International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2019): 7.583

Research on Logistics Vehicle Path Based on Ant Colony Algorithm

WANG Li[1], WANG Yaozhao[2], WANG Wei[3]

[1, 2, 3]Xi'an Aeronautical University, Department of Electronic Engineering, Xi'an Shaanxi 710077, China
wangli871016[at]163.com

Abstract: ***Aiming at the problem of vehicle route optimization, this paper studies the optimization method based on ant colony algorithm, reasonably determines the distribution route, improves the logistics income, and realizes the logistics distribution. This paper studies the basic theories of vehicle routing optimization problems, including problem definitions, basic requirements, constraints and main rules, and constructs a mathematical model of vehicle routing optimization problems. The principle and algorithm steps of the ant colony algorithm are studied, and the realization process of the ant colony optimization algorithm to solve the vehicle path model is presented. MATLAB software is used for simulation to verify the feasibility of the ant colony algorithm for vehicle path optimization.***

Keywords: vehicle routing optimization; mathematical model; ant colony algorithm; optimization solution

1. Introduction

The logistics distribution industry is playing an increasingly important role in national economic construction and strategic security. Logistics distribution is a related link that directly contacts consumers in logistics activities. The connotation of modern logistics is mainly reflected in two aspects: one is to reduce the total cost of logistics and transportation, improve individual economic benefits, reduce the capital expenditure of enterprises, and make the efficient and reasonable use of material resources [1] [2]. The second is to reduce the consumption of natural resources, protect the ecological environment, and realize the harmonious and sustainable development of talents and society, and man and nature. Optimizing logistics vehicle routing problems (VRP) can reduce economic costs and realize scientific logistics [3] [4].

This paper studies the technology of using ant colony algorithm to realize logistics vehicle path optimization, and uses related software to verify. The second part gives the basic requirements and mathematical model of the vehicle routing optimization problem, and the third part gives the bionic principle and mathematical description of the ant colony optimization algorithm. The fourth part presents the realization process of ant colony algorithm to solve the logistics vehicle routing problem and the simulation calculation result using MATLAB. Section 5 gives conclusions.

2. Vehicle path optimization model

2.1 Brief description of the problem

The basic description of the logistics distribution vehicle path optimization problem is: Knowing multiple customers who need to deliver goods and their distribution points, there are several logistics vehicles starting from the distribution center and completing all the distribution tasks according to the transportation route. The distribution route can only pass once, and finally return to the distribution center. The purpose of route optimization is to reduce transportation costs, meet customer needs, and complete distribution tasks.

The VRP problem is a problem of handling route selection. Our goal is to reduce the number of transportation vehicles as much as possible and choose the shortest transportation route possible. The basic assumptions include:

1) The distribution point of each freight center and the cargo demand of each distribution point are known.
2) The vehicle travels around and serves each distribution point, only unloading at the distribution point without loading.
3) The place to be delivered, the cargo concentration center and the freight vehicle are known.
4) Only one vehicle provides distribution services at each distribution point.
5) Each vehicle will be distributed by its distribution center and returned to the distribution center.
6) The load capacity of the vehicle is constant during logistics transportation, and the vehicle is a unified delivery model of the logistics company.
7) The speed of the logistics vehicle during distribution and transportation is constant, which is regarded as a constant speed.

2.2 Mathematical model

The vehicle routing optimization problem is intuitively described as: Under certain constraints, the vehicle will go from a delivery point to another customer point to design an optimal route to minimize the total cost and meet the following conditions,

1) Each city or customer can only be visited once by the same vehicle.
2) All vehicles start from the distribution center and eventually return to the distribution center.
3) Meet other constraints.

Suppose the delivery task number is 1, 2, ... , L, the weight of each customer point is g_i, the load limit of each vehicle is q, and the distribution center has a total of K vehicles.

