Multi Routes Programming TSP Model Based on Shortest Path Method for Express Delivery

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Abstract: With the rapid development of C2C economy, logistics distribution service has become an important industry of national economy, which greatly promotes the circulation of goods. However, the rapid development of express delivery business has brought great challenge to the express delivery service. At the same time, with the upgrading of distribution services, in order to meet the specific requirements of customers, some mails need to be distributed within the specified time. How to reasonably arrange the delivery order of mails and minimize the delivery time is a very meaningful task for optimizing the delivery service. Different from the traditional route programming problem, express delivery needs multi trips to and from the Express Center due to the limited loading capacity of the couriers' vehicles. In this paper, a novel route programming model is designed based on the shortest path algorithm. It allows couriers to pass each delivery location multiple times. Firstly, the shortest path and path between any two locations are calculated by the shortest path algorithm. Then, the delivery locations are divided into multiple classes and delivered in different trips. In each trip, the optimization model of the total delivery distance is established on both the class and order of the locations to realize the multi routes programming for express delivery. In addition, we design a solution method based on genetic algorithm for the multi routes programming. The coding of this method includes two parts. One part is the order of delivery locations, and the other part encodes the trips of delivery locations. Finally, the model is verified by actual delivery tasks, and the experimental results fully verify the effectiveness of the proposed method.

1. Introduction

C2C has fundamentally changed people's lifestyle, promoted the rapid development and growth of logistics industry, and has become an important industry related to people's livelihood. Among them, delivery is an important work in express delivery, which constitutes a vital link in the logistics industry. With the increasingly mature development of the logistics industry, the increasing volume of express delivery, and the more humanized delivery service, it puts forward higher requirements for the courier to deliver orders [1]. Firstly, from the perspective of customers, for some customers' express mail, the delivery time of the courier needs to meet specific requirements (delivered before a certain time). Secondly, from the perspective of express companies, in order to control costs, express companies need to control the number of employees and hope to use fewer employees to complete work, which increases the workload of employees [2,3]. In addition, from the perspective of couriers, the income of couriers is closely related to the completed business volume. The more express mails sent at the same time, the richer the income. Therefore, the research on the optimization of courier delivery route has very important research significance and practical value, and plays an important role in promoting the development of logistics industry. With the progress of society, online shopping has become one of the main consumer behaviors in people's life.

As we can see that the route programming problem is typical a Travelling Salesman Problem (TSP) [4-8]. The methods of TSP problem are wildly used in the fields including transportation, circuit board circuit design, tourism and logistics distribution. Courier delivery needs to complete the delivery of all express items in the task list through multiple destinations. Delivery route optimization problem is to shorten the total distance required to complete the delivery of all express items in the task list and improve work efficiency by reasonably arranging the order of delivery

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locations. Couriers need to meet some constraints when delivering express mails. Some express mails need to be delivered before the specified time node. At the same time, they need to meet the constraints of the total volume and weight of express mails carried in a single time. However, due to the large number of courier distribution locations, the number of distribution sequence combinations is huge. At the same time, there are constraints on the total weight and volume of goods sent each time, which requires multiple trips to and from the sorting center. These factors pose a great challenge to the optimal distribution of couriers.

From the perspective of the shortest path problem and based on the relevant methods of TSP problem, this paper establishes an optimization model for courier dispatch, and further improves the model by considering the constraints of time, weight, volume and other factors. Finally, according to this model, a model solving method based on genetic algorithm is designed, and the effect of this method is verified by simulation experiments. The innovative work of this paper mainly includes the following points:

(1)We establish a multiple round-trip distribution path combination optimization model based on distribution point classification. By classifying distribution points, the model allocates all tasks to multiple paths for optimization.

(2)Aiming at the optimization of express delivery route, this paper designs a solution method based on genetic algorithm. This method encodes the distribution point and the category of each distribution point respectively. Then, the chromosomes are crossed by a special operation.

(3)Finally, the method is verified by the actual distribution data. Through extensive comparative experiments, the effectiveness of the proposed algorithm is fully verified.

