Path planning for drones reconnaissance based on ant colony algorithms

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Abstract. Firstly, the traditional ant colony algorithm is introduced. Then it compares the difference between drone reconnaissance path planning problem and TSP, improving the traditional ant colony algorithm, which constrains the state transfer equation of ant colony algorithm so that the algorithm can simultaneously Planning multiple paths. Finally, we conducted an example analysis of road detection in Puerto Rico with the DroneGo disaster response system, and covered the island with a minimum number of drones.

1. Introduction
Due to the monsoon climate, coastal countries or cities are vulnerable to natural disasters such as hurricanes, and Puerto R—co is a typical example of a hurricane attack. In the face of major natural disasters, the Puerto Rican government has limited assistance to the people. Therefore, it is often necessary for some NGOs to help. The emergency capacity of these NGOs is being challenged at this time. HELP.inc is one of them. HELP.inc decided to use the DroneGo disaster response system to provide medical assistance and road detection to severely affected areas. The DroneGo disaster response system includes drone, drone transport container and medicine. It needs to be loaded into container for shipping, so it can only be put into port city. Based on the actual situation, the DroneGo disaster response system will be deployed in coastal cities with population concentrated areas, and drone will start from the launch point. The whole island of Puerto Rico is surrounded by mountains and roads are staggered. Our research will plan the flight path of drone fleet based on ant colony algorithm. In the range of drone flight, use the fewer drones to detect more road information.

2. Ant colony algorithm

2.1 Traditional ant colony algorithm
Ant colony algorithm comes from the activity of ants in nature. The ant releases the pheromone on the path; when it hits the intersection that has not yet passed, it randomly picks a path; at the same time, releases the pheromone related to the path length; the pheromone concentration is inversely proportional to the path length; the later ants encounter again At the intersection, the higher pheromone concentration path is selected; the pheromone concentration on the optimal path is larger and larger; the ant colony finally finds the optimal feeding path.

Based on the above theory, I assume that $m$ is the number of ants, $n$ is the road node to be reconnoitered by drone, and the variable $D_{ij} (i, j = 1, 2, 3... N)$ represents the flight path of drone from
point $i$ to point $j$, and $\tau_{ij}(t)$ represents the concentration of pheromones on the path between point $i$ and point $j$ after $t$ iterations, which is used to simulate the secretion of pheromones by ants in the process of foraging. At first, we assume that the pheromone intensity on each path is the same, that is $\tau_{ij} = d$ ($d$ is a constant). The ant calculates the transition probability to the next node according to the formula of (1), as follows:

$$p_j^k = \begin{cases} \arg \max \left \{ \left[ \frac{\tau(i,s)^\alpha}{\eta(i,s)} \right]^\beta \right \}, q \leq q_0 & \text{if } j \in \text{allowed}_k \\ \frac{\tau(i,s)^\alpha}{\eta(i,s)}^\beta, & q > q_0 \end{cases}$$

(1)

In the above formula, $\alpha$ and $\beta$ are important parameters for ants in selecting a certain path. The larger $\beta$ is, the faster the convergence speed of the algorithm, but the randomness of the search path is reduced, and the local optimal solution is easy to obtain.

The Ant-Cycle model uses global information, that is, the ant updates the pheromone on all paths after completing a loop. After a period of time, pheromones on several paths are updated to:

$$\tau(t+1) \leftarrow (1-\rho) \cdot \tau(t) + \rho \Delta \tau(i, j)$$

$$\Delta \tau(i, j) = Q / L_{gd}$$

$$L_{gd} = \min(L_k), k = 1, 2, \ldots, m$$

(2)

In the above formula, $\rho$ is an important parameter in the simulation of pheromone evaporation.

When $\rho$ is too small, there are too many pheromones remaining on each path, which causes the invalid path to continue to be searched, which affects the convergence speed of the algorithm. When $\rho$ is too large, the search of the effective path may be abandoned, affecting the optimal value.

2.2 Improved ant colony algorithm

2.2.1 Differences between drone path problems and TSP

Firstly, for TSP, the starting point is not fixed, and the starting point of our path problem is fixed.

