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Analysis of Route Optimization Based on Genetic Algorithm

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Abstract—**In the logistics system, distribution process plays a very important role, whether the distribution route was reasonable arranged influences the cost of distribution and benefit. The optimization of the route is affected by the customer's address and delivery time. Minimizing the transportation cost is the purpose of this paper when satisfying the customer's requirement. On this basis, the traffic conditions are introduced to optimize the distribution route, and the effectiveness of the algorithm is tested and verified by simulation**

Keywords- Route optimization; time window; road condition; genetic algorithm;

I. INTRODUCTION

In the logistics scheduling, whether reasonable the distribution route is directly affect the benefit and costs of the distribution and the quality of service, so the optimize of transportation route is one of the hottest issues in modern logistics theory research and practice. As the demand for consumers tends to be diversified, the requirements for delivery time are becoming more stringent. If the distribution is not timely, the value of the goods will be greatly reduced, and the transportation costs will increase substantially. In order to save the cost of transportation, the first consideration is the route problem, which can be seen as a branch of Travelling Salesman Problem [1]. In this context, many goods need to be distributed as soon as possible because of the immediacy itself—such as vegetables, fruits and some perishable goods or the requirements of customers [2]. However, the traditional logistics is difficult to meet the strict timeliness requirements, to change this situation, the key is to seek a breakthrough from the distribution time, so how to improve the existing distribution methods and minimize the delivery time is necessary [3]. The problem of route optimization for immediate distribution belongs to Vehicle Routing Problem with Time Windows(VRPTW) [4]. This problem can be seen as a branch of Vehicle Routing Problem(VRP) [5] and just increase a constraint of time window on its basis. According to the strictness of time window constraints, this problem can be divided into Soft-time Window Vehicle Routing Problem and Hard-time Window Vehicle Routing Problem [6]. Based on the above situation, this paper mainly studies the route optimization problem of real-time distribution of goods, aiming at finding the optimal distribution route in the distribution process. Taking the actual situation into account, the greatest impact on the delivery time is the traffic information, in transport process. For this situation, a route optimization scheme based on traffic information is proposed in this paper. Niche technology is introduced to solve the problem of distribution route optimization based on standard Genetic Algorithm. And the corresponding MATLAB calculation program is compiled to realize the rapid solution of the problem.

II. SIMPLE INTRODUCTION OF GENETIC ALGORITHMS

Genetic Algorithms is a widely adapted calculate model, based on natural selection and population genetic mechanism, which was first proposed in 1975 by professor John Holland of the University of Michigan, reflecting the natural selection process of survival of the fittest. By applying a genetic operation to the population to achieve the iterative process of individual structural reorganization within the population, each iteration gets a set of solutions, each of which is evaluated by a fitness function, which repeats until some form of convergence. A new set of solutions not only has the option of retaining some of the old solutions with high fitness values, but also include some new solutions that are combined with other solutions. The three most critical parts are selection, crossover and mutation. Compared to the traditional search methods and general optimization search methods, genetic algorithms have the following technical characteristics:

1. The genetic algorithm takes the encoding of the object to be processed as the operation object.
2. Genetic algorithm search for multiple solutions simultaneously of search space, which makes the genetic algorithm has a good global search ability.
3. Genetic algorithm search information targeted the fitness function directly.
4. Genetic algorithm uses probabilistic search technology to guide the search process.

The basic flow chart is shown in figure 1:

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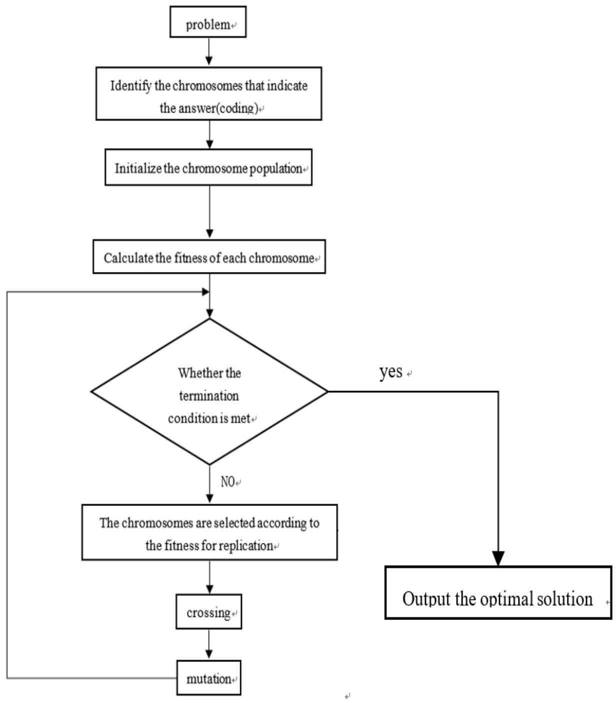

Figure 1. basic flow chart

III. ESTABLISHMENT OF VRPTW MODEL BASED ON TRAFFIC CONDITION

A. problem analysis

Before modeling the route optimization problem, the main problems and the time window constraints and traffic information modules involved in the model are analyzed firstly. They are transformed into mathematical language to finally establish the mathematical model.

1) Analysis of Route Optimization Problems

Given a distribution center and the distribution of distribution location which within the radiation range of the center, requiring all the delivery task should be complete in the situation of meeting the delivery time that customers required. In this case, the reasonable choice of routes can shorten the total stroke. In order to simplify the solution of the problem, the following assumptions need to be met:

1. All users' addresses are known and all users are delivered by just one distribution center.
2. The distribution center can meet the needs of all users.
3. All users' goods are delivered once and delivered to the vehicle only.
4. A car can complete the distribution of all users.

The route optimization problem can be described in the mathematical language as follows:

A vehicle set off from distribution center"1" and dispatch followed by n customers" $2,3 \dots\dots n+1$ ", the distance matrix $x = (x_{ij})$, x_{ij} represent the distant from customer "i" to customer "j". Arrange the route reasonable so that the total distance can be the shortest.

2) Analysis of time window constraint problem

In the whole distribution process, goods must be served at the time that customers request, according to the customer's requirement are strict or not, the time window constraints of route optimization problem can be divided into soft time window optimization and hard time window optimization, the former means that if you can't reach the specified time, you need to take some punishments according to the length of the violation time, the latter refers to no acceptance whether it is late or early. This paper uses soft time window, the mathematical language description language as follows:

Assuming that the required arrival time of task i is t_s, the actual arrival time of the delivery vehicle is t_i, so the time penalty cost is:

$$z_2 = \mathrm{m}\sum_1^n |t_i - t_s|$$

Where m is the penalty coefficient and a positive real number that is considered large enough, z_2 represent time cost based on traffic conditions,

3) Analysis of Traffic condition Problem

The most direct factors that affect the time of delivery of the vehicle to each delivery site are the traffic conditions between the two places. The quality of the traffic condition affects the delivery speed of the distribution vehicle, which directly determines the delivery time. The mathematical language is described as follows:

To the n customers from 2 to n+1, the matrix of traffic condition is $\mathrm{rcn} = (rcn_{ij})$, where rcn_{ij} represent the traffic condition between two distribution point i and j, and rcn is a symmetric matrix with all angles of zero.

B. The establishment of the VRPTW model

There are many factors that affect the cost of distribution. In this paper, the distribution cost and the time cost affected by traffic conditions are chosen as the objective function values of the route optimization problem constrained by traffic conditions, and the corresponding mathematical model is established as follows:

$$\mathrm{z} = z_1 + z_2 = c_1 \sum_i \sum_j c_{ij} x_{ij} + c_2 m \sum_1^n |(t_i - t_s)|$$

The symbols in the model are described below:

z represent objective function values, z_1 represent Route cost, z_2 represent time cost based on traffic conditions, c_1, c_2 represent the weights of route costs and time costs, c_{ij} represent the selection variable for the vehicle from the location i to the location j, x_{ij} represent the distance from location i and location j, m represent a penalty coefficient that considered to be large enough, t_i represent the actual arrival time for each location i, t_s represent the arrival time that required of each location i

IV. ALGORITHM DESIGN

A. Coding

Aiming at the characteristics of the problem studied in this paper, it is more appropriate to adopt the natural coding method, and the solution vector in the mathematical model is compiled into a chromosome with length n + 1, which indicates the distribution route.

$$s = (1, s_1 \dots s_i \dots s_n)$$

where s represents chromosome structure, s_i represents the i item delivery task.

