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Optimal Arrangement Strategy of Unmanned Aerial Vehicle Fire Monitoring Based on Comprehensive Evaluation Model-Take the Impact of the Australian Fire Season on the State of Victoria

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Abstract: The fires seasons in Australia have disastrous impacts on Victoria. In order to enable the commanding center to obtain the information of the fires front-line in time so that conduct the front-line firefighters safely and effectively is one of the core tasks. Based on the evaluation model, this paper determines the optimal number and combination of the two UAVs, adapts to the occurrence of extreme fire in the future, and provides fire information for the command center in time. We decide the best solution for 38 SSA drones and 14 radio-repeater drones.

Keywords: Comprehensive Evaluation Model; Bush Fires in Australia; Working Drones

1. Introduction

Bush fires in Australia are wildfires that occur frequently in hot and dry seasons. In order to detect and report wearable device data of front-line personnel and more complex environmental conditions, firefighters have used drones for surveillance and situational awareness (SSA) for several years. The radio repeater can greatly expand the range of low-power radio in front-line and ensure the reliable contact between firefighters and EOC. So, we established the analytic hierarchy process (AHP [1]) evaluation model to assess our scheme, and finally selected the best combination of drones.

2. Model Establishment and Solution

We collected satellite data on fires in Australia originally on the NASA website. Then we used Python to integrate the data. After that we used Tableau software to visualize the integrated data. Thus, we used the visualized images to decide the combination schemes of SSA drones and radio repeater drones which can provide disaster relief. And we defined the weight of the index by AHP model [2].

2.1. Processing Data Visually

First, we collected the fire data in Australia. There were four sets of data, and we used Python program to preprocess and integrate these data [3]. We determined the visualization scope of Victoria data based on further analysis of the first step data. The visual images are as follows:

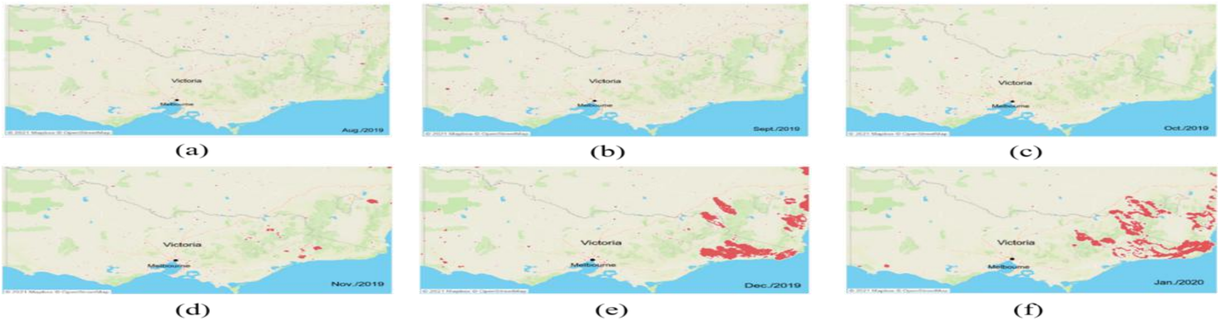

Figure 1 Fires distribution in Victoria

(a-f in the figure show the fire distribution of each month from August 2019 to January 2020, and the red dots indicate that there has been fires in the area)

2.2. Determine the Best Combination of Two Types of Drones

By observing the visual images of fire in Victoria, we can clearly see that the scale and frequency of fires in August were the smallest while in December were the largest. Notably, in October, the scale and frequency of the Victoria fires were in the middle.

We believe that the larger number of SSA and radio transponder UAVs must have better disaster response capabilities and safety considerations. However, if there are too many of these two types of drones, they will not meet the requirements of economic conditions. So we choose August, October and December to represent the change of parameters of the size and frequency of fire in Victoria.

First, we defined the general area of the fire according to the fire visualization image in August. At the same time, we took the terrain condition of the fire area as a parameter.

