Problem Chosen	2021	Team Control Number
B	MCM/ICM Summary Sheet	2106317

Trajectory Planning of Drone Formation Based On Artificial Fish Swarms Algorithm

Summary

Australia has seen big wildfires in recent years. When fighting a fire, the SSA drones used by the fire brigade for communication and fire observation is the shining star in the fight against the fire. However, in the face of the two antagonistic demands of economy and safety, it is of great significance to use SSA drones with the least budget to ensure the safety of firefighters. In order to get the optimal number of drones, we established a drone flight planning model based on artificial fish school algorithm. By generating environmental variables in a specific disaster relief area, and then optimally planning the orbits of different numbers of SSA drones, we get the cost and safety performance of arranging a specific number of drones. Through our simulation experiment in a forest-urban area in Victoria, we have obtained that a single EOC fire brigade that safely controls a 5x5 km requires 15 SSA drones and 4 radio repeaters drones.

In the model, we quantitatively describe the possibility and hazard of fire at a specific location based on fire data over the years. Each SSA drone executes a predetermined drone trajectory cooperation scheme to make the trajectory close to the optimal. Therefore, by calculating the safety performance of different tracks, we have obtained a scheme that guarantees the safety and uses the least cost to improve the highest performance. All orbital schemes and indicators for evaluating their performance can be quantified and visualized.

In order to study how the model adapts to extreme fire conditions in the next 10 years, we combined with the climate conditions in a specific area and called the gray prediction model to get the wildfire trend in the next decade. We generate predicted environmental data from these trends, and perform another simulation on the existing orbit planning model. We found that the model will perform well in the next 6 years. Considering the influence of altitude on the radio repeater drone, we then add altitude information to the environmental variables, and optimize the position through the traditional artificial fish swarm algorithm.

Sensitivity analysis shows the strong robustness of our model and the importance of setting constant parameters to the algorithm. Later, we will combine the geographic location and urban distribution of Victoria Forest to write a drone budget table with purchase basis to the Victorian government.

key words: Artificial fish swarm algorithm; Quantitative visualization; Grey prediction;

Contents

1 Introduction

1.1 Background

From 2019 to 2020, devastating wildfires occurred in all states of Australia, with the worst impact in New South Wales and eastern Victoria. To monitor the fire, firefighters have used drones for surveillance and situational awareness(SSA). Drones are divided into SSA drones and Radio Repeater drones. It is necessary to design the number of drones and the combination of drone formations.

1.2 Restatement of the Problem

Consider the background information, the requirements identified in the problem statement, and the information provided in the problem attachment to address the following issues.

- In order to purchase for a proposed new division, “Rapid Bushfire Response”, of Victoria’s Country Fire Authority (CFA), a model needs to be created to determine the optimal number and combination of SSA drones and Radio Repeater drones. The model needs to consider capability and safety with economics, and consider observational and communications mission needs and topography. In addition, your model should also incorporate fire event size and frequency as parameters.
- Explain how your model adapts to the changing likelihood of extreme fire events in the next decade, and if the cost of the drone systems stays constant, how much equipment cost is expected to increase.
- Determine a model for optimizing hovering VHF/UHF radio-repeater drones on different terrains with different levels of firepower. An example map is given.
- Prepare a one- to two-page annotated Budget Request supported by your models for CFA to submit to the Victoria State Government.

1.3 Our Works

- First, we build a model to analyze the optimal number and combination of drone to purchase, and determine the selection based on the model.
- Then we estimate the equipment cost based on the predicted development and transformation in ten years.
- We use artificial fish swarms algorithms to plan the drone path of action reasonably, and determine the route by considering fire event size and frequency as parameters. And then optimize the position of VHF/UHF radio-repeater drones in r fires of different sizes on different terrains.
- Finally we will write a one- to two-page annotated Budget Request supported by our models.

2 Assumptions and Notations

2.1 Assumptions

Due to the lack of necessary data, we make the following assumptions to help us perform modeling.

1. Assuming that multiple WileE-15.2X hybrid drones are used in the deployment process, which are equipped with monitoring equipment and repeaters. The drones, monitoring equipment and repeaters are in good working condition, and air resistance and weather are ignored during the flight. Keeping the maximum flight speed of 20m/s moving at a constant speed, the flight height will not affect the flight status of the drones.
2. Assuming that the drone mission environment is a rectangular area mainly composed of the wildfire-prone areas in Victoria in recent years, the environmental model is appropriately simplified, and the map is simplified to a distribution map of flat areas and rugged areas according to the terrain and urban-rural distribution. And according to the wildfire data in recent years, corresponding to the latitude and longitude coordinates, set the corresponding parameters of the coordinates. According to known conditions, the range of the handheld radio carried by the forward personnel is 5km in the flat area and 2km in the urban area. This is equivalent to the

SSA drones' monitorable signal range of 5km and 2km in the flat area and the urban area respectively.

3. Assuming that the EOC position is fixed, the drone carrying the repeater will hover after reaching the position, and the radio signal will not be affected by weather factors

2.2 Notations

Here are all the notations and their meanings in this paper.

Symbol	Meaning
X_i	Drone location
Visual	Artificial fish field of view
E_i	Longitude of coordinate point
W_i	Latitude of coordinate point
P_{f_i}	Probability of fire at coordinate point
δ_i	Drone charging desire
L_i	Drone track length
d_i	Distance from charging point
ε_i	Remaining battery t
J_i	Various cost functions
Y_i	Evaluation function
η_i	Refreshing rate

3 Optimal Combination of Drones(Question 1)

3.1 Environment Modeling

We use grid method to divide the planning space. The track is connected by adjacent grid nodes. Each grid node contains the longitude and latitude coordinates, fire probability and terrain information (city or forest) in the planning environment, and records the point Refresh rate.

