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SSA Drones and Radio Repeater Drones

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Abstract: After analyzing the background and requirements of fighting wildfires, we decide to set two models, linear programming model and grey prediction model.We start the analysis strictly from the actual situation. Since the number of drones depends on the distance between the EOC and the fire points, we creatively transform the problem of the optimal number of drones into the evaluation problem of EOC site selection. We use the sum of the distances between the EOC and various ignition points as the objective function to establish a linear programming model. Then we summarized the fire situation into three typical periods according to the actual situation, comprehensively considering the characteristics of fire incidents, the number and location of EOC, to balance ability, safety and economy. Through the immune optimization algorithm (Immune Algorithm), the problem of best address is solved, and then the number of drones required is calculated, and the best solution for the Victoria fire incident is analyzed. We not only give the number of SSAs and UAVs carrying repeaters required in various situations, but also give an accurate and optimal distribution of UAV positions through a large number of computer simulations. This shows our determination and efforts to balance economy and safety.

1. Introduction

During the Australian wildfire season from 2019 to 2020 (commonly known as the black summer), a series of forest fires broke out in many parts of Australia. The New South Wales and Victoria regions were particularly affected. As of March 9, 2020, the fires A total of 18.6 million hectares of land have been ravaged, the homes of nearly 3 billion terrestrial vertebrates have been destroyed, and at least 34 people have died. Nearly 80% of Australians are directly or indirectly affected by forest fires, which have caused irreversible adverse effects on air quality and global warming.[1]At this time, it is particularly important to extinguish wildfires. This article will start with firefighters' use of drones for wildfire detection and communication, and study its optimization problems.

2. Preparation of the Models

2.1 Analysis of Problems

First of all, the number and combination of the two drones must meet the tasks of observation and communication during the actual firefighting period. On this basis, comprehensive consideration of the characteristics of the actual fire event, Victoria’s topography, the number and location of EOCs, balance capabilities, and safety Sex and economy. In the end, the best location for EOC, and the best number and combination of the two drones.

2.2 Assumptions

According to the meaning of the question, in order to facilitate the research of the question, the following six assumptions can be made about the question:

● In order to simplify the problem model, only the active fire point is considered, and the range of the repeater is simplified to a 40-kilometer radius and 20-kilometer radius. It is assumed that the repeater is in a fixed position when it is working, regardless of terrain alignment. The influence of relay position;

● Regarding the SSA drone as a mass point, considering the influence of terrain on the signal and the terrain of the area where the fire occurred in the Victoria area, the handheld radio signal range of frontline personnel is assumed to be 4 kilometers;

● Do not consider the longitudinal distance between human and SSA UAV and between SSA UAV and UAV carrying a repeater; when multiple SSAs share a repeater, there will be no signal interference and other issues.

● For the best position found, there is always a suitable place to hover the drone and the place where the EOC is stationed nearby.

● EOC has enough ability to command multiple fire fighting operations;

● The deployment personnel do not look at the quantity, but only look at the location, thinking that the deployment personnel are near the fire point and their distance is negligible;

2.3 Analysis of Victoria Fire Scene

Using Tableau software to analyze the fire areas in Victoria over the years, it is found that the fire-prone areas over the years can be divided into the following four areas, of which B, C, and D are areas with severe fire disasters over the years.

Figure 1: Fire-prone areas over the years

Taking the fire disaster from 2019 to 2020 as the analysis object, using Tableau software to make a distribution map of the fire points in Victoria, analyze the distribution and change trend of fire points in Victoria, and find that the fire situation in Victoria can be summarized into the following three situations.

