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Research and Application of Supply Chain Distribution Optimization Model based on Improved Genetic Algorithm

Yanrong Wang and Annan Chen*

Management & Economics School of North China University of Water Resources and Electric Power, Zhengzhou, 450046, China,
can5151@126.com

Abstract

Optimal solution and simulation has been made for model through improved genetic algorithm based on the established mathematical model. Distribution route optimization problem can be solved by algorithm in a better way based on the features of distribution optimization problem of complicated path and through improved genetic algorithm and adding population pretreatment operator; finally, simulation experiment has been made through MATLAB simulation software.

Keywords: *Supply Chain Distribution, Optimization Model, Improved Genetic Algorithm, Distribution route optimization*

1. Introduction

Distribution path optimization problem is a subject draws the great attention from current manufacturing industry and logistics industry; the decrease of logistics cost is very important for the development of manufacturing enterprises. For solving the distribution optimization problem, the first task is to confirm solution strategies and methods. In recent years, enterprises and scholars have made a lot of explorations for distribution path optimization problem; genetic algorithm has good flexibility and robustness in solving path optimization and its theory and practical application has also made great success [1].

For the problem of small distribution demand as well as multiple and scattered distribution problem of customer demand, research on the distribution problem of various customer demand points has been made and combination strategy of distribution path optimization has been proposed by taking path optimal and lowest vehicle cost as objective and through combination analysis of vehicle path optimization problem and traveling salesman problem.

*Corresponding Author

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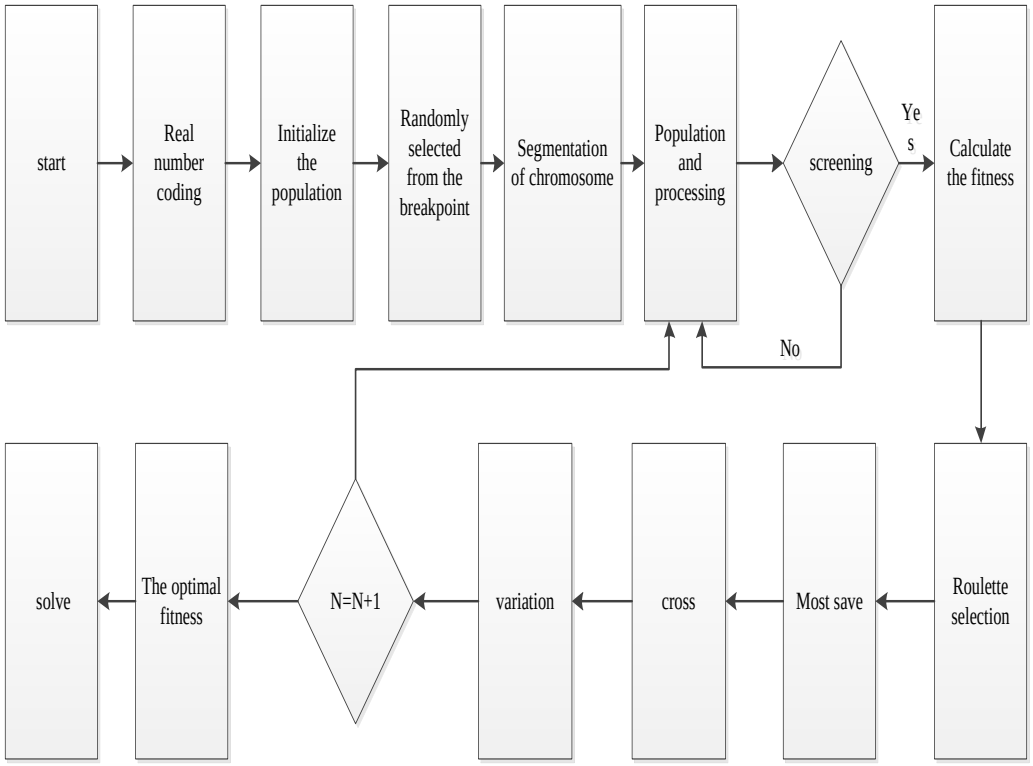