Figure 1 depicts the link of track points, that is, the next node of each node intelligently appears in eight adjacent nodes. Thus, the trajectory planning can

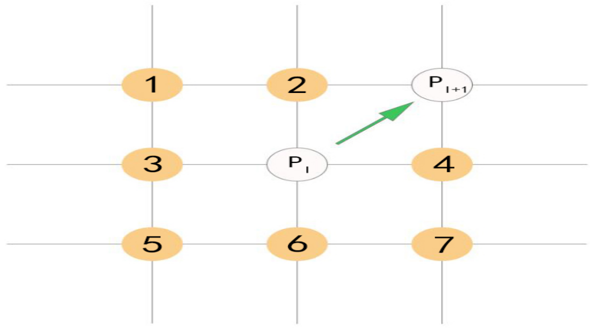

Figure 1: Node diagram

be described as:

$$S(x_s, y_s) \xrightarrow{\Gamma(q)} P_1(x_1, y_1)...P_{n-1}(x_{(n-1)}, y_{(n-1)}) \xrightarrow{\Gamma(q)} G(x_g, y_g) \tag{1}$$

Formula 1 $S(x_s, y_s)$ is the starting point ; $G(x_g, y_g)$is the target point ; $P_1(x_1, y_1)$... $P_{n-1}(x_{(n-1)}, y_{(n-1)})$ is the intermediate track node; $\Gamma(q)$ represents the constraint condition; q is the track constraint parameter.

More importantly, to refine the environmental conditions, we visualized the fire probability of the map, and selected the rectangular area in the map where the fire probability distribution and the city / forest distribution are more suitable.

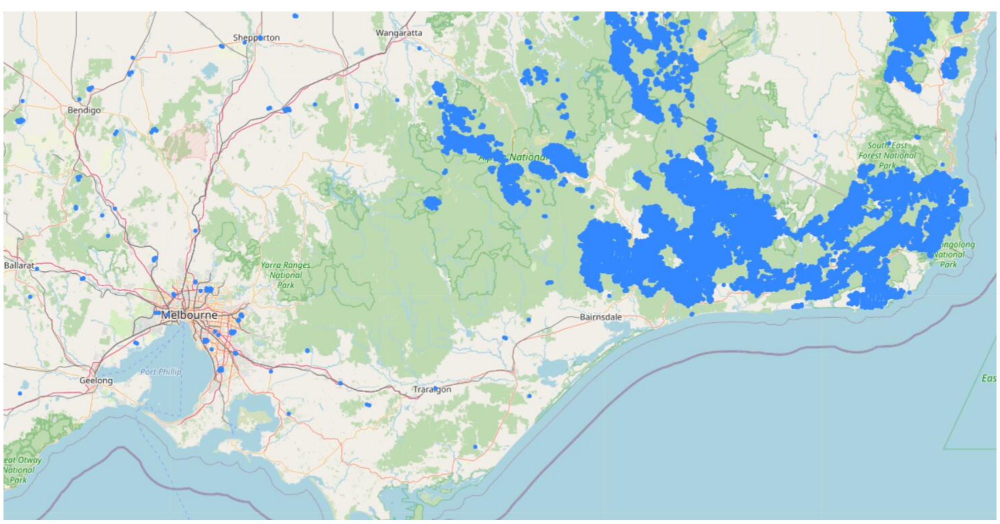

Figure 2: Wildfire probability distribution map of Victoria

As is illustrated in Figure 3, the longitude and latitude coordinates of the four corners of the rectangular region are:

$$\begin{cases} (-37.790163, 148.017149), (-37.790163, 148.567343), \\ (-37.413923, 148.017149), (-37.413923, 148.567343) \end{cases} \tag{2}$$