2. Tsp Based Multi-Routes Model for Express Delivery Task

The research on the optimization of courier delivery route is to determine the order of all delivery locations of the courier task list. The goal is to find the most efficient delivery sequence scheme. In this paper, a courier is taken as an example, and the express center $\mathbf{O}=\left(x_0,y_0\right)$ is given. Define $\mathbf{X}=(\mathbf{x}_1,\mathbf{x}_2,\mathbf{x}_3,\cdots,\mathbf{x}_n)$ as the set of locations in the task list, where *n* stands for the number of all locations the courier needs to delivery packages. $\mathbf{x}_i=(x_i,y_i)$ denotes the coordinates of the *i*-th delivery location. In this paper, the straight-line distance between two coordinates is used to represent the distance between two locations. Assuming that the courier moves at a uniform speed during delivery, the average speed on the road is v. Let $\left\{a_1,a_2,\cdots,a_n\right\}, a_i=1,2,\cdots,n$ denote the delivery route. $\left\{a_1,a_2,\cdots,a_n\right\}$ stands for an arrangement of all delivery locations. $a_i\neq a_j, \forall i,j=1,2,\cdots,n$.

The optimization of express delivery route programming is a typical TSP problem. Let $\mathbf{V}=\left\{\mathbf{x}_1,\mathbf{x}_2,\cdots,\mathbf{x}_n\right\}$ denote the set of all delivery locations. Let $\mathbf{D}=\left\{d\left(\mathbf{x}_i,\mathbf{x}_j\right)\mid \mathbf{x}_i,\mathbf{x}_j\in\mathbf{V}\right\}$ denote the adjacency distance matrix between delivery locations. $d\left(\mathbf{x}_i,\mathbf{x}_j\right)$ denotes the distance between the location $\mathbf{x}_i$ and $\mathbf{x}_j$. As there are *n* delivery location in $\mathbf{V}$. Then, the number of scheme of delivery routes is the number of permutation and combination of all locations $n!$. For any route arrangement, it is defined as in formula (1):

$$\mathbf{y}=\left(\mathbf{x}_{a_1},\mathbf{x}_{a_2},\cdots,\mathbf{x}_{a_n}\right), \tag{1}$$

where $a_i,a_j=1,2,\cdots,n$, and $a_i\neq a_j$. The route starts from express center O, and then pass the locations $\mathbf{x}_{a_1},\mathbf{x}_{a_2},\cdots,\mathbf{x}_{a_n}$ in turn. Finally, return to the express center O. Then, the travel distance corresponding to the route is expressed as $s=f(\mathbf{y})$. The route programming problem is to find the shortest path scheme $s^*=f(\mathbf{y}^*)$. The optimization model is established as in formula (2):

$$\min f(\mathbf{y})=\sum_{i=1}^{n-1} d(\mathbf{x}_{a_i},\mathbf{x}_{a_{i+1}})+d(\mathbf{x}_0,\mathbf{x}_1)+d(\mathbf{x}_{a_n},\mathbf{x}_0) \tag{2}$$

Considering the problem of multiple trips of couriers, the corresponding delivery locations are divided into multiple classes. Let k denote the number of round trips. The corresponding scheme is represented as

$$\mathbf{y}=\left(\mathbf{x}_{a_1^{(1)}},\mathbf{x}_{a_2^{(1)}},\cdots,\mathbf{x}_{a_{n_1}^{(1)}},\cdots,\mathbf{x}_{a_1^{(r)}},\mathbf{x}_{a_2^{(r)}},\cdots,\mathbf{x}_{a_{n_r}^{(r)}},\cdots,\mathbf{x}_{a_1^{(k)}},\mathbf{x}_{a_2^{(k)}},\cdots,\mathbf{x}_{a_{nk}^{(k)}}\right) \quad (3)$$

where $\mathbf{x}_{a_1^{(r)}},\mathbf{x}_{a_2^{(r)}},\cdots,\mathbf{x}_{a_{n_r}^{(r)}}$ denotes the order of delivery locations in the r-th trip. n_r denotes the number of delivery locations in the r-th trip. Therefore, the optimization model in function (2) can be rewritten as in function (4):