Figure 1. Search the Shipping Order Algorithm Process

2. Process of Genetic Algorithm

This paper solves the above model through genetic algorithm, confirms each demand point and inputs the coordinate of the demand point and calculates straight line distance (virtual distance) between coordinates through calculating coordinate point distance formula [2-3]. Number the demand point based on the distance from demand point to enterprise distribution center, the farther the bigger number; when the distance is the same, select one randomly for numbering. Code the numbered demand points and then search for distribution order through genetic algorithm [4]. After searching for the optimal distribution order, start from vehicle of number 1 and make distribution path searching from enterprise distribution center to the first demand point. Confirm searching range based on method for searching radius in Figure 1 and confirm searching center. Code the points within searching range based on the distance to searching center, the further of the distance, the bigger of the code [5]. Code these points until numbering all the points within searching range and then solve through genetic algorithm. After searching for the distribution path between these two points, continue to search for the distribution path from the first demand point to the second demand point until searching for all the paths [6].

Under the premise of attaining the coordinates of distribution center and demand point, this paper codes the demand points through calculating the distance from demand point to enterprise distribution center and according to the way from near so far [7]. The number of distribution center is 0, the number closest to distribution center is 1, and so on. Form initial individual code string through random combination, such as

32 40 22 34 35 6 3 16 11 30 33 7 38 28 17 14 8 36 29 21 25 37 31 27 26 19 15 1 36 23 2 4 18 24 39 13 9 20 10 12.

Select V-1 random numbers between 2 and 39 (V is the number of vehicle) and divide one chromosome into V chromosomes randomly[8]. For example, V=5 indicates that 5 vehicles will make the delivery, producing breakpoints 7 12 20 32. The distribution order of the first vehicle is 0-32-40-22-34-35-6-3-0; the distribution order of the second vehicle is 0-16-11-30-33-7-0; the distribution order of the third vehicle is 0-38-28-17-14-8-36-29-21-0; the distribution order of the fourth vehicle is 0-25-37-31-27-26-19-15-1-36-23-2-4-0; the distribution order of the fifth vehicle is 0-18-24-39-13-9-20-10-12-0.

Select chromosomes exceeding the maximum load of vehicle through the max load of vehicles and then re-select the break points [9-11]. After illegal individual treatment in population is accomplished, make calculation for the adaption of population and then select 80 individuals as population for genetic operation through roulette selection method. Save the adaptive optimal individual at the first place of population to reach an optimal saving effect. Select V chromosomes divided after selecting break points from the same set of code string, select randomly for V chromosomes and make crossover operation. Select chromosomes randomly, select two gene points randomly from gene site to make mutation operation and turn the genes between two gene points [12-13].

Make research on specific patch of distribution optimization, not only find out suitable distribution order through genetic algorithm but also search for the specific path by analyzing the specific path between two points and with adoption of improved genetic algorithm. First process coordinates of distribution center and 40 client points, calculate the straight line distance between each client point and distribution center $D_{IJ}=\sqrt{(X_I-X_J)^2+(Y_I-Y_J)_2}$, code the demand points based on distance D_{IJ} from small to big, take distribution center as 0 point, number the clients points from 1 to 40 and code in way of real number coding[14-17].

Make population initialization with adoption of genetic algorithm and through real number coding, produce initial population and the chromosomes produced randomly are:

32 40 22 34 35 6 3 16 11 30 33 7 38 28 17 14 8 36 29 21 25 37 31 27 26 19 15 1 36 23 2 4 18 24 39 13 9 20 10 12.

Based on the number of used vehicles V, produce V-1 increasing random numbers smaller than 40 randomly. The produced random numbers are breakpoints, indicating that different vehicles deliver goods for different clients. For example, V=5 indicates that 5 vehicles are adopted for delivery, producing breakpoints: 7 12 20 32.

The delivery order of the first vehicle is 0-32-40-22-34-35-6-3-0;

The delivery order of the second vehicle is 0-16-11-30-33-7-0;

The delivery order of the third vehicle is 0-38-28-17-14-8-36-29-21-0;

The delivery order of the fourth vehicle is 0-25-37-31-27-26-19-15-1-36-23-2-4-0;

The delivery order of the fifth vehicle is 0-18-24-39-13-9-20-10-12-0.