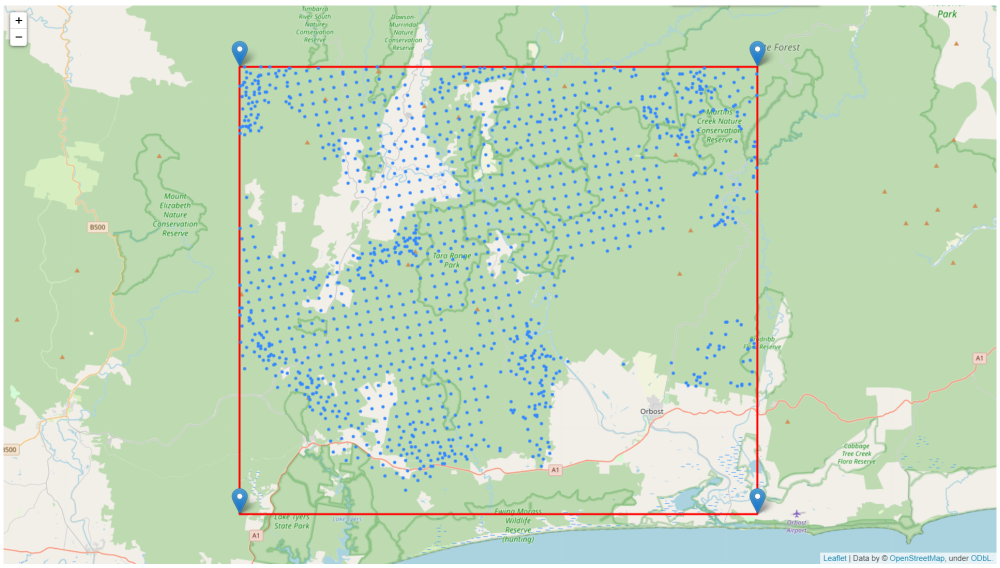

Figure 3: Target region overview

3.2 Determine Details of Algorithm

In the artificial fish school algorithm, the topographic map is abstracted as a two-dimensional plane containing only coordinate points, and each coordinate point records information, including the probability of future fire at that point and the refresh frequency. At each moment, at least one drone's monitoring signal range can cover the coordinate point, then the coordinate point is said to be safe; if the coordinate point is out of the monitoring signal range of all drones from a certain moment, then from that moment Ts starts to record the time until the coordinate point is covered by the drone monitoring signal again (recorded as Te at this time), this time period is called the refresh time $Tr = Te - Ts$ Define refresh frequency: refresh time divided by unit time Treat the drone as an artificial fish, set it in the target search space, there are N artificial fish forming a formation, The vector represents the individual state of the artificial fish, including charge desire Define the desire to charge: the desire to go to the charging point that determines the charging needs such as the distance from the charging point and the remaining power. This desire is higher than the desire to charge when looking for food. The current food concentration of the artificial fish is the refresh frequency. The planning goal is to make the refresh frequency of the coordinate points within a specific range reach a higher level, select a specific number of artificial fish, record and compare the refresh frequency and cost of the coordinate points when the target is reached Cost, comprehensive consideration of efficiency and cost, to arrive at the best UAV arrangement strategy

According to the actual situation and budget constraints, set the range of the number of drones to . For each possible number of drones, call the artificial fish school algorithm for planning and testing, and record the number of drones when the target is reached Refresh frequency and cost of time coordinate points, and finally get the best UAV formation number.

Define the foraging behavior of artificial fish. Suppose that the current status of the i artificial fish is$X_i = (E_i, W_i, P_{f_i}, \delta_i)$, charge desire is $\delta_i = f(d_i, \varepsilon_i)$, the refresh rate function for the current location is $P_{r_i} = f(T)$. On the basis of the following equation, check the state of the surrounding eight points within the range of perception $X_V = (X_1, X_2, \cdots, X_8)$ and the refresh rate of each status$P_{f_i} = (P_{f_1, P_{f_2}, \cdots, P_{f_8}})$.

$$X_V = X + visual \cdot rand() \tag{2.1}$$

Then obtain the minimum fire probability state point in the nearby lattice, we establish the following equation and move the fish as follows so that X_i could reach a new state:

$$X_{next} = X + \frac{X_v - X}{\|X_v - X\|} \cdot step \cdot rand() \tag{2.2}$$

Define the charging behavior of artificial fish. The distance from the charging point d_i and the remaining power $\sigma_i = f(L_i)$ determine the charging desire to the charging point $\varepsilon_i = f(d_i, \sigma_i)$, when this index is higher than the foraging desire$\phi_i = f(P_{f_i})$, return to the charging point. Therefore, we establish the following equation:

$$X_{next} = \begin{cases} X + \frac{X_v - X}{\|X_v - X\|} \cdot step \cdot rand(), & \varepsilon_i < \phi_i \\ X_{charge}, & \varepsilon_i \geq \phi_i. \end{cases} \tag{3}$$

Define the anti clustering behavior of artificial fish. Each artificial fish moves to the center far away from its companion as far as possible in the process of swimming, so as to prevent overcrowding and flight direction aggregation.

Suppose that the current status of the i artificial fish is$X_i = (E_i, W_i, P_{f_i}, \delta_i)$, charge desire is $\delta_i = f(d_i, \varepsilon_i)$, the refresh rate function for the current location is $P_{r_i} = f(T)$. Take the position of the current fish as the center, the number of artificial fish within its sensing is N_f and these fish form an aggregateS_i.The fish aggregate obeys the following formula.

$$S_i = X_i | \, \|X_j - X_i\| \leq visual, j = 1, 2, \cdots, i, i+1, \cdots, n \tag{3}$$

If the aggregate $S_i \neq \varnothing$ ($\varnothing$ means a empty set), it illustrates that there is at least one artificial fish in the perceptual range of the i artificial fish, namely $N_f \geq 1$.Then check the status of the points X_V in the aggregateS_i and the refresh rate P_{r_i} of each state, find out the minimum refresh rate state point $minP_r$ in the nearby lattice. Thus, we find the center position of the aggregate X_{center} and the fish moves forward towards the position.The trajectory accords with the following equation:

$$X_{next} = X + \frac{X_{centre} - X}{\|X_{centre} - X\|} \cdot step \cdot rand() \tag{4}$$

If the aggregate $S_i = \varnothing$($\varnothing$ means a empty set), it indicates that there is no other artificial fish in the perceptive range of artificial fish i, namely$N_f = 0$. Then it will perform foraging behavior.

3.3 Determining the Price Function

Define the fire threat cost. We determine the formula below to describe the fire threat cost quantitatively.

$$J_F = \sum_{i=1}^{n} J_{F-i} \tag{4}$$

J_{F-i} refers to fire threat cost of UAV in track segment i. Its detailed model is as follows:

$$J_{F-i} = \sum_{i=1}^{n} J_{F-i} = \sum_{i=1}^{n} (\mu P_{ff_j}^{i} + (1-\mu) P_{fs_j}^{i}) \tag{5}$$

$J_{F_j - i}$ refers to the cost of fire threat to the surrounding points in track segment i; N_F means the sum total of fire threat;$P_{ff_j}^{i}$ and $P_{fs_j}^{i}$ refers to the fire threat index of track segment i, namely the frequency and scale of wildfires.

