MTSP UAV detection problem based on ant algorithm

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***Abstract*—To study the problem of UAV detection, a multi-traveler problem (MTSP) model and a two-dimensional in-plane point circle coverage model are established . The ant algorithm and the Monk Carlo algorithm are used to solve the model according to the minimum time. First, extract the number of effective cities under the constraints of effective detection range and maneuverability of the drone. Secondly, the minimum time of flight is minimized as the objective function, and the MTSP UAV detection model based on 1936 traversal points is established. Finally, using the ant algorithm to iteratively solve, and smoothing the track by cubic B-spline interpolation to obtain a flight plan that satisfies the constraints. The shortest time to get is 7.28241h**

Keywords-Drone detection ， ， Ant algorithm ， Monte Carlo algorithm

I. INTRODUCTION

Track /Mission planning is the ability that the drone must have [1].If you want to achieve autonomous flight of the drone [2].Then the system is required to have a high degree of in-flight track/task re-planning capability [3]. The mission planning of the drone is to perform a higher-level task analysis of the tactical target[4] based on the map and terrain information data, weather data, mission content, [5]and armament configuration[6]. Track planning is the core of mission planning. Generally it refers to the track optimization problem immediately after the starting point, the target point and some target nodes are determined [7]. Its basic function is to plan a number of trajectories that meet the requirements for known or potential targets based on the performance of the drone,[8] the geographical environment through which the flight passes, the threat environment and political conditions[9]. This article considers the target detection and situation reconnaissance of a mountainous area by a drone team[10]..

II. MINIMIZED MTSP MODEL FOR THE LONGEST TIME

2.1 Problem description and analysis

Six drones are required to complete the detection of the entire area in the shortest time, and the detection coverage is as high as possible. The Core idea of （Multi-traveler problem） [1]is that elevating the elevation point that meets the requirements. Then, the traversal time is required to be the shortest, the optimization model is established, and all the feature points are traversed by the ant algorithm to obtain the optimal path and navigation time. Combined with the constraint conditions, the cubic B-spline interpolation is used to obtain the flight path in the three-dimensional space.

2.2 Model establishment

2.2.1 Data preprocessing

City screening：

This paper collects more than one million elevation points. If you do not preprocess them, but directly use each elevation point as a virtual city to establish the MTSP model, it is relatively difficult to get the optimal path solution in a short time. So we try to satisfy the constraint （2）（4）（5）（6）and combine accuracy requirements.At the same time taking into account the computing power of the computer, we divided the detection area into 1936 copies.

Among them, the drone constraints are as follows:

（1）Maximum flight time constraint:

tk<<tmax, k=1,2,..,6

（2）Flight height constraint:

H<<H,ax

（3）Flight Turning Radius Constraints:

R>>100m

It is judged whether the track is flightable by judging whether the curvature radius of each point of the track is greater than or equal to the minimum turning radius of the drone.

（4）Maximum climb (dive) angle constraint:

-15C<< θ <<15C

$$\theta = \frac{|z_i - z_{i-1}|}{\sqrt{(x_i - x_{i-1})^2 + (y_i - y_{i-1})^2}}$$

（5）Safety distance constraint:

lsafety>>50m

（6）Detect effective distance constraints:

leffect<<500m

Combining the accuracy requirements with the computing power of the computer, we divided the detection area into 1936 copies.

2.2.2

Multi-traveler problem (MTSP) is a multi-objective planning problem. Given N cities (including F starting cities, N-F starting cities), K travelers. Each traveler is required to go through different tourist cities from their respective starting cities. Each tourist city has one and only one traveler can pass, and finally each traveler returns to the corresponding starting point to obtain the lowest cost combination route.

2.2.3 MTSP model establishment for a specified number of drones

Firstly， the feature points (preprocessed elevation points) are regarded as all cities in the MTSP, and the drones are regarded as travel agents, the number of travel agents is k=6, and the number of tourist cities is 1936.Assuming that the drone is flying at the average flight speed, the cost function translates into the longest time-consuming loop, which is the time traveled by the traveler .

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Then, the objective function with the least cost is required to be converted into the problem of minimizing the minimum time of . which is

$$T=min\ t6 \tag{1}$$

Among them, each traveler spends time is

Define the following variables

$$x_{ik}=\begin{cases}1,\ \text{Traveler k route}(i,j)\\0,\ \text{Traveler k does not pass the route}\ (i,j)\end{cases}$$

$$y_{ik}=\begin{cases}1,\text{Traveler k visit city i}\\0,\text{Traveler k does not visit city i}\end{cases}$$

Among them， lij is the distance traveler passes route A(i,j), v is the time that traveller tk needs to traverse the corresponding city. Based on the above analysis, with (1) as the objective function, the optimization model is established as follows：

$$T=\min t_6$$
$$t_k=\frac{\sum_{i=0}^{n}\sum_{j=0}^{n}l_{ij}x_{ij}}{v};k=1,2\ldots6 \tag{2}$$

Restrictions：

$$s.t\begin{cases}t_{ij}\ll t_{max} & i,j\in(1,2,3\ldots\ldots n)\\ \sum t_{ij}<24 & i,j\in(1,2,3\ldots\ldots n)\\ \sum_{j=1}^{N}x_{ijk}\le 1 & i=0,k\in\{1,2,3\ldots\ldots k\}\\ \sum_{j=1}^{N}\sum_{k=1}^{k}x_{ijk}=1 & i\in\{1,2,3\ldots\ldots n\}\\ \sum_{k=1}^{m}y_{ki}=\begin{cases}m, & i=0\\1, & i=1,2,\ldots,l\end{cases}\end{cases} \tag{3}$$

Equation (2) represents the travel time of each traveler. Formula (3) represents that each travel city has only one traveler to visit once and formula (4) represents the elimination of the incomplete route solution, that is, the traveler must eventually return to the original starting point.