Define the following variables,

$$x_{ijk} = \begin{cases} 1, & \text{When the vehicle go from i to j} \\ 0, & else \end{cases} \quad (1)$$

$$y_{ik} = \begin{cases} 1, & \text{the custom i is served by vehicle k} \\ 0, & \text{else} \end{cases} \quad (2)$$

$$x_{ijk}, y_{ik} \in \{0,1\} \quad i,j=1,2,\ldots,L, \quad k=1,2,\ldots,K \tag{3}$$

There are M vehicles in the distribution center, and the mathematical description is,

$$\sum_{k=1}^{K} y_{0k} = K \tag{4}$$

The load capacity of each vehicle does not exceed the load limit. The mathematical description is,

$$\sum_{i=1}^{L} g_i y_{ik} <= q, \quad k=1,2,\ldots,K \tag{5}$$

Each car only serves one customer point, and the mathematical description is,

$$\sum_{k=1}^{M} y_{ik} = 1, \quad i=1,2,\ldots,L \tag{6}$$

The vehicle completes the services of all distribution points, the mathematical description is,

$$\sum_{i=0}^{l} x_{ijk} = y_{ik}, \quad j=1,2,\ldots,L, \quad k=1,2,\ldots,K \tag{7}$$

$$\sum_{j=0}^{l} x_{ijk} = y_{ik}, \quad j=1,2,\ldots,L, \quad k=1,2,\ldots,K \tag{8}$$

The total cost of the distribution process is required to be the lowest, then the mathematical model can be described as:

$$MinZ = \sum_i \sum_j \sum_k C_{ij} x_{ijk} \tag{9}$$

Among them, C_{ij} represents the transportation cost from city i to city j.

3. Ant colony optimization algorithm

3.1 Principles of bionics

In nature, ants are a group of creatures with the same high intelligence as humans, and ants have a keen perception of changes in the surrounding environment. In the process of driving, the ants will leave pheromone on the passing route. Other ants can recognize the presence and strength of this pheromone, and decide the direction of advancement according to the strength of the signal and choose the line with more hormone signals to continue on. In the end, the shortest route between food and ant colony will be formed.

Due to the large number of individuals in the ant colony, the ant colony exhibits a positive feedback. Through this information exchange mechanism, individual ants can find food sources along the shortest path. Inspired by ants looking for food, humans have evolved an ant colony algorithm, which makes the following assumptions:

1) When the ants go out for food, they leave pheromone on the path they travel to identify the surrounding environment.
2) Ants are so sensitive to the environment because they are genetic organisms. Ants respond because of the stressful response made by genetic inheritance and adaptability to the environment.
3) From an individual level, a single ant only stresses its environment. From the perspective of the ant colony, the motivation of a single ant is random, while the ant colony activities are organized group activities.

3.2 Mathematical description of ant colony algorithm

Taking the traveling salesman problem as an example, the basic ant colony algorithm model is analyzed. Suppose the total number of ants in the algorithm is m, the number of cities is n, and $b_i(t)$ is used to denote the number of ants in city i.

$$m = \sum_{i=1}^{n} b_i(t) \tag{10}$$

$\tau_{ij}(t)$ is the amount of information on the path from city i to city j at time t, $\tau_{ij}(t) = u$, where u indicates that the pheromone on each path is the same and constant at the initial time.

In order to prevent the same ant from repeating the participation of a certain city, each ant K (K=1,2,...,m) has a tabuk table, which is used to record the cities that each ant has walked. Each time it visits a city, it will modify its own tabuk. At the same time, according to the pheromone left behind when the ant moves forward, the next operation and path selection are confirmed.

Use $P_{ij}^{K}(t)$ to represent the probability that ant K chooses city j at city i at time t, then,

$$f(x) = \begin{cases} \frac{[\tau_{ij}(t)]^{\alpha} \cdot [\eta_{ij}(t)]^{\beta}}{\sum_{s \in J_K(i)} [\tau_{is}(t)]^{\alpha} \cdot [\eta_{is}]^{\beta}}, & \text{if } j \in J_K(i) \\ 0, & \text{else} \end{cases} \tag{11}$$

Among them, α represents the influence of the pheromone on the next step, and β represents the influence of the path distance on the next step. $\eta_{ij}(t)$ is a heuristic function whose expression is,

$$\eta_{ij}(t) = \frac{1}{d_{ij}} \tag{12}$$

Among them, d_{ij} represents the distance from city i to city j. When α is too small, the path of the ant depends on the size of d_{ij}, so the algorithm is easy to fall into a local optimal solution; if β is too small, the ant colony will fall into a purely random search and it is difficult to find the optimal solution.