As a result, we concluded that in August, the combined number of SSA and Radio Transponder UAVs was 18 SSA and 6 Radio Transponder UAVs.

We have decided to combine the number of SSA drones and radio repeater drones in October as follows: 26 SSA drones and 10 radio repeater drones. Besides, the quantity and combination of December are as follows: 38 SSA drones and 14 radio repeater drones.

2.3. Define the Weight of a Given Index through AHP Model

We need to integrate the four indicators of disaster relief capability, security, economy, observation field of vision and communication task completion of the scheme. We use AHP model to determine the weight of these four indexes.

In the first place, we compared the four indicators in pairs to construct a judgment matrix.

Later, we check the consistency of the judgment matrix, it is easy to get:

$$\lambda_{\min} = 4.0206 \tag{1}$$

The consistency index is

$$CI = \frac{\lambda_{\max} - n}{n-1}, (n = 4) \tag{2}$$

Next, according to the consistent proportion formula, the average random consistency index RI is obtained:

$$CR = \frac{CI}{RI} \tag{3}$$

Consistency ratio calculated was $CR = 0.0077$ and it satisfied the condition of $CR < 0.1$ .So it passed the consistency test.

Finally, the weight vector of each index is

$$\varpi = (0.1508, 0.5143, 0.1899, 0.1899)^T \tag{4}$$

It should be emphasized that in previous papers, when AHP is used to solve practical problems. However different calculation methods may lead to some deviation in the results. For the sake of ensuring the robustness of the results, we use the three methods to calculate the weight respectively.

2.4. Normalize the Data

In the previous modeling process, we have obtained three plans with quantity and combination about two drones. We quantify the security, economy, business observation scope and communication task completion of the three schemes. We assume that the number of SSA UAVs is m, and radio repeater UAVs is n. We quantify the security side, with using the scope of relief and the ratio in Victoria

$$Z = 10000 \times (m + n) \tag{5}$$

We make use of the observable range of SSA drones to carry out quantitative processing on the index of observation field of vision. A SSA drone can fly a distance of 30km, so the observable range of each scheme is

$$S = 30^2 \times \pi \times m \tag{6}$$

We use the range of the signal that can be transferred between the radio repeater drones and the front-line personnel to quantify the communication range. A radio repeater UAV can achieve a signal transmission radius of 30 km by hovering at high altitude. Therefore, the signal transmission range of each scheme is

$$S = 30^2 \times \pi \times n \tag{7}$$

Through the above analysis, we can determine the quantitative data of each scheme in each index. We set up the table as follows. After normalization, the results are as follows,

Table 1 Normalized data

Indexes \ Plans	FIRST	SECOND	THIRD
Security	0.1588	0.3012	0.5400
Economy	0.2146	0.3214	0.4643
Field of vision	0.2195	0.3171	0.4634
Completion of communication tasks	0.2000	0.3333	0.4667

2.5. Determination of the Best Scheme

We have decided the weight of each index and the quantitative data and normalized data of each scheme in each index. Then we evaluate the three schemes

FIRST:

$$0.1588 \times 0.1508 + 0.2146 \times 0.5143 + 0.2195 \times 0.1899 + 0.2000 \times 0.1899 = 0.2139$$

SECOND:

$$0.3012 \times 0.1508 + 0.3214 \times 0.5143 + 0.3171 \times 0.1899 + 0.3333 \times 0.1899 = 0.3342$$

THIRD:

$$0.5400 \times 0.1508 + 0.4643 \times 0.5143 + 0.4634 \times 0.1899 + 0.4667 \times 0.1899 = 0.4970$$

According to the above analysis, the highest score of the third scheme is 0.4970, which means that the third scheme can better balance four indexes. As a result, our final scheme is 38 SSA drones and 14 radio repeater drones.

3. Conclusion

In order to maximize the transmission of fire information from the front line to the command center, we established a model which can determine the best combination scheme of SSA drones and radio repeater drones. Later, we adopted 38 SSA drones and 14 radio repeater drones.

References

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