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Network Analysis and Distribution Route Optimization of Logistics Positioning Route Based on Trans CAD

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Abstract

Trans CAD-based logistics positioning route problem network analysis and allocation route optimization technology effectively solve the characteristic value, which solves the positioning of the logistics route by applying trade-offs. This technology has established and delivered an eigenproblem around basic conditions that converges inaccessible algorithmic obstacles. The successful development of distribution route optimization based on Trans CAD's network analysis and logistics positioning route problem has fast search capabilities for the entire logistics distribution process and provides services for logistics.

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Introduction

With the rapid development of the logistics industry, transportation costs have exceeded inventory, and the current congestion of urban traffic has directly caused the increase in logistics transportation costs[1-3]. Therefore, how to deliver the goods to the customer according to the optimal route can not only reduce the transportation cost but also ensure the satisfaction of the public[4-6]. In order to obtain a better logistics distribution route optimization plan, a Trans CAD logistics distribution route optimization method is proposed. First, establish a mathematical model of logistics distribution route optimization, then use Trans CAD to solve it, and finally use simulation experiments to test its effectiveness and superiority.

2. Logistics distribution route optimization problem and mathematical model

2.1. Description of distribution route problem

There are a total of M customer points in a logistics distribution network. Knowing the demand qi and location of each customer point i, at most K cars will reach the demand point from the distribution center, and each car will depart from the distribution center and finally return to the distribution center. The maximum load Pk of each car k is fixed (k=1,2,...,K), it is required to arrange the driving route of the vehicle to minimize the total cost (such as distance, time, etc.).

2.2. Mathematical model of logistics distribution route optimization

The essence of logistics distribution vehicle scheduling is the question of what route to take for transportation. It is described as: Under the premise that the load capacity of the vehicle and the demand of each customer are known, at least how many vehicles can be sent to meet the demand and the total travel distance of the vehicle is the shortest. In order to find the smallest cost distribution plan, the following conditions are required to be met:

1) All distribution vehicles start from the distribution center and eventually return to the distribution center.

2) Each customer is only visited once by one car, and each car can only serve one route.

3) The sum of customer demand on each delivery

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route cannot exceed the load capacity of the vehicle.

4) The route taken by each car cannot be repeated.

Suppose the distance between the customer from point i to point j is $b_{i,j}$, i,j=0,1,...,M, $b_{0,0}$ represents the distribution center, then the mathematical model of logistics distribution path optimization is:

$$\text{Min}\, F=\sum_{k=1}^{K}\left(\sum_{i=1}^{n_k} b_{r_k^{i-1},r_k^i}+b_{r_k^{nk},0}\right)\times \text{sgn}\left(n_k\right) \quad (1)$$

In the formula, nk represents the total number of customers delivered by vehicle k. When nk=0, it means that vehicle k does not participate in the delivery. Among them:

$$\text{sgn}\left(n_k\right)=\begin{cases}1, n_k=0\\ 0, n_k\geq 1\end{cases} \quad (2)$$

The constraints of logistics distribution route optimization are:

$$\text{Min}\, F=\sum_{k=1}^{K}\left(\sum_{i=1}^{n_k} b_{r_k^{i-1},r_k^i}+b_{r_k^{nk},0}\right)\times \text{sgn}\left(n_k\right)$$

$$\begin{cases}\sum_{i=1}^{n_k} p_{r_k^i}\leq pk; n_k\neq 0\\ \sum_{i=1}^{n_k} b_{r_k^{i-1},r_k^i}+b_{r_k^{nk},0}\leq B_k; n_k\neq 0\\ R_{k1}\bigcap R_{k2}=\phi, k_1\neq k_2\\ \bigcup_{k=1}^{K} R_k=\{1,2,\cdots,M\}; 0\leq n_k\leq M\end{cases}$$

(3)

In the formula, Bk represents the maximum travel distance of vehicle k; Rk represents the set of customer points delivered by vehicle k; r_k^j represents the order of the customer points in the delivery route of vehicle k is j.

According to formula (1), it can be seen that logistics distribution not only requires fewer delivery vehicles, but also the shortest delivery path, but also delivers the goods to customers within a specified time. It is to find an optimal logistics distribution route that meets multiple constraints at the same time. A typical multi-constraint combinatorial optimization problem.

