Research on Vehicle Routing Optimization of Urban Express Delivery

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Abstract

The choice of city express delivery route is very important for the development of logistics enterprises. The cost of vehicle distribution directly determines whether the enterprise can survive in a fierce competitive environment. This paper uses ant colony algorithm to optimize the path of existing distribution sites and find the shortest path yields the least cost, and finally the validity of the algorithm is verified by an example.

Keywords

Urban express delivery, colony algorithm, optimization.

1. Introduction

In recent years, with the progress of knowledge and the rapid development of science and technology, people have stepped into the information society quickly. In order to be convenient, more and more people are keen on online shopping, and express delivery has gradually entered People's Daily life. According to the latest statistics of cloud finance and economics, the operating income of express delivery business in China in 2017 was 495 billion yuan, up 24.5 percent year on year. Among them, the express delivery volume reached 40.1 billion pieces, up 28% year on year. The growth of express delivery has brought about a certain impact on transportation. How to choose the right distribution line, both to meet the requirements of customers and enterprises to save costs is particularly important.

As for the research on urban express delivery, Zhang Xiao pointed out that there are many characteristics in the process of urban express delivery, so a two-category express delivery model is established. According to the characteristics of urban express delivery, Yang Zhiqing built a multi-objective vehicle path problem model with time window, considering the factors of vehicle type and uncertain time. The mathematical model of urban distribution path optimization with time window was established by Lurce. Lingo software is used to optimize the urban distribution path and verify the applicability of the model.

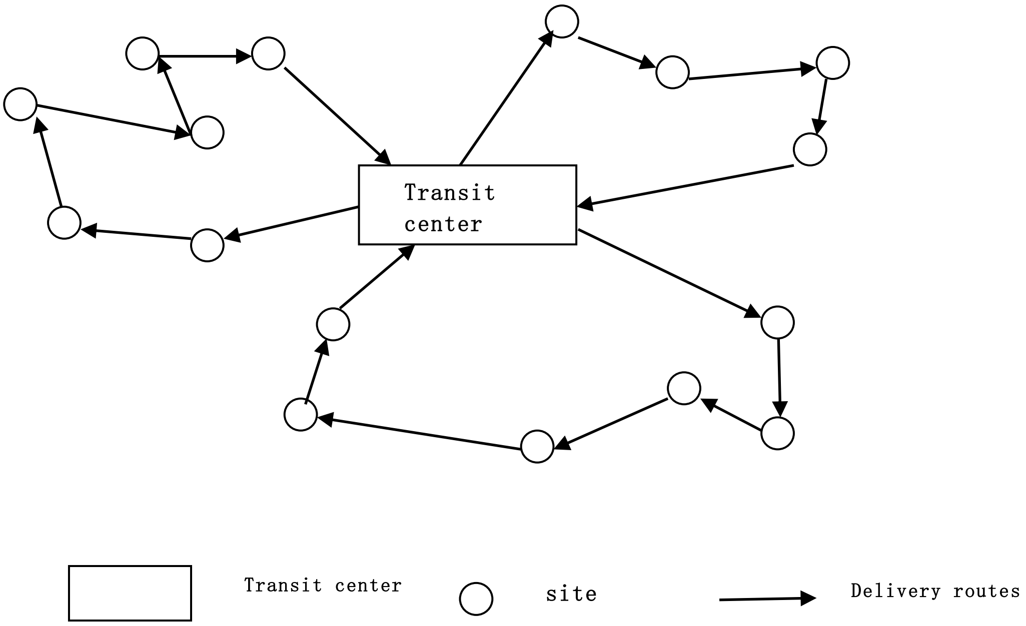
In the existing literature, scholars' researches are more inclined to improve algorithms or build new heuristic algorithms. In this paper, according to the feature components of the express delivery path optimization problem conforming to the mathematical model of urban express delivery path optimization problem, ant colony algorithm is applied to solve the model.

