Fresh Produce Delivery Path Optimization Based on Improved Genetic Algorithm

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Abstract. Aiming at the current problems of low transportation on-time rate and high product spoilage rate in the cold chain logistics industry, we constructed a fresh produce distribution path optimization model considering the fixed cost, transportation cost, cargo damage cost, refrigeration cost and time window penalty cost minimization, and solved the model by using improved genetic algorithm. The results show that the total cost after optimization is reduced by 8% compared with the pre-optimization, and the total distance is reduced by 13% compared with the pre-optimization. It is verified that the improved genetic algorithm is more effective than the traditional genetic algorithm through examples.

Keywords: Cold chain logistics, Time window, Improved genetic algorithm, Path optimization.

1 INTRODUCTORY

1.1 A Subsection Sample

With the rapid development of China's economy and the continuous improvement of people's consumption level, people's demand for the quality of fresh agricultural products is getting higher and higher, which also promotes the rapid development of China's cold chain logistics industry. However, fresh agricultural products are characterized by high requirements for storage and distribution temperature accuracy, high cargo loss rate and high demand. Therefore, it is the focus of cold chain logistics enterprises to reduce the distribution cost of enterprises and increase the consumer satisfaction of customers.

Regarding the cold chain logistics vehicle distribution problem, Ma Chengying [1]et al. constructed a multi-objective optimization model by considering the complexity of real-time road conditions and the importance of distributor satisfaction, and applied an improved adaptive large-scale neighborhood search algorithm to solve the model; Tan Xiaowei [2]et al. established a cold chain logistics vehicle optimization model for multi-distribution centers by taking into account the changes in customer dynamic demand and replenishment strategies along the way; Fan Houming[3] established a cold chain logistics vehicle optimization model for the cold chain logistics of multi-crossing

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depot centers, hybrid vehicles, and joint distribution. vehicles, and joint distribution of cold chain logistics vehicle path problems, and establish the optimization model with the minimum total cost.

Regarding the path optimization problem with time windows, many scholars at home and abroad have carried out researches. Bogue [4]proposes a column generation algorithm and a heuristic algorithm to solve the problem after variable neighborhood search for the vehicle path problem with multiple time windows; Fan[5] et al. solve the time-varying green vehicle path problem based on the fuzzy problem of demand and use chaotic genetic algorithm with variable neighborhood search; Keskin [6]et al. consider the path optimization model of cold chain logistics vehicles with time windows and charging station random waiting time. window and charging station random waiting time, and propose a two-stage simulation-based heuristic algorithm solution model; Luo Mingliang [7]et al. construct a vehicle path optimization model based on the fuzzy time window to maximize customer satisfaction and minimize the total cost of delivery; Gao Zijian [8]et al. consider multiple factors, such as order priority and time window, and apply a priority strategy particle swarm algorithm to deal with the order allocation and VRP problem Chen Gaohua[9] et al. establish a dual-objective vehicle path optimization model by considering soft time window and capacity limitation;Wu Junhao[10] et al. establish a vehicle path optimization model with time window.

In summary, based on the existing research, this paper establishes a fresh produce distribution path optimization model with the minimum total cost of distribution as the objective function, and improves the traditional genetic algorithm by using examples to confirm the effectiveness and feasibility of the model and algorithm.

2 MODELING

2.1 Problem Description

The research problem can be described as follows: a distribution center uses k refrigerated trucks of the same model to distribute to n customers with different demands, and scientifically and reasonably plans the paths based on the consideration of the objective of minimizing the total distribution cost.

To facilitate the analysis, the following problem assumptions are made:

(1) Each customer can be served by only one vehicle;

(2) The speed of all vehicles is constant and the models are the same;

(3) Vehicles are not allowed to be overloaded during the distribution process;

(4) Information about the distribution center and the demand point is known;

(5) Vehicles depart from the distribution center and return to the initial distribution center after completing the distribution task.

2.2 Symbol Definition

(1) Set. N={0,1,2,..., n} is the set of distribution centers and the number of customers to be served, with 0 being the distribution center and a total of n customers; K={1,2..., k} is the set of distribution vehicles, totaling k reefer trucks.

(2) Parameters. p is the unit value of fresh produce; q_i is the demand of customer i;ε is the spoilage rate of the product in transit; f is the unit price of fuel; s_{ik} is the service time for delivery vehicle k at customer point i; $t_{ik}$is the time for delivery vehicle k to arrive at customer i; t_{ok} is the time when the distribution vehicle k leaves the distribution center; c_1 is the unit fixed cost; c_2 is the unit transportation cost; $\alpha_1$is the fuel consumption of the goods in transit; $\alpha_2$is the fuel consumption of the cargo during unloading; $\beta_1$is the early arrival waiting cost; $\beta_2$is the late arrival penalty cost; $[ET_i, LT_i]$ is an acceptable time window for customers; $[et_i, lt_i]$is time window for customer expectation.