$$\min f(\mathbf{y})=\sum_{r=1}^{k}\sum_{i=1}^{n_r-1}d(\mathbf{x}_{a_i^{(r)}},\mathbf{x}_{a_{i+1}^{(r)}})+d(\mathbf{x}_0,\mathbf{x}_{a_1^{(r)}})+d(\mathbf{x}_{a_{n_r}^{(r)}},\mathbf{x}_0) \quad (4)$$

where $\mathbf{x}_{a_i^{(r)}}$ denotes the i-th delivery location in the r-th trip. It is worth noting that at each delivery, the loading capacity of the distributor is limited. Therefore, if there is an upper limit on the total weight and volume of express mail installed in the Express Center every time:

$$\sum_{i=1}^{n_r} w_{a_i^{(r)}} \le W_0 \quad (5)$$

$$\sum_{i=1}^{n_r} v_{a_i^{(r)}} \le V_0 \quad (6)$$

Where W_0 denotes the maximum weight in each trip. V_0 denotes the maximum volume in each trip. In addition, despite the upgrading of the demand for distribution services, for some goods, customers have the demand for distribution time and need to deliver the goods within the specified time. Therefore, we need to constrain the arrival time of each distribution point. Firstly, we define $t_i, i=1,2,\cdots,n$. It denotes the time constraint of delivery location $\mathbf{x}_i$. For the convenience of calculation, we convert the time constraint into the distance constraint. Let $s_i=t_i*v, i=1,2,\cdots,n$ denote the distance constraint of delivery location $\mathbf{x}_i$. v is the verage travel speed. Then, we have the time constraint as follow:

$$\left(\begin{array}{l}\sum_{r=1}^{m-1}\left(\left(\sum_{i=1}^{n_r-1}d(\mathbf{x}_{a_i^{(r)}},\mathbf{x}_{a_{i+1}^{(r)}})+N_{a_{i+1}^{(r)}}*d_0\right)+d(\mathbf{x}_0,\mathbf{x}_{a_1^{(r)}})+N_{a_1^{(r)}}*d_0+d(\mathbf{x}_{a_{n_r}^{(r)}},\mathbf{x}_0)\right)\\ +\sum_{i=1}^{c}d(\mathbf{x}_{a_i^{(m)}},\mathbf{x}_{a_{i+1}^{(m)}})+d(\mathbf{x}_0,\mathbf{x}_{a_1^{(m)}})+N_{a_1^{(m)}}*d_0\end{array}\right)\le s_{a_c^{(m)}} \quad (7)$$

According to the meaning of function (7), for delivery location $\mathbf{x}_{a_c^{(m)}}$, It is arranged in the m-th trip. The time constraint is $s_{a_c^{(m)}}$. That is to say that the courier should arrive location $\mathbf{x}_{a_c^{(m)}}$ before the total distance reaches $s_{a_c^{(m)}}$. Before arrive this location, the total travel distance of the courier is calculated. $N_{a_{i+1}^{(r)}}*d_0$ denotes the waiting time cost at location $\mathbf{x}_{a_{i+1}^{(r)}}$. $N_{a_{i+1}^{(r)}}$ denotes the number of express mails at location $\mathbf{x}_{a_{i+1}^{(r)}}$. $d_0=3*v/60$ km denotes the distance that courier can travel in the waiting time.

We calculate the shortest distance matrix between any two places by Floyd algorithm $\mathbf{M}'$. We use it as a distance matrix $\mathbf{D}=\left\{d\left(\mathbf{x}_i,\mathbf{x}_j\right)\mid \mathbf{x}_i,\mathbf{x}_j\in\mathbf{V}\right\}$, and find the solution of optimal routes for express delivery by the model in function (4).

3. Genetic Algorithm Based Method for Solution of Multi Routes Programming

The solution method of combinatorial optimization problem based on genetic algorithm includes five main steps: parameter initialization, coding, population initialization, fitness function value calculation and genetic operation (crossover, mutation and selection).

