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Research on the Fresh Product Distribution Problem based on the Improved Particle Swarm Optimization Algorithm

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Abstract

The distribution of the fresh products is the key link to connect the producers of fresh products and the consumers. How to arrange the vehicle for each node of the fresh product distribution relates the freshness of the fresh products and the transportation costs. Therefore, the optimization problem of the logistics distribution routing is a very important decision problem. In this paper, we set up a model for the distribution of the fresh products. Then, we propose an improved PSO algorithm and use this algorithm to optimize the distribution model of the fresh products. The experimental results show that the model considers more. The results obtained by the improved PSO algorithm are much closer to the actual results.

Keywords: PSO, Fresh products, Distribution

1.INTRODUCTION

Along with the continuous increase in the standard of living and the continuous increase of the population of the urban residents, the quality of the life has changed. They have the higher demand for the agricultural product. Fresh product logistics volume is also increasing year by year. The development of the fresh product logistics not only meets the needs of the urban residents, but also increases the income of farmers. It has the great research value. To optimize the fresh product logistics path not only ensures the freshness of the fresh products, but also reduces the logistics cost and increase the revenue.

Liu and Li (2015) studied the path optimization of the fresh products which was based the Internet of things. The author analyzed the transportation path optimization problem of the fresh products under the cold chain logistics distribution and the Internet of things. According to the application of the RFID, GPS, GRS technologies, the author constructed the transportation line scheduling system based on the Internet of things. This article described the system's overall train of thought and the design of the core module. The article also analyzed the optimal path algorithm for the application of the transportation line scheduling system. Through an example analysis, it proved that it was feasible to optimize the transportation route of the fresh products based on Internet of things. Li Hong studied the vehicle distribution routing problem of the urban cold chain logistics. The author made the vehicle routing problem of the traditional window constraints as the basis, analyzed the line distribution characteristics of the fresh product and constructed the relevant cost function. In addition, the author also analyzed the vehicle fixed cost and the transportation cost in the traditional vehicle routing problem. At the same time, the author studied the characteristics of the time and temperature change of the urban cold chain logistics distribution vehicle. Then the author established the distribution path model. Finally, the author made the example analysis and sensitivity analysis for the main parameters in order to verify the rationality and feasibility of the model constructed in this paper. Zhu Jinfeng studied the vehicle routing problem under the traditional time

window. The author analyzed the characteristics of the fresh perishable product line distribution, constructed the cost function and studied the cold chain logistics vehicle routing model. During the research process, the author considered the various possible costs and used the soft time window constraints to optimize the objective function. Then, the author obtained the optimization model of the cold chain logistics vehicle routing problem. Finally, this paper verified the rationality and effectiveness of the proposed model by the example analysis. Liao Xiaohong applied the second development software which had the GIS technology functions to the logistics system to assist in solving the path planning problem. The software made the full use of the characteristics of spatial data. According to the actual situation, the author made the shortest path planning for any two distribution points. Then, the author studied the key technology based on the logistics distribution system of the GIS and discussed the data collection and function integration. Finally, it achieved the unified storage management for the spatial and attributed database, electronic map basic operation function and the vehicle travel the shortest path search function component. In addition, many scholars had studied the path optimization of the fresh products (Zhao, 2016; Tang et al., 2016; Zheng, 2016)

Zhu (2011) and other researchers presented a meta-heuristic approach to portfolio optimization problem using Particle Swarm Optimization (PSO) technique. The model was tested on various restricted and unrestricted risky investment portfolios and a comparative study with Genetic Algorithms was implemented. The PSO model demonstrated high computational efficiency in constructing optimal risky portfolios. Preliminary results showed that the approach was very promising and achieved results comparable or superior with the state of the art solvers. Hansen et al., (2011) investigated the behavior of PSO (particle swarm optimization) and CMA-ES (covariance matrix adaptation evolution strategy) on ill-conditioned functions. They found the search costs (number of function evaluations) of PSO increasing roughly proportional with the condition number and CMA-ES outperformed PSO by orders of magnitude. Mehmet Ali Cavuslu et al., (2012) introduced hardware implementation of artificial neural networks (ANNs) with learning ability on field programmable gate array (FPGA) for dynamic system identification. The results indicated that ANN converged faster and produced more accurate results with a little extra hardware utilization cost. Fathi et al., (2013) presented a new learning method for RBF neural networks. A novel PSO had been applied in the proposed method to optimize the Optimum Steepest Decent (OSD) algorithm. To initialize the RBF united more accurately, the new approach based on PSO had been developed and compared with a Conventional PSO clustering algorithm.