(3) Decision variables. $x_{ijk}$when refrigerated truck k transports goods from node i to node j; Otherwise, x_{ijk} =0; $y_{ik}$when the service is completed by vehicle k for the needs of customer point i; Otherwise, y_{ik}=0.

2.3 Modeling

Objective function:

$$MinZ = C_1 + C_2 + C_3 + C_4 + C_5 \tag{1}$$

$$C_1 = c_1 k \tag{2}$$

$$C_2 = c_2 \sum_{k=1}^{k} \sum_{i=0}^{n} \sum_{j=0}^{n} x_{ijk}\, d_{ij} \tag{3}$$

$$C_3 = \sum_{k=1}^{k} \sum_{i=0}^{n} \sum_{j=0}^{n} y_{ik}\, pq_i\left(1 - e^{-\varepsilon(t_{ik}-t_{ok})}\right) \tag{4}$$

$$C_4 = f \sum_{k=1}^{k} \sum_{i=0}^{n} \sum_{j=0}^{n} (\alpha_1 t_{ij} x_{ijk} + \alpha_2 s_{ik} y_{ik}) \tag{5}$$

$$\omega(S_i) = \begin{cases} \lambda_1\left(ET_i - t_i^k\right) & t_i^k \le et_i \\ 0 & et_i < t_i^k \le lt_i \\ \lambda_2\left(t_i^k - LT_i\right) & lt_i < t_i^k \le LT_i \\ M & t_i^k < ET_i or t_i^k > LT_i \end{cases} \tag{6}$$

$$C_5 = \sum_{k=1}^{K} \sum_{i=1}^{n} \omega(S_i) \tag{7}$$

s.t.

$$\sum_{i=1}^{n} q_i y_{ik} \le Q \tag{8}$$

$$\sum_{j=1}^{n} x_{ijk} = \sum_{j=1}^{n} x_{jik} = 1,\ \ k \in \{1,2,\dots,\ K\} \tag{9}$$

$$\sum_{k=1}^{k} \sum_{i=0}^{n} \sum_{j=0}^{n} x_{ijk} = 1 \tag{10}$$

Where Eq. (1) represents the minimization of the total distribution cost; Eq.(2) represents fixed costs;Eq.(3) represents transportation costs; Eq. (4) represents the cost of cargo damage; Eq. (5) represents the cost of refrigeration; Eq. (6) represents the penalty cost function; and Eq. (7) represents the total penalty cost;Eq. (8) represents that the total customer demand on a path is less than the maximum carrying capacity of a vehicle; Eq. (9) represents that all reefer trucks return to the distribution center upon completion of the distribution center's task; and Eq. (10) represents that each customer is visited by a reefer truck only once.

3 IMPROVED GENETIC ALGORITHM DESIGN

Cold chain logistics distribution path optimization belongs to the NP-hard problem, the traditional genetic algorithm is easy to repeat the search and fall into the local optimum, this paper adopts the improved genetic algorithm to solve the model, to avoid repetition and explore the new domain.

3.1 Chromosome Coding and Population Initialization

This paper adopts the natural coding method, the length of the chromosome is n+k+1, where 0 represents the distribution center, n represents the customers, and k represents the total number of vehicles. According to the number of customers to be served, a natural sequence of the same number of non-repeating numbers is randomly generated. That is, if the number of populations is N, then N chromosomes are randomly generated as the initial solution.

3.2 Fitness Function

Adaptability value is used to determine the degree of individual quality standards, the higher the value, the stronger the individual adaptive capacity, the greater the chance of being selected as the next generation. In this paper, the objective function is to minimize the total cost, and the inverse of the objective function is chosen when finding the optimal solution, i.e.

$$\mathrm{fit} = \frac{1}{Z} \tag{11}$$

3.3 Selection Operation

In this paper, we choose to follow the traversal of the sampling selection operator, to provide the opportunity for the selection of the operators with lower fitness, to avoid the monopolization of the next generation by the operators with high fitness.