(1) Parameter initialization

In this paper, the initialization of parameters mainly includes population size, iteration number and mutation probability. In the express route programming problem, the maximum weight, volume in one trip and the travel speed of the courier should be defined.

(2) Coding

In the route programming problem, the combination of location numbers is commonly used as the chromosome coding of genetic algorithm. Define $\left[a_1, a_2, \cdots, a_n\right]$ to be a chromosome which corresponds to a solution of route programming. That is to say that the courier starts from express center O, passes through the locations $a_1, a_2, \cdots, a_n$, and finally returns to the express center O. However, the express delivery problem is a multi routes programming task. Therefore, we propose a novel coding method for route programming, which is defined as $\left[a_1, a_2, \cdots, a_n; b_1, b_2, \cdots, b_n\right]$. $b_i \in \{1, 2, \cdots, k\}$. It is corresponding to a_i. b_i stands for the number of trip that location $\mathbf{x}_{a_i}$ belonging to. That is to say that location $\mathbf{x}_{a_i}$ is arranged in the b_i-th trip for express delivery. Each chromosome is a solution of multi routes programming. It is determined by the orders and classes of the locations. Permutations and combinations of all locations consists the search space of multi routes solutions.

(3) Population Initialization

Firstly, we get the code of order of all locations by random arrangement, $\left[a_1, a_2, \cdots, a_n\right]$. Then, we generate a class code $\left[b_1, b_2, \cdots, b_n\right]$ with length *n*. by generating random integers between 1~k. For any b_i, the initialization method is as follows:

$$b_i = \lfloor rand * k \rfloor + 1, \tag{8}$$

where $rand$ stands for a random number between 0~1. $\lfloor x \rfloor$ is function of round down operation.

(4) Calculation of fitness function

The fitness function value is calculated according to the objective function of the optimization model. It evaluates the advantages and disadvantages of each individual according to the optimization objective function value in formula (4). The goal of the optimization model is to solve the minimum function value. Then, the calculation method of fitness function value is as follows,

$$fitness = \max\left\{f(\mathbf{y}_i)\right\} - f(\mathbf{y}_i) \tag{9}$$

According to the definition in formula (9), we subtract the objective function value of each individual from the maximum value of all individuals. Then we have the fitness function value of each individual. The larger the objective function value, the smaller the corresponding fitness function value. It is worth noting that multi routes programming is an optimization model with constraints. Therefore, we transform the constraints to penalty terms. The objective function in formula (4) is transformed into the following form:

$$\min f(\mathbf{y}) = \sum_{r=1}^{k} \sum_{i=1}^{n_r - 1} d(\mathbf{x}_{a_i^{(r)}}, \mathbf{x}_{a_{i+1}^{(r)}}) + d(\mathbf{x}_0, \mathbf{x}_{a_1^{(r)}}) + d(\mathbf{x}_{a_{n_r}^{(r)}}, \mathbf{x}_0) + \alpha_1 P_1 + \alpha_2 P_2 + \alpha_3 P_3 \tag{10}$$

where α_1, α_2 and α_3 are balance parameters. P_1, P_2 and P_3 are respectively penalty terms of weight, volume, and time constraints. These penalty terms are defined as in formulas (11)-(13):

$$P_1 = \sum_{r=1}^{k} \left(\left(\sum_{i=1}^{n_r} w_{a_i^{(r)}} \le W_0 \right) * sign\left(\sum_{i=1}^{n_r} w_{a_i^{(r)}} \le W_0 \right) \right) \tag{11}$$

$$P_2 = \sum_{r=1}^{k} \left(\left(\sum_{i=1}^{n_r} v_{a_i^{(r)}} \le V_0 \right) * sign\left(\sum_{i=1}^{n_r} v_{a_i^{(r)}} \le V_0 \right) \right) \tag{12}$$

$$P_3 = \sum_{r=1}^{k} \sum_{i=1}^{n_r} \left(\left(R\left(\mathbf{x}_{a_i^{(r)}}\right) - s_{a_i^{(r)}} \right) * sign\left(R\left(\mathbf{x}_{a_i^{(r)}}\right) - s_{a_i^{(r)}} \right) \right) \tag{13}$$