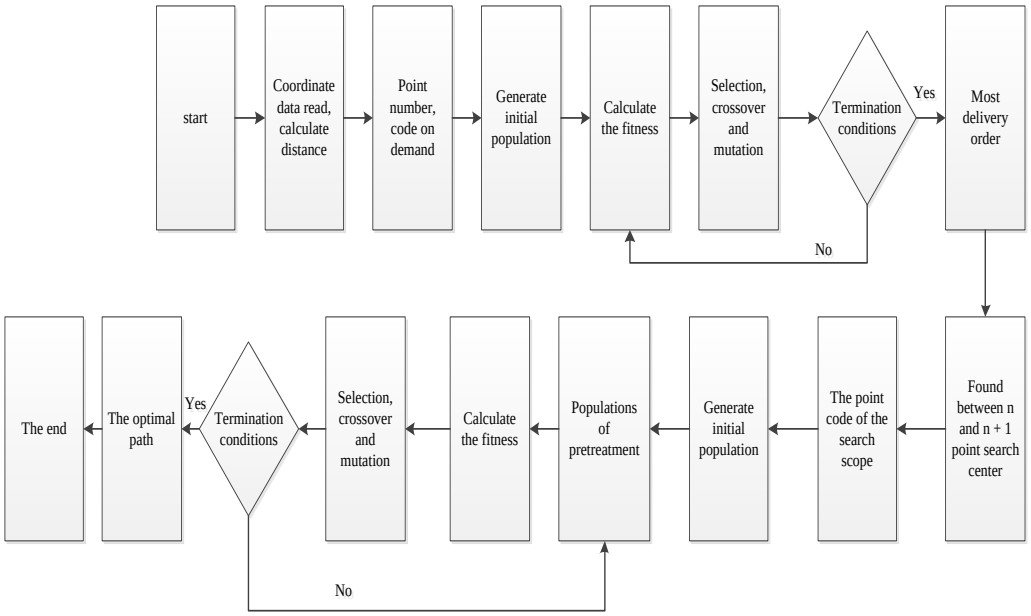

Figure 2. Search Distribution Path Algorithm Flow Char

Calculate the total length of five distribution virtual paths as chromosome adaptability. Select individual chromosome with high degree of adaptability in way of roulette selection method to make genetic operation. First, confirm two cross positions randomly and exchange the fragments among intersections. For example, two parent individuals p_1=[264 | 7358 | 91] and p_2=[452 | 1876 | 93], if cross positions are 3, 7, and then exchange fragments (7358) and (1876). From the 2nd cross position, p_1 deletes (1 8 7 6) to get (2 4 3 5 9); and then fill in q_1 based on original order in p_1, attain offspring individual q_1=[243 | 1867 | 59] and then attain individual q_2=[421 | 7358 | 69] accordingly. The mutation method is turnover variation; select two mutation points randomly on chromosome and then make mutation through turnover method, individual q_4=[24 | 76813 | 59] can be attained after q_3=[24 | 3187 | 59] making turnover mutation. The termination condition is the 5000 generations for genetic operation.

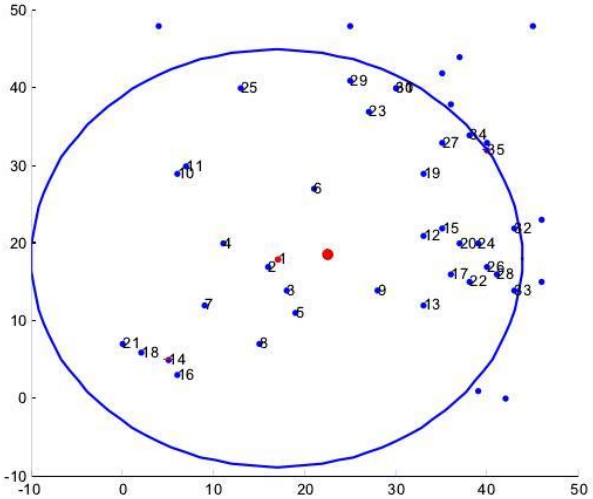

Figure 3. Distribution Path Search

Operate distribution order attained from Figure 2, to get specific distribution path. Figure 2 includes distribution order searching module and specific distribution path

