Cold-Chain Logistics Distribution Routing Optimization Based on PSO

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Abstract. Recently, cold chain which aims to keep agricultural product fresh before arrive to the designated customers has been greatly developed. The distribution routing optimization problem of cold chain has been an attractive research hotspot. In this paper, we introduce the basic PSO method and it’s advantages about good robustness, global convergence, and intelligent search. Then, we put forward a method for distribution path optimization based on PSO. Taking an example, the evaluation results show that our proposed method can achieve the optimal solution effectively.

Keywords: Cold chain logistics; Distribution routing optimization; PSO.

1. Introduction

In recent years, cold chain logistics, especially for agricultural products has been greatly developed. It aims to keep food fresh throughout the whole transportation, so low temperature environment should be kept to refrigerate and frozen them through all links until arrive at consumers. Cold chain has been applied to many fields, includes: primary agricultural product, aquatic products, flower products, processed food and other packaging cooked food. So cold chain logistics is a huge system engineering which has higher and more complex requirements than ordinary normal temperature logistics system. According to relevant media reports, the value of rotten fruits, vegetables and other food during transportation is about 70 billion yuan each year, causing huge economic waste. The development of cold chain logistics can promote the circulation of commodities such as poultry meat, aquatic products, vegetables and fruits, reduce the loss of resources, and enhance the utilization rate of social resources. So there is a huge space for the growth of cold chain logistics [1-3].

Due to the late start and backward technology, the cold chain logistics in China is relatively backward. There are three factors restricting the development of China's food cold chain industry. First of all, facilities and equipment are insufficient. Most agricultural products are transported by ordinary trucks. Secondly, the absence of technical standards. China's cold chain system is still an early market of refrigeration equipment, which is far behind developed countries. Third, China's food cold chain industry has not formed an independent and perfect operation system [4-5]. Saving the transport time by path optimization of the vehicle line is an important method to reduce the loss of cold chain. The problem of cold chain distribution Vehicle Routing Problem (VRP) can be defined as: under certain constraints, the driving route is reasonably planned, so that the total transport time is the shortest. It is a typical Non-deterministic Polynomial (NP) hard problem. Particle Swarm Optimization (PSO) which
has good robustness, fast convergence, and intelligent search has been widely used in solving the NP hard problem.

2. Cold Chain Logistics Distribution Routing Problem

The problem of cold chain distribution path can be defined as: There are a certain number of customers and a distribution center with a certain number of transport vehicles. Each customer has a different number good needs, and the transport vehicle is responsible for distributing goods to each customer with correct goods and minimum cost, time and so on. The needs and coordinate of each customer are clear given, and the maximum load of each vehicle all are fixed. The logistic distribution route optimization model is defined as follows:

K is the number of distribute vehicles. \( Q_k \) means the deadweight of per vehicle and \( D_k(k=1,2,...,K) \) represents it’s maximum traveling distance. \( q(i=1,2,...,L) \) is the needs of each customer. \( d_{ij} \) means the distance from customer \( i \) to \( j \). \( n_k \) is the number of customers in the \( k \) path; \( R_k \) means a \( K \) path; \( r_{ki} \) is customer \( i \) int the path \( k \). \( r_{k0} \) represents distribution center int the path \( k \). The mathematical model of the VRP problem is as fellows [6]:

\[
\begin{align*}
\text{min } Z &= \sum_{k=1}^{K} \sum_{i=1}^{n_k} \left( d_{r_{k0}r_i} + d_{r_{k1}r_i} \cdot \text{sign}(n_k) \right) \\
\text{s.t.} \\
\sum_{i=1}^{n_k} d_{r_{k0}r_i} &\leq Q_k \\
\sum_{i=1}^{n_k} d_{r_{k0}r_i} + d_{r_{k1}r_i} \cdot \text{sign}(n_k) &\leq D_k \\
0 &\leq n_k \leq L \\
\sum_{k=1}^{K} n_k &= L \\
R_k &= \{ r_{i} \mid r_{i} \in \{1,2,...,L\} , i = 1,2,...,n_k \} \\
R_{k_1} \cap R_{k_2} &= \emptyset \quad \forall k_1 = k_2 \\
\text{sign}(n_k) &= \begin{cases} 1 & n_k \geq 1 \\ 0 & \text{other} \end{cases}
\end{align*}
\]

Equation (1) is the objective function which aim to find the minimum total transport distance. Equation (2) means the total demand is less than the car carrying capacity in \( k \) path. As Equation (3) shows, in \( k \) path the total delivery time is less than the maximum traveling time of the vehicle. Equation (4) is the limitation of the number of customers in \( k \) path. From Equation (5), we can see that the total demand points of all path equals the total demand points. Equation (6) is the definition of the \( k \) path. Equation (7) means each demand point is only in one path. Equation (8) shows the relationship between customers and cars used in \( k \) path.

