Research on Solving Hamiltonian Loop of Material Distribution Based on Ant Colony Algorithm

Lixuan Liu[1], Zhixian Kong[1], Junrong Ma[1], Yaying Deng[1], Liangchuan Ma[1], Xingding Wu[1]

* Lixuan Liu's e-mail: 652813493@qq.com

* Zhixian Kong's e-mail: 1191568282@qq.com

* Junrong Ma e-mail: 2233904724@qq.com

* Yaying Deng's e-mail: rejiaya@163.com

* Liangchuan Ma's e-mail: 573798202@qq.com

* Xingding Wu 's e-mail: 2486829152@qq.com

[1] Space Engineering University, Beijing, 101400, China

Abstract: With the increasing popularity of 5G communication technology, the high speed and low latency of 5G network provide information technology support for the development of the UAV industry. Nowadays, the material distribution mode of "delivery vehicle + drone" is widely used in many tasks such as disaster relief and cargo transportation. At present, in order to improve the transportation efficiency and reduce operating costs in this mode, it is particularly important to reasonably plan the distribution scheme of drones and vehicles. Based on the given location, route and distribution demand, the optimal distribution scheme is solved, the Dijkstra algorithm is used to calculate the shortest distance between any two points in the network diagram and the corresponding path to build a fully connected network, and then the genetic algorithm is used to solve the TSP problem with the shortest distance of the vehicle as the objective function, so as to approximate a Hamilton loop, and finally find the actual driving path of the vehicle.

Keywords: Dijkstra algorithm, genetic algorithm, TSP problem

1 Introduction

With the increasing popularity of 5G technology, the high speed and low latency of 5G networks provide an efficient and stable interconnection network, providing information technology support for the rapid development of UAVs. Nowadays, in many fields such as disaster relief and cargo transportation, UAVs show many advantages such as high mobility, easy operation, and no risk of casualties, making the "vehicle + UAV" model favored in many large-scale engineering tasks. At present, according to the actual situation such as road conditions and material requirements of each distribution point, it is particularly important to reasonably plan the transportation path of "vehicle + drone" to improve efficiency and reduce costs.

ICIDC 2023, June 02-04, Nanchang, People's Republic of China

DOI 10.4108/eai.2-6-2023.2334611

2 Description of the problem and model building

2.1 Description of the problem

Under the 14 locations and existing routes given, emergency supplies are distributed to all locations from the 9th location, with a known maximum load of 1,000 kg and the day's emergency supplies requirements for the remaining points. We are required to build a mathematical model to complete the overall distribution and give the optimal distribution plan.

2.2 Model establishment

Combined with the existing conditional assumptions in the problem, in order to simplify the model and facilitate the solution, we put forward the following assumptions:

1. UAVs can only be launched and collected by vehicles, vehicles can only launch or recover UAVs at the site, and the time of launch and collection is negligible.

2. The realistic influence of road conditions and terrain is not considered during vehicle driving and drone flight, and linear motion is only done in a two-dimensional plane on a given road.

3. Both the drone and the vehicle travel or fly at an even speed, and the weight of the cargo carried has no effect on the speed of both.

The symbols of the model and the description of each parameter are shown in Table 1.

Table 1 Description of symbols

serial number	symbol	**significance**
1	A	The adjacency matrix of the network diagram
2	W	The weight matrix of the network diagram
3	D	A fully connected network diagram with the shortest path between any two points
4	v_p	Drone flight speed
5	v_c	Speed of the vehicle
6	T	Total time spent on the entire delivery package
7	T_1	Time spent on vehicle lines
8	T_2	Complete a delivery in the time the vehicle waits for the drone at the node
9	ΔT_1	Time difference matrix

We know that the maximum load of the delivery vehicle is 1000 kg, but the total weight of emergency supplies required at each location is 762 kg, so the distance planning problem of the vehicle to complete the overall distribution can be transformed into a Hamilton loop[1] problem. Since there is a cutpoint in the network diagram of problem 1, that is, node 4, here I can bind node 4 with node 6 to solve the cut point problem; At present, no effective algorithm has been found for Hamilton loops, so we use the traveling salesman problem (hereinafter referred to as the TSP problem) to approximate a Hamilton loop, that is, allow vehicles to pass through the same node multiple times to minimize the total distance. That is, the objective function is that the total distance traveled by the vehicle is the smallest, and the decision-making variables are the location of material concentration, the distribution destination, the route situation of each point, and the material demand of each point. We use the Dijkstra algorithm [2]to calculate the shortest distance and corresponding path between any two points in the network diagram. Since the TSP problem is solved in a fully connected network, we record the weight between two points in the network that are not connected as the minimum distance obtained by the Dijkstra algorithm. Then, the genetic algorithm [3] is used to search for the optimal path using the total distance of the vehicle as the objective function, and the shortest path of the vehicle is obtained.