According to the laws of nature, ants will update pheromones when they walk through each position. The update rules are as follows [5] [6],

$$\tau_{ij}(t+n) = (1-\rho) * \tau_{ij}(t) + \Delta\tau_{ij}(t) \tag{13}$$

$$\Delta\tau_{ij}(t) = \sum_{K=1}^{m} \Delta\tau_{ij}^{K}(t) \tag{14}$$

Among them, ρ represents the volatilization speed of pheromone, 1-ρ represents the residue of pheromone, $0<\rho<1$, $\Delta\tau_{ij}(t)$ represents the increase of pheromone on the path (i, j) of the current cycle, $\Delta\tau_{ij}^{K}(t)$ represents the pheromone increment of ant K on the path (i, j), and $\Delta\tau_{ij}(0)$ represents the pheromone increment on each path in the initial state.

4. Ant colony algorithm optimizes logistics vehicle path

4.1 Implementation process

The ant colony algorithm is used to optimize the vehicle path. The flowchart is shown in Figure 1. The specific steps [7] are summarized as follows,

1) Set the number of ants and initialize the pheromone.
2) Randomly select the starting point i for the kth ant, and put i into the search taboo tag of the kth ant.

3) Calculate the transition probability and select the next delivery customer point.
4) Calculate the total ant load sum_g on the path. If sum_g <= u (u is the maximum capacity of the vehicle), go to step (5); otherwise, go to step (7).
5) Count the number of vehicles, and then determine the allowed list. If the allow list is empty, go to step (6). Otherwise, get the unsearched point from the authority as the starting point and go to step (3).
6) Calculate the updated pheromone and pheromone increment.
7) Find the least cost path in the route of ant K, and update the pheromone.
8) Determine whether the maximum number of iterations has been reached. If Ncmax has been reached, the final value is iterated to calculate the shortest path length and the shortest path, otherwise, go to step (2).

4.2 Analysis of results

Assuming that the carrying capacity of the car is 3 tons during delivery, the maximum driving distance for each delivery cannot exceed 100Km. The coordinate positions of the distribution center and each customer are shown in Table 1, where the customer number 0 represents the distribution center.

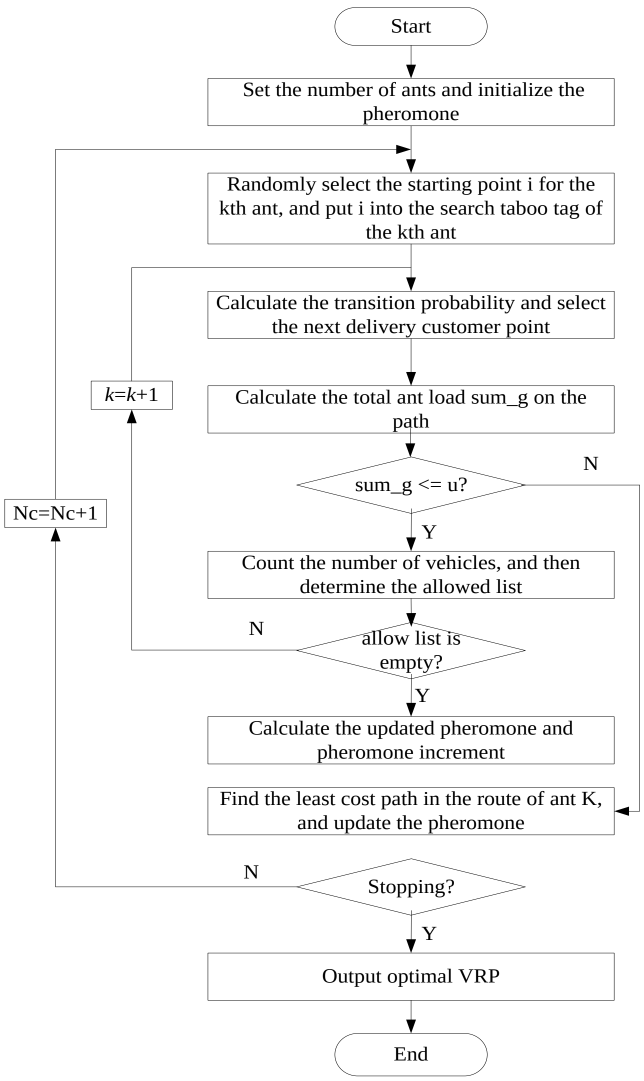

Figure 1: Flow chart of ant colony optimization algorithm

Table 1: Coordinate position

Custom number	Abscissa (Km)	Ordinate (Km)	Delivery volume(Kg)
0	28.4	25.4	0
1	32	20.2	0.1
2	31.4	15.5	0.4
3	46	25.8	1.2
4	51	38.7	1.5
5	32	34.6	0.8
6	21.2	27.9	1.0
7	14.3	18.6	1.5
8	17.1	1.9	0.6
9	19.7	38.4	1.2