To study the optimization path of the fresh products not only can ensure the freshness of fresh products, but also can reduce the cost of transport. In this paper, we set up a distribution model for fresh products. Then, we propose an improved PSO method. We use the improved PSO method to optimize the distribution model of fresh products and get the result of the path optimization. The main structure of this paper is as follows. The first part is the introduction. In the first part, we introduce the research background of this paper. The second part and the third part introduce the particle swarm optimization algorithm and the characteristics of the distribution. The fourth part is the establishment of the model. In this part, we set up the distribution model of the fresh product. In the fifth part, we propose the improved PSO algorithm. In the experimental part, we use the improved PSO algorithm to optimize the model of fresh product. The last part is the conclusion.

2. PARTICLE SWARM OPTIMIZATION ALGORITHM

Particle Swarm Optimization (PSO) algorithm has the topic research. It was proposed by the American scholars Kennedy and Eberhart in 1991 (Lu et al., 2010). Kennedy and Eberhart were inspired by the foraging behavior of social animals such as birds. The birds in search activities such as foraging were according to share the information of the

food location by the members. It can greatly speed up the speed of finding food. That is, they speeded up the speed of finding food according to the cooperation. Usually, the benefit of the group search is greater than the loss caused by the competition among the group members. When the whole group researches a target, for one individual, it often references groups in the best position of the individual and its own has reached the optimal position to adjust the next step of the search. Kennedy and Eberhart put the model of the interaction of the simulation group through modification and designed into a common method to solve the optimization problem. It was called the particle swarm optimization algorithm.

Firstly, PSO initializes random particles in the space. Then, these particles composite a particle swarm $X = \{X_1, X_2, \dots, X_m\}$. The position $X = \{X_{i1}, X_{i2}, \dots, X_{im}\}$ of each particle expresses a solution of the optimization problem (Karahan and BİNGÜL, 2009). According to updating the speed $V = \{V_{i1}, V_{i2}, \dots, V_{im}\}$, PSO algorithm adjusts their positions to search the new positons. In the constant iteration, the particle will adjust itself according to the global and individual extremum. The individual extremum is the best position of the particle itself P_{id} . The global extremum is the optimal position P_{gd} of the whole population (Shimizu et al., 2009). When the two extremes are found, each particle adjusts its velocity and position iteratively according to the formula 1 and 2.

$$v_{id}^{k+1} = wv_{id}^k + c_1r_1(p_{id}^k - x_{id}^k) + c_2r_2(p_{gd}^k - x_{id}^k) \quad (1)$$

$$x_{id}^{k+1} = v_{id}^{k+1} + x_{id}^k \quad (2)$$

Where, v_{id}^{k+1} expresses the speed of the i in the $k+1$ iteratively in d dimension. x_{id}^{k+1} expresses the positon of the i in the $k+1$ iteratively in d dimension. w is the inertia weight. c_1 and c_2 are the acceleration constant. r_1 and r_2 are the random numbers between 0 and 1. In addition, we assume that,

$$v_{id}^{k+1} = \begin{cases} v_{\max}, & v_{id}^{k+1} > v_{\max} \\ -v_{\max}, & v_{id}^{k+1} < -v_{\max} \end{cases} \quad (3)$$

PSO algorithm flow chart is shown as below.

