Problem Chosen	2021	Team Control Number
B	MCM/ICM	2120710
	Summary Sheet	

Fighting Wildfire with Unmanned Aerial Vehicle

Summary

在这里写 summary

key words : 关键词 1; 关键词 2; 关键词 3

Budget Request

FROM: Team 2120710 , MCM
To: The group of Governors
Date: February 8, 2020

这里是 br 正文。

Sincerely yours,
MCM Team 2120710

Contents

1 Introduction

1.1 Restatement of the Problem

Many people...Therefore we are facing the following problems:

- aaaaaa
- aaaaaaa

1.2 Our Works

- aaaaaaa
- aaaaaa

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. The circumstance remain unchanged in the time interval we investigated.
2. We omit the possibility of any other kinds of aerial vehcle or flying creature hitting our UAV.
3. Accroding to Bureau of Meteorology of Australian Government, litghting is the major causation of bushfire in some area, Victoria included. [1] Based on this fact, we evaluat the possibility for a certain place to catch fire with the possibility of a lightning to occour there.
4. We adopt the Equal Possibility Hypothesis when our UAVs are patrolling for the purpose of monitoring any outbreak of fire.Under this hypothesis, an area of high possibility to catch fire indicates the frequency of fire outbreak here is high, thus the command center should pay closer attention to this area to alarm fire outbreaks timely.
5. All UAVs are equipped with a timer.

6. All UAVs are directed by a preprogrammed system given by us, which means they are all automatic.
7. Staffes are always available in any charging stations, which guarantees the UAVs will always work in the stanterd situation.
8. A drone can carry either a set of thermal imaging cameras and telemetry sensors or a radio repeater. The former combination can and can only detect any fire outbreak, while the latter can and can only extend the valid zone of radio wave signals.

2.2 Notations

2.2.1 *ijk*-coordinate system

Before illustrating the notations for model construction, we would like to introduce a special coordinate system called ***ijk*-coordinate system**[2], which was first proposed by Uber Technologies Inc.

Discrete hexagon planar grid systems naturally have 3 coordinate axes spaced $120°$ apart. We refer to such a system as an *ijk* coordinate system, for the three coordinate axes i, j, and k.

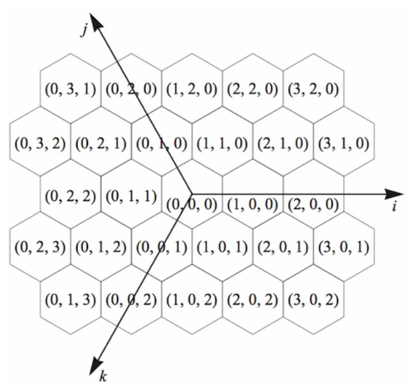

Figure 1: One possible map example that using the *ijk* coordinate system

2.2.2 Notations

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

Table 1: Notations used in model construction

Notation	Meaning
$M(i,t)$	Location of the i-th drone I at time t
$R(j,t)$	Location of the j-th drone II at time t
$h(x,y,z)$	Elevation of the point (x,y,z)
$S(x,y,z)$	Fire history of the point (x,y,z) in the passed 5 years
$a_i(x,y,z)$	Fire history of the point (x,y,z) in the $2020-i$-th year, $i \in [1,5] \cap \mathbb{N}$
$F(x,y,z)$	Vegetative and structural condition of the point(x,y,z)
$S(i,x,y,z,t)$	Strength of the signal from the i-th drone at point (x,y,z) at time t
$E(x,y,z,N)$	Supervisory density of the point (x,y,z) when there are N drones in the field
$Slope(x,y,z)$	Maximum slope of the point (x,y,z)
γ	Factor related to the weight of slope in causing bushfire
$\beta(x,y,z)$	Weight of slope in causing bushfire
$\omega(x,y,z)$	Decreasing rate of signal at point (x,y,z)
α	Factor related to the weight of elevation in causing bushfire
$Chg(q,x,y,z)$	Location of the q-th charging station
V_{max}	Maximum flying velocity of a drone
N_{SSA}	Amount of drone I
N_{rep}	Amount of drones II
PF	Power consumption for a flying drone
PH	Power consumption for a hovering drone
$t_{\text{fl}}(t,l)$	Flight time of the l-th drone until time t
$t_{\text{hov}}(t,l)$	Hovering time of the l-th drone until time t
T	Duration of a day (i.e. $T = 1440\,\text{min}$)
t	Current time
Br	Total battery power of a drone
Ini	Location of the EOC

3 Model Construction

3.1 Multi-factor Evaluating Model

In this section, we introduce a H3 and multi-factor evaluating model to data-orienting the topographic conditions of the state Victoria in Australia.