where $sign(\cdot)$ is indicative function. It is defined as follows:

$$sign(x) = \begin{cases} 1, if \ \ x > 0 \\ 0, else \end{cases} \quad (14)$$

$R\left(\mathbf{x}_{a_i^{(r)}}\right)$ stands for the travel distance when courier arrives location $\mathbf{x}_{a_i^{(r)}}$. It is defined as in formula (15):

$$R\left(\mathbf{x}_{a_i^{(r)}}\right) = \sum_{r=1}^{m-1}\left(\left(\sum_{i=1}^{n_r-1} d(\mathbf{x}_{a_i^{(r)}}, \mathbf{x}_{a_{i+1}^{(r)}}) + N_{a_{i+1}^{(r)}} * d_0\right) + d(\mathbf{x}_0, \mathbf{x}_{a_1^{(r)}}) + N_{a_1^{(r)}} * d_0 + d(\mathbf{x}_{a_{n_r}^{(r)}}, \mathbf{x}_0)\right)$$
$$+ \sum_{i=1}^{c} d(\mathbf{x}_{a_i^{(m)}}, \mathbf{x}_{a_{i+1}^{(m)}}) + d(\mathbf{x}_0, \mathbf{x}_{a_1^{(m)}}) + N_{a_1^{(m)}} * d_0 \quad (15)$$

(5) Genetic operations

Genetic operation is the core of genetic algorithm, which lies in chromosome crossover, mutation and selection. In this section, the operation methods of crossover, variation and selection are introduced:

Crossover: In our model, the chromosome code of multi routes programming model consists of two parts. The first part is the permutation and combination of delivery locations. The gene codes of this part are unique. Therefore, the traditional crossover operation is not suitable for the chromosome code of our model. The second part is the class codes of all locations. It can use the crossover operation for the code of the second part. Therefore, we divide the chromosome code of our model into two parts. The crossover operation is conducted on the two parts with two different approaches respectively. In this section, we design a novel crossover operation for the first part of permutation and combination of locations. Define $\mathbf{a}_1 = (a_{11}, a_{12}, \cdots, a_{1n})$ and $\mathbf{a}_2 = (a_{21}, a_{22}, \cdots, a_{2n})$ stands for combinations of locations of two chromosomes. The operation is as follows:

1) Randomly generated crossover site. Generate a random site p between 1~n. Then we have the subset of $\mathbf{a}_1$, which is $\mathbf{a}_1' = (a_{11}, a_{12}, \cdots, a_{1p})$.

2) Find the complementary set $\mathbf{a}_1'$ of $\mathbf{a}_2$. Then, we have $C_{a_2} a'_1$. It is worth noting that the order of all locations in $C_{a_2} a'_1$ is consistent with that in $\mathbf{a}_2$.

3) Combine $\mathbf{a}_1'$ and $C_{a_2} a'_1$. Then we have a new chromosome $\mathbf{a}_3$.

4) Similarly, we do the crossover operation by exchanging $\mathbf{a}_1$ and $\mathbf{a}_2$. Then, we have $\mathbf{a}_2' = (a_{21}, a_{22}, \cdots, a_{2p})$ and $C_{a_1} a'_2$. Combining $\mathbf{a}_2'$ and $C_{a} a'_2$, we get a new chromosome $\mathbf{a}_4$.

Mutation:Same as the crossover operation, we divide the chromosome into two parts in the mutation operation. The difference is that the mutation operation does not conduct on every individual. The mutation is conduct with a probability. Assume that the mutation happens on chromosome $[a_1, a_2, \cdots, a_n; b_1, b_2, \cdots, b_n]$. Firstly, we randomly generate two different gene sites p_1 and p_2 of mutation, $p_1, p_2 = 1, 2, \cdots, n$, and $p_1 \neq p_2$. If $p_1 < p_2$, we exchange the positions of a_{p_1} and a_{p_2}. Then, we have the mutated chromosome

$$\left[a_1, \cdots, a_{p_1-1}, a_{p_2}, a_{p_1-1}, \cdots, a_{p_2-1}, a_{p_1}, a_{p_2-1}, \cdots, a_n; b_1, b_2, \cdots, b_n\right].$$

Secondly, we randomly generate a gene site $p_3 = 1, 2, \cdots, n$. The value of b_{p_3} is changed to an random integer b'_{p_3} between 1~k. $b'_{p_3} = 1, 2, \cdots, n$, and $b_{p_3} \neq b'_{p_3}$.

