Research on Genetic Algorithm in distribution path planning

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Abstract: This paper is based on the genetic algorithm, access to the Amap path planning API, under the constraints of the weight of goods purchased by users and the vehicle itself, the goal of minimizing the total distance of all distribution vehicles is achieved, and finally the distribution sequence of vehicles is obtained. Through path planning, we can improve the efficiency of distribution and the satisfaction of customers.

1. Introduction
Path planning[1] refers to the design of the optimal driving route from the starting position to the target position under the condition of following the agreed criteria in advance.

With the rapid development of science and technology and information technology, path planning has been applied in many fields. Therefore, as long as the topology is the planning of points, lines, graphs and other networks, it can be transformed into path planning to deal with. In the path planning problem, the most important thing is the design of algorithm. Since the beginning of traditional algorithms, there has been a hybrid algorithm which combines traditional algorithms with bionics, and now intelligent algorithms are widely used. Commonly used intelligent path planning algorithms[2] are Dijkstra algorithm, genetic algorithm, ant colony algorithm, Floyd algorithm, particle swarm optimization algorithm and so on. This paper adopts genetic algorithm[3][4], which is a method of calculating the optimal solution by simulating the natural evolution process, so its search efficiency is relatively low[5]. However, its convergence speed is faster, and it can iterate by itself. Other algorithms can be optimized and improved based on it.

2. Path planning

2.1 Problem description
A company has a distribution center in a county. As shown in Figure 1, Pentagon represents the location of distribution center and point represents the location of customers. The center stores all the company's goods and owns five trucks. After the user orders, the distribution dispatching system carries out vehicle routing planning according to the sum of orders at a certain time point. Each distributor picks goods from the distribution center according to the distribution route planned by the system. After the picking is completed, the goods are distributed smoothly to the customers one by one and then returned to the distribution center. As shown in Figure 2:
The company needs to achieve the following functions: under certain conditions, the most objective is to minimize the distance traveled by vehicles, and calculate the sequential route plan of vehicle distribution commodities. The constraints are as follows:

1. Distribution center and customer points must have addresses. Each distribution vehicle should start from the distribution center, deliver goods according to the order of customers on the line, and then return to the distribution center.

2. Customer's demand (commodity weight) is certain, each customer has and only one distribution vehicle to serve it.

3. The weight of goods required by a customer should not exceed the maximum cargo carrying capacity of a single distribution vehicle, and the total demand weight of a distribution line should not exceed the maximum cargo carrying capacity of a single distribution vehicle.

4. The maximum driving distance of each distribution vehicle is fixed, and the mileage of each distribution vehicle on each route does not exceed the maximum driving distance of the vehicle.

2.2 Mathematical model

Variables in the model are defined as follows:

\[ X_{ijc} = \begin{cases} 1, & \text{If vehicle } C \text{ travels from customer } I \text{ to customer } J \\ 0, & \text{else} \end{cases} \]

\[ Y_{ci} = \begin{cases} 1, & \text{If Customer } I \text{ is delivered by Vehicle } C \\ 0, & \text{else} \end{cases} \]

\[ d_{ij} \] denotes the actual distance between customer I and customer J (including customer point to distribution center)

\[ q_c \] denotes the maximum load-bearing capacity of the vehicle C itself

\[ l_c \] denotes the maximum driving distance of the vehicle C itself

\[ v_c \] denotes the average speed of the vehicle C itself

\[ g_i \] denotes the weight of goods required by customer I

\[ n_c \] denotes the number of distribution customers of vehicle C on each route

The mathematical model is as follows:

Decision variables:

\[ x_{ijc}, y_{ci} : \] is a 0-1 decision variable, that is:

\[ X_{ijc} = \begin{cases} 1, & \text{If vehicle } C \text{ travels from customer } I \text{ to customer } J \\ 0, & \text{else} \end{cases} \]  

(1)
\[ y_{ci} = \begin{cases} 1, & \text{If Customer } i \text{ is delivered by Vehicle } C \\ 0, & \text{else} \end{cases} \tag{2} \]

Objective function:
\[ \min F (x) = \sum_{c=1}^{C} \sum_{i=0}^{N} \sum_{j=0}^{N} d_{ij} x_{iec} \tag{3} \]

Constraint condition:
\[ \sum_{i=0}^{N} x_{0ic} = 1 \tag{4} \]
\[ \sum_{j=0}^{N} x_{j0c} = 1 \tag{5} \]
\[ \sum_{c=1}^{C} y_{ci} = 1 \tag{6} \]

\[ \sum_{i=1}^{n} g_{i} y_{ci} \leq q_{c} \tag{7} \]
\[ \sum_{i=0}^{n} d_{i(i+1)} y_{ci} \leq l_{c} \tag{8} \]

Among them, \((3)\) denotes the objective function, which solves the minimum of all vehicle travel distances. \((4)\) and \((5)\) indicate that each distribution line of vehicle \(C\) should start from the distribution center, deliver the goods according to the order of customers on the line, and then drive back to the distribution center. \((6)\) indicates that each customer can only have one vehicle \(C\) for its service, that is, the required commodity weight of a customer does not exceed the maximum carrying capacity of the vehicle \(C\). \((7)\) indicates that the total weight of goods required for distribution of vehicle \(C\) on each route does not exceed the maximum load weight of vehicle \(C\). \((8)\) indicates that the total distance traveled by vehicle \(C\) on each line is less than or equal to the maximum distance traveled by the vehicle.

3. Algorithm design

3.1 Overall design

The design of the distribution path planning will be based on genetic algorithm and access to the Amap path planning API to solve the problem of path planning.