searching module. Based on vehicle coding, select vehicle with number 1 and analyze its path. For example, the distribution order of the first vehicle is 0-32-40-22-34-35-6-3-0. There are seven demand points need to be delivered and then select distribution path based on the order [18]. Code the path as 0-32-40-22-34-35-6-3-01-2-3-4-5-6-7-8, firstly extract 0-32, 0 indicates distribution center and 32 represents No. 32 demand point. Search for path 1. After attaining the path link relationship of each intersection within searching range, make genetic operation for it. First, code the path as string, generate population randomly and each individual in population is the solution for the problem, for example, individual E=[10473028]. But this solution may not be an effective solution, it needs to legalize it through population pretreatment and then make crossover and mutation operation for it through selecting operation and selecting individuals. After searching for the optimal path, import path 2 and make distribution path searching for path 2. And so on, search for the distribution path of the second vehicle after searching for all the distribution paths.

3. Optimize the Structure of Genetic Algorithm for Distribution Path

The main operation step of genetic algorithm includes coding for solution. Each set of solution through coding is one chromosome. Combine population through selecting several chromosomes and make genetic operation for population. First, select the individuals in population, make crossover and mutation operation for selected individuals based on certain probability. Stop the operation of algorithm through given termination conditions and the searching range of path is as shown in Figure 3.

3.1. Coding of Genetic Algorithm and Group Composition

In genetic algorithm, each solution of problem has been coded as one chromosome. The set of all solutions is called as population; one solution is the individual in population. In the example, the individual is expressed in way of real number string. When searching for optimal distribution order, set the codes of n demanding points as D=[p_1, p_2, p_3, …, p_n]. As it is to find the optimal distribution order, for example, one set of gene codes after distribution sequence D mapping with 20 demand points is D_1=[6,3,16,11,7,17,14,8,5,19,15,1,24,18,13,9,20,10,12]

The code of one solution set is:

$$D=\begin{bmatrix} 6,3,16,11,7,17,14,8,5,19,15,1,2,4,18,13,9,20,10,12 \\ 12,20,2,14,15,10,13,18,8,9,1,5,17,11,7,6,16,3,4,19 \\ 15,14,5,20,11,18,2,1,7,6,16,19,8,13,12,9,10,3,4,17 \\ \vdots \\ 8,9,17,14,18,12,2,10,16,20,3,7,19,4,1,13,11,5,15,6 \end{bmatrix} \quad (1)$$

Code each demand point through real number coding and solve the optimal distribution order with genetic algorithm; for confirming distribution order, the length of path and time can be attained through calculation.

Under the premise of attaining the optimal distribution order, it needs to plan the path from distribution center to distribution point, from distribution point to distribution point. After confirming the search range, code the points within searching range and confirm the length of coding after the number is confirmed. Under the situation with starting point and end point are already confirmed, for example, when there are 18 road intersections between two distribution points, searching center is the first point; based on the distance to search center, confirm the search point to start from

point 9 and end at point 16. One set of gene codes after path K_1 mapping is: K_1=[9,3,0,11,7,17,14,8,0,0,0,1,2,4,0,13,0,0,11,16]

The code of one solution set is:

$$D=\begin{bmatrix} 9,3,0,11,7,17,14,8,0,0,0,1,2,4,0,13,0,0,11,16 \\ 9,0,1,0,0,10,0,0,0,0,0,0,17,0,0,0,0,0,0,16 \\ 9,14,5,0,0,18,0,0,7,6,0,0,8,13,12,0,10,0,0,16 \\ \vdots \\ 9,0,17,14,18,12,0,0,0,3,7,19,0,1,0,0,5,0,16 \end{bmatrix} \quad (2)$$

Attain each solution through combination of coding. In matrix K, the 0 included is to ensure the same length of chromosomes. The chromosomes with the same length are easier to make genetic operation. The actual gene coding of path K_1 is: K_1=[9,3,11,7,17,14,8,1,2,4,13,10,16], vehicle passes each intersection from demand point (point 9) to another demand point (point 16).