In general, the method of solution of multi routes programming based on genetic algorithm is as shown in Figure 4.1.

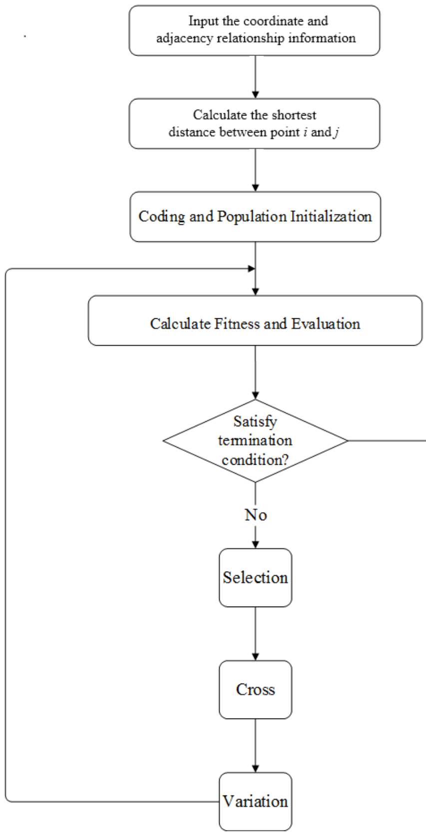

Fig.1 Diagram of Genetic Algorithm Method of Solution

4. Experiment

4.1 Test Data and Setting

In order to fully verify the effectiveness of the multi routes programming model proposed in this paper, this paper tests it on a set of express task data sets. The task data set is shown in table 1-3. Among them, Table 1 gives the relevant information of 100 express goods distribution tasks, including goods serial number, destination number, distribution time requirements, weight, volume, etc. The coordinates of 50 distribution locations and express center are given in table 2. The adjacency relationship between 50 distribution locations and express center is given in table 3.

In addition, for parameter setting. The speed of the courier is v=25km/h. The maximum loading capacity for a single distribution is $W_0 = 50$ kg, $V_0 = 1\text{m}^3$. The number of trips is set to k=3.

Table 1 Express Delivery List with Time Constraints

Package	Location	Weitht(kg)	Volume(m^3)	Time	Package	Location	Weitht(kg)	Volume(m^3)	Time
1	13	2.5	0.032	9:00	51	21	1.38	0.042	-
2	18	0.5	0.035	9:00	52	22	0.39	0.0001	-
3	31	1.18	0.024	9:30	53	23	1.66	0.050	-
4	26	1.56	0.035	12:00	54	24	1.24	0.053	-
5	21	2.15	0.031	12:00	55	25	2.41	0.001	-
6	14	1.72	0.010	12:00	56	26	1.26	0.006	-
7	17	1.38	0.011	12:00	57	27	0.42	0.022	-
8	23	1.4	0.043	12:00	58	28	1.72	0.058	-
9	32	0.7	0.048	12:00	59	29	1.34	0.037	-
10	38	1.33	0.022	10:15	60	30	0.06	0.040	-
11	45	1.1	0.029	9:30	61	31	0.6	0.027	-
12	43	0.95	0.023	10:15	62	32	2.19	0.050	-
13	39	2.56	0.060	12:00	63	33	1.89	0.049	-
14	45	2.28	0.030	9:30	64	34	1.81	0.033	-