It has the significant impact for the performance of PSO algorithm to choose an appropriate parameter. In the PSO algorithm, the three-main parameter are the inertia weight w , the acceleration constant c_1 and c_2 . The inertia weight w can keep the momentum of the particle. The acceleration constant c_1 expresses the acceleration weight that the particle is towards to the optimal location. The acceleration constant c_2 expresses the acceleration weight that the particle is towards to the global location. If $w=0$, it expresses that the particle velocity has no memory. Particle swarm will converge to the current global optimal position with losing the ability to search for a better solution. If $c_1=0$, the particle will lose the cognitive ability and accelerate the convergence. However, it is easy to fall into the local minimum. If $c_2=0$, the particle will lose the mass which is equivalent to the search of a number of particles. Therefore, it is difficult to find the optimal solution.

3. DISTRIBUTION CHARACTERISTICS

Distribution refers to use the goods vehicles and other transportation equipment to transport the goods from the location where the goods are to the location where the customers are.

The distribution characteristics are as follows.

The first distribution characteristic is the timeliness.

Distribution is the last link of the supply chain network system. The probability of logistic delay is very high. Therefore, it is very important for the quality of the delivery service to complete the delivery of the goods timely and accurately. The specific operation of the adverse effects of the timeliness of distribution activities includes the unscientific driving routes, distribution vehicle accident, unloading and long-time waiting etc.

The second distribution characteristic is the convenience.

Distribution activities have the opportunity to face the consumers directly. Therefore, distribution activities should meet customer demand at the greatest extent. We can enhance the flexibility of the distribution system and provide customers with convenient as far as possible through the increase of emergency distribution, waste and auxiliary resource recovery.

The third distribution characteristic is the security.

Security refers that we transport the goods to the customer location without the loss or damage. Security is the purpose of distribution services. The links that may affect the safety of the distribution services are the loading and unloading of the goods, the impact of the transportation process, the working environment of the customer's location, the basic quality of the delivery personnel and other unexpected conditions etc.

The fourth distribution characteristic is the communication.

Distribution is in the logistics activities of the terminal. It can contact face to face. It is the most direct bridge to communicate with customers. It is conducive to understand the customer demand for the supply of goods and the evaluation of distribution services.

The fifth distribution characteristic is the economy.

It is the management target of the enterprise to obtain the maximum economic benefits. For the enterprises and logistics distribution companies, the distribution of the cost control is to strengthen cooperation between the two sides to establish a win-win mechanism foundation in the premise of ensuring the quality of distribution services. Therefore, the distribution company is not only to provide efficient timely and accurate the distribution services, but also to enhance the efficiency of the distribution in order to strengthen the cost control and management, to provide customers with quality and the economic distribution services.

4. THE ESTABLISHMENT OF THE MODEL

In this paper, we establish a path optimization model. The parameters of the model are described in the following table 1.

At the same time, we set the function,

$$\sum_{i=1}^m Z_{jt} = \begin{cases} 1, j = 1, 2, \dots, m \\ m, j = 0 \end{cases} \quad (4)$$

This function ensures that each supermarket's distribution task is completed by one vehicle and all the tasks are completed by the vehicle.

Firstly, we calculate the transportation cost of the vehicle. In terms of the transportation costs, it includes fuel consumption, maintenance and other costs. In this paper, we assume that the cost is proportional to the number of miles traveled.

$$\sum_{l=1}^m \sum_{j=0}^n \sum_{i=0}^n C_{ijl} X_{ijt} \quad (5)$$

Where, C_{ijl} is the transportation cost of the vehicle l in the section (v_i, v_j) and $C_{ijl} = C_{jit}$. X_{ijt} is the variable and it is 0 or 1. If the vehicle l goes through (v_i, v_j) , $X_{ijt} = 1$. Else, $X_{ijt} = 0$.

