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UAV rescue combination problem based on integer multi-objective linear programming and TOPSIS method

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Abstract

To develop a drone disaster response system, this paper aims at the relationship between drone fleet, medical kit, and ISO container to meet the needs of medical kits. Restrictions. Finally, the optimal combination of drone rescue was selected by TOPSIS method.

Keywords

Drone rescue combination, integer multi-objective linear programming, TOPSIS method.

1. Introduction

Natural disasters have sudden characteristics, and the key to disaster emergency rescue is a rapid response after disasters. Timely and rapid disaster information plays a vital role in formulating rescue strategies promptly and improving rescue efficiency and quality. Compared with satellite remote sensing and manned aerial remote sensing, the UAV aerial remote sensing system has the characteristics of reliable real-time, flexible maneuverability, high image resolution, and low cost, and can operate in high-risk areas.

2. Introduction to the problem

In 2017, Puerto Rico in the United States was hit by the worst hurricane. The hurricane caused severe damage to the island, killing more than 2,900 people. Storms from storms and heavy rains knocked down 80% of Puerto Rico's utility poles and all transmission lines, causing almost all islands to lose power. Also, the storm destroyed or destroyed most of the island's cellular communications networks. Power and battery service disruptions in most parts of the island lasted for months and longer in some areas. Extensive flooding has blocked and destroyed many highways and roads on the island, making it almost impossible for emergency service ground vehicles to plan and navigate their routes. Dozens of areas in Puerto Rico were isolated, and there was no communication. Non-governmental organizations (NGOs) often face the challenge of providing an adequate and timely response during or after natural disasters, such as the hurricane that hit the US territory of Puerto Rico in 2017. In particular, a non-governmental organization, HELP Inc, will use the International Standards Organization (ISO) standard dry cargo container to quickly transport the complete DroneGo disaster response system to a specific disaster area. Each container of all drones in DroneGo, as well as all required medical packages, must accommodate up to three ISO cargo containers for transport to one location. If three cargo containers are used in the disaster area, up to three different locations can be accommodated. The contents of each shipping container should be packaged to minimize the need for buffer material for unused space.

The DroneGo Disaster Response System recommends a drone fleet and a medical kit to meet the requirements of the Puerto Rico hurricane scenario. Design the relevant packaging configuration for each of up to three ISO cargo containers to transport the system to Puerto Rico.

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3. Integer multi-objective linear programming model establishment

3.1 Integer programming model

Due to different models of aircraft, with specific types of drone cargo,

$$N_{kj}^{H}=\begin{cases}1, i\rightarrow j\\ 0, i\neq j\end{cases}$$

In order to meet the daily needs of disaster relief supplies, the number of medical kits in all cargo holds in the container (CC) should be equal to the number of cargo tank models required by the hospital:

$$\sum_{i=1}^{i<3} N_i^{CB}=\sum_{k=1}^{5}(N_{k1}^{H}+N_{k2}^{H}+N_{k3}^{H}+N_{k4}^{H})$$

$$\sum_{i=1}^{i<3} N_i^{CB2}=\sum_{k=1}^{5}(N_{k3}^{H}+N_{k5}^{H}+N_{k6}^{H}+N_{k7}^{H})$$

3.2 Objective function establishment:

Objective function 1: For the drone cargo compartment, the medical kit should be installed as much as possible, making the drone cargo compartment the largest

Objective function 2: For drones, the disaster is sudden, considering the aircraft's emergency capability, so the flight time;

Objective function 3: In order to maximize the number of drones installed in the container, the drone is the smallest:

Objective function 4: In order to install as many medical kits as possible, the UVA has the highest load capacity:

3.3 Constraint establishment

Definition 1: Number of medical kits in the cargo compartment of the drone:

$$MED_j^{CB}=(a_1,a_2,a_3) \qquad j=1,2$$

Definition 2: Number of medical kits (MEDs) required for each medical center:

$$MED_k^{H}=(b_1,b_2,b_3) \qquad k=1,2,\cdots 5$$

Constraint 1: For the i-th drone cargo hold, the model number and number of medical kits installed in each type of aircraft cargo hold must meet at least one medical center's demand for medical kits. It can be expressed as:

$$MED_j^{CB}\geq MED_k^{H}$$

Constraint 2: The weight of the medical kit loaded in the cargo hold carried by the drone we selected for the transport function does not exceed its load.