Secondly, although both problems are to traverse all points, the final result of TSP is a path, and the UAV path problem is ultimately to find multiple paths whose length is less than the specified value.

2.2.2 Introducing crawling distance

In order to make each path length smaller than a prescribed value, a creep distance and a maximum crawl distance are introduced. Calculated as follows:

$$L = L_0 + \sum D_y$$

In the above formula, $L$ is Ant crawling distance. And $L_0$ is distance between initial point and starting point.

2.2.3 Determine if the path ends

In the traditional ant colony algorithm, each time an ant encounters an intersection, the transition probability matrix is calculated, and then the next point is selected according to it.

In the improved ant colony algorithm, each time an ant encounters an intersection, the transition probability matrix is calculated, and then, according to it, the next point is selected and judged:
whether the selected point will exceed the maximum creep distance. If it is not exceeded, the ant advances toward this point; if the maximum creep distance is exceeded, the point is ignored and the transfer transition probability matrix is calculated again within the range of allowable points, and then the next point is selected and judged according to it. Until the feasible point is found; if there is no feasible point, the path is completed under the maximum creep distance, the ant needs to be moved to the starting point, and then the above steps are repeated to get the next path. The judgment equation is as follows:

\[
\begin{cases}
    j \in \text{allowed}_{i,k}, L \leq R \\
    \text{allowed}_{i,k} = \text{allowed}_{i,k} - \{j\}, \text{allowed}_{i,k} - \{j\} \neq \emptyset \\
    i = 1
\end{cases}
\]

In the above formula, \( R \) is Maximum crawling distance.

3. Path planning of drones reconnaissance

3.1 Location of container

The DroneGo disaster response system has two main tasks, one is destroying road survey, the other is emergency medicine delivery. When considering the location of the DroneGo disaster response system, first of all, we need to consider the location relationship between the drug delivery place and the DroneGo disaster response system delivery point. Secondly, the location of the drone system in Puerto Rico islands, and the coverage of the drone on the island road survey in this location. At the same time, the space of drone containers is limited, so it is necessary to coordinate the quantity of drones, drone containers and drugs.

| Location Number | Latitude | Longitude |
|-----------------|----------|-----------|
| 1               | 18.33    | -65.65    |
| 2               | 18.22    | -66.03    |
| 3               | 18.44    | -66.07    |
| 4               | 18.40    | -66.16    |
| 5               | 18.47    | -66.73    |

In order to facilitate the model calculation below, we first model the map of Puerto Rico. Since the coordinates on the map are composed of latitude and longitude, it is not conducive to us to calculate the actual distance through the map. Therefore, we select a point O on the map as the coordinate origin, and use O point as the reference point to establish the coordinate system. The latitude and longitude coordinates of the origin are (-67, 18). The eastward direction is the x-axis and the northward direction is the y-axis as shown in Figure 1. The unit is kilometers.
Considering the various factors mentioned above, we determined the A, B, C placement point and their longitude and latitude are shown in the table.

| Location | Latitude | Longitude |
|----------|----------|-----------|
| A        | 18.38    | -66.07    |
| B        | 18.23    | -65.65    |
| C        | 18.47    | -66.73    |

Distribution of container and drug supply scheme are shown in the figure 2:

![Figure 2. Location of container and drug supply scheme](image1)

### 3.2 Road Data Processing

Our goal is to make the drone view the road damaged. For so many roads, it is difficult to directly model the solution. Therefore, we choose to select points on the road at intervals of 2.5 km. The reason for this is that the drone can detect the road. It is very easy to shoot the road within 2.5 km at high altitude. It is not necessary to fly along the road, as long as it can When you reach these points, you can detect the entire road. However, according to our previous assumptions, due to power outages, drones cannot be recharged in towns along the way, and they can only continue to shoot before reaching the maximum flight distance.

![Figure 3. Feature point of the road](image2)

As a result, the problem becomes How many drones can be dispatched from the same starting point in order to access all the points when all drones have the maximum flight distance? Because each drone
3.3 Model results and analysis
According to the improved ant colony algorithm, we calculate path planning of drone detection. It is stipulated that the drones can fly under different reconnaissance radii (40, 43, 45, 48, 50 km), run the program (see appendix), and finally get the drone needed to shoot this area clearly.

