Research on Obstacle Avoidance of UAV for Optical Cable Route Inspection

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Abstract: Firstly, UAV is proposed to be used in optical cable route inspection, which is the main promotion direction of optical cable route inspection in the future. Then, an improved ant colony algorithm is proposed to solve the path planning problem of UAV, and the feasibility is verified by simulation.

1. Introduction
With the rapid development of China's optical cable lines, the line inspection work is faced with many problems, such as high working intensity, long period, bad environment of some lines, and the traditional manual inspection method is facing great challenges. In order to improve the automation degree of line inspection and improve the inspection mode, UAV inspection is the technical improvement of traditional manual inspection. The UAV is remotely controlled by the flying hand, and the optical cable line is inspected by airborne sensor equipment (such as camera, infrared imager.). Compared with manual inspection, UAV inspection has the advantages of simple equipment, low cost, flexible, safe and efficient mobility, easy to find hidden dangers and so on. It is easy to integrate with manual inspection and become a daily inspection method[1], which is the main promotion direction of optical cable route inspection in the future.

In the process of UAV's mission, it does not always fly in an obstacle free environment. When there are obstacles on the flight route, the UAV should be able to achieve autonomous obstacle avoidance, which requires the design of a path planning algorithm so that the UAV can safely avoid obstacles in the flight process. The UAV path planning problem can be modeled as a constrained optimization problem.

Many scholars have accumulated rich research results on the path planning of UAV for patrol inspection[2]. In the application of power system line inspection, some scholars divide UAV path planning into line corridor inspection path planning and tower inspection path planning according to different tasks. They abstract them into different types of traveling salesman problems and use genetic algorithm to solve them, but the research does not involve the problem of environmental obstacle avoidance. Xu Haadong of Nanjing University of Aeronautics and Astronautics used support vector machine and improved A* algorithm to avoid environmental obstacles, and achieved good planning results[3]. However, this study only involves the obstacle avoidance between the starting point and the target point, and does not consider the patrol path planning problem under the multi-target point. Compared with power system line inspection[4], optical cable line inspection has its special environmental characteristics and task objectives. In the inspection of optical cable lines, it is necessary to consider not only the specified line inspection, but also the obstacle avoidance problem, which can be summarized as the traveling salesman problem with obstacle avoidance constraints.

The essence of path planning is to intelligently plan a better motion path (the shortest length, the least time, the least energy consumption, etc.) for UAV in the environment with obstacles. During the process of path planning modeling, the environmental information will be mastered in detail, and then the spatial form will be described. According to the degree of mastering and describing, path planning can be divided into global, local and hybrid methods.
The global planning method is to obtain information details in the environment first, and then give the UAV intelligent search for the optimal or suboptimal path in this environment. This method is divided into offline and online, which belongs to the offline planning method. The accuracy of obtaining environmental information determines the accuracy of planning path. Generally, this method can get the optimal path planned by the algorithm, but the premise is that the environmental information should be mastered accurately and the calculation amount is very large; the local method is to obtain the environmental information of the current UAV first, which is local, that is, the size, specific shape, spatial position and other relevant information of the obstacles, so that the UAV can avoid collision better. Because the information obtained by local planning method is only obtained by sensor induction. And when the environment changes, it will change in real time, so most navigation control usually uses the local method. Compared with the global method, the biggest characteristic of the local method is real-time, and the biggest defect is that it can only rely on the obtained local information for planning, which often results in the local optimal solution, so the pre planned path will lose significance, making the UAV unable to reach the destination as expected. The method based on graph theory is widely used in the field of UAV path planning, but most of these methods are sampling the planning space, so the performance of the route obtained is limited by the degree of sampling. It is suitable for small and medium-sized track planning. The evolutionary algorithm can solve the problem with large space scale, but it also has low efficiency. Ant colony algorithm is a simulation of the foraging mechanism of real ant colony in nature. By introducing heuristic information and pheromone update mechanism based on positive feedback mechanism[5], the efficiency of the algorithm is improved.

2. Principle of ant colony algorithm
In the process of finding the path, ants will leave a special substance on the way they pass. The substance here is called pheromone in ant colony algorithm. Ants perceive the intensity of this substance, and use this substance concentration to guide their movement direction. The direction with high pheromone concentration is the first direction for ants to choose to move. In the same time, the information concentration with short path length will volatilize more slowly, and more ants will choose this path. Ants use pheromones as a medium for indirect information exchange, and determine the best path from the cave to the food place.