Firstly, the order sum of goods purchased by customers is obtained, and then the set is coded. The parameters include: distribution center address, customer address, the weight of goods, the actual distance between the two points, and so on. The probability of crossover and mutation, the number of iterations needed and the size of the population are allocated for the vehicle routing module. Then Initialization () is initialized, Fitness () is calculated, and the function is \[ \min F_{1}(x) = \sum_{k=1}^{K} \sum_{i=0}^{N} \sum_{j=0}^{N} d_{ijk} x_{ijk} \] . Judging that the current iteration number is less than the preset iteration number, if it is not satisfied, Fitness Assess () is evaluated by fitness degree, that is, genetic operation. GENETIC OPERATION: If the current population size is less than or equal to the preset population size, the selection operator ChooseBestGene () is performed; if the current probability is less than 90% of the preset population size, the OXC () operation is performed; if the current probability is less than the preset mutation probability, the Mutation () operation is performed; After the genetic operation, a new generation of population is generated and enter the Fitness () calculation again. When the number of previous iterations is larger than the number of preset iterations, the best chromosome bestGene () can be obtained. The final output of the current shortest driving distance and sequential route scheme, and through the access path planning API, displayed on the Amap.
3.2 Genetic Operational Design

1. Coding

This paper will adopt natural number coding mechanism. In natural number coding, 0 is used to represent the distribution center, which is fixed, and other natural numbers (1, 2, ..., n) are used to represent customer points. The order of natural numbers is used to express the order in which vehicles deliver goods to customers. Assuming 20 randomly generated customer points, the order is 8 4 11 2 10 13 5 18 16 20 14 1 9 17 15 7 3 6. Distribution vehicles start from Distribution Center 0 and arrive at Customer Point 8 to determine whether the weight of demand for goods at Customer Point 8 is less than the carrying capacity of Distribution Vehicle, and whether the total distance from 0 to 8 to 0 is less than the longest driving distance of Distribution Vehicle. If the above conditions are met, then the Customer Point 8 will be Delivery. Then, according to the above constraints, judge whether to distribute to the next customer (customer 4). Similarly, other distribution lines are calculated. Then, we can get how many distribution routes we need, which can also indicate the current number of distribution vehicles.

2. Selection Operator

In this paper, roulette method is used to select operators. Selecting the individuals with the best fitness to participate in the evolution and adopting the best individual retention strategy, in order to make the genome with the best fitness have a higher probability of entering the offspring. ChooseBestGene() is the method of selecting algorithm in programming.

3. Crossover Operator

This paper will adopt the sequential crossover method, the crossover rate is 90%, as follows:

Suppose the parent 1 is 123456789 and the parent 2 is 574913628. As shown in Figure 3.

In parent 1, the starting and ending positions of nine genes were randomly selected (the starting and ending positions in parent 2 were the same as that in parent 1), as shown in Figure 4.

Genes selected from parent 1 and parent 2 are stored from the first place to generate offspring 1 and 2, as shown in Figure 5.

Then the location of the selected gene is found in the parent 1 and 2, and the remaining genes are sequentially placed in the offspring 1 and 2, as shown in Figure 6 and Figure 7.

According to the above methods, we can get two offspring, one is 345679128, and the other is 491325678.

4. Variant Operator

Reverse variation is used in this paper. At a certain probability, two chromosomes (genes) are randomly selected in the individual, and the chromosomes (genes) at the two locations are stored in reverse. As shown in Figure 8.
4. Application of Vehicle Distribution Route Planning

4.1 Example Design
The company's distribution center is located at 450 Yihui Road in Ninghai County. The company owns five trucks with a maximum driving distance of 60 km and a maximum commodity carrying capacity of 1 ton per vehicle. Now we need to distribute goods to 20 customers. The assignment of program operation parameters is shown in Table 1:

| Operating parameter information |  |
|---------------------------------|---|
| Maximum number of iterations    | 400 |
| Population size                 | 100 |
| Crossover rate                  | 0.9 |
| Mutation rate                   | 0.01 |

4.2 algorithm implementation
According to the customer order address in section 4.1 and coordinate transformation, we can get the corresponding location on the Amap map. There are 20 customer locations and one distribution center locations. As shown in Figure 9:

From the figure above, we can see that the "center" is the distribution center, 1, 2, 3, 4.. For customers and their location.

The results obtained by the algorithm are the shortest distance and distribution order under the current iteration number and population size, as shown in Figure 10:

As can be seen from the figure, the total distance of distribution is 37.14 kilometers, and the distribution routes are 0-12-17-9-19-16-0, 0-15-8-4-20-0, 0-11-10-13-6-0, 0-1-18-7-2-3-14-0 and 0-5-0, respectively.

Route planning, as shown in Figure 11:
5. Conclusion
Based on the genetic algorithm, the Amap path planning API is accessed to minimize the travel distance of the distribution vehicle, and a sequential route scheme is obtained under the constraint of the user's wine demand weight and the vehicle's own load and travel distance. In this paper, we mainly consider the single distribution center, the known user's geographical location, demand, and the average speed, maximum distance and maximum carrying capacity of the known distribution vehicles. Under the above constraints, we aim at the shortest total distance of all vehicles to plan a smooth distribution route. In the later research of path planning, we can consider the following factors: multiple distribution centers, customer service priority, dynamic user demand, dynamic distribution time and so on. To achieve the goal, we can also consider: minimizing the vehicle, minimizing the cost, optimizing the customer service level, minimizing the waiting time of the vehicle and so on. Ultimately, maximize the interests of enterprises.

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