Environment, Resource and Ecology Journal (2021) 5: 56-61
Clausius Scientific Press, Canada

DOI: 10.23977/erej.2021.050109
ISSN 2616-3756

Research on Fire extinguishing Model Construction of UAV based on ACA Model

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Keywords: ACA, SARIMA, Fire, The shortest path

Abstract: Australia suffers from fires all the year round, especially in the eastern part of Victoria in the past two years, causing huge casualties, property losses, and environmental damage. In the face of this situation, the equipment of drones is particularly important. Our team has used some official data to give opinions on the combination of drones taking into account the possibility of future fires and the impact of terrain. The process is roughly OK. Divided into the following three stages. The paper first analyzed the fire data of Victoria, established the ACA optimization model in the eastern region where the fire was the most serious, and obtained the shortest path traversing all the heavy fire areas. Th paper calculate the scan radius. After obtaining the area of the hardest-hit area and the drone scanning area, through the differential equation, th paper believe that 10 Radio Repeater drones and 28 SSA drones are needed. At this time, the coverage rate reached 79.154%, and a road map was made.

1. Introduction

From 2019 to 2020, Australia was seriously affected by the continuous high temperature, drought and windy th paperather conditions [1], which intensified the flammability of vegetation in the forest and caused serious damage to the ecological environment. As shoth paperd in figure 1 Among them, New South Wales and eastern Victoria have suffered the most damage. Therefore, strengthening emergency rescue measures are of great significance [2].

Figure. 1 Australian Fire Satellite Data

2. Model analysis

First of all, the larger the scale of the fire, the greater the threat to personnel. Therefore, it is a need to ensure that the UA V can detect every member of the army. Therefore, it is necessary to assure that the UA V's scanning range is as large as possible. Th paper dealt with the data set provided by Carlos Paradis and got the fire distribution map in eastern Victoria. Through MA TLAB programming, the five areas with the highest frequency and degree of fire occurrence, such as figure 2 [3].

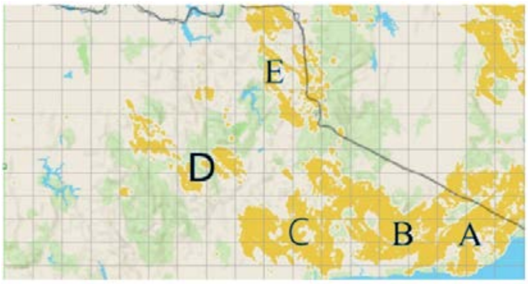

Figure. 2 Fire Distribution Map

Ant colony algorithm: use the walking path of ants to represent the feasible solution of the problem to be optimized, and all paths of the entire ant colony constitute the solution space of the problem to be optimized. Ants with a shorter path release more pheromones [4]. As time progresses, the concentration of pheromone accumulated on the shorter path becomes higher and higher, and the number of paths chosen will increase. In the end, the entire ant will be concentrated on the best path under the action of positive feedback, and at this time the corresponding is the optimal solution of the problem to be optimized. The algorithm is as follows [5]:

$$P_{ij}^{k}=\begin{cases}\dfrac{\left[\tau_{ij}(t)\right]^{\alpha}\left[\eta_{ij}(t)\right]^{\beta}}{\sum_{s\in allow_k}\left[\tau_{is}(t)\right]^{\alpha}\left[\eta_{is}(t)\right]^{\beta}}, & s\in allow_k\\ 0, & s\notin allow_k\end{cases} \tag{1}$$

m is the number of the entire ant colony, n is the number of cities; dij is the distance betth paperen city i and city j Tij s the pheromone concentration on the link path betth paperen city i and city j at time t; ants k (k=1,2…,m) Determine the next city to visit according to the pheromone concentration on the connecting path betth paperen cities; Pij represents the probability of ant k transferring from city i to city j at time t;ηij is the heuristic function, which means the ant transfers from city i to city. A is the importance of trajectory; β is the relative importance of visibility; allow k is the collection of cities that ant k has not yet reached.

$$\tau_{ij}(t+1)=(1-\rho)^{*}\tau_{ij}(t)+\Delta\tau_{ij} \quad (2)$$

According to the principle of ant colony algorithm, five points of UA V traversal and its optimal path are calculated. Th paper set up differential equations to solve the scanning time of each area and the proportion of the scanning area to determine the number of drones in each area and the safety inspection.

3. Model building

a. Objective function

Assuming that a single drone scans n points, the flight time to reach the i point is ti, i=1,2,…,n, and the time required to scan each point is ti1, i=1,2,…,n, The time for a drone to perform a task is 480 minutes. When it reaches a certain point, you can choose to scan a part of the point that is the fire area. In order to complete the task, choose the least drone, then:

$$\max \sum_{i=1}^{n}\left(t_i+t_i^1 x_i\right) \quad (3)$$

$$G(t)=1-e^{-\beta t} \quad (4)$$

In the formula, xi is the scanned ratio of the i point.

b. Constraints

Time per task:

$$\max \sum_{i=1}^{n}\left(t_i+t_i^1 x_i\right)\le 480 \quad (5)$$

Scan time:

$$\sum_{i=1}^{n} t_i^1 x_i \le c \quad c>0 \quad (6)$$

In the formula, c is the sum of the optimal scanning time in each area.