2. Problem description and model

2.1 Problem description

The route problem of urban express delivery vehicles can be described in detail as follows: according to the number of express deliveries required by each station in the region, the express enterprise should find the best express delivery route under the condition of known transfer center to minimize the express delivery cost of the enterprise and deliver the express within the time limit required by the site.

Practical scenario: simplify nodes in the express delivery system into transport centers and stations. As shown in the structure diagram of the distribution network, the distribution vehicle starts from the transfer center, passes through various stations to provide services according to a certain line, and finally returns to the transfer center to form a closed loop.



2.2 Model Assumes.

①The coordinates of the transport centre and stations are known;

②The number of express deliveries required by each station is known and does not exceed the maximum load of the distribution vehicle;

③Each vehicle only performs one delivery service and must start from and return to the transfer center;

④Each site must be serviced and only once;

⑤$d_{ij}=d_{ji}$.

2.3 Model Parameters and Establishment

0：Signify the transit center；

m: Signify the total number of vehicles;

n: Signify the total number of sites;

q_i(i=1,2,...,n): Signify the delivery quantity of site i;

Q: Signify the load capacity of a vehicle;

d_{ij}: Signify the distance from site i to site j；

$$X_{ijk} = \begin{cases} 1, & \text{vehicle K travels from i to j;} \\ 0, & else \end{cases}$$

$$Y_{ki} = \begin{cases} 1, \text{vehicle K visits i site;} \\ 0, \text{else;} \end{cases}$$

According to the above conditions, set the objective function and constraints and establish the mathematical model to optimize the logistics path:

$$MinZ = \sum_i \sum_j \sum_k d_{ij} X_{ijk}$$

S.t:

$$\sum_{i}^{n} q_i y_{ki} \le Q(k=1,2,...,K)$$

$$\sum_{k} y_{ki} = 1(i=1,2,...,n)$$

$$\sum_{k} y_{0k} = K$$

$$\sum_{i} x_{ijk} = y_{ki}(j=1,2,...,n)$$

$$\sum_{j} x_{ijk} = y_{ki}(i=1,2,...,n)$$

$x_{ijk} \in \{0,1\}(i,j=0,1,...,n;k=1,2,...,K)$

$y_{ki} \in \{0,1\}(i=0,1,...,n;k=1,2,...,K)$

The objective function means the shortest distribution distance. Constraints: Function ① constrains the capacity of transport vehicles, that is, the delivery capacity of each distribution line k can not exceed the maximum load of the vehicle. Constrains Constraint ② ensures that each customer is served; Constraint ③ ensures that the vehicle starts from the distribution center and returns to the distribution center. Constraint ④, ⑤ guarantee that if customer points i and j are on the driving line of vehicle k, then customer points i and j will be served by vehicle K. Constraints ⑥and ⑦ define the scope of x_{ijk} and y_{ki}.

3. Ant colony algorithm

3.1 Basic principles

Although individual ants are relatively simple, ant groups are highly organized, capable of performing complex tasks far beyond the capabilities of individual ants in many cases. In real life, a large number of ants can be observed forming a nearly straight path from the nest to the food source, rather than a circle or curve or other shapes. In addition to perceiving pheromones left on the path by the ants in front of them, individual ants can hardly perceive the information of the environment. When there is no pheromone in the environment, ants' behaviors are completely random. Ants can leave pheromones in their path from the nest to the food source. Later ants can perceive the existence and intensity of pheromones, and ants tend to move in the direction of high pheromone concentration. The more ants pass by in the same time, the more pheromones are left behind. The ant colony behavior of a large number of ants shows a positive feedback phenomenon of information, which eventually leads to the colony marching along the shortest path.