The chromosome structure of the distribution route is that the distribution vehicle starts from the distribution center "1" and completes the tasks $s_1 \dots s_i \dots s_n$, and then returns to the distribution center "1". For example, a chromosome structure of s = (1,3,7,4,9,8,2,6,5) represent that the distribution vehicles set off from the distribution center, followed by the completion of tasks of customers 3, customers 7, customers 4, customers 9, customers 8, customer 2, customer 6, customer 5 and then back to the distribution center”1”.

B. Population initialization

Choosing the appropriate population size is the primary problem faced by the genetic algorithm. A large population size will bring a long search time while a small population size may cause the local optimum. Therefore, in the actual process, the population size is generally given in advance. Randomly generate N chromosomes, constitute the initial population as follows:

$$G_0 = (g_1, g_2 \dots \dots, g_n)$$

C. Selection

In this paper, the chromosomes are selected by roulette, and the fitness of each chromosome is obtained first, and then the proportion of each chromosome fitness is obtained as follows:

$$f_i = \frac{f_i}{\sum_1^n f_i}$$

Each selection produces a random number between 0 and 1 as the standard of selection, which allows candidates with less adaptive have the chance to be selected. on this basis, this paper introduces the selection model of 1+1 [7] — that is, the fitness value of descendants were compared with parent in each generation, then the first n individuals were selected from the whole 2n individuals according to fitness value, as well as niches Technology [9]—that is, before selection in each generation, calculate the value of share function of each individual, which can express the degree of similarity of individual, then each individuals’ fitness value were adjust through a punishment function calculated by share function to ensure the diversity of the population, the specific calculation steps are:

1. Calculate the Haiming distance [10] between each individual and other individual
2. Calculate the value of share function for each individual
3. Calculate the number of niches for each individual
4. Recalculate the fitness value of each individual

D. Crossover

This process conducts gene recombination through the pre-set crossover rate, resulting in new chromosomes. Commonly used crossover methods are single point cross method, two points cross method, partial matching cross method and sequential cross method and so on. Considering the characteristics of each customer's number in the chromosome representing the path that must appear and appear only once, partial matching cross method was used in this paper—for the two random parents A and B, produce two random cross point firstly, and take the parts between two random cross point as the matching area for crossing secondly, then check whether there are some repeat between the coding inside the matching area and the outside. for the last, the repeat area was replaced one by one according to the position in the matching area.

E. Mutation

In the same way as the crossover process, taking into account the characteristics of chromosomes, this paper uses the method of reversal mutation, that is, randomly generate two mutation point, the chromosomes between the two variants are reversed.

V. EXPERIMENTAL RESULTS AND ANALYSIS

This paper optimized the distribution route for 30 users based on MATLAB platform, the coordinates of distribution center was set into (0,0). The coordinates of each customer is shown in the table □. The population size is 200, the evolutionary algebra is 500, the crossover probability is 0.8, and the probability of mutation is 0.5, The weight coefficients are 0.5, 0.5, respectively.

TABLE I. CUSTOMER INFORMATION TABLE

Customer Number	Customer coordinates	Request arrival time	Customer Number	Customer coordinates	Request arrival time
1	（55，67）	12	16	(25,38)	23
2	（37，84）	20	17	（24，42）	29
3	（54，67）	28	18	（58，69）	30
4	（25，62）	15	19	（71，71）	31
5	（7，64）	32	20	（74，78）	29
6	（2，99）	17	21	（87，76）	39
7	（68，58）	38	22	（18，40）	16
8	（71，44）	18	23	（13，40）	31
9	（54，62）	33	24	（82，7）	17
10	（83，69）	15	25	（62，32）	13
11	（64，60）	18	26	（58，35）	28
12	（18，54）	12	27	（45，21）	23
13	（22，60）	27	28	（41，26）	24
14	（83，46）	31	29	（44，35）	30
15	（91，38）	26	30	（4，50）	33

Before simulating the VRPTW model, the traditional TSP simulation of 30 cities was completed first for comparing with the following simulation. The five results were shown as table □ where the TSD means the shortest distance while TGRTSD means the generation that reach the shortest distance.