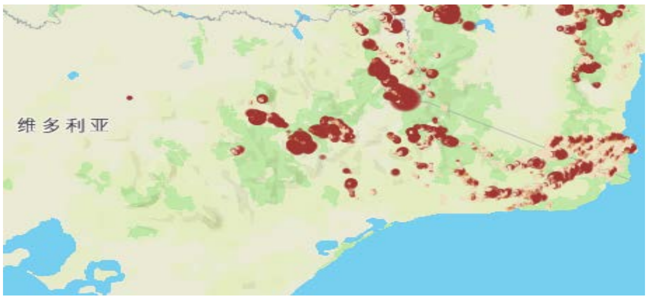

Figure 2: Fire situation one

Situation one: The fire situation is severe, and the number of fire spots in the three fire-prone areas is large and scattered

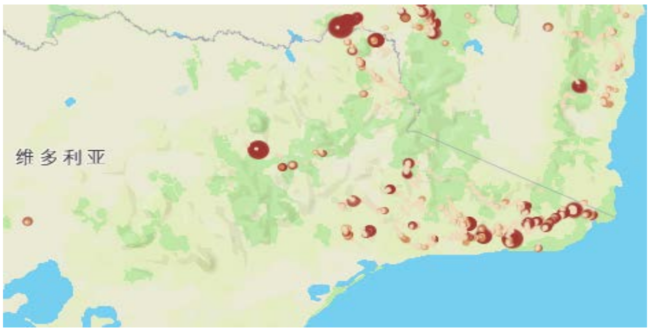

Figure 3: Fire situation two

Situation two, the fire areas are scattered, and only one or two fire situations are severe.

Figure 4: Fire situation three

2.4 Model Construction

First of all, because the number of drones depends on the distance between the EOC and the fire point, in order to simplify the problem model, we transformed the problem into solving the shortest path problem, that is, choose the EOC position with the smallest total distance from the fire point to achieve the lowest hardware equipment cost. In order to realize the model, we creatively transformed the problem of the optimal number of drones into an evaluation problem of ECO site selection. We use the sum of the distances between the EOC and the fire points as the objective function to establish a linear programming model.

The EOC site selection problem is described as selecting a certain number of locations (p) from a limited number of locations (m), establishing a command center on a reasonable scale, and commanding n fire locations, which are collectively referred to as demand points below, making the selection On the premise of meeting the command requirements, the EOC established by the outpoint has the lowest cost (including the cost of drones and EOC construction, and labor costs), thereby achieving a balance of capability, safety and economy. Therefore, the following assumptions are made in the EOC location model:

(1) EOC has enough ability to command multiple fire fighting operations.

(2) Only one EOC is in charge of a fire point.

(3) Assuming that the calculated location, there is a suitable place for the hovering of the repeater drone and a place where the EOC is stationed nearby.

(4) When multiple SSAs share a repeater, there will be no problems such as signal interference.

Based on the above assumptions, the following model is established. This model is a site selection/allocation model. In the case of meeting the upper limit of the distance, it is necessary to find the command center from n demand points, and communicate and command with the deployment personnel at each fire point. The objective function is the smallest sum of the product of the demand and the distance from the EOC to each demand point. The objective function is

$$\min F = \sum_{i \in N} \sum_{j \in M_i} w_i d_{ij} Z_{ij} \tag{1}$$

The constraints are

$$\sum_{j = M_i} Z_{ij} = 1, i \in N \tag{2}$$

$$Z_{ij} \le h_j, i \le N, j \le M_i \tag{3}$$

$$\sum_{j \in M_i} h_j = p \tag{4}$$

$$Z_{ij}, h_j \in \{0,1\}, i \in N, j \in M_i \tag{5}$$

$$d_{ij} \le s \tag{6}$$

Among them, is the set of serial numbers of all demand points; is the set of candidate EOCs whose distance to the demand point is less than s, which represents the demand for the demand point; represents the distance from demand point i to the nearest EOC, which is 0- 1 variable, when it is 0, it means it is not commanded by the EOC, when it is 1, it means it is commanded by the EOC. s is the upper limit of the distance from EOC to the demand point.

Equation (2) ensures that each demand point can only be commanded by one EOC; Equation (3) ensures that the demand point can only establish a communication relationship with EOC; Equation (4) specifies that the number of EOCs selected is p; Sub (5) means that the sum of variables is 0-1 variable; Formula (6) ensures that the distance between the demand point and the EOC is within the set range.