3. Particles Swarm Optimization
3.1. The Basic Particles Swarm Optimization

In 1995, Kennedy and Eberhart first put forward PSO as an evolutionary optimization algorithm [7]. This algorithm is inspired by observation of social behaviors of animals (e.g., bird flocking). In PSO, a population of particles are used to correspond to individuals. Given that \( p_{\text{best}_i} \) is the best fitness value recorded so far by the \( i \)-th particle in all the preceding iterations. Moreover, the \( g_{\text{best}} \) is the best fitness value recorded so far by the entire swarm. The velocity of each particle is updated as Equation (9), and the position of them can be updated according to Equation (10).

\[
v_{id}(t+1) = w*v_{id} + c_1*r_1(p_{\text{best}_id} - x_{id}) + c_2*r_2(g_{\text{best}} - x_{id}) \tag{9}
\]

\[
x_{id}(t+1) = x_{id}(t) + v_{id}(t+1) \tag{10}
\]

Where \( w \) is constrained to the interval [0.0, 1.0], it is the inertia weight and means the impact of historical value. \( c_1 \) and \( c_2 \) are learning rates of local fitness and global fitness. \( r_1, r_2 \) are two random number in the range [0, 1].

3.2. Steps to Solve VRP Based on PSO

1) The particle \( X(x_1, x_2, \ldots, x_n) \) represent the demand point, randomly generated initial population.
2) Calculate fitness and constraints. As Equation (1) shows, \( Z \) is the objective function of this optimization problem. So the particles fitness = \( Z \).
3) Initialized the \( p_{\text{best}} \) and \( g_{\text{best}} \). \( p_{\text{best}} \) is the local optimum value among current particle position; \( g_{\text{best}} \) is the global optimum value.
4) Position and velocity of particles are updated in accordance with Equation (9) and Equation (10).
5) Calculate finished. If the maximum generation is reached or the designated fitness value is achieved, the calculate end.

4. Experimental Results and Discussion

4.1 Data Set Description

A Sichuan Fruit Industry is taken as an example and its logistics distribution path problems is studied. According to latitude and longitude, the distance between customers \( i \) and \( j \) is calculated by the formula (11). The distance among all customers are given in Table 1. In table 1, customer 0 represents distribution center. In this example, we suppose that the distribution center has one car which has enough transportation capability. The number of particle swarm is set to 100. Set iterations to 100.

\[
d_{ij} = R \sqrt{\cos(x_i/180) \cos(y_i/180) \cos(x_j/180) + \sin(x_i/180) \sin(y_i/180) \sin(x_j/180)} \tag{11}
\]

From the above formula, \( R \) is radius of the earth, usually be set to 6371 kilometers. \((x_i, y_i)\) represents latitude and longitude of the demand point \( i \). \((x_i, y_i)\) can be achieved from the open WebGIS platform. \( \pi \) is 3.14159.

| \( d_{ij} \) | 0 | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 17 | 24 | 26 | 28 | 23 | 8 |
| 1 | 17 | 0 | 12 | 9 | 11 | 17 | 19 |
| 2 | 24 | 12 | 0 | 10 | 18 | 9 | 18 |
| 3 | 26 | 9 | 10 | 0 | 9 | 20 | 24 |
| 4 | 28 | 11 | 18 | 9 | 0 | 27 | 24 |
| 5 | 23 | 17 | 9 | 20 | 27 | 0 | 15 |
| 6 | 8 | 19 | 18 | 24 | 24 | 15 | 0 |

Table 1. The distance among all customers.
Figure 1 shows the relative position in a rectangular coordinate system of the distribution center and demand points. Figure 2 shows the locations of these points on online map.

4.2. **Experimental Result and Discussion**

According to our proposed method, cold chain distribution routing problem is performed. The optimal distribution routing scheme based on the proposed method is 0-6-5-2-3-4-1-0. Figure 3 shows the optimal path plan which has the shortest delivery time. Figure 4 shows an online map of the optimal path, that is the true distribution path. According to our example, it is obvious that the VRP of cold chain can be solved by PSO effectively.

Figure 5 shows the algorithm training procession for searching the optimal fitness value.
As Figure 5 shows, particle swarm algorithm has some advantages for the simulation research. PSO has good robustness, global convergence, and intelligent search. Moreover, PSO which has no genetic operators could update themselves simply only by the internal velocity. PSO has been widely used in solving the NP hard problem.

5. Summary
In the cold chain distribution system, the optimization of distribution path can reduce costs, enhance economic efficiency. A heuristic approach about PSO has been applied to cold chain logistics distribution optimization problem. Experimental results show that our proposed approach can get the optimal solution effectively.

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