TABLE II. THE RESULT OF ROUTE OPTIMIZATION THAT THE TRAFFIC CONDITION IS NOT TAKE IN CONSIDERATION

experiment	The first time	The second time	The third time	The fourth time	The fifth time	Average value
TSD	282.38	288.20	288.42	283.43	246.43	273.77
TGRTSD	308	337	468	192	204	301.8

It can be seen from table □ that the traditional method has its disadvantages of unstable results, large convergence algebra—that is, a slow speed of convergence and the easiness of trapping into locally optimal solution. The procedure produced a significantly better solution at once for jumping out of the locally optimal solution, the optimized route shown as figure 2.

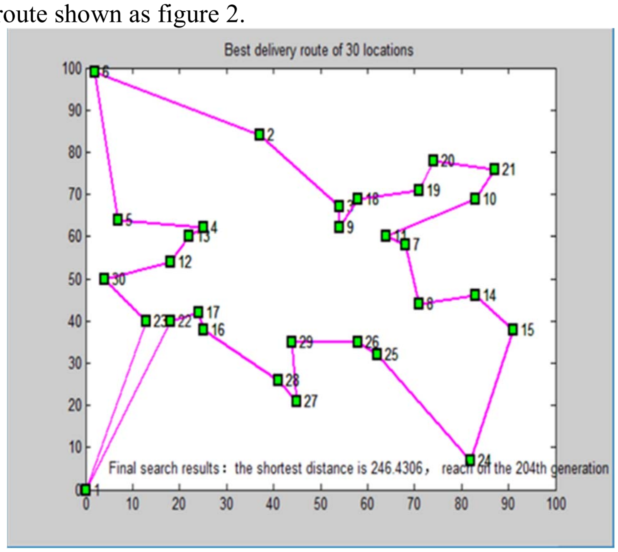

Figure 2. One of the best results of the optimization route

In Fig 1, each green dot represents a city whose horizontal and vertical coordinates represent its corresponding geographical position. The red line represents the distribution route. As can be seen from Fig. 1, the distribution vehicle starts from the distribution center "1", followed by the location of 22,17,16,⋯⋯,12,30,23, and then back to the distribution center, the total distribution distance of this shortest route is 246.4306.

After traditional TSP model was simulated, the simulation of VRPTW model based on traffic condition for the same 30cities was completed, the 5results are shown as table □:

TABLE III. THE RESULT OF ROUTE OPTIMIZATION THAT THE TRAFFIC CONDITION IS TAKE IN CONSIDERATION

experiment	The first time	The second time	The third time	The fourth time	The fifth time	Average value
TSD	354.58	358.09	357.05	375.52	364.04	361.86
TGRTSD	133	59	279	136	121	145.6

After adding the traffic condition and time constraints in the simulation model, the total distribution distance becomes longer but not obviously a lot than traditional TSP model. The best optimized route figure, the search process of optimal solution figure, a part of the traffic condition table and the compare table between the required time of clients and the real time that vehicle arrived are given:

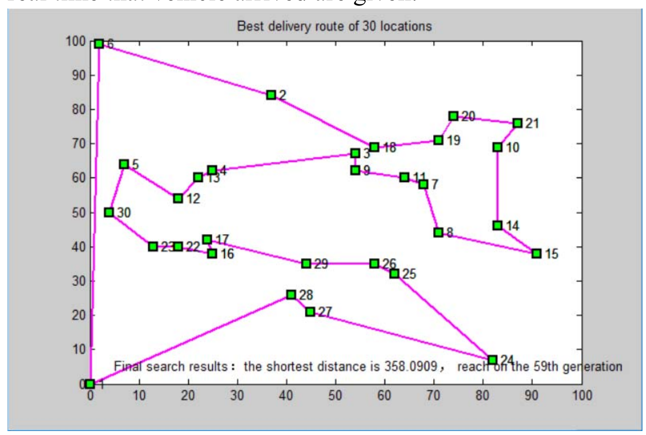

Figure 3. One of the best results of the optimization route that the traffic condition is take in consideration