We should also consider the loss cost of the goods. In the course of the transport for the fresh products, there are some fresh products being damaged. With the increase of time, the proportion of damaged fresh products will be greater. The proportion of physical loss of fresh products will increase with the increase of transportation time. If the transport time is equal to the life cycle of the fresh products, the fresh products are all damaged.

The relationship between the loss ratio of the number for the fresh products and the transportation time is as follows.

$$\lambda(t) = e^{\frac{\ln^2}{T}t} - 1 \quad (6)$$

Where,

$$\lambda_{il}(t) = e^{\frac{\ln^2}{y_{il}}t} - 1 \quad (7)$$

Therefore, the loss cost of goods is,

$$\sum_{l=1}^m \sum_{i=0}^n \lambda_{il}(t) \cdot v_{il} \cdot p_e \quad (8)$$

In this paper, we introduce the freshness $D(t)\theta\alpha e^{\beta t}$ and the freshness factor θ , α , expresses the maximum demand for fresh products. β expresses that the demand decreases with the decrease of the freshness. This formula is used to reflect the relationship between the freshness and the demand of the product. That is, the demand and fresh degree are the proportional relationship in a certain range. The profit can be expressed by the following formula.

$$\sum_{l=1}^m p \cdot D(t) \quad (9)$$

At the same time, we set the penalty function. The penalty function is assumed as follows.

$$p_i(l_i) = \begin{cases} a_i \cdot (s_i - l_i), & l_i < s_i \\ 0, & s_i < l_i < r_i \\ b_i \cdot (l_i - r_i), & r_i < l_i \end{cases} \quad (10)$$

The penalty cost is,

$$\sum_{i=1}^m p_i(l_i) \quad (11)$$

To sum up, the structure of the model is as follows.

$$\max \left[\sum_{l=1}^m p \cdot D(t) - \sum_{i=1}^m p_i(l_i) - \sum_{l=1}^m \sum_{i=0}^n \lambda_{il}(t) \cdot v_{il} \cdot p_e - \sum_{l=1}^m \sum_{j=0}^n \sum_{i=0}^n C_{ijl} x_{ijt} \right] \quad (12)$$

Due to the different vehicle route, it will lead to the different arriving time. The transportation costs are also different. The damage costs and earnings penalty cost is a function about time. It can be seen that the route of the vehicle distribution will determine the results of the whole model.

5. IMPROVED PSO ALGORITHM

Aiming at the shortcoming of easily local optimum of PSO, the accuracy of the standard particle swarm optimization algorithm is not very good. In this paper, the particle swarm optimization algorithm is improved to overcome its own shortcomings. In the speed updating formula, the part of the embodiment of the cognitive ability is improved. It makes the optimal value of individual particles improved. It uses the average value of the individual optimal value of all particles to replace. The speed and position update formula of the improved particle swarm algorithm is as follows.

$$\begin{cases} v_{id}^{k+1} = w v_{id}^k + c_1 r_1 (p_{mean}^k - x_{id}^k) + c_2 r_2 (p_{gd}^k - x_{id}^k) \\ x_{id}^{k+1} = v_{id}^{k+1} + x_{id}^k \end{cases} \quad (13)$$

P_{mean}^k is the average optimal solution. n is the total number of the particles. k is the current iteration number. d is the particle dimension. For the improved PSO algorithm, each particle is no longer in accordance with its own trajectory to fly. It makes the decisions after the experience of other particles for reference.

The inertia weight has a great influence on the particle swarm algorithm. The advantages and disadvantages of the algorithm are largely determined by the adjustment of the parameters. In this paper, we use the linear decreasing inertia weight strategy. Its formula is as follows.

$$w = w_{max} - \frac{w_{max} - w_{min}}{T} \cdot t \quad (14)$$

$w_{\max}$ is the maximum value of inertia weight. $w_{\min}$ is the minimum value of inertia weight. t is the current iteration number. T represents the maximum number of iterations. The basic idea of the strategy is to give greater value to the inertia weight. With the increasing number of iterations, the value of the inertia weight will be decreased in the nonlinear form. This strategy has the advantages that the algorithm in the iterative period begins to have good global search ability. It can find the best solution to the general position of the optimal solution in a short period of time. With the iteration running to the last period, it has good local search ability. It can search more accurately. This strategy is beneficial to improve the performance of the algorithm.