Define the refresh interval cost. We also suppose the cost function of refreshing interval for information stored on coordinate points.

$$J_F = \sum_{i=1}^{n} J_{T_i} \tag{6}$$

J_{T_i} represents refresh interval cost of UAV in track segment i. Its detailed model is listed below:

$$J_{T_i} = \sum_{k}^{S_m} \eta_{i_k} \tag{7}$$

In the above equation, η_{i_k} refers to the refresh time interval of each point corresponding to the coordinate set in track segment i; S_m equals to the aggregate of coordinates corresponding to each position in the track segment i.

3.4 Determining the Objectives of the Model

Determining the Minimization Function of Track Model In order to realize the optimal formation design, the track model minimization function is established.

$$J = min \sum_{\tau=1}^{n} (\omega_1 J^{\tau_F} + \omega_2^{\tau_T}) \tag{8}$$

In the above formula, $\omega_k, k = 1, 2$ refers to the weight of each cost while J_F^τ and J_T^τ represents the cost of fire threat and refreshing time interval for the i drones in the formation.

Determining the Evaluation of the Model Determine an indicator called **performance** to evaluate the performance of formations with different number of SSA drones. The performance of each point in the map matrix should at least reach the qualified level. And the fire probability is positively correlated with the refresh rate which means that the point with high fire probability should also have a higher refresh probability. The evaluation function is listed below:

$$Y_i = max \sum_{=1}^{n} ((\gamma) P_{ff_i} + (1 - \gamma) P_{fr_i} \cdot \eta_i) \tag{9}$$

3.5 Algorithm Flow of Artificial Fish Swarm Planning

The first step is to initialize the size of the fish swarm, define the moving step size and searching range, iterative threshold and crowding degree of the artificial fish; the second step is to record the position and food concentration of the artificial fish in the field of vision at random; the third step is to calculate and select the next step of the artificial fish behavior and update it; the fourth step is to select the optimal position of the fish swarm; the fifth step is to judge whether it has reached the pre-set of the algorithm If the termination condition of the stroke design has been reached, the result of the operation will be output; if not, return to step 3.

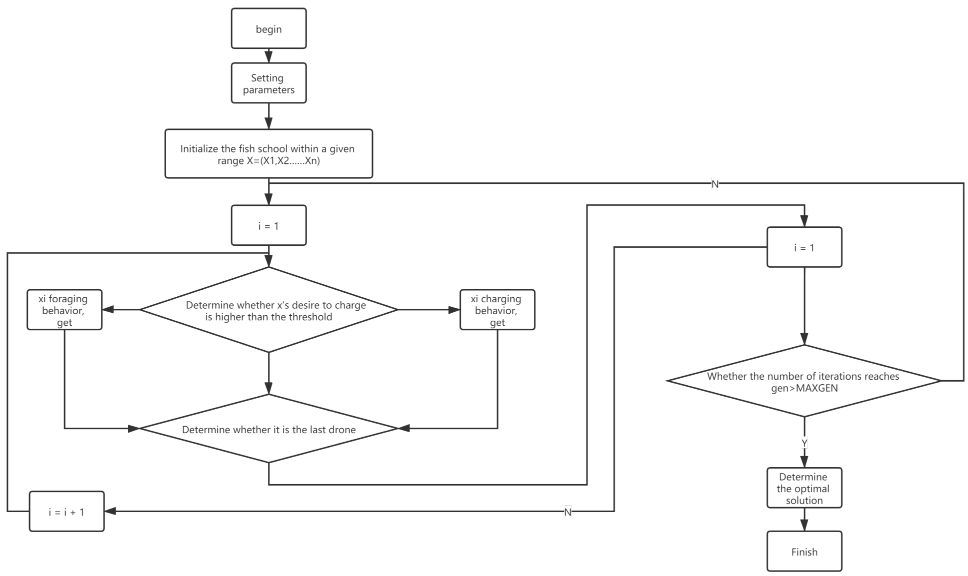

Figure 4: Algorithm Flow of Artificial Fish Swarm Planning

3.6 Model Simulation and Analysis

Using the collected data, we perform simulation on our model to simulate flight trajectory of the SSA dones, then analyze the resulting characteristics of this model.

We set the iteration threshold to 500 and test the refreshing rate of each point on the map when the number of SSA drones ranges from 1 to 40.Finally, we get some results about the relationship between the refreshing rate and the number of SSA drones, and produce a thermodynamic diagram as shown in the figure below.

As shown in the Figure 5, the thicker the color, the higher the refresh rate is. With the gradual increase of the number of UAVs, the area covered on the map is gradually becoming larger, indicating that the scope of UAV monitoring