Using MATLAB software for optimization simulation, the basic parameters of the ant colony algorithm are set as follows: the number of ants M = 20, the maximum number of iterations Ncmax = 100, the path pheromone Q = 10, the information enlightenment factor $\alpha = 1$, the expected enlightenment factor $\beta = 1$, The pheromone volatilization coefficient ρ=0.15, and the maximum pheromone intensity τmax=50. The program is run 10 times, and the simulation results are shown in Table 2. Judging from the results in Table 2, there is little difference in the results of the ten runs, indicating that the algorithm is robust. The result of each operation can guarantee the route of the delivery route, and the search time is very short, which greatly improves the efficiency of vehicle route optimization.

Table 2: Optimization results of ant colony algorithm

Calculation number	Minimum delivery distance(m)	Vehicles number	Runtime (s)
1	163.92	3	1.2
2	165.02	3	1.3
3	162.8	3	1.1
4	165.6	3	1.31
5	161.97	3	1.0
6	165.02	3	1.37
7	165.6	3	1.33
8	162.8	3	1.3
9	161.97	3	0.99
10	163.92	3	1.4
Average	163.88	3	1.36

5. Conclusion

This paper studies the logistics vehicle routing optimization problem based on the ant colony algorithm, mathematically modeling the vehicle routing optimization problem, uses the ant colony optimization algorithm to solve the problem, and uses MATLAB software for simulation calculation. The realization process and experimental results of the optimization solution are given, and the effectiveness of the algorithm is verified.

6. Acknowledgements

This work was supported by the National Natural Science Foundation of China (grant number 61901350); and Science Research Fund of Xi'an Aeronautics University (grant number 2019KY0208).

References

[1] Li Changmin, Tao Ying, Peng Xian, et al. Vehicle routing problem based on customer time satisfaction [J]. Journal of Shanghai University (Natural Science Edition), 2020, 26(3): 472-480.

[2] Sun Liang, Wang Bing, Guo Dong, et al. A weakly robust optimization method for solving uncertain vehicle routing problems[J]. Journal of National University of Defense Technology, 2020, 42(3): 30-38.

[3] Bai Guoxing, Meng Yu, Liu Li, et al. Vehicle path tracking control based on variable prediction time domain and speed[J]. China Mechanical Engineering, 2020, 31(11): 1277-1284.

[4] Pang Yan, Luo Huali, Xia Yangkun. Discarded furniture recycling vehicle path optimization based on taboo search algorithm [J]. Computer Integrated Manufacturing System, 2020, 26(5): 1425-1433.

[5] Zhang Jin, Bi Guotong, Dai Erzhuang. Two-objective cold chain logistics vehicle routing problem and its genetic ant colony solution [J]. Science Technology and Engineering, 2020, 20(18): 7413-7421.

[6] Wang Xiufan, Liang Feng. Research on logistics vehicle path optimization and control based on PSO-ACO fusion algorithm [J]. Machine Tool and Hydraulics, 2020, 48(12): 155-160.

[7] Liu Qinghua, Wang Jing. Improved ant colony algorithm based on electronic map and its optimization of vehicle path [J]. Journal of Jiangsu University of Science and Technology (Natural Science Edition), 2020, 34(1): 75-81.

Author Profile

WANG Li received the B.E. degree in electronic and information engineering from Xi'an University of Architecture and Technology, Xi'an, China, in 2009 and the M.S. degree in signal and information processing from Beihang University, Beijing, China, in 2012. She received the Ph.D. degree from Northwestern Polytechnical University, Xi'an, China, in 2018. She now is lecturer in Xi'an Aeronautics University. Her research interests include compressed sampling, hyperspectral image processing, and optimization algorithm.