At the same time, we also have to change the learning factor. The concrete formula is as follows.

$$c_1 = c_{1i} + (c_{1f} - c_{1i}) \frac{t}{T} \quad (15)$$

$$c_2 = c_{2i} + (c_{2f} - c_{2i}) \frac{t}{T} \quad (16)$$

Where, c_1 and c_2 represent the initial value of the learning factor. c_{1f} and c_{2f} represent the final value of the learning factor. t is the current iteration number. T represents the maximum number of iterations.

The flow chart of the improved PSO algorithm is shown as follows, fig.1.

6. NUMERICAL TEST

In this paper, we use the improved PSO algorithm to solve the path optimization model. The point coordinate of the distribution center is A(80, 100). There for 10 distribution points. Distribution task is carried out by 3 vehicles. Its specific coordinate distribution is shown in the following table 2.

Time windows and demand values are shown in the following table 3.

The control table between the freshness and transport distance are shown in the following table 4.

Through the improved PSO algorithm, we optimize the path and the results obtained are as follows table 5.

From the table 5, we can see that the solution of the model is,

The vehicle 1: 0-3-1-0

The vehicle 2: 0-4-7-8-10-0

The vehicle 3: 0-2-5-6-9-0

From the optimization results, we can see that the distribution of the path is not only to take into account the cost of distribution, but also to take into account the freshness of the fresh products. This makes that the model considerably more comprehensive and the results are more close to the actual results.

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Table 1 Parameters of the model

m	Number of vehicles
C_{ijt}	transportation cost for l vehicle in the section (v_i, v_j) and $C_{ijt} = C_j t$
x_{ijt}	If l vehicle goes through (v_i, v_j) , $x_{ijt} = 1$, else, $x_{ijt} = 0$
θ	Freshness factor, $0 < \theta < 1$
$D(t) = \theta \alpha e^{\beta t}$	Demand function. The demand is proportional to the degree of freshness in a certain extent
y_{sl}	Departure Time of the l vehicle
y_{rl}	Return time of the l vehicle
S_i	Upper bound on the time of delivery of goods that the customer i can accept
r_i	Low bound on the time of delivery of goods that the customer i can accept
t_{ijl}	Distribution time for the l vehicle from i to j
k_i	The load of the l vehicle
p	The price difference between the cost and the selling price of the product
l_i	Actual vehicle arrival time
a_i	Penalty function of vehicle arrival
b_i	Penalty function of vehicle delay arrival
$p_i(l_i)$	Penalty function. If the vehicle arrives supermarket before S_i , it needs to wait. It wastes and has the penalty cost. If the vehicle arrives supermarket after r_i , the demand of the market does not meet. It wastes and has the penalty cost.
v_{il}	The number of the goods in the vehicle l when arriving at supermarket i
r_l	Actual loading of the agricultural products of the vehicle l
p_e	Evaluation value of the product.

Table 2 Distribution point coordinate

Coordinate	x	y
1	30	80
2	115	95
3	60	130
4	70	75
5	130	78
6	120	135
7	90	70

Table 3 Time windows and demand

	1	2	3	4	5	6	7	8	9	10
Upper time	6:00	6:30	5:30	5:50	7:20	7:40	6:10	6:40	8:10	7:15
Time limit	6:30	7:00	6:00	6:20	7:50	8:10	6:40	7:10	8:40	7:45
demand	0.7	0.8	0.6	0.5	0.8	1	0.6	0.8	1.2	0.9

Table 4 The freshness and transport distance

Transportdistance	0-5	6-10	11-15	16-20	21-25	26-30
Freshness	1	0.9	0.85	0.8	0.75	0.7