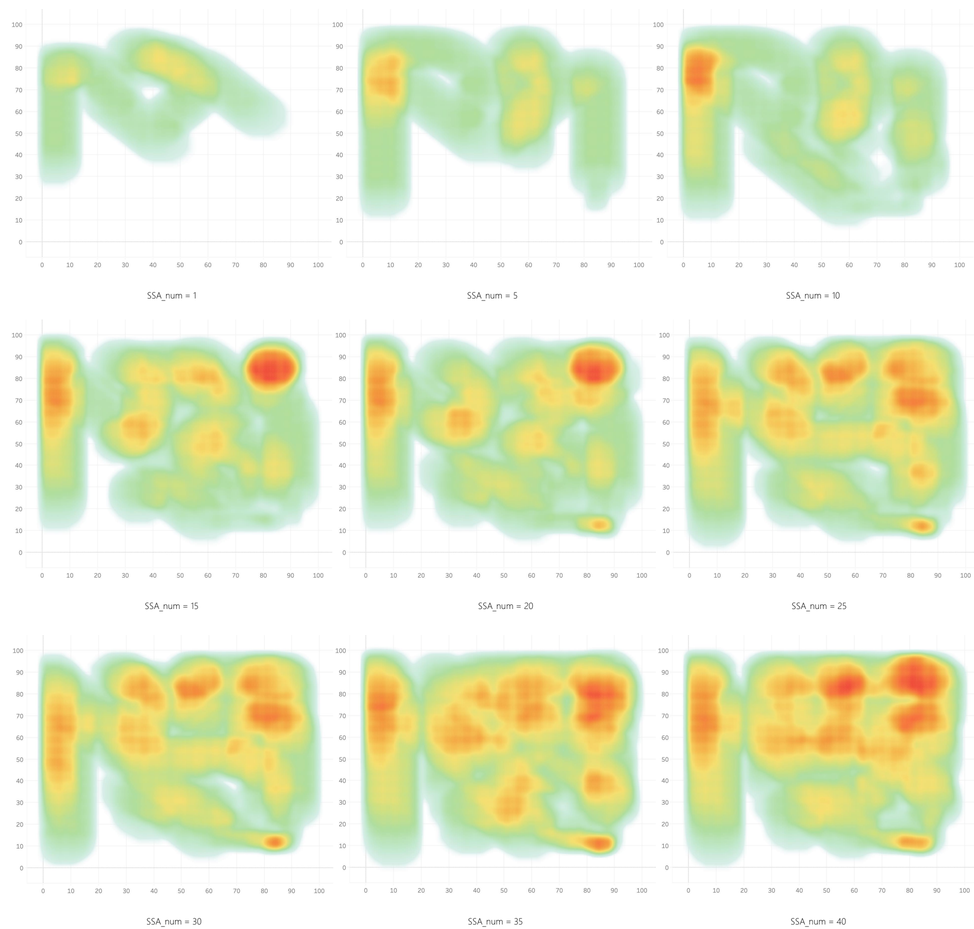

Figure 5: Thermodynamic chart of refresh rate of each point on the map

is gradually expanding. Besides, according to the distribution of points with high refreshing rate on the map, it can be seen that with the increase of the number of SSA drones, the probability of receiving monitoring (that is, the refresh rate of the location) at the place with high fire incidence is also higher, which meets the logical requirements of on-the-spot observation.

However, by comparing the thermal maps with the number of UAVs ranging from 20 to 40, it can be found that the improvement speed of the map refresh rate is decreasing. Compared with the linear growth of the economic cost, the cost performance of increasing the current monitoring capability of UAVs is lower.

Therefore, only from the perspective of qualitative analysis, 15 SSA UAVs and 4 UAVs equipped with repeaters are needed in the region under the assumption of this paper, so as to realize the global saturated fire monitoring and early warning under the premise of low cost.

Moreover, we output a UAV track image which shows the effect of multi

UAVs flying and monitoring together in this model intuitively.

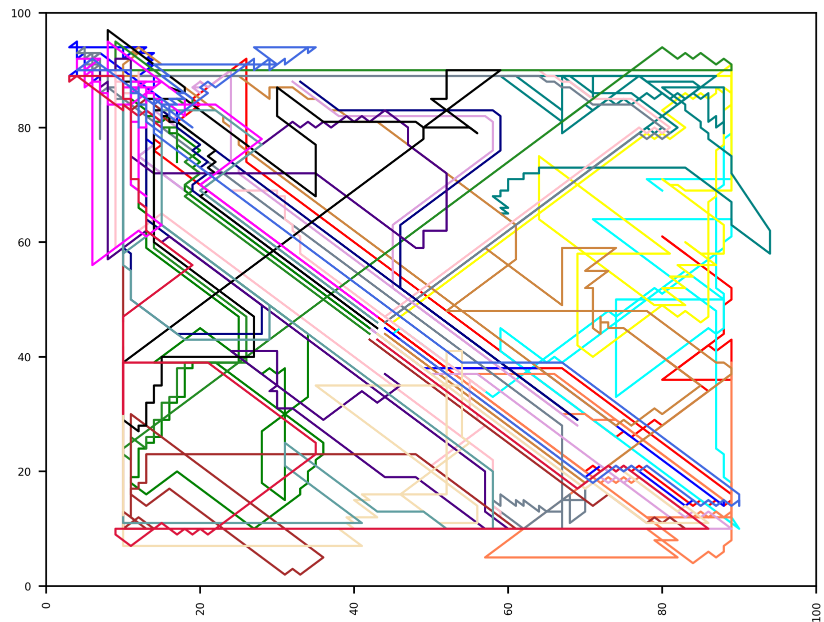

Figure 6: Dynamic track chart of specified number of SSA drones

4 Forecast of Future Situation(Question 2)

4.1 Data Description and Model Adjustment

We collecte the data of Australian mountain fire in the past ten years, and use the gray prediction model to predict the probability of fire at each point on the map in the next ten years. Based on the model we forme in the question 1, we adjust our model to adapt to new problems. By changing the fire frequency dataset, we successfully get the following results in the Figure 7.