3.2. Initial Population and Population Pretreatment

In the process of searching for distribution order, it is not the same vehicle to deliver the goods to each distribution point, so divide the 50 individuals attained randomly in way of selecting breakpoint randomly. When the number of distribution vehicle is N, the selected number of breakpoints is N1. For example, when the number of vehicles is 5, select randomly on D_1=[6,3,16,11|7,17,14,8,5,19|15,1,2,4|18,13,9|20,10,12]

Population after selecting breakpoints randomly is:

$$D=\begin{bmatrix} 6,3,16,11\vert 7,17,14,8,5,19\vert 15,1,2,4\vert 18,13,9\vert 20,10,12 \\ 12,20,2\vert 14,15\vert 10,13,18,8,9,1,5,17\vert 11,7,6\vert 16,3,4,19 \\ 15,14,5,20,11\vert 18,2,1,7\vert 6,16,19,8\vert 13,12,9,10\vert 3,4,17 \\ \vdots \\ 8,9,17,14,18,12,2\vert 10,16\vert 20,3,7,19,4\vert 1,13,11\vert 5,15,6 \end{bmatrix} \quad (3)$$

Population pretreatment is to make breakpoint adjustment for some illegal solutions in population. As the load capacities of distribution vehicles are limited and one vehicle can't be over loaded, so under the situation of less vehicles, it needs to coordinate the number of each vehicle to customer point, for example, the second chromosome D_2: D_2=[12,20,2|14,15|10,13,18,8,9,1,5,17|11,7,6|16,3,4,19]. When there is no super customer, which is that the demand of each client does not exceed 60% of the vehicle load capacity and the number of client points of vehicle distribution does not exceed the 51% of the total number. The third distribution vehicle delivers for 8 demand points; the length does not exceed 51% of the total number, but in simulation process, it has been found out that the total amount of this path exceeds vehicle load capacity. Even the path is optimized, but the solution is an illegal solution. Deal with illegal chromosome through pretreatment operator. Find two endpoints 10 and 17 of overload path on overload path D_{bk3}=[10,13,18,8,9,1,5,17] and adjust chromosome through moving breakpoint location. After finding out endpoints 10 and 17, determine to move the 10 point to the left or move the 17 point to the right through comparing the vehicle load capacity of the path D_{bk3}=[14,15] on the left of 10 and path D_{bk3}=[11,7,6] on the right of 17. In the simulation process, vehicles on path D_{bk2} are with smaller loading

capacity, therefore, move demand point 10 to the left and process this process repeatedly until all the solutions are effective solutions. Finally, 2D is improved through pretreatment as: D_2=[12,20,2|14,15|10,13,18,8,9,1,5,17|11,7,6|16,3,4,19].When searching for the path between two demand points, generate one population in a random way.

$$K^{initial}=\begin{bmatrix} 9,3,9,11,7,17,14,8,9,3,3,1,2,1,13,1,17,11,16 \\ 9,9,1,1,9,10,10,1,9,10,1,1,17,10,17,17,1,9,10,16 \\ 9,14,5,5,9,18,18,5,7,6,9,6,8,13,12,8,10,8,14,16 \\ \vdots \\ 9,9,17,14,18,12,17,12,17,9,3,7,19,7,1,3,3,5,19,16 \end{bmatrix} \quad (4)$$