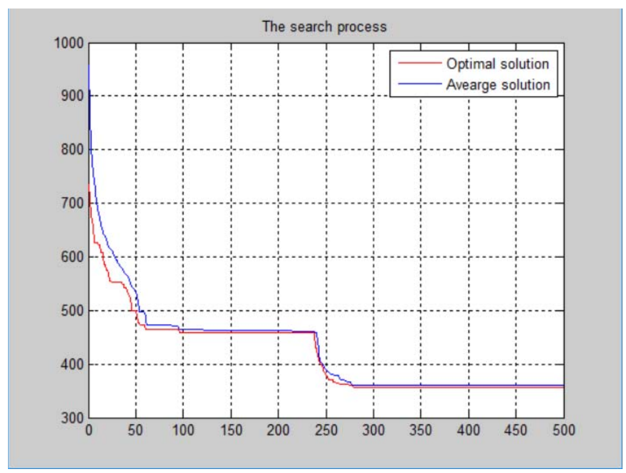

Figure 4. the search process of optimal solution

As shown in figure 3, the program obviously jumps out of a locally optimal solution, this is the niche technology has played a role.

In figure 4, a locally optimal solution was found at about 50 generation and last for about 200 generations, then, the program jumped out of the locally optimal solution, that means, the niche technology application in this paper was successful.

TABLE IV. A PART OF TRAFFIC CONDITION

City number	1	2	3	4	5	……	29	30
1	0	5	5	1	5		2	4
2	5	0	1	4	1		1	5
3	5	1	0	2	3	……	3	3
4	1	4	2	0	5		3	4
5	5	1	3	5	0		4	1
⋮			⋮			⋱	⋮	
⋮			⋮				⋮	
29	2	3	3	4	2	……	3	5
30	4	5	3	4	1		4	5

In table □, the traffic condition was divided into 5 levels, level 5 represent excellent traffic condition, level 4 represent good traffic condition, level 3 represent general traffic condition, level 2 represent poor traffic condition, level 1 represent a bad traffic condition, and the speed of vehicle depends on the traffic condition.

TABLE V. TIME COMPARISON

The order of the city's distribution	required time of clients	real time that vehicle arrived	Time difference
1	0	0	0
28	5	3.03	1.97
27	3	3.31	0.31
24	2	4.54	2.54
25	7	5.34	1.66
26	9	5.87	3.13
29	12	6.98	5.02
17	8	8.63	0.63
16	7	8.76	1.76
22	13	9.68	3.32
23	12	10.08	1.92
30	18	10.87	7.13
5	8	11.28	3.28
12	14	11.63	2.37
13	10	11.82	1.82
4	13	13.54	0.54
3	23	14.25	8.75
9	20	15.28	4.72
11	18	16.62	1.38
7	1	17.91	16.91
8	21	17.28	3.72
15	17	17.69	0.69
14	21	18.13	2.87
10	18	18.38	0.38
21	24	18.71	5.29
20	19	19.03	0.03
19	17	19.78	2.78
18	23	21.14	1.86
2	15	21.53	6.53
6	22	22.14	0.14

In table □, required time and real time that vehicle arrived of each city were shown, for distribution center "1", all its date is 0, as for other city, the time difference of most of them were within 3 hours, a few of them were late of early for a long time.

VI. CONCLUSION

In this paper, traffic condition was taken into consideration in VRPTW model, then compare it with traditional TSP model after using niche technology. In terms of distance, VRPTW model is longer than traditional TSP model to some extent, however, the VRPTW model based on traffic condition is more in line with the actual situation after adding traffic information and time window constraints. In terms of convergence speed, the VRPTW model based on traffic condition obviously batter than traditional TSP model. In the process of searching for optimal solution, the VRPTW model based on traffic condition is more easily to jump out of the locally optimal solution. In general, the simulation strategy adopted in this paper is successful.

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