4.2 Model Simulation and Analysis

In the Figure 7, we can see that the time nodes in the next three years and

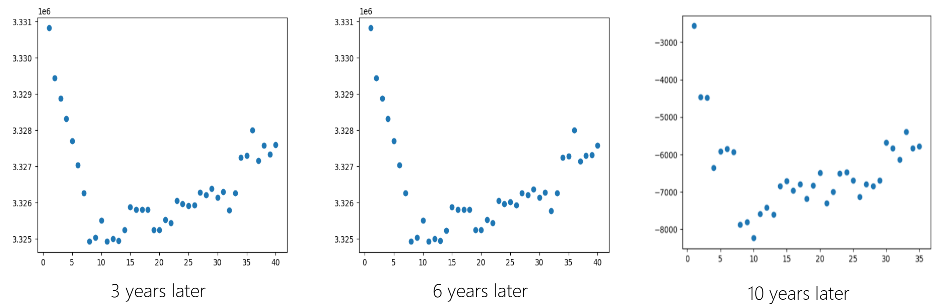

Figure 7: Model performance in the next decade

the next six years have achieved good planning performance, which is basically consistent with the change trend of the current model, and both maintain a steady growth trend with the increase of the number of UAVs.

However, with the continuous growth of time, considering the serious fire caused by global warming and other climate factors year by year, the UAV monitoring model still maintaining the current number of configuration has been unable to meet the needs of the corresponding years. In the figure of '10 years later', we can see that the performance indicators have shown abnormal negative values. Therefore, The old parameter setting can not adapt to the changing possibility of extreme fire events in the next decade.

If you want to restore the performance of this model and continue to use similar schemes to arrange UAVs to monitor the fire, you need to increase the number of UAVs. By increasing the number of UAVs, you can offset the weakening effect of the model caused by the increase of fire probability parameters, so as to make this model come back to life.

Assuming that the cost of UAV system remains unchanged, it is necessary to increase the number of UAVs to adapt to the extreme fire changes in the next decade. Therefore, the increase of equipment cost will have a linear relationship with the increase of the number of UAVs.

5 Repeater Location Optimization(Question 3)

5.1 Environment Model Adjusting

We consider a cellular system where a UAV provides wireless access to terrestrial mobile devices, serving as an aerial base station. The UAV is placed in an adjustable altitude h, aiming to communicate with a ground node either directly or through a terrestrial relay, as illustrated in Figure 8

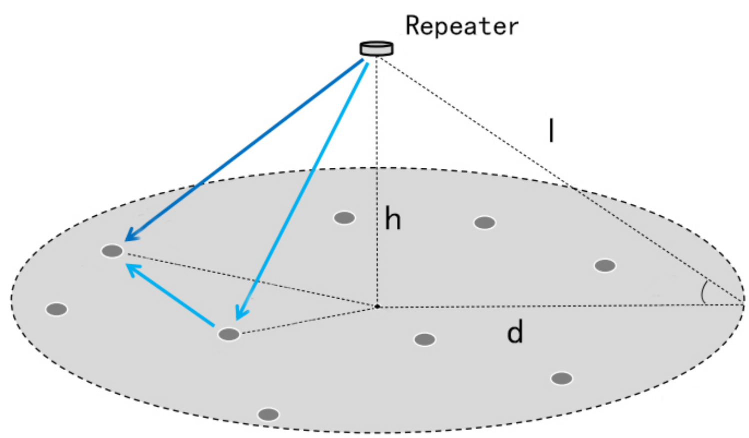

Figure 8: A simplified air-to-ground wireless network using a UAV in presence of randomly distributed ground relays over the coverage region, which radius refers to d

Considering the influence of altitude on repeater signal, we add altitude information el to environment variables based on **Question 1** environment model.

5.2 Model Optimization

On the basis of the original problem route planning model, the constraint conditions are added to the problem three model, so that the location of repeaters can be optimized.

Determine the repeater signal diameter as l shown in the Figure 8. According to Pythagorean theorem, we gain the following equation:

$$h^2 + d^2 = l^2 \Rightarrow l = \sqrt{h^2 + d^2} \tag{10}$$

It is obvious that the value of l is affected by height h while the value of d remains unchanged.So if we want to find the best placement of multiple repeaters, we have to meet the following **constraints:**

(1) Assume that repeater i covers a signal range of d_i, then the corresponding area is πd_i^2. In order to achieve better monitoring effect, multiple repeaters need

to cover the largest total area, recorded as:

$$S_i = \sum_{=1}^{n} \pi d_i^2 - \sum_{=1}^{n} S_{overlap_i} \tag{11}$$

$S_{overlap_i}$ refers to the overlap of coverage of all the repeaters.

(2) Determine l_{c_i} as the distance between the repeater i and the nearest EOC, then the distance condition should satisfy the inequality listed below:

$$l_{c_i} <= d_i \tag{12}$$

(3) In view of the frequent occurrence area of mountain fire disaster, to ensure the timely monitoring and extinguishing of mountain fires, the relay coverage should be positively correlated with the fire frequency P_{ff_i} which means the higher the fire probability, the higher the relay coverage η_{r_i}.

The model of **Question 3** is optimized by traditional artificial fish swarm algorithm. The artificial fish of this model represents the position information of the repeater, which is the feasible solution we need. After several iterations, the optimized repeater position can be obtained.

5.3 Model Stimulation and Analysis

Using the collected terrain data, we perform simulation on our model to simulate hovering positions of UAVs with repeaters, then analyze the resulting characteristics of this model.

We set the iteration threshold to 500 and test the hovering positions corresponding to the point on the map when the number of SSA drones ranges from 1 to 40. We gain a figure showing all the positions of the hovering drones, as illustrated in Figure 9

For the terrain information mentioned in the stem, the optimal solution can be obtained within the number of iterations, and the optimized repeater position can be obtained after multiple iterations.

6 Strengths, Weaknesses and Future Discussion

Based on the modeling process, we make some comments on our model as listed below.