2.3.4 Model solution

This problem is a multi-traveler problem, which belongs to the NP-hard problem. Combined with the above model, the ant algorithm is designed to approximate the solution. The ant algorithm has strong adaptability, global optimization ability, and strong nonlinearity for solving nonlinear problems. It is a more effective global method for solving NP complete problems.

To analyze the topographic map, we divide it into two areas with the upper left-lower right diagonal line, and set three unmanned aerial vehicles from the two starting points of AB to solve the problem by using the ant algorithm. By classifying MUAS as an MTSP problem, we use the GA algorithm to derive the route planning route. However, the track planned by the intelligent algorithm is often not flyable, and the track must be smoothed according to the maneuverability of the drone. The drone constraints in this question mainly include the maximum range, the maximum detection range, the maximum climb angle, and the minimum turning radius. At this stage, the UAV constraint (3) and the minimum turning radius constraint are mainly considered.

Because the B-spline curve interpolation method can solve the contradiction between the approximation and the convexity of the curve, and the curvature changes more uniformly, we can use the B-spline curve smoothing method to smooth the track, so that the track curve is The curvature changes little before and after the turning point, and the minimum turning radius constraint is satisfied.

Refer to the relevant literature, as shown in Figure (1),Radius of curvature ri. It can be considered that the B-spline curve interpolation method is effective for smoothing the route.

is the height of Fig.1，li is the width，ri is Radius of curvature.

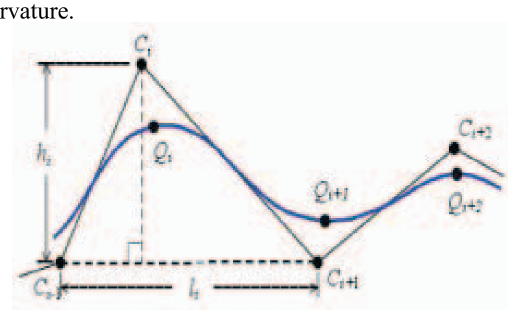

Figure 1. B-spline curvature approximation

The result is interpolated by three B-splines to achieve smoothing, and the route map of the drone is obtained,see Fig.2:

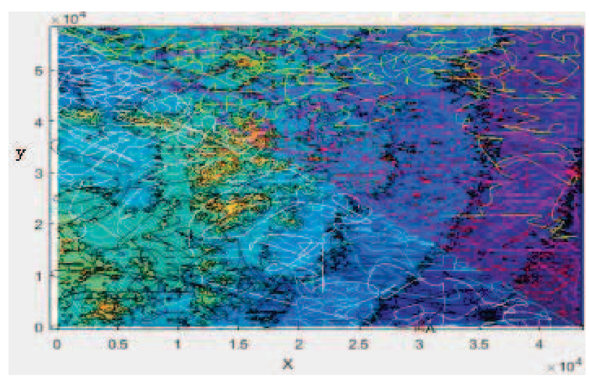

Figure 2. Contour line drone route map

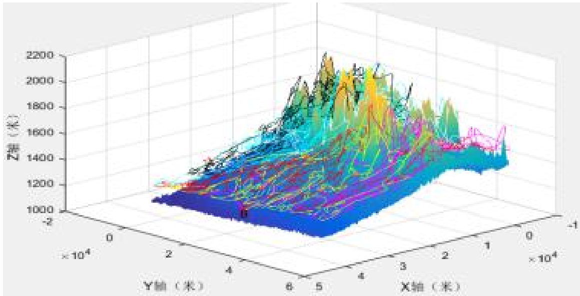

Figure 3. 3D UAV route map

2.3 Result analysis

Through the above steps, we have obtained the navigation route and flight schedule of each of the six UAVs. (1) Analysis of the flight time We can know that the six UAVs have completed the detection of the area within the specified maximum life time of 8 hours. The task, and the goal of minimizing the longest time, the time distribution obtained is basically uniform, and there is no case where the load of a certain drone is too light, so we think the result is more reasonable.

TABLE I. UAV FLIGHT SCHEDULE

Numb	**1**	**2**	**3**	**4**	**5**	**6**
Time (h)	7.15	7.16	7.16	7.26	7.27	7.28

In addition, in the data preprocessing, we replace the detection area with 1936 feature points, transform it into a multi-traveler problem, and traverse all the points that satisfy the constraint in a certain order, so that the detection coverage reaches an acceptable higher level. In this way, we turn multi-objective into a single-objective problem and get a better solution under this condition.

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III. CONCLUSION

This paper builds a mathematical model around the problem of UAV detection. Firstly, the data preprocessing transforms the area coverage into the traversal of the feature points. The problem of the UAV detection patrol scheme is classified as MTSP. Solving the classic problem simplifies the problem. Model 3 simplifies the 3D communication coverage problem into a two-dimensional circle coverage problem, rationalizes the problem, and makes the problem easy to solve.

Although the problem is reduced to MTSP (Multiple Traveling Salesman Problem), the problem is simplified, but in the result, there is a crossover phenomenon of the trajectory relative to the projection of the XY plane, which causes a certain amount of time waste. Moreover, although the ant algorithm can find a solution in a short time, it is easy to fall into a local optimal solution. Although we have certain rationality for the simplification of the model, it is easy to make the error of the solution to the problem larger.

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