3.2 Algorithm design

3.2.1 Transfer rules

According to the algorithm idea of Dorigo, ant k (k=1, 2, 3... , m) in the process of motion, the transfer direction is determined according to the amount of information on each path. $Tabu_k$(k=1, 2, 3... , m) to record the cities currently traveled by ant s. The set is dynamically adjusted with $tabu_k$. $P_{ij}^{k}(t)$ represents the probability that ant k moves from i to j at time , then

$$P_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha}.[\eta_{ij}(t)]^{\beta}}{\sum_{s \subset allowedk}[\tau_{is}(t)]^{\alpha}.[\eta_{is}(t)]^{\beta}} \quad \textbf{(1)}$$

Among them, $\tau_{ij}(t)$ refers to the information on the path (i, j) at time t; $Allowed_k$={c-$tabu_k$} means the node that ant k can choose next; α is the information heuristic factor, indicating the effect of residual information on ants. β is an expected heuristic factor, indicating the degree to which ants attach importance to inspired information during movement; $\eta_{ij}(t)$ is the prime prime minister function, its function is:

$$\eta_{ij}(t) = \frac{1}{c_{ij}} \tag{2}$$

c_{ij} represents the distance between the two sites.

3.2.2 Pheromone update rules:

When pheromone update is carried out, if the information released each time is an invariant constant, it is easy to fall into local optimization and limit the global nature of the algorithm. Therefore, with the change of the search state of the algorithm, the amount of information released each time should be constantly adjusted. The adjustment principle is that the more attractive the path is to ants, the less information will be released. If Q(t) is the pheromone release quantity, then:

$$Q(t) = Q(1-\frac{r}{R}) \tag{3}$$

R is the number of ants in the result node i， r is the number of ants in the result path (i, j).

Assuming that the ant k reaches the i point, a total of R_k ants have passed the i point, and R_k only selects the path (i, j). Then the local update rule is:

$$\tau_{ij}^{new} = \sum_{k=1}^{m} \Delta\tau_{ij}, \forall i, j \text{且} i \neq j \tag{4}$$

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{5}$$

$$\tau_{ij}^{k} = Q_1(1-\frac{r_k}{R_k}), \text{ represents ants move from i to j, else } \tau_{ij}^{k} = 0 \tag{6}$$

3.2.3 Algorithm steps

Step 1: initialize parameters and set N_c=0;

Step 2: randomly place s ants on n nodes, initialize $tabu_k$= 0, The process variable Pro [k]= 1 for 0-node ants and pro [k]= 2 for nodes whose initial point is not 0;

Step 3: determine whether node i is the transport center point 0. If it is the transport center, the next node j is determined according to formula (1), and the values of s_i, b_i and $tabu_k$ are updated. If pro[k]=1, make pro[k]= 2 and go to step 4. If pro [k]=2 and j is the transport center point 0, then j+ 1 and repeat step 3; otherwise, skip to step 4. If the transport center is not 0, the next node j is determined according to formula (1), and the values of s_i, b_i and $tabu_s$ are updated at the same time. When pro[k]= 1 and j is the transport center 0 point, make pro[s]=2 and transfer to step 3; When pro [k]=2 and j is the 0 point of the distribution center, then j+1 is transferred to step 3; otherwise, step 4 is skipped.

Step 4: update s_j, repeat step 3 and step 4 until b_i=0;

Step 5: after all ants move once, update the pheromone according to formula (4);

Step 6: update node bi. If the number of ants on all nodes is 0 or 1=S, go to step 7; otherwise, go to step 3.

Step 7: generate path set {L_1, L_2... L_m}, and find the feasible solution. If no feasible solution can be found, myopia strategy can be adopted to solve the problem.

Step 8: compare the size of N_c and N_{cmax}. If Nc is greater than or equal to N_{cmax}, the algorithm is terminated. Otherwise, make N_c+ 1 go to Step2.

4. Calculation example verification

This paper takes Baishi Express Chongqing Branch as an example, Taking forever express Chongqing branch as an example, suppose that only a transit center (YuBei District), the main package contains 12 sites, such as 1Shapingba ,2Nanan ,3Jiangbe ,4Yubei ,5Dadukou , 6Jiulongpo ,7Yuzhong , 8Banan, 9Beibei,10Bishan ,11Jiangjin ,12Fuling.