3.4 Crossover Operation

OX crossover is adopted, and the specific process is shown in Figure 1:

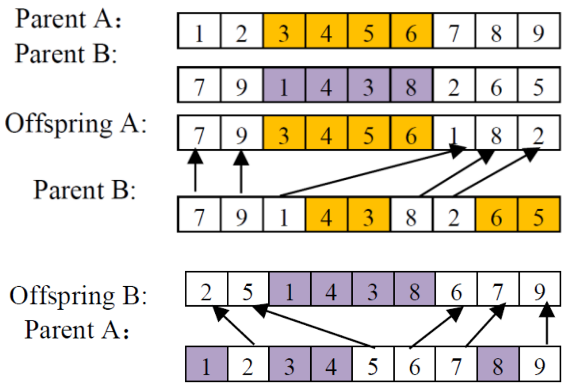

Fig. 1. Crossover Operation

3.5 Mutation Operation

In this paper, according to the mutation probability, the mutation operation is carried out by using the reversed mutation method, and the specific process is shown in Figure 2:.

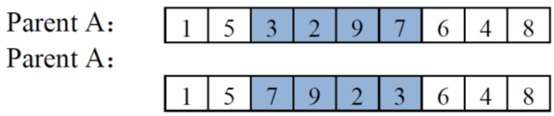

Fig. 2. Reverse order mutation operation

3.6 Algorithm termination principle

The program runs to the maximum number of runs, the run results will be filtered to the global optimal solution.

4 EXAMPLE ANALYSIS

4.1 Data Preparation

A fresh food distribution center in Jinan City, Shandong Province, as the object of study, selecting RT-Mart, Ginza Superstore and so on 20 as the customer point, the number of vehicles that can be used in the distribution center is 3, and the speed of the vehicle is 50km/h, the specific customer information as shown in Table 1.

Each parameter setting: the fixed cost of the vehicle c_1=200RMB/v, the transportation cost of the vehiclec_2=4 RMB/km, refrigerated truck capacity Q=1.5t, the price of fresh agricultural products p=10,000 RMB/t, the corruption rate of dairy products during transportation ε=0.003, the price of fuel f=6.8 RMB/L, the fuel consumption of the refrigeration equipment during transportation and unloading α_1 =2RMB/h,

α_2 =2.5RMB/h, early arrival waiting cost β_1 =40RMB/h, late arrival penalty cost β_2=60RMB/h.

Table 1. Customer Information

serial number	horizontal coordinate	vertical coordinate	quantity demanded	Optimal time window	Acceptable time window	Service time
0	117.1510	36.9617	0	5:30-10:00	5:00-11:30	
1	116.9879	36.6808	0.34	7:20-7:50	6:50-8:20	25
2	116.9172	36.7234	0.30	8:00-7:00	7:30-9:00	20
3	116.9966	36.6377	0.28	7:50-8:20	7:20-8:50	20
4	116.9036	36.6048	0.30	6:20-6:50	5:50-7:20	15
5	116.9891	36.6372	0.15	8:00-8:30	7:30-9:00	20
6	116.9840	36.7025	0.19	7:20-7:50	6:50-8:10	15
7	116.9897	36.6820	0.10	8:30-9:00	8:00-9:30	10
8	116.9902	36.6820	0.14	7:40-8:10	7:10-8:40	15
9	117.0709	36.6907	0.14	8:10-8:40	7:40-9:10	15
10	117.0685	36.7083	0.28	6:30-7:00	6:00-7:30	25
11	117.0240	36.7075	0.18	6:50-7:20	6:20-7:50	20
12	117.0068	36.6105	0.15	8:10-8:40	7:50-9:10	15
13	117.1393	36.7279	0.32	7:10-7:40	6:50-8:10	25
14	117.0439	36.6614	0.24	7:30-8:00	7:00-8:30	20
15	117.1013	36.6634	0.35	6:40-7:10	6:10-7:40	25
16	117.1652	36.6573	0.12	6:10-6:40	5:40-7:10	10
17	117.1028	36.6512	0.1	6:30-7:00	6:00-7:30	10
18	117.0834	36.6594	0.15	6:30-7:00	6:00-7:30	15
19	117.0829	36.6601	0.105	7:30-8:00	7:00-8:30	10
20	117.1155	36.7032	0.15	8:20-8:50	8:00-9:30	15

4.2 Model Solving and Comparative Analysis

The relevant parameters of the improved genetic algorithm designed in this paper are set as population size of 300, crossover probability of 0.9, mutation probability of 0.1, and the maximum number of iterations of 500.According to the above specific data for solving, the genetic algorithm before and after the optimization of simulation experiments are programmed using Matlab R2018a software, and the results are obtained as shown in Figures 3, 4, 5, and 6, The results are analyzed as shown in Table 2 and Table 3:

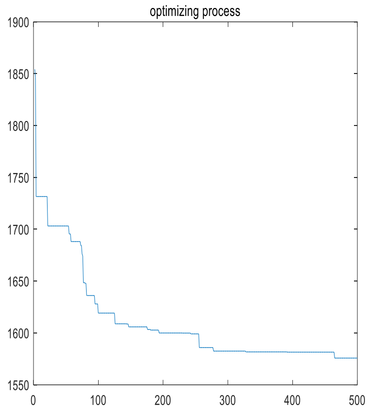

Fig. 3. iteration curve

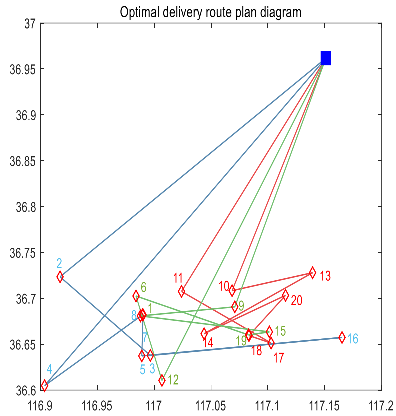

Fig. 4. Vehicle routing program

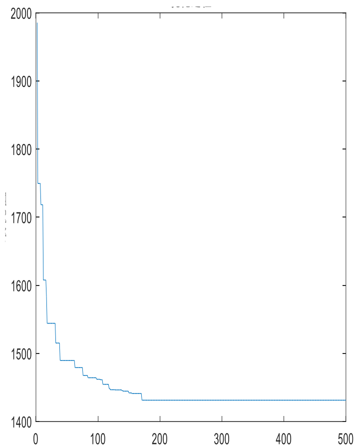

Fig. 5. iteration curve

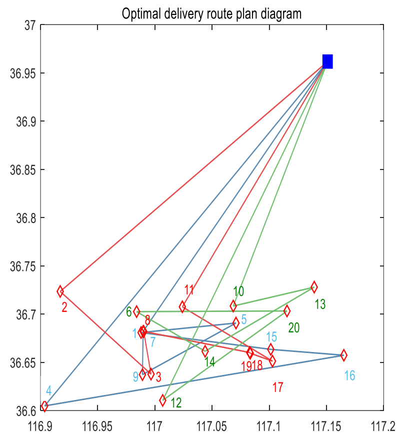

Fig. 6. Vehicle routing program

Table 2. Path comparison before and after algorithm improvement

Traditional genetic algorithms			Improved genetic algorithms		
traffic	optimal path	path/km	traffic	optimal path	path/km
1	4-7-8-5-16-3-2	50.02	1	4-16-15-1-9-5-7	57.17
2	11-17-18-20-14-13-10	66.54	2	11-17-18-19-8-3-2	48.03
3	9-1-15-19-6-12	50.12	3	8-10-13-14-6-20-12	39.81

Table 3. Comparison of distribution costs

costs	Traditional genetic algorithms /RMB	Improved genetic algorithms /RMB
fixed costs	600	600
transportation cost	667	580.64
cost of goods	105.34	88.78
cooling costs	80.11	70.75
penalty costs	110.38	94.75
total costs	1562.83	1434.32

From Table 2 and Table 3, it can be seen that the number of vehicles dispatched by the improved genetic algorithm and the traditional genetic algorithm is the same, but the number of iterations of the algorithm before and after the optimization and the distribution path are significantly different; the total distance of the distribution, the total cost, the cost of transportation, the cost of cargo damage, refrigeration cost, and penalty cost are reduced by 13%, 8%, 13%, 16%, 12%, and 14%, respectively, compared with the traditional genetic algorithm. It can be seen that the improved genetic algorithm can not only reduce the total cost of the enterprise, improve the competitiveness of the enterprise, but also better guarantee the quality of fresh agricultural products, and achieve the purpose of maximizing the economic and environmental benefits, and at the same time, it also confirms the scientific nature and feasibility of the improved genetic algorithm.

5 CONCLUSION

In this paper, on the vehicle path optimization problem with time window, taking the customer point demand and vehicle load as constraints, constructing the vehicle path optimization model considering the minimum total cost of cargo damage cost, refrigeration cost, etc., and improving the traditional genetic algorithm selection, crossover, and mutation, the improved genetic algorithm is used for solving the model, and finally, specific arithmetic examples are applied to solve the effectiveness and applicability of the model. The results show the effectiveness and applicability of the improved genetic algorithm in practical applications with better arithmetic efficiency.

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