4. Topics method to solve the optimal model of the drone

The TOPSIS method [2] is based on the method of ranking the finite number of evaluation objects to the idealized target and is based on the evaluation of the relative merits of the existing objects. Since this problem is an NP-hard problem, we combine the integer linear programming model with the TOPSIS method to select the optimal combination of UAV and cargo model.

4.1 Selection of Topics Evaluation Indicators

It has the function of transporting medical kits, considering the load capacity, endurance, and endurance of the drone. The load capacity is reflected by the volume of the cargo compartment and the drone; the flight distance of the drone reflects the endurance capability; it has the function of reconnaissance video, considering the support capability of the drone and the stability (wind

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resistance) and endurance. The flight speed reflects the support capability; the volume represents the stability; the stability (wind resistance) is proportional to its mass, and the assumed material density of the aircraft is constant, so the stability is represented by the volume; The flight distance of the aircraft is reflected.

Table 1 Indicator data table

UVA type	load ability		cruising ability	supportability	anti-wind ability
	CB volume （$inch^3$）	payload （lb.)	flight distance (km)	flight distance (km)	UVA volume （$inch^3$）
a	1120	3.5	23.33	40	1400
b	1120	8	52.67	79	19800
c	9600	14	37.33	64	90000
d	1120	11	18.00	60	12500
e	9600	15	15.00	60	13500
f	9600	22	31.6	79	40000
g	9600	20	17.07	64	17408

5. Topics method to solve the result

Step1: Data preprocessing, in order to eliminate the influence of the dimension, normalize the vector, the larger the value, the better:

Step2: Construct a weighted normalization matrix: $C=(c_{ij})_{m\times n}$; Weight vector for each attribute: $w_{delivery}=[0.3,0.2,0.5]$, $w_{video}=[0.1,0.1,0.8]$

Step3: Get one positive ideal solution: $C_{delivery}{}^{*}=[0.07,0.05,0.14]$

Negative ideal solution: $C^{0}_{delivery}=[0.01,0.01,0.04]$

Two positive ideal solution: $C_{vedio}{}^{*}=[0.02,0.04,0.22]$

Negative ideal solution: $C^{0}_{vedio}=[0.01,0.01,0.06]$

Step4: Get the distance between the positive ideal solution and the negative ideal solution. The distance from alternative d_i to the positive ideal solution is:

$$s_i^* = \sqrt{\sum_{j=1}^{n}(c_{ij}-c_j^*)^2}$$

The distance from an alternative d_i to the negative ideal solution is:

$$s_i^* = \sqrt{\sum_{j=1}^{n}(c_{ij}-c_j^0)^2} \quad i=1,2\cdots m$$

Step 5: Calculate the ranking indicator values of each scheme (i.e., the comprehensive evaluation index), and then sort by f_i^* from large to small:

$$f_i^* = s_i^0/(s_i^0+s_i^*)$$

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Table 2 Distance value and comprehensive sort value

UVA type	medical supply delivery			ranking	video reconnaissance			ranking
	SI*	S0*	fi*		SI*	S0*	fi*	
a	0.1	0.02	0.17	6	1.22	0.38	0.24	4
b	0.07	0.1	0.59	3	0.29	1.55	0.84	1
c	0.04	0.09	0.67	1	0.63	0.97	0.61	2
d	0.11	0.02	0.14	7	1.46	0.13	0.08	5
e	0.1	0.07	0.4	5	1.58	0.04	0.03	7
f	0.05	0.08	0.61	2	0.89	0.7	0.44	3
g	0.09	0.07	0.44	4	1.49	0.1	0.06	6

According to the ranking table, the C-type drone can be selected for the transport function, and the B-type drone is selected for the reconnaissance function.

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