3 Basic model approach

(1) TSP problem [4]

The TSP problem can be described as the distance between 14 known locations, i.e. the vehicle chooses a route from the 9th location, so that each location is visited only 1 time, and finally returns to the 9th location. That is, a search for a natural subset (where the number of the place) is permutation such that:

$$T_d = \sum_{i=1}^{n-1} d(V_i, V_{i+1}) + d(V_n, V_1)$$

Gets the minimum value, which represents the distance from place to place.

The basic algorithm of the TSP problem is as follows:

1. Encoding

A method of encoding using integer permutations. Suppose that for a site TSP problem, the chromosome is divided into segments, where each segment corresponds to the number of the site.

2. Population initialization

According to the genetic algorithm flow, an initialized population must be generated as the initial solution, so the number of initialized populations needs to be decided first. In general, the size of the population is determined according to the size of the site, and the value varies between 50 and 200.

3. Fitness function

Set to a coded chromosome, which is the distance from place to place, then change the individual's fitness to be:

$$fitness = \sum_{i=1}^{n-1} D_{k_i k_j} + D_{k_{14} k_1}$$

The fitness function is the distance that you have traveled through exactly one place and then back to the starting point. The goal of optimization is to select chromosomes with the smallest possible fitness function value, and the smaller the fitness function, the better.

4.Select Actions

The selection operation is to select individuals from the old group with a certain probability to the new group, and the probability of the individual being selected is related to the value of the fitness, and the smaller the fitness of the individual, the greater the probability of being selected.

5. Cross operation

Using partial mapping hybridization, determine the parent of the crossover operation, group the parent in pairs, and repeat the process for each group (assuming the number of sites is 10)

Random integers within two [1,10] intervals are generated to determine 2 positions, and the intermediate data of the two locations are crossed. As.

$$\begin{array}{ccc} 9 & 5 & 1 \\ 10 & 5 & 4 \end{array} \left|\left| \begin{array}{cccc} 3 & 7 & 4 & 2 \\ 6 & 3 & 8 & 7 \end{array} \right|\right| \begin{array}{ccc} 10 & 8 & 6 \\ 2 & 1 & 9 \end{array}$$

After crossing

$$\begin{array}{ccc} 9 & 5 & 1 \\ 10 & 5 & * \end{array} \left|\left| \begin{array}{cccc} 6 & 3 & 8 & 7 \\ 3 & 7 & 4 & 2 \end{array} \right|\right| \begin{array}{ccc} 10 & * & * \\ * & 1 & 9 \end{array}$$

6. Mutation operations

The mutation policy takes two randomly selected points and swaps them in place. Random integers in two [1,10] intervals are generated and 2 positions are determined, swapping their positions. As:

$$9\ \ 5\ \ 1\ |\ 6\ \ |\ 3\ \ \ 8\ |\ 7\ |\ 10\ \ 4\ \ 2$$

After variation

$$9\ \ 5\ \ 1\ |\ 7\ |\ 3\ \ \ 8\ |\ 6\ |\ 10\ \ 4\ \ 2$$

7. Perform a reversal operation

In order to improve the local search ability of genetic algorithms, multiple evolutionary reversal operations are introduced after selection, crossing, and mutation. "Evolution" here refers to the unidirectionality of the reversal operator, that is, only after the reversal, the fitness value has increased to accept it, otherwise the reversal is invalid.

Random integers in two [1,10] intervals are generated and 2 positions are determined, swapping their positions. As:

$$9\ \ 5\ \ 1\ |\ \ 7\ \ 3\ \ 8\ |\ \ 6\ \ 10\ \ 4\ \ 2$$

After the reversal

$$9\ \ 5\ \ 1\ |\ \ 7\ \ 3\ \ 8\ |\ \ 6\ \ 10\ \ 4\ \ 2$$

Each individual is cross-mutated, and then evaluated by substituting the fitness function, and individuals with large adaptation values are selected for the next generation of crossover and mutation and evolutionary reversal operations. Cyclic operation: determine whether the set maximum genetic generation is met, and jump into the calculation of fitness value if it is not satisfied; Otherwise, end the genetic manipulation. Here, we use the genetic algorithm to solve the flow chart of the TSP problem, as shown in Figure 1.

