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Research on the optimal distribution scheme of emergency materials dominated by VU mode

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Abstract: *This paper mainly studies the distribution of emergency materials under the 5G network environment, which is characterized by the vehicle and UAV (VU) mode. By establishing a memory search model and using genetic algorithm, the optimal emergency material distribution scheme and the optimal location of material concentration point are obtained after numerous iterations and selections. The study of this problem can provide guiding opinions for material distribution in disaster relief in reality, so that materials can be provided to the disaster area in time.*

Keywords: *5G; VU; Memory search model; Genetic algorithm*

1. Introduction

In recent years, natural disasters and public health emergencies have occurred repeatedly in China. Since 2000, many emergencies with great impact have occurred, such as the "SARS" in 2003, the "5.12 Wenchuan earthquake" in 2008, the "4.20 Ya'an earthquake" in 2013, and the "new type of coronary pneumonia" epidemic in 2020. The sudden occurrence of these catastrophes often leads to casualties, road damage, building damage, water and electricity interruption and other phenomena. For disaster victims, the timely delivery of emergency supplies is a critical factor to ensure their life safety. At this time, the distribution of emergency materials has become the top priority of emergency rescue, and the reasonable scheduling of emergency materials distribution vehicles is the fundamental link of emergency materials distribution. However, in the actual distribution process, the damage or interruption of the road will cause the distribution vehicles to proceed without deliver the emergency supplies in time. With the continuous development of science and technology and the gradual expansion of 5g network coverage, the application of unmanned aerial vehicles began to expand to various fields. However, due to the constraints of UAV load capacity and endurance time, it is sometimes difficult to use UAV alone for material distribution. In order to shorten the service distance of unmanned aerial vehicles and speed up the progress of material distribution, the distribution vehicles and unmanned aerial vehicles should be connected in series to serve the material demand points. The distribution mode of VU came into being and gradually became a new and effective distribution method [1-3].

The distribution mode of VU refers to that in the process of distributing emergency supplies, while the distribution vehicle to a certain place, the UAV can simultaneously distribute to nearby accessible places [4,5] After delivery, return to the delivery vehicle to reload materials and replace batteries. This distribution mode can not only give full play to the advantages of large capacity of distribution vehicles and fast distribution speed of UAVs, significantly improve the distribution efficiency of emergency materials, but also solve the problem of material distribution under complex road conditions, while avoiding secondary injury to distribution personnel.

By establishing a memory search model, this paper uses a genetic algorithm to obtain the optimal emergency material distribution scheme and the optimal location of material concentration point after many iterations and selections. The study of this problem can provide guiding opinions for material distribution in disaster relief in reality, so that materials can be delivered to the disaster area in time.

2. Model of optimal vehicle scheduling scheme

Assuming that the vehicle carrying capacity is 1000kg, the overall distribution can be completed at one time. Therefore, this problem can be abstracted as the shortest distance to traverse all material demand points from the material concentration point. Considering that the general depth first search

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algorithm does not save the current state in the recursive process, which increases the computational complexity, we use the memory search algorithm, which can retain the previous calculation results in the search process, thus reducing the computational complexity and improving efficiency.

This section takes the shortest distance and the shortest time as the optimization objectives to establish the distribution model [3], and solve the total distance and time of the distribution vehicle from being the basis to the destination after the distribution is completed.

2.1. Model establishment

State compression is used to indicate whether each location is currently distributed, $S \in [0214 - 1]$, which can represent 14 binary numbers at most. The value of the *i*th S_i is shown in Eq. 1,2:

$$S_i = S\delta(1 << i) \tag{1}$$

$$S_i = \begin{cases} 0 & \text{The } i+1 \text{ location is not delivered} \\ 1, & \text{The } i+1 \text{ location is delivered} \end{cases} \tag{2}$$

The status definition is shown in Table 1:

Table 1: Description of symbols used in this section

Symbol	Range	Definition
$d[i][j]$		Represents the shortest path from location i to location j
i	$i \in [0, 13]$	The i+1 place
S	$S \in [0, 2^{14} - 1]$	Indicates the scheduling of all locations
S_i	$S_i = S\&(1<<i)$	Indicates the distribution of location i+1
$dp[i][S]$		Indicates the shortest path from all points of delivery and back to the starting point when the i+1 location status is S_i
$vis[i][S]$		Indicates whether the i+1 location has been calculated in the status

The state transition equation is shown in Eq. 3, 4.

$$S_2 = S\delta(1 << i) \tag{3}$$

$$dp[i][S] = min\begin{cases} dp[i][S] \\ dp[i][S] + dfs[j][S_2] \end{cases} \tag{4}$$

The return result is dp[8][0], indicating the shortest time to complete a complete material distribution from the 9th place.

2.2. Model solving

The above model is coded by C++ language. The optimal scheme of the vehicle one-time overall distribution scheme is shown in Figure 3, and the red line represents the distribution route of the distribution vehicle. The distribution route is 9 → 8 → 12 → 11 → 1 → 7 → 5 → 2 → 3 → 2 → 6 → 4 → 6 → 10 → 14 → 13 → 9. The distribution time is 11.64h, and the total distance of distribution is 586km (Figure 1).

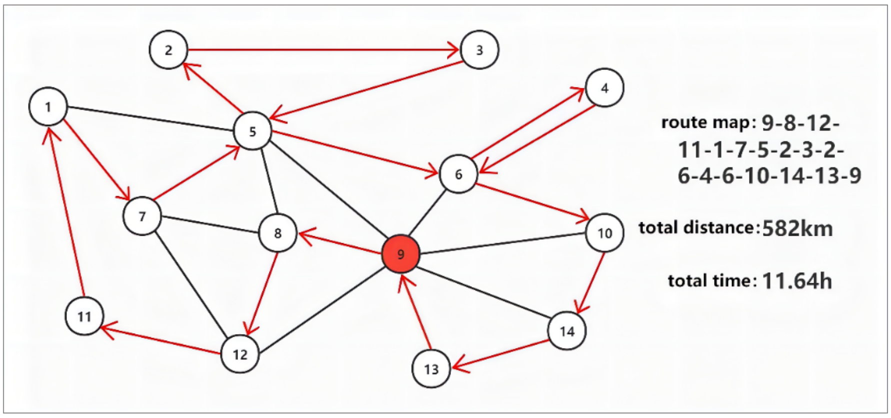

Figure 1: Best route map

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3. VU optimal scheduling scheme

The farthest flight distance of a single UAV delivery is 87.5km, and the sum of the distances of the four adjacent locations is greater than 87.5km [2]. Therefore, the UAV can only be delivered to 2 locations at most in a single delivery. In order to ensure the accuracy of the model, it is assumed that in the process of UAV distribution, the car is only distributed to one place [4], so the single distribution location scheme of UAV and car has the following two cases:

(1) Starting from a certain point, the drone is distributed to two places, and the car is distributed to one place. The drone returns to the end of the car, as showed in Figure 2.

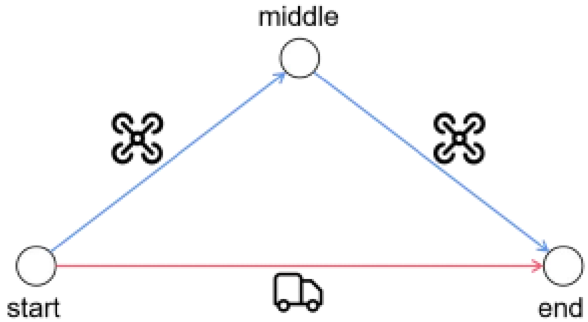

Figure 2: Schematic diagram of UAV distribution to a location

(2) Starting from a certain point, the drone is delivered to a place, and the car is delivered to a place, and the drone returns to the end of the car, as showed in Figure 3.