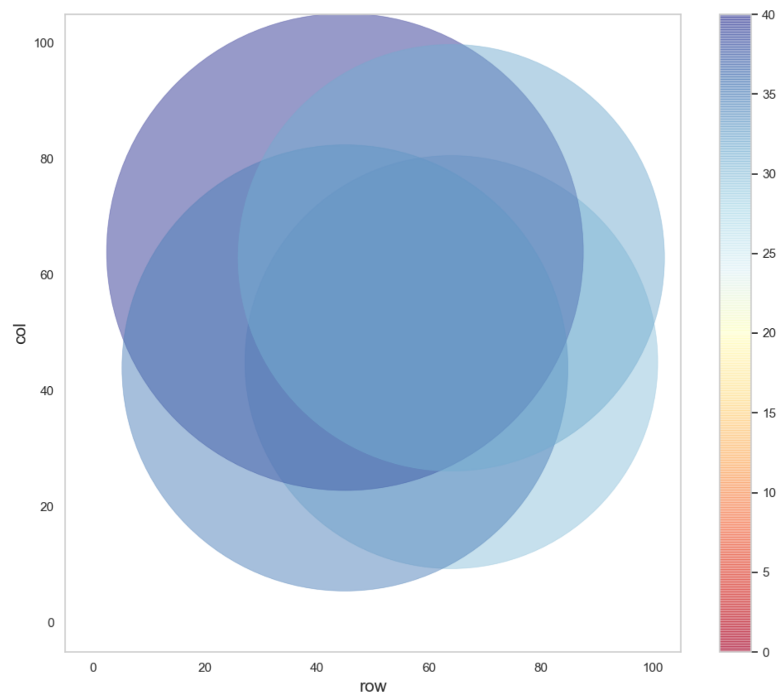

Figure 9: Hovering positions of UAVs with repeaters

6.1 Strengths

- Our model is formulated on a certain theoretical basis. After consulting a large number of literature, we have carefully selected the parameters of the model. In this way, we can make our model as close to reality as possible. Considering the actual conditions, we selected an appropriate area on the map based on the temperature, fire frequency and the distribution of forests and cities as the terrain reference area for our modeling. The experimental results are good and have high credibility.
- Our model is flexible enough to test more situations. We only need to change a few parameters to do deeper research. For example, the model can judge the combination of drones formations by modifying different terrains; and what will be different if we adjusted the drone field of view.
- The model can also be tested according to the model of the drone. If a new drone is introduced, it can be recalculated to meet the needs of the

department by modifying the corresponding parameters.

6.2 Weaknesses

- Limited to the limitaion of equipment performance, we did not perform more calculations to fit the model, and the quality of the model may not meet our higher expectations.
- Ignore the impact of drone flight speed, so the applicability of drones in larger environments needs to be further improved.
- In fact, in some cases, some assumptions may be not hold. There still be some controversy about our model.

6.3 Future Discussion

We tried to use simulation methods to simulate the flight status of the drone group. However, due to time constraints, we have made many assumptions about the actual situation. For example, regardless of the effect of flame on the drone, the environment around the drone is regarded as unchanged, and so on. Next, we can try to release some assumptions to make the drone combination more flexible. We can explore more possibilities by changing some parameters of the program and adding more rules.

7 Sensitivity Analysis

Through the above analysis, we have got the best UAV formation situation. At the same time, we simplified many parameters in the model. In order to ensure the robustness of the algorithm, we mainly tested the model from the following aspects. (Due to time constraints, only the observation field is analyzed this time) First of all, the probability of fire in different areas will have an impact on the flight status of the drone. The greater the probability of a fire, the easier the drone will travel. Second, the UAV's field of view has a certain degree of influence on efficiency. The model we designed allows us to change these parameters. Next, we will analyze in detail the influence of the field of view on the model. Under ideal experimental conditions, the drone can fly freely without gathering, and set the drone to move at the highest speed. Set the field of view to 10 and 20 respectively, and check the result of the image change, the result is shown in the figure below:

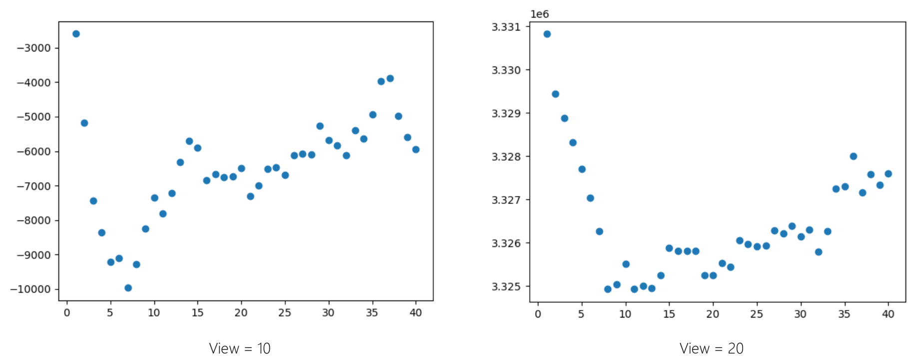

Figure 10: Model performance in the next decade

It can be seen from the above data that these parameters have a certain degree of influence on stability. The analysis result of the field of view indicates that a larger field of view can be beneficial to the stability of the UAV. Choosing the largest possible field of view for observation is of great benefit to UAV monitoring. In addition, the analysis results of fire probabilities in different areas show that different probabilities have a greater impact on the flight situation of UAVs.