First, in order to simplify the question, we cover the state with hexagons in dense tiled layout. We consider that the valid zone of radio wave signal radiated by a UAV is a spherical area of radius 20 km, and the length of each side of hexagon is 1.22 km.

Next, we evaluated each segment from 4 dimensions, which are: density of forest coverage, elevation, slope and fire history. We consider the influence of the listed dimensions from two aspects: how dose it influence the possibility to catch fire for the area and how does it influence the propagation of radio wave signal. The mechanism and significance of these factors are discussed below.

3.1.1 The Influence of Vegetation and Other Ground Facilities

According to Dissing and Verbyla(2003)[3], thermal circulations triggered by differential heating among distinct types of vegetation results in a higher probability for a lighting strike to occur. But according to a later research based in the State of Victoria (Kilinc and Beringer 2006[****]), vegetation type and density in Southern region of Australia have little impact on the occurrence rate of lightning. Mainly because of the homogeneity of forests.

On the other hand, the leafage has a significant impact on the reflection behavior of radio wave, which plays an important part in the propagation process. Different researches have been done to estimate the decreasing rate of radio wave in varies situations, the shared mechanism underneath is Fresnel's Law. We divided the surroundings into three categories: forests, plain, cities, then we estimated the decrease factor and valid zone for the radio signal distinctively.

Since the given signal's frequency ranges from 300 megahertz to 3,000 megahertz and from 30 megahertz to 300 megahertz, which are considerably high, so it is difficult for the signal to steer by high-rise structures, including tall buildings and mountains. When our drones are passing through the plain area, the the energy lose for the signal strengths is in the air, so the radius of the valid zone for the signal reaches it's maximum of 20km. When the drone is passing a urban area, high obstacles diminished the zone and the radius reaches it's minimum of 5km. When the drones are flying or hovering in forest region, two situations should be discussed separately, the ground signal from wearable devices on frontline personnel and the aerial signal from another drone. According to the data of the experiments done by Y.S. Meng.et.s(2010) [*****], when the signal is launched in woods, the signal strength decreases linearly with the frequency of radio wave, and distance(Y. S. Meng.et.s2009[******]). According to their model, the foliage loss in forests can be described by the equation belowequ.1 公式我都写在另一个文档里面. While considering the drone-to-drone signal propagation, we simply omit the influence of trees, for it is reasonable for flying vehicles to stay above the forests. According to Meng, the background noise is around -75dBm, so we consider the signal to be undetectable if it's strength is lower than -70dBm. Which means that when the strength loss is over 18dB, we consider this point to be inaccessible. Using equation (1) and the data we have, we can verify the decreasing coefficient for different area as followequ.2.

3.1.2 The Influence of Elevation and Slope

blabla

3.1.3 The Influence of Fire History

blabla

3.1.4 The Functions We Adopted to Describe the State

blabla

3.1.5 Future situation in a decade

blabla

3.2 Use Nervous System Model to find the best arrangement of UAVs

blabla

3.3 Model for Rapid Bushfire Response

blabla

3.4 Model for Hovering Drones for Fires of Different Sizes on Different Terrains

blabla

4 Model Simulation

blabla

4.1 Nervous System model for UAVs Monitoring System

blabla

4.1.1 Adapting for Future

blabla

4.2 Modeling for Rapid Bushfire Response

blabla

4.3 Model for the hovering drones SSA and Radio Repeater

blabla

5 Sensitive Analysis

5.1 ensitivity of parameters

abaaba

5.2 Robusticity of the models

blabla

6 Strength and Weakness

6.1 Strength

blabla

6.2 Weakness

blabla

7 Conclusion

We build a.....interesting findings:

- aaaaaaa
- aaaaaaa

References

[1] M. Kilinc and J. Beringer, "The spatial and temporal distribution of lightning strikes and their relationship with vegetation type, elevation, and fire scars in the northern territory," *Journal of Climate*, vol. 20, no. 7, pp. 1161 – 1173, 01 Apr. 2007. [Online]. Available: https://journals.ametsoc.org/view/journals/clim/20/7/jcli4039.1.xml

[2] "The h3 core library documentation: Coordinate systems," https://h3geo.org/docs/core-library/coordsystems.

[3] D. Dissing and D. L. Verbyla, "Spatial patterns of lightning strikes in interior alaska and their relations to elevation and vegetation," *Canadian Journal of Forest Research*, vol. 33, no. 5, pp. 770–782, 2003. [Online]. Available: https://doi.org/10.1139/x02-214

Appendices

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Appendices A

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