15	42	2.85	0.019	10:15	65	35	1	0.006	-
16	43	1.7	0.078	10:15	66	36	1.24	0.018	-
17	32	0.25	0.041	12:00	67	37	2.51	0.036	-
18	36	1.79	0.018	12:00	68	38	2.04	0.011	-
19	27	2.45	0.045	12:00	69	39	1.07	0.044	-
20	24	2.93	0.042	9:00	70	40	0.49	0.033	-
21	31	0.8	0.011	9:30	71	41	0.51	0.009	-
22	27	2.25	0.002	12:00	72	42	1.38	0.046	-
23	26	1.57	0.021	12:00	73	43	1.31	0.012	-
24	34	2.8	0.010	9:30	74	44	1.26	0.001	-
25	40	1.14	0.016	9:30	75	45	0.98	0.041	-
26	45	0.68	0.038	9:30	76	46	1.35	0.024	-
27	49	1.35	0.014	10:15	77	47	2.12	0.023	-
28	32	0.52	0.002	12:00	78	48	0.54	0.054	-
29	23	2.91	0.049	12:00	79	49	1.01	0.057	-
30	16	1.2	0.043	12:00	80	50	1.12	0.028	-
31	1	1.26	0.025	-	81	25	0.79	0.001	-
32	2	1.15	0.050	-	82	46	2.12	0.049	-
33	3	1.63	0.048	-	83	32	2.77	0.003	-
34	4	1.23	0.001	-	84	23	2.29	0.005	-
35	5	1.41	0.039	-	85	20	0.21	0.049	-
36	6	0.54	0.007	-	86	25	1.29	0.009	-
37	7	0.7	0.013	-	87	19	1.12	0.025	-
38	8	0.76	0.035	-	88	41	0.9	0.004	-
39	9	2.14	0.009	-	89	46	2.38	0.043	-
40	10	1.07	0.012	-	90	37	1.42	0.002	-
41	11	1.37	0.051	-	91	32	1.01	0.030	-
42	12	2.39	0.043	-	92	33	2.51	0.013	-
43	13	0.99	0.005	-	93	36	1.17	0.002	-
44	14	1.66	0.049	-	94	38	1.82	0.031	-
45	15	0.45	0.021	-	95	17	0.33	0.035	-
46	16	2.04	0.010	-	96	11	0.3	0.017	-
47	17	1.95	0.032	-	97	15	4.43	0.054	-
48	18	2.12	0.055	-	98	12	0.24	0.006	-
49	19	3.87	0.026	-	99	10	1.38	0.018	-
50	20	2.01	0.032	-	100	7	1.98	0.049	-

Table 2 Coordinate Data of Delivery Location

Number	X (m)	Y(m)	Number	X (m)	Y(m)	Number	X (m)	Y(m)
1	9185	500	18	8825	8075	35	15305	11375
2	1445	560	19	5855	8165	36	12390	11415
3	7270	570	20	780	8355	37	6410	11510
4	3735	670	21	12770	8560	38	13915	11610
5	2620	995	22	2200	8835	39	9510	12050
6	10080	1435	23	14765	9055	40	8345	12300
7	10025	2280	24	7790	9330	41	4930	13650
8	7160	2525	25	4435	9525	42	13265	14145
9	13845	2680	26	10860	9635	43	14180	14215
10	11935	3050	27	10385	10500	44	3030	15060
11	7850	3545	28	565	9765	45	10915	14235
12	6585	4185	29	2580	9865	46	2330	14500
13	7630	5200	30	1565	9955	47	7735	14550
14	13405	5325	31	9395	10100	48	885	14880
15	2125	5975	32	14835	10365	49	11575	15160
16	15365	7045	33	1250	10900	50	8010	15325
17	14165	7385	34	7280	11065			

