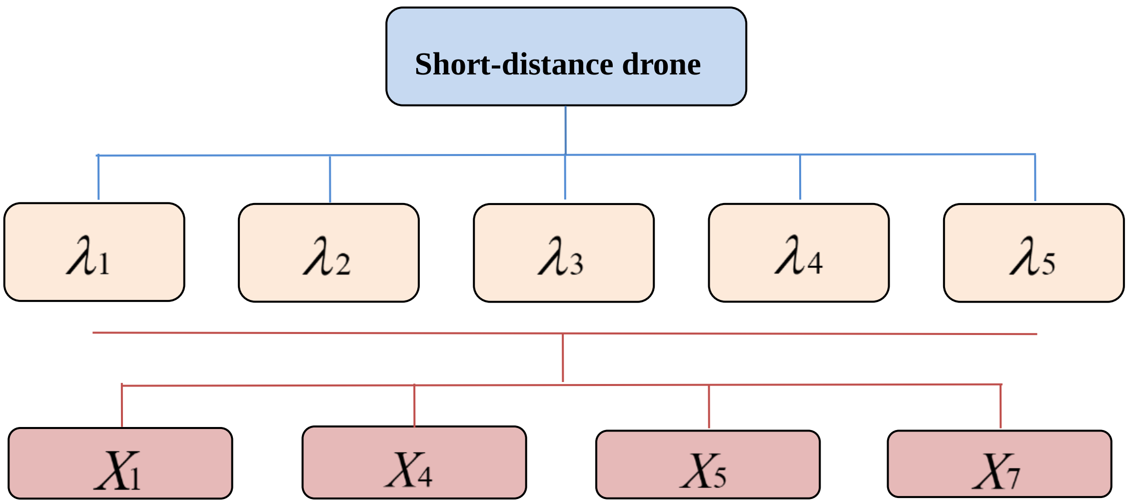

Figure 4: Hierarchies of AHP

$\lambda 1$is the factor of shipping container dimension;

λ2is the factor of max payload capability;

λ3is the factor of speed;

λ4is the factor of fight time with no cargo;

λ5is the drone cargo bay type.

According to the data we collect, we analyze the influence of each factor on drones' dispatching capability in disaster areas. And we obtain the judgement matrix of five factors. We standardize it to the following matrix and get the value weight of each factor. After calculation, we know that the matrix pass the consistency test.

$$\lambda = \begin{pmatrix} 0.1330 & 0.2500 & 0.2140 & 0.2667 & 0.0925 \\ 0.0440 & 0.0830 & 0.0710 & 0.0667 & 0.1181 \\ 0.0889 & 0.1667 & 0.1428 & 0.1333 & 0.7574 \\ 0.0670 & 0.1667 & 0.1428 & 0.1333 & 0.1574 \\ 0.6670 & 0.3330 & 0.4286 & 0.4000 & 0.4274 \end{pmatrix} \quad (3)$$

We can obtain the value weight of each factor by solving the eigenvectors of the above matrix.

$$\alpha = \begin{pmatrix} 0.1850 & 0.0745 & 0.1330 & 0.1277 & 0.4791 \end{pmatrix}^T \quad (4)$$

For element, we establish a comparison matrix of four drone models.

$$m_1 = \begin{pmatrix} 0.0625 & 0.0670 & 0.0940 & 0.0526 \\ 0.4375 & 0.4670 & 0.5625 & 0.4737 \\ 0.1250 & 0.1560 & 0.1875 & 0.1579 \\ 0.3750 & 0.3110 & 0.9375 & 0.3158 \end{pmatrix} \quad (5)$$

We also get the comparison matrix of the other four aspects, and all the matrices pass the consistency test. The characteristics vectors of four drone models in five aspects are as follows.

$$\beta = \begin{pmatrix} 0.0644 & 0.2321 & 0.2727 & 0.6410 & 0.1000 \\ 0.4598 & 0.1745 & 0.2273 & 0.1579 & 0.3000 \\ 0.1479 & 0.2502 & 0.2273 & 0.0987 & 0.3000 \\ 0.3279 & 0.3432 & 0.2727 & 0.1024 & 0.3000 \end{pmatrix} \quad (6)$$

Eventually, we derive the final score:

$$F = \beta \cdot \alpha$$

Table 3: The Final score of each drone

Drone model	X_1	X_4	X_5	X_7
Final score	0.0745	0.1336	0.1277	0.4791

By ranking them, we consider as the type with highest comprehensive ability in short-distance. And we choose as our short-distance transport drone.

Thus, our DroneGo fleet includes four drones:

Table 4: The DroneGo fleet

short -distance	medium-distance	long-distance
X_4	X_3 and X_6	X_2

2.4 Flying Plan

We assume that drones can be recharged at the site of ISO containers and densely populated areas. Therefore, the drones can fly to all the destinations. Thus, the drones can fly continuously.In order to constantly monitor road conditions throughout the island, we analyze the flight routes and flying time of drones so as to maintaining monitoring of road conditions throughout the island. We need to capture constant information of road conditions.

Therefore, every drone will fly at the maximum speed. The monitoring scope is divided into three parts, and the flight plan is analyzed according to the order of short-distance, mid-distance and long-distance. Each part is divided into small areas. The drones all fly in the same direction.Duplicate roads are divided into two equal sections, which are put into two areas respectively. Two nodes of the duplicate road will have two drones from two areas respectively.

Figure 5: The flying route for video reconnaissance

3. Conclusions

In 2017, Puerto Rico, the United States, suffered the worst hurricane in history. It caused serious damage and casualties. In our paper, a series of methods are implemented to help improve its capability. Through this article, we have realized the classification of drones, and selected the appropriate drones using modeling methods such as analytic hierarchy process, and finally planned the flight direction of the drones to achieve effective rescue and monitoring in response to disasters.

References

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