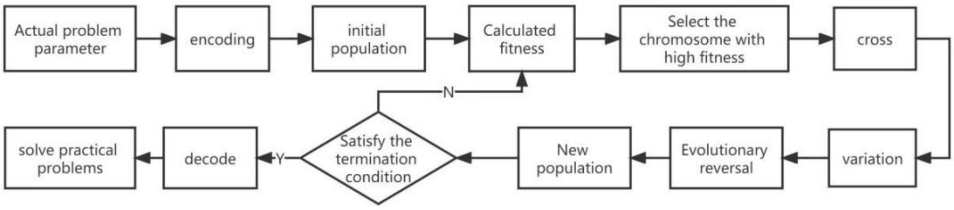

Figure 1 Flow chart of genetic algorithm solving TSP problem

4 Solving of the model

(1) Dijkstra algorithm [5]is used to construct the adjacency matrix of the fully connected network

First, according to the adjacency matrix of the network diagram, the weight matrix of the network diagram of the problem is obtained. Then, using the Dijkstra algorithm, the shortest path between any two points is calculated, which is a fully connected network diagram, which is suitable for solving TSP problems.

(2) Use genetic algorithms to plan the shortest distance of an overall delivery[6]

The solution process using genetic algorithm is as follows:

In the fully connected network diagram, the vehicle starts from location 9, and the total distance of the vehicle after passing each location and back to site 9 is the objective function.After calculation, it is found that the result of iterating to about 30 generations has reached the optimal value. Under the fully connected network diagram, the vehicle route pattern is. The TSP preliminary solution found that there was no direct connection, so the transition point 5 in the middle should be supplemented; In the same way, there is no direct connection, and the transition point 6 in the middle must be supplemented. Therefore, according to the network diagram adjacency matrix of the actual diagram, the actual path is , as shown in Figure 2.3, the shortest distance to complete an overall distribution is 582 kilometers, and the shortest time is 11.64 hours. The solid blue line in Figure 3 represents the path of the vehicle, and the black broken line indicates the path where the vehicle is not traveling.

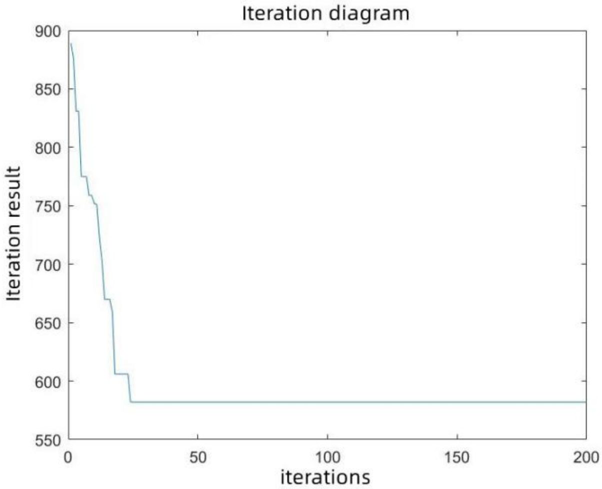

Figure 2: Problem 1: Iterative diagram of the genetic algorithm

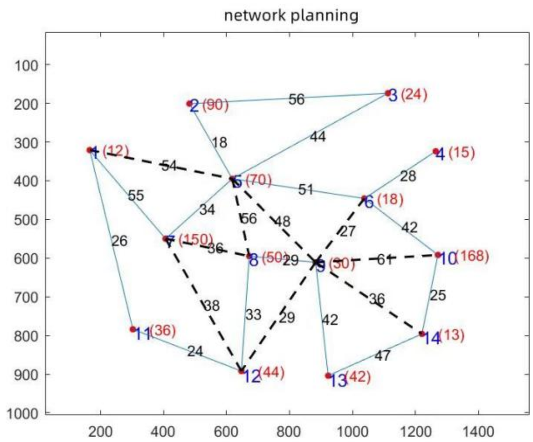

Figure 3: The actual path of the vehicle in question 1

5 Summary

For TSP problems in mathematical models such as optimizing distribution routes, genetic algorithms are mainly used, and multiple iterations are carried out to search for the global optimal scheme. Planning the UAV path based on the optimal vehicle path makes the implementation of the overall scheme relatively convenient, avoiding the long calculation time of conventional algorithms and the inadequacy of local optimal solution.

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