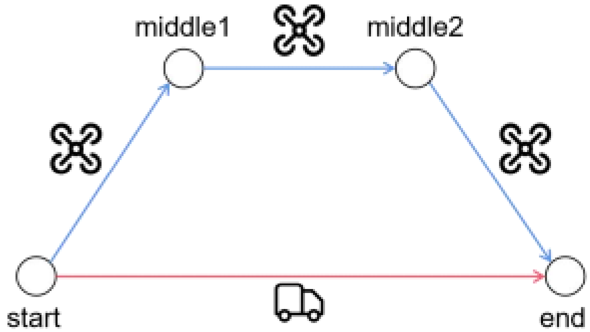

Figure 3: Schematic diagram of UAV distribution at two locations

The maximum load capacity of the UAV is 50kg. Considering the assumption that the goods are inseparable in this paper, the UAV will not distribute to places with a demand of more than 50kg.

Since the distribution speed of UAV is, which is greater than the speed of the vehicle, we hope to use UAV to distribute more nodes as much as possible, so as to reduce the total time of distribution. Therefore, scheme (2) is a priority when carrying out a single distribution. If the sum of the weight of goods required by the two places of UAV distribution is greater than 50kg, scheme (1) is expected to be adopted.

Because the speed of UAV and vehicle is different from that of a definite delivery, the time for them to reach the destination of a single delivery may also be different. There is a waiting situation. The combined time of a single UAV and vehicle delivery is the greater of the two. The time required for the scheme (1) is shown in Eq. 5:

$$t = max\begin{cases} \frac{1}{V_P}(dp[i][j] + dp[h][j] + dp[h][k]) \\ \frac{1}{V_C}dp[i][k] \end{cases} \tag{5}$$

$$t = max\begin{cases} \frac{1}{V_P}(dp[i][j] + dp[h][j]) \\ \frac{1}{V_C}dp[i][h] \end{cases} \tag{6}$$

The time required for scheme (2) is shown in Eq. 65:

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3.1. Model establishment

According to the above model analysis and assumptions, the distribution problem of cars and UAVs belongs to NP hard problem. With reference, this paper selects a genetic algorithm to solve the problem [6,7]. Genetic algorithm has strong global search ability The solution time is less, which avoids the inefficiency of the successive approach algorithm and avoids falling into the local optimal solution. The explanation of biogenetic concept in this algorithm is shown in Table 2.

Table 2: Corresponding relationship of biological genetic concept in genetic algorithm

Biogenetic concept	The role of genetic algorithm
Survival of the fittest	When the algorithm stops, the feasible solution of the optimal goal is most likely to be retained
Individual	Feasible solution
Chromosome	Coding of feasible solutions
Gene	Characteristics of each component in the feasible solution
Adaptability	Fitness function value
Population	A set of feasible solutions selected according to the value of fitness function
Mating	The process of generating a new set of feasible solutions through mating principles
Variation	The process of changing a component of the code

The parameter setting of genetic algorithm solved in this paper is shown in Table 3 [8,9]:

Table 3: Description of symbols used in this section

Symbol	Range	Definition
M	M=50	Population size
G	G= 10000	Maximum iterated algebra
p_c	p_c=1	Crossover rate
p_m	p_m=0. 1	Initial variation rate
num	num=200	The optimal number of iterations that have not occurred at present
p_n	$Pn = min\begin{cases} 1 \\ p_0 * (1+\frac{num}{200}) \end{cases}$	Variation rate at a certain time

3.2. Solution of model

The model is implemented by C++, and the optimal one-time distribution scheme of UAV and vehicle is calculated, as shown in Figure 4. The red line represents the distribution route of the distribution vehicle. The blue line is the distribution route of the UAV, and the pink line represents the distribution route of the vehicle when the UAV does not perform the distribution task.