Both the continuous and periodical inflows lead to increase in the number of opioids in the state. The result shows that the continuous inflow of opioids has the greatest impact. Although the indirect inflows are incidents, they should also raise the government's concern. In conclusion, the government should not only impose strict regulations on opioids inside the state, but also pay attention to the inflow of opioids from outside the state, and monitors the logistics constantly.

8 Conclusion

In our experiments, we designed a drone trajectory model based on artificial fish swarm algorithm. The model simulates the use of drones. First, we built a model while balancing safety and economy, and simulated the best formation of drones. It is found that under certain conditions, 4 radio repeater drones and 15

SSA drones are the optimal combination. Then use the grey prediction model to predict the fire situation in the next ten years, combined with the fire situation prediction, the existing combination is not enough to meet the demand ten years later, the number of drones needs to be increased, so the budget has increased. Then we discuss the influence of terrain on the layout of radio repeater drones in combination with terrain. After sensitivity analysis, the results have good robustness and the results are credible. Although our model has good scalability and flexibility, it still has certain flaws. There are too many assumptions, so there is still a certain gap between the model and the actual situation. However, we discussed some practical ways to improve the reliability of the results. For example, how to achieve the charging state, how to choose a suitable initial location and so on. In the future, we still have the opportunity to continue to optimize our model.

Annotated Budget Request

Team # 2106317
MCM/ICM Contest
Problem B
February 8,2021

From CFA
To the Victoria State Government

*Item*Number*	*Price*
WileE-15.2X Hybrid Drone * 209	**$ 10000**
Total	**$ 2.09 million**

Description

1、Backgroud

From 2019 to 2020, devastating wildfires occurred in all states of Australia, with the worst impact in New South Wales and eastern Victoria. Tomonitor the fire, firefighters have used drones for surveillance and situational awareness (SSA). Drones are divided into SSA drones and Radio Repeater drones. It is necessary to design the number of drones and the combination of drone formations.

2、Requirements

In order to face frequent devastating wildfires, we will set up a new department ”Rapid Bushfire Response” to purchase new equipment to respond future needs. We use the artificial fish swarm algorithm to estimate and find that the best combination of a group of drones is four Radio Repeater drones and fifteen SSA drones to ensure the monitoring of the fire range and the safety of personnel. We have also considered the actual situation in Victoria, balanced economy and safety, and believed that eleven groups of drones should be purchased to deal with future extreme wildfires.

3、Budget

a total of 273 drones will be purchased. The cost of a drone is about $10,000, so all of them will cost $2.09 million.

4、Usage

These drones will be used to detect bush fires. We will deploy these drones in cities near forests and surrounding fire-prone cities to prevent fires and quickly go to the fire scene when a fire occurs. Observe the situation. SSA drones can not only be used to monitor the situation of the fire scene, but also can monitor the wearable devices of frontline personnel to further ensure the safety of forward teams. The radio repeater drone expands the radio transmission range and can help front-line personnel get information about the fire better.

5、Conclusion

We believe that the purchase of these drones is enough to complete the monitoring of fires, while balancing economy and safety. It should be noted that these drones are vital to the future development trend of fires. We hope to purchase drones through budgeting as soon as possible.

References

[1] R. Li, S. Pan, H. Fang, Y. Xiong and F. Wang, ”Fault Prediction Technology of Civil Aircraft Based on Qar Data,” 2017 International Conference on Sensing, Diagnostics, Prognostics, and Control (SDPC), Shanghai, 2017, pp. 468-472, doi: 10.1109/SDPC.2017.94.

[2] Z. Xiao, P. Xia and X. Xia, ”Enabling UAV cellular with millimeter-wave communication: potentials and approaches,” in IEEE Communications Magazine, vol. 54, no. 5, pp. 66-73, May 2016, doi: 10.1109/MCOM.2016.7470937.

[3] C. Zhang and W. Zhang, ”Spectrum Sharing for Drone Networks,” in IEEE Journal on Selected Areas in Communications, vol. 35, no. 1, pp. 136-144, Jan. 2017, doi: 10.1109/JSAC.2016.2633040.

[4] L. Gupta, R. Jain and G. Vaszkun, ”Survey of Important Issues in UAV Communication Networks,” in IEEE Communications Surveys & Tutorials, vol. 18, no. 2, pp. 1123-1152, Secondquarter 2016, doi: 10.1109/COMST.2015.2495297.

[5] Li Shoujun.Grey Forecasting Model Based on Fuzzy Sets and It Application[D].Jiangsu:China University of Mining and Technology,2018.

Appendices

Here is Code we used in our model, which python is the main development language.

Appendices: The Program for Calculating Performance

```
def calc_per_with_files(self, times):
    performance = 0
    self.sf_df = pd.read_csv('./result/freq/num' +
        str(self.SSA_num) + 'times' + str(times) + '.
        csv')
    if self.sf_df.shape[0] == 100 or self.sf_df.shape
        [1] == 100:
        print('OK')
    else:
        self.sf_df = self.sf_df.iloc[1:, :]
        performance = 0
        print(self.sf_df.shape[0], self.sf_df.shape
            [1])

    self.max_view_time_df = pd.read_csv(
        './result/max_view_time/num' + str(self.
            SSA_num) + 'times' + str(times) + '.csv')

    def calc_importance(row_, col_):
        importance = (self.ff_df.iloc[row_, col_] *
            1000 + self.fs_df.iloc[
              row_, col_] / 100 + 2) * (self.sf_df.iloc
                  [row_, col_] / times) - \
                         self.max_view_time_df.iloc[row_,
                             col_] * 0.03
        return importance

    for row in range(100):
```

```
        for col in range(100):
            performance += calc_importance(row, col)
    print(performance)
    return performance
```