Table 5 Path optimization results

Vehicle	Path					
1	0	3	1	0		
2	0	4	7	8	10	0
3	0	2	5	6	9	0

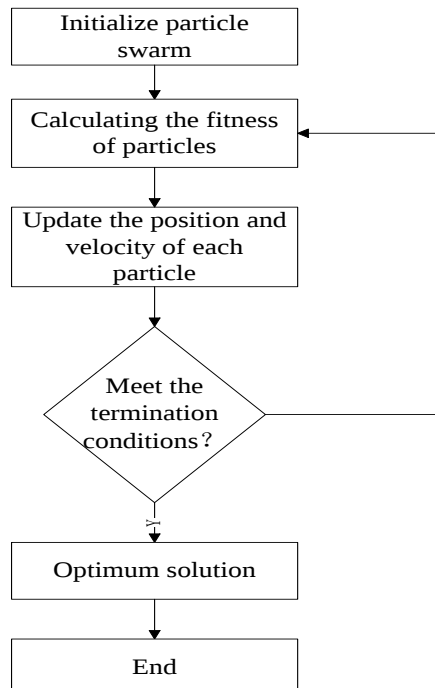


Figure 1. PSO algorithm flow chart

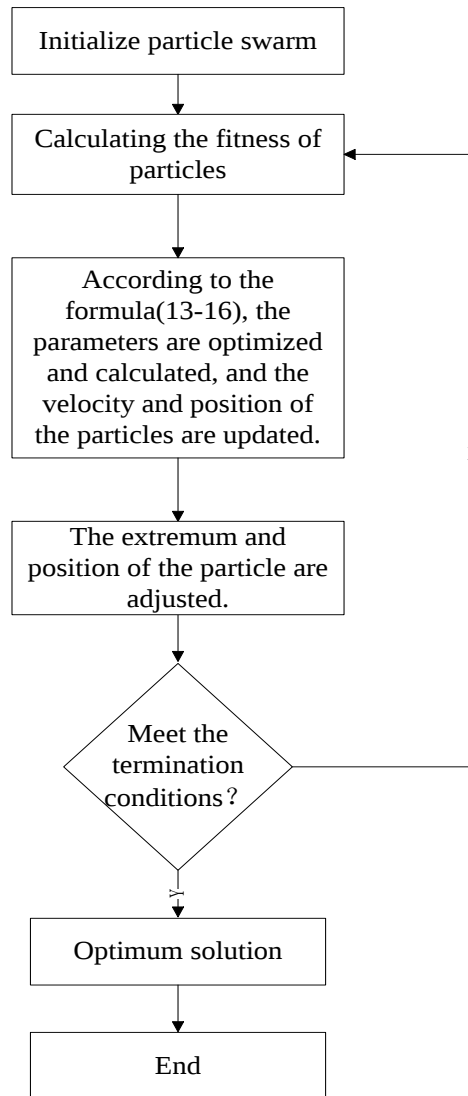


Figure 2. Improved PSO algorithm flow

7. CONCLUSION

With the rapid development of economy and the improvement of people's living standard, the urban and rural residents have higher requirements for the fresh product quality. Therefore, it is very important to solve the problem of route optimization in the distribution of fresh products. In the reality of the distribution activities, there are still a lot of wastes. Now, the key problem to be solved is to control the freshness of the fresh products and the lower distribution efficiency. In this paper, we set up the distribution model of the fresh products according to the characteristics of the distribution. Aiming at the characteristics of this model, we propose an improved PSO algorithm. Then, we use the improved PSO algorithm to optimize the distribution model of the fresh products. The main work of this paper is as follows. Firstly, we briefly introduce the research background of this paper. Secondly, we introduce the characteristics of distribution and the PSO algorithm. Thirdly, we establish the fresh product distribution model. Fourthly, we propose the improved PSO algorithm. Then, we use the distribution model of the fresh product to optimize the distribution model of the fresh products. The optimization results which using the improved PSO algorithm are closer to the reality. It obtains a better effect.

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