Scan ratio:

$$0\le x_i<1, i=1,2,\ldots,n \quad (7)$$

$(4)\, t_i^1>0, t_i>0, c>0$

4. Model solving

Th paper assume that the average flight speed of the SSA UA V is 60km/h, and it can fly continuously for 8 hours. Suppose the average altitude of the five target points to be inspected by the drone is h. If the radius of the inspection circle at altitude is r, then:

$$r = \frac{\sqrt{3}\left(4200 - \mathrm{h}\right)}{3}\left(\mathrm{m}\right) \tag{8}$$

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Figure. 3 Scanning Method Diagram

Through the ant colony algorithm, the optimal path explored by the ant colony can be achieved. Next, the number of drones sent and the number of points that the drones pass are analyzed. Considering that UA Vs have multiple flight plans, 1-5 UA Vs can be utilized to simulate the path respectively, such as figure 4.

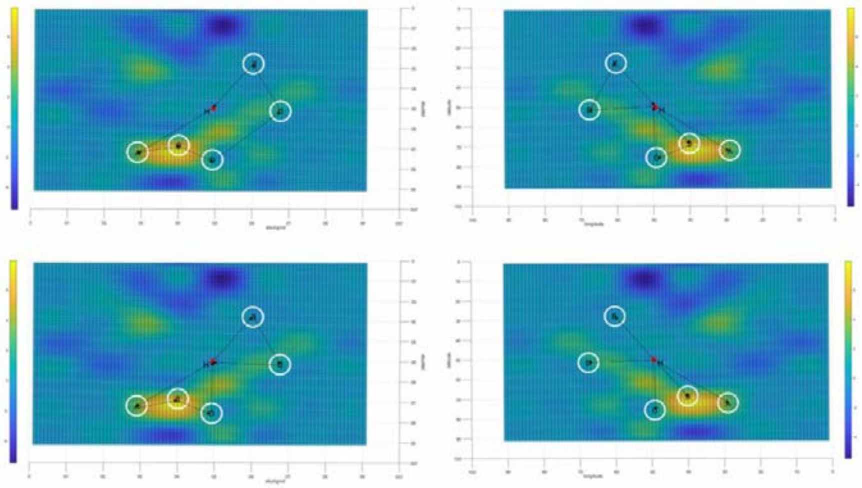

Figure. 4 Simulation Road Map

According to calculations, the paths of the four options are as follows table 1:

Table 1 Path Length

Plan	Route	Length of each route	Longest road length	Total path length	Number of UAVs
1	HABCDE	405.4	405.4	405.4	1
2	HABC HDE	210.5 164.5	210.2	374.7	2
3	HA HBC HDE	198.5 150.1 64.5	198.5	513	3
4	HA HB HC HD HE	198.5 143.2 100.3 152.6 90.4	198.5	685	5

Since the maximum flight distance of the UA V is 480km, the UA V needs to start from the base station and then back to the base station for charging. Therefore, the solution of taking off five UA Vs from the base station at the same time is most suitable.

Solve the differential equation, know the flying speed of the UA V, the effective scan width uses the scan radius r scan method. Such as figure 3. The scanning time of each area and the proportion of the area that cannot be scanned can be calculated.

Table 2 Area Scan Time Proportion of Unscannable Area

Area	A	B	C	D	E
Area scan time	169.32	174.28	127.23	139.46	159.87
Proportion of unscannable area	5.483%	4.447%	8.463%	0.709%	1.564%

It can display in table 2that the scanning time of A, B and other areas is longer. If a single drone is utilized to scan, it cannot be scanned completely in a sustainable time. It can assumes that an area can be scanned multiple times. The drone traverses and scans the fire area.

5. Conclusions

In the mountainous areas of eastern Victoria, the higher the fire frequency, the larger the communication range may be needed to coordinate the location of personnel and work with each other at any time. Repeaters must be appropriately configured. Secondly, the more complex the terrain, the stronger the signal interference, so more repeaters is needed to enhance signal transmission. In addition, the high-rise buildings in the city also hinder the propagation of UA V signals, so in order to make the signal transmission unhindered, repeaters should be placed in appropriate locations to strengthen the signal transmission. Th paper combined the topographic map of eastern Victoria and the distribution map of the city to find a reasonable location for the four repeaters. According to the area decomposition of the grid in the environment modeling, th paper traverse all the areas where fire may occur, and 11 paths are required. Considering the condition of UA V loop detection: 28 SSA UA Vs are required. as follows figure 6.

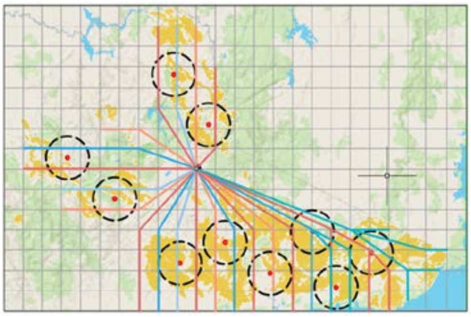

Figure. 5 Road Map

A total of 28 SSA drones and 10 Hovering Drones are required for the entire process.

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