The distribution route of the distribution vehicle is 9 → 8 → 7 → 5 → 2 → 5 → 6 → 10 → 9, the distribution route of the UAV is 9 → 13 → 8 → 12 → 7 → 11 → 1 → 2 → 5 → 3 → 6 → 4 → 10 → 14, and distribution time is 6.32h.

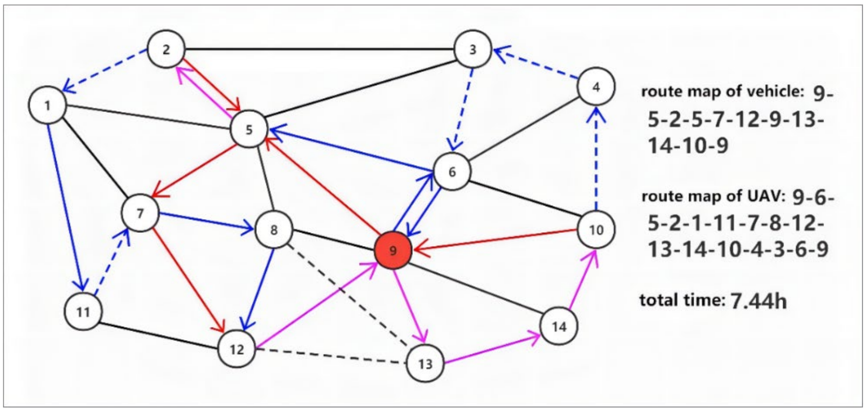

Figure 4: Vu distribution route map

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The calculation iteration diagram of the model is shown in Figure 5:

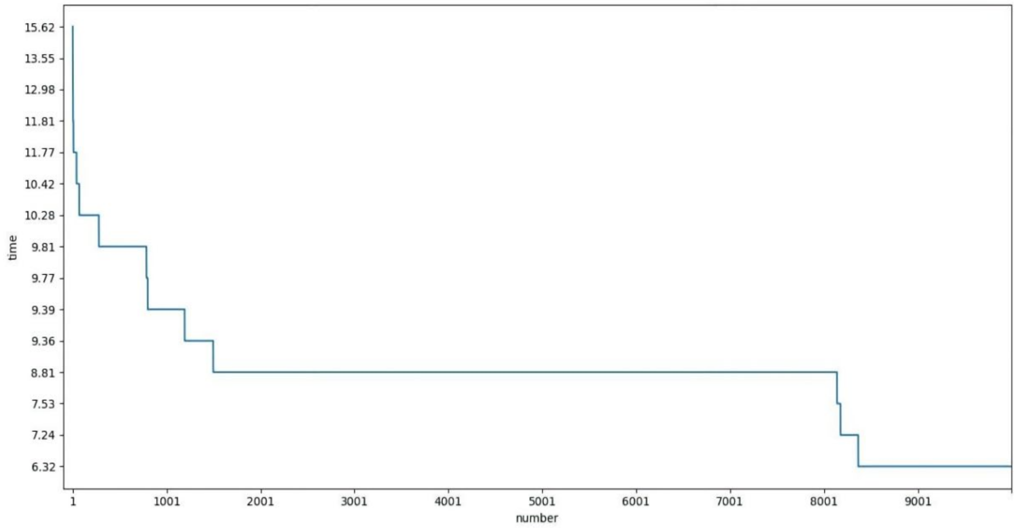

Figure 5: Calculation iteration diagram

4. Model features and promotion

4.1. Advantages and disadvantages of the model

Genetic algorithm is used to solve the problem, and the shortest time-consuming material distribution scheme is obtained after many iterations, which have a strong guiding significance for reality.

However, when the UAV in the model performs tasks alone, the action of the distribution vehicle is limited, and there are certain errors.

4.2. Generalization of the model

This paper is based on the emergency material distribution under the VU mode, which can also be used to deal with other material distribution problems, such as express delivery, takeout delivery, etc., because they all belong to a class of problems, which can be solved by applying this model.

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