Table 3 Adjacency Relation Information Table

Number	Location 1	Location 2	Number	Location 1	Location 2	Number	Location 1	Location 2
1	1	3	29	15	22	57	35	38
2	1	8	30	15	25	58	36	45
3	2	20	31	16	23	59	36	27
4	2	4	32	17	23	60	37	40
5	3	8	33	18	31	61	38	36
6	3	4	34	19	24	62	39	27
7	4	2	35	20	22	63	40	34
8	5	15	36	21	26	64	40	45
9	5	2	37	21	36	65	41	44
10	6	1	38	21	17	66	41	37
11	7	18	39	22	30	67	41	46
12	7	1	40	23	17	68	42	43
13	8	12	41	24	31	69	42	49
14	9	14	42	25	41	70	43	38
15	9	10	43	25	19	71	44	48
16	10	18	44	25	29	72	44	50
17	10	7	45	27	31	73	45	50
18	11	12	46	28	33	74	45	42
19	12	13	47	29	22	75	46	48
20	12	25	48	30	28	76	47	40
21	12	15	49	30	41	77	48	44
22	13	18	50	31	26	78	49	50
23	13	19	51	31	34	79	49	42
24	13	11	52	32	35	80	50	40
25	14	18	53	32	23	81	O	18
26	14	16	54	33	46	82	O	21
27	14	17	55	33	28	83	O	26
28	14	21	56	34	40			

4.2 Result and Analysis

According to the genetic algorithm, the tasks in Section 4.1 are solved. In this paper, the multi routes programming problems with and without time constraints are solved respectively. Figure 2 shows the convergence curve of the objective function. Among them, the blue curve is the convergence curve without time constraint, and the green curve is the convergence curve with time constraint. It can be seen from the results in the figure that the scheme without time constraint converges faster.

The final delivery routes scheme is given in table 4. In Table 4, the routes of 3trips are given. And the total weights and volumes of 3 trips are given. According to the results, the routes programme reaches an optimal performance. The total weights and volumes of the second trip and the third trip are very close to the limits. The total volume of the second trip exceeds the maximum volume limit a little. And the total weight of the first trip is also close to the weight limit.

The total distance of the routes programme is 233.7km. It cost 558 minutes to finish all the mails delivery.

Table 4 Solution Of Delivery Routes

Trip	Route	Total Weight	Total Volume
1	O->26->27->36->35->32->31->34->40 ->47->49->42->43->38->O	48.83	0.84
2	O->18->13->11->12->8->3->1->7->9->14->16-> 17->21->39->19->22->4->6->50->45->O	49.63	1.01
3	O->23->37->44->48->46->41->15->25-> 29->20->33->28->30->5->2->10->24->O	49.54	0.95

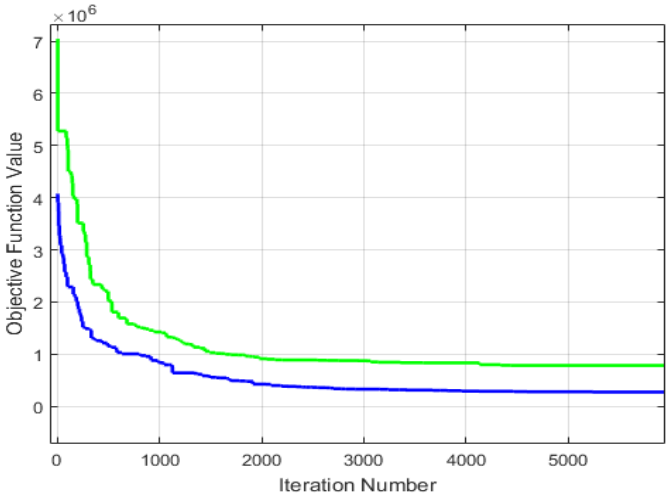

Fig.2 Convergence Curve of Genetic Algorithm

5. Conclusion

Route programming is an meaningful problem in our daily life. This paper studies the optimization of express delivery route based on route programming method. Different from the traditional route programming problem, the express delivery problem needs to complete the distribution of all mails through multiple trips. Therefore, multiple paths need to be planned at the same time. To solve this problem, a multi routes programming model based on shortest path algorithm is proposed in this paper. At the same time, we designed an effective solution method based on genetic algorithm. It also encodes orders of locations and class of trips of all locations. According to the coding method designed in this paper, the corresponding crossover and mutation operations are proposed. Finally, the effectiveness of this algorithm is verified by actual data.

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