Next, we aim at three typical scenarios of actual fire events in Victoria, and use the immune algorithm to solve the best address of the EOC based on the linear programming model analyzed above.

3. Results

Situation 1:

Fire point	Location (latitude, longitude)	Distance to EOC (km)	Handheld radio range(km)	Number of repeaters	SSA quantity
1	(-37.6711°,147.89732°)	39.2363	5	1	**2**
2	(-37.65982°,148.78326°)	36.0669	5	1	**2**
3	(-37.54973°,148.64256°)	35.3035	5	1	**2**
4	(-37.44067°,149.5961°)	78.9148	5	2	**3**
5	(-36.945°,146.77679°)	239.7879	5	6	**7**
6	(-36.03945°,147.82362°)	188.123	5	5	**6**
7	(-35.93152°,147.51044°)	220.2957	5	6	**7**
EOC	**(-37.3536°,148.8924°)**				

Analysis: Combined with the actual coordinate points and the cost, draw the distribution of EOC and repeaters as shown in the figure:

Note: In the figure below, the red serial number point represents the repeater, and the blue serial number point represents the location of the fire point

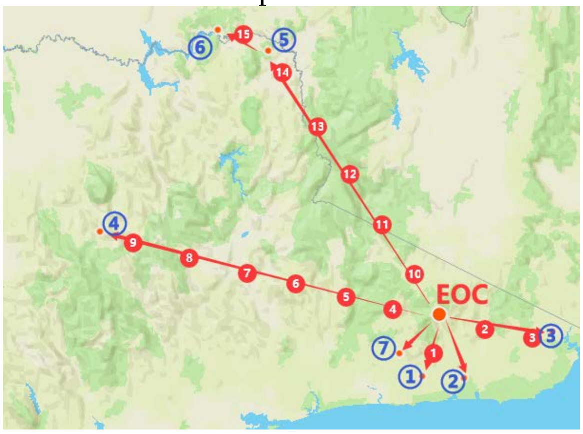

Figure 5: EOC and Drones distribution results of fire situation 1

4. Conclusion

We start the analysis strictly from the actual situation. Since the number of drones depends on the distance between the EOC and the fire points, we creatively transform the problem of the optimal number of drones into the evaluation problem of EOC site selection. We use the sum of the distances between the EOC and various ignition points as the objective function to establish a linear programming model. Then we summarized the fire situation into three typical periods according to the actual situation, comprehensively considering the characteristics of fire incidents, the number and location of EOC, to balance ability, safety and economy. Through the immune optimization algorithm (Immune Algorithm), the problem of best address is solved, and then the number of drones required is calculated, and the best solution for the Victoria fire incident is analyzed.We not only give the number of SSAs and UAVs carrying repeaters required in various situations, but also give an accurate and optimal distribution of UAV positions through a large number of computer simulations. This shows our determination and efforts to balance economy and safety.

References

[1] Wikipedia: 2019–20 Australian bushfire season. 2021.2.5. https://en.wikipedia.org/wiki/2019%E2%80%9320_Australian_bushfire_season
[2] Wang Yingjie, Ding Mingtao, Zhang Minghui. Application of gray GM (1,1) model in the prediction of debris flow activity trend in Wenchuan County [J]. Geological Hazards and Environmental Protection, 2020, 31(01): 23-29.
[3] Li Zhibin. Forest fire disaster prediction in Changting County based on grey system theory [J]. Subtropical Soil and Water Conservation, 2016, 28(02): 26-29.
[4] Wikipedia:https://en.wikipedia.org/wiki/Bushfires_in_Australia
[5] Wikipedia: https://en.wikipedia.org/wiki/Climate_change_in_Australia#Pre-instrumental_climate_change
[6] Goverment:https://www.kerncountyfire.org/en/operations/divisions/office-of-emergency-services/operations-center.html#: ~:text=The%20cost%20of%20the%20EOC, voice%20data%20equipment%2C%20and%20furniture.
[7] http://forex.hexun.com/rmbhl/#zkRate