The results are as follows:

Table 3. Reconnaissance radius and relationship table of required drones

| Reconnaissance radius (km) | 40  | 43  | 45  | 48  | 50  |
|----------------------------|-----|-----|-----|-----|-----|
| Number of drones sent by each container | A   |     |     |     |     |
|                             | 8   | 9   | 9   | 11  | 12  |
|                             | 4   | 5   | 6   | 8   | 9   |
|                             | 10  | 14  | 16  | 19  | 23  |
| Proportion of undetected points | 0.3341  | 0.26959  | 0.23733  | 0.19585  | 0.17051  |

It can be seen from the table that although the proportion of undetected points is the smallest when the reconnaissance radius of 50 km is specified, the loss of the drones in container C is huge; but when the reconnaissance radius is less than 48 km, although the drone The loss is significantly reduced, but the proportion of undetected is too high compared to 48km and 50km, mainly because the area between 45km and 48km below the container A is just the southernmost coastal road in Puerto Rico. Therefore, the final detection radius is 48km. At this time, the proportion of undetected points is reduced for the radius of 50km, but the loss of drones is greatly reduced, and the comprehensive benefits are better.

So the final drone flight plan: the reconnaissance radius is 48km. Each time the reconnaissance, Container A dispatches 11 Drones, Container B dispatches 8 Drones, and Container C dispatches 19 Drones. The flight route is as shown below.

Figure4. Drone flight route

4. Conclusion
This paper mainly improves the traditional ant colony algorithm to solve the problem of drone path planning in the region. Because of the limited flight distance of drone, one drone cannot complete the reconnaissance mission to the whole area. Traditional ant colony algorithm can only plan the path planning problem from the designated starting point to the end point, and the distance of the whole path cannot be controlled, so it cannot solve the path planning problem of multiple drones. In drone path planning problem, drones start at the same point and ends at the maximum point of its flight distance. By adding restrictions to the state transition equation of ant colony algorithm, we complete the planning of multiple routes in a certain area, and obtain the optimal solution of drone flight plan, so as to minimize the use of drone flight plan. Unmanned aerial vehicles can complete all road
investigation tasks within a certain area. In the process of rescue in Puerto Rico, the improved ant colony algorithm is used to minimize the use of drones, mentioning the loss of drones and the rescue of drones. The improved ant colony algorithm has good portability and can be used in other practical problems of coverage investigation.

References
[1] Hai Yang. Improved Ant Colony Algorithm and Its Application on the QoS Routing Problem[P]. DEStech Transactions on Computer Science and Engineering,2018.
[2] Chen Yingxin. Research on vehicle routing optimization based on improved ant colony algorithm[J]. Application Research of Computers,2012,29(6):2031-2034.
[3] Wu Bin, Shi Zhongzhi. A Segmentation Algorithm for TSP Problem Based on Ant Colony Algorithm[J]. Chinese Journal of Computers,2001,24(12):1328-1333.
[4] Huang Mai. The number and path optimization of drones in disaster relief [J]. China Science and Technology, 2018, (15): 240-241.
[5] Hong-Jun Wang, Yong Fu,Zhuo-Qun Zhao,You-Jun Yue,Keigo Watanabe. An Improved Ant Colony Algorithm of Robot Path Planning for Obstacle Avoidance[J]. Journal of Robotics,2019,2019
[6] Jayaprakash,C. KeziselaVijila. Feature selection using Ant Colony Optimization (ACO) and Road Sign Detection and Recognition (RSDR) system[J]. Cognitive Systems Research,2019,58.
[7] Hadi Nobahari, Saeed Nasrollahi. A terminal guidance algorithm based on ant colony optimization[J]. Computers and Electrical Engineering,2019,77.
[8] Hao Li,Xiaowei Liu,Kun Yang. Capacity Optimization of High-speed Railway Train in Established Schedule Plan Based on Improved ACO Algorithm[P]. 2018 3rd International Conference on Modelling, Simulation and Applied Mathematics (MSAM 2018),2018.