Each distribution point shall be equipped with a two-ton van, a total of 12 distribution vehicles; The distribution vehicles return from the original route after arriving at the distribution points from the transfer center, so the distribution distance is twice as long as the distance from the transfer center to the distribution sites, and the total vehicle distribution distance is

$$L = \sum_{i=1}^{n} l_{0i} \tag{7}$$

Among them, L is the total distance of distribution routes; l_{0i} is the distance from 0 point of transshipment center to distribution point i.

So, the total distance is 2 × (143 + 66 + 86 + 93 + 124 + 104 + 118 + 17 + 13 + 60 + 108 + 66) = 1996 km.

Table 1 Highway Distance between Distribution Nodes in Chongqing Main Urban Area (Unit: km)

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0	143	66	86	93	124	104	118	17	13	60	108	66
1	143	0	74	107	----	102	----	----	126	145	----	----	----
2	66	74	0	----	88	58	----	----	49	69	----	----	----
3	86	107	----	0	----	----	----	----	----	73	----	----	----
4	93	----	88	----	0	60	----	----	----	----	----	96	----
5	124	102	58	----	60	0	----	----	107	----	----	----	----
6	104	----	----	----	----	----	0	32	----	----	127	----	38
7	118	----	----	----	----	----	32	0	----	----	----	43	52
8	17	126	49	----	----	107	----	----	0	18	----	----	74
9	13	145	69	73	----	----	99	----		0	47	----	55
10	60	----	----	----	----	----	127	----	----	47	0	----	108
11	108	----	----	----	----	----		43	----	----	----	0	47
12	66	----	----	----	----	----	38	52	74	55	108	47	0

In order to improve the efficiency of distribution and reduce the cost of distribution, this paper takes Chongqing as an example to optimize the path by ant colony algorithm. The distance between two nodes is defined as the road distance above the second-class highway. If the two nodes are not adjacent to each other use ---- representation, the distance between Chongqing Transit Center and distribution stations and the road distance between distribution stations are shown in Table 1.

Distribution vehicles are defined as trucks with a load of 10 tons. Each distribution station needs 2 tons. Take (α, β) = (2, 2), ρ= 0.7, Q = 10, the maximum number of iterations N_C = 500, run ant colony algorithm, and get the following results:

Number of vehicles = 3, The total distance of the vehicle is 931 km.

Route 1: Route length 336 km, loop path 0 (transshipment center) - 9 (Beibei) - 3 (Jiangbei) - 1 (Shapingba) - 0 (transshipment center).

Route 2: The length of the route is 315 km, and the loop path is 0 (transshipment center) - 12 (Fuling) - 11 (Jiangjin) - 7 (Yuzhong) - 6 (Jiulongpo) - 10 (Bishan) - 0 (transshipment center).

Route 3: Route length 280 km, loop path 0 (transshipment center) - 8 (Banan) - 2 (south bank) - 5 (Dadukou) - 4 (north Chongqing) - 0 (transshipment center).

Through ant colony algorithm, the distribution routes are improved. Vehicles are reduced from 12 to 3. Distribution distance is reduced from the original 2 × (143 + 66 + 86 + 93 + 124 + 104 + 118 + 17 + 13 + 60 + 108 + 66) = 1996 km, which reduces the distance of 1065 km, increases the distribution scale, improves the distribution efficiency and reduces the delivery cost of express companies.

5. Conclusion

The problem of distribution route has a great impact on the cost of logistics distribution, which is a difficult problem of e-commerce logistics. By using the heuristic search algorithm of ant colony algorithm, taking the distribution route as the primary objective and the distribution vehicle as the secondary objective, the logistics distribution route of Baishi Express in Chongqing was optimized under the condition of satisfying the vehicle load constraint. Through route optimization, the number of vehicles is reduced, the scale of transportation is improved, and the distribution route is shortened, which can greatly reduce the distribution cost of express companies. This paper only optimizes the local area of the main urban area. If we consider all the nodes of Chongqing as a whole and break the regional restrictions, we will not only consider the optimization in the municipal area, but also optimize the distribution route. This is also the focus of the next research.

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