The search of artificial ants mainly includes three kinds of behaviors:

Ants use pheromones to communicate with each other: ants will release a kind of pheromone substance on the selected path. When other ants choose the path, they will choose according to the pheromone concentration on the path, so that pheromones become the communication medium between ants.

Memory behavior of ants: the path searched by an ant is no longer selected by the ant in the next search, so a promotion table is established in the ant colony algorithm for simulation.

Colony activity of ants: it is difficult to reach the food source through the movement of one ant, but the whole ant colony is totally different. When more and more ants pass through some paths, the number of pheromones left on the path will increase, resulting in the increase of pheromone intensity, and the probability of ants choosing the path will increase, thus further increasing the pheromone intensity of the path, and the pheromones on the path passing through less ants will volatilize with the passage of time, thus becoming less and less.

Ant colony algorithm not only uses the principle of positive feedback, which can speed up the evolution process to a certain extent, but also is an essentially parallel algorithm. The continuous information exchange and transmission between individuals is conducive to finding better solutions.

3. Environmental model based on grid method
The method of using grid to represent the working environment of UAV originated from the University of Carnegie Mellon (CMU). In essence, UAV environment modeling is based on the information around the environment, which can be known or unknown, and then extracted and distinguished by analyzing the relevant environmental features. Finally, the information can be transformed into machine feature language space that can be understood by multiple UAV Systems. Since the selection of environment modeling method is closely related to the path planning algorithm, the reasonable selection of environment modeling method can effectively reduce the amount of search and operation time in the process of path planning. The grid method used in this paper can well meet the above requirements. Through this method, the environment of UAV is described in detail, and the two-dimensional grid is used to replace the actual working environment. In order to facilitate the description of the environment space, the established grid environment is sequentially coded from bottom to top, from left to right.

For UAV, a corresponding matrix should be established according to the environment map to represent the state of each grid. In this work environment matrix, 0 is the free grid and 1 is the obstacle grid. Each obstacle can occupy a grid and store it in the obstacle array, of course, it can also occupy multiple grids, and those less than one grid are also represented by one grid.
4. The flow of obstacle avoidance control algorithm based on ant colony algorithm

Step 1 The grid method is used to establish the environment model and the map matrix corresponding to the environment map. Initialize basic parameters. Set the time \( t = 0 \), the number of ants \( m = 50 \), the number of cycles \( N_c = 0 \), the maximum number of cycles \( N_{c\text{max}} = 50 \), set the tabu table as empty, put \( m \) ants at the starting point, and then add the starting point to the tabu table.

Step 2 Initialize the amount of information in each direction, input the initial pheromone matrix, select the initial point and the end point, and set various parameters.

Step 3 Select the next node that can be reached from the initial point, and calculate the probability of going to each node according to the pheromone of each node. The next initial point is selected by using the wheel algorithm.

Step 4 Update path and route length.

Step 5 Repeat steps 3 and 4 until the ant reaches the destination or has no way to go.

Step 6 Repeat 3-5 until the iteration of a generation of \( M \) ants ends.

Step 7 Update the pheromone matrix, in which the ants not arriving are not included.

Step 8 Repeat 3-7 until the iteration of the nth generation ant is over.

5. Simulation and Conclusions

The characteristics of ant colony algorithm are distributed and robust. After summarizing the rules of ant search, it is easy to get the basic ideas of UAV formation search: first, move in the direction of the target point, obstacles may be encountered on the road, and then the UAV formation will choose a direction to avoid obstacles; second, in the process of movement, it must follow the established rules, avoid obstacles, and then continue to follow the direction of the target point. According to the above way of thinking, we can usually get a collision free path from the starting point and the target point, and then optimize the collision free path to find the shortest path. During the operation, there will be some obstacles between the starting point and the destination point. Suppose a database records all the free grid sets and obstacle grid sets, and finds the collision free path under the guidance of ant colony algorithm according to the rules in advance, until the destination location is found, the program ends.

Matlab 2017 software is used in the simulation. UAV plans and codes in the environment space with grid dimension of 20 * 20. Black indicates obstacles, and white indicates feasible grid. Only free grid can be selected in the process of path optimization. It can be seen from the simulation results that the UAV successfully avoids all obstacles in the process of reaching the target point.

![UAV trajectory](image1.png)

Figure 1. Top view of UAV trajectory
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