One population with multiple individuals has been generated initially. It can be found out that the initial population includes a lot of tour paths, while this result in practical distribution is not reasonable and not realistic in distribution activities. For example, in $K_1^{initial}$=[9,3,9,11,7,17,14,8,9,3,3,1,2,4,1,13,1,17,11,16], path [9 3 9] is a tour path, which is not allowed in operation. Design pretreatment operator and deal with the repeated path and tour path in the path. Pretreatment operator mainly operates through searching for the same points, when searching the node is the same as the node in former path, assign this node as 0. This treatment can decrease the complexity of the path and then make the searching more convenient. Finally get:

$$K=\begin{bmatrix} 9,3,0,11,7,17,14,8,0,0,0,1,2,4,0,13,0,0,11,16 \\ 9,0,1,0,0,10,0,0,0,0,0,0,17,0,0,0,0,0,0,16 \\ 9,14,5,0,0,18,0,0,7,6,0,0,8,13,12,0,10,0,0,16 \\ \vdots \\ 9,0,17,14,18,12,0,0,0,0,3,7,19,0,1,0,0,5,0,16 \end{bmatrix} \quad (5)$$

Attain **distribution path through removing the 0 point in the path.**

Table 1. Customer Point Coordinates and Demand

Number	X	Y	Needs	Number	X	Y	Needs
0	50	50	none	21	88	51	0.3
1	47	42	8.1	22	65	29	8.4
2	79	26	9	23	44	64	9.3
3	99	91	1.2	24	91	64	6.7
4	30	33	9.1	25	74	92	7.5
5	65	20	6.3	26	1	68	7.4
6	53	10	0.9	27	53	35	3.9
7	40	83	2.8	28	44	35	3.9
8	53	95	5.4	29	58	51	1.7
9	53	7	9.5	30	88	10	7
10	35	17	9.6	31	49	36	0.6
11	72	90	1.5	32	71	13	2.8
12	35	80	1.5	33	84	57	0.9
13	58	69	9.3	34	39	62	0.9
14	14	22	4.8	35	30	30	8.2
15	44	14	8.0	36	17	49	6.9
16	46	46	1.5	37	10	25	3.1

17	94	40	4.2	38	18	74	9.3
18	42	19	9.1	39	18	13	0.3
19	42	19	9.1	40	10	26	2.2
20	70	47	6.5	Total	8	55	9.5

Table 2. Virtual Distribution Path Distance

Number of test	the shortest distance of N-5	the shortest distance of N-6	the shortest distance of N-7	the shortest distance of N-8	Number of test	the shortest distance of N-5	the shortest distance of N-6	the shortest distance of N-7	the shortest distance of N-8
1	702.35	716.25	792.65	879.23	11	702.25	771.36	805.23	832.36
2	717.54	730.65	845.25	829.45	12	707.30	713.69	852.23	830.25
3	718.54	735.25	826.35	819.51	13	772.25	772.65	788.25	821.12
4	684.25	748.58	845.69	854.25	14	720.15	720.41	838.36	838.12
5	687.49	718.45	845.26	851.23	15	775.25	756.95	804.12	845.21
6	691.23	734.69	795.32	832.36	16	690.23	707.25	849.25	835.23
7	707.54	722.15	785.45	846.36	17	707.51	786.36	823.62	824.15
8	681.23	713.65	832.15	812.32	18	684.25	684.36	835.62	836.23
9	717.26	774.12	790.23	843.26	19	717.23	717.25	836.25	849.36
10	697.85	739.85	781.69	836.36	20	710.69	710.36	848.36	806.58

4. Genetic Algorithm Simulation

One manufacturing enterprise makes products distribution for 40 customer points and load capacity of distribution vehicles are 250,000 products. Set coordinate (50,50) for enterprise distribution center through arcgis software, position 40 demand points, attain coordinate and each demand as table 1.

Genetic algebra T is 5000 generations, number of initial population is 80 generations, crossover probability p_0 is 0.8 and mutation probability p_1 is 0.1. Experimental results of 20 experiments are as shown in Table 2, and the shortest path is 681.2km, as shown in Table 2.

5. Conclusions

This chapter has adopted the improved genetic algorithm to solve the mathematical model. Process illegal solution produced randomly through constructing population pretreatment operator, in which way to make the algorithm searching for solutions more effectively; in addition, improve genetic operator to enable the algorithm to solve distribution order model and distribution path optimization model in a better way; finally, make simulation for algorithm through MATLAB simulation software and verify its feasibility.

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