3. Trans CAD for logistics distribution route optimization

Inspired by quantum evolution software, Li Panchi and others combined quantum computing with ant colony software and proposed Trans CAD. Each ant of the software carries a set of quantum ratios representing the current position information of the ant, and selects the forward goal of the ant based on the selection probability constructed by the pheromone intensity and visibility; then the quantum revolving door is used to update the qubit carried by the ant, The movement of the ant; the quantum NOT gate is used to realize the mutation of the ant's position and increase the diversity of the position; finally, the ant colony pheromone intensity and visibility are updated according to the moved position, which can better solve the problem of the ant colony software The convergence speed is slow and it is easy to fall into the problem of local optimum.

3.1. Quantum Information Coding

In quantum computing, quantum bits (qubits) are used to represent information. A simple qubit is a two-state system. A qubit can be represented by the probability amplitude X1. Then the individual probability amplitude of n qubits can be expressed as :

$$\begin{bmatrix}\alpha_1 & \alpha_2 & \cdots & \alpha_n\\ \beta_1 & \beta_2 & \cdots & \beta_n\end{bmatrix} \quad (4)$$

In the formula, αi and βi satisfy |αi|2+|βi|2=1,i=1,2,...,n, the quantum individual can represent any quantum superposition state.

In Trans CAD, qubits are used to represent the pheromone on the path. The quantum pheromone code of the kth ant on each path can be expressed as:

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$$Q\tau_k = \begin{pmatrix} \begin{pmatrix}\alpha_{11}\\ \beta_{11}\end{pmatrix} & \begin{pmatrix}\alpha_{12}\\ \beta_{12}\end{pmatrix} & \cdots & \begin{pmatrix}\alpha_{1n}\\ \beta_{1n}\end{pmatrix} \\ \begin{pmatrix}\alpha_{21}\\ \beta_{21}\end{pmatrix} & \begin{pmatrix}\alpha_{22}\\ \beta_{22}\end{pmatrix} & \cdots & \begin{pmatrix}\alpha_{2n}\\ \beta_{2n}\end{pmatrix} \\ \vdots & \vdots & & \vdots \\ \begin{pmatrix}\alpha_{n1}\\ \beta_{n1}\end{pmatrix} & \begin{pmatrix}\alpha_{n2}\\ \beta_{n2}\end{pmatrix} & \cdots & \begin{pmatrix}\alpha_{nn}\\ \beta_{nn}\end{pmatrix} \end{pmatrix} \quad (5)$$

In the formula, n is the number of customers, $\begin{pmatrix}\alpha_{ij}\\ \beta_{ij}\end{pmatrix}$ represents the probability of pheromone on the delivery path between customer i and customer j, and has:

$$\begin{cases} |\alpha_{ij}|^2 + |\beta_{ij}|^2 = 1, i \neq j \\ |\alpha_{ij}|^2 = |\beta_{ij}|^2 = 0, i = j \end{cases} \quad (6)$$

For customers i and j, when ants pass the path from customer i to j, the value of the pheromone probability amplitude βij on the length of the road will increase, and the pheromone will be enhanced; otherwise, the pheromone on the path will be volatile .

3.2. Pheromone update rules

After all the ants have constructed the path, the pheromone on each path will be updated. First, the pheromone on all sides will be reduced by a constant factor, and then the pheromone will be added on the path that the ant passes. The evaporation of pheromone is performed according to the following formula:

$$\tau_{ij} = (1-\rho)\tau_{ij}, \forall (i,j) \in E \quad (7)$$

In the formula, ρ is the evaporation rate of pheromone. After the pheromone has evaporated, all ants release the pheromone on the path they pass:

$$\tau_{ij} = \tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^k, \forall (i,j) \in E \quad (8)$$

In the formula, $\Delta\tau_{ij}^k$ is the amount of pheromone released by the kth ant to the delivery route it passes.

3.3. Adjustment of quantum revolving door

With m ants, the n×n matrix R is a solution path from the distribution center to all customers in n customer logistics systems. R[i,j]=1 means that there is a path from customer i to customer j in the path R When i=j, R[i,j]=0. The software uses the matrix Rk,k=1,2,...,m to record the path obtained by the k-th ant, and Rbest records the optimal solution obtained during the operation. The quantum revolving gate is used to update the quantum of the ant on each path. The probability amplitude, the adjustment method of the quantum revolving door is:

$$\begin{pmatrix}\alpha_{ij}^{t+1}\\ \beta_{ij}^{t+1}\end{pmatrix} = \begin{pmatrix}\cos(\theta) & -\sin(\theta)\\ \sin(\theta) & \cos(\theta)\end{pmatrix}\begin{pmatrix}\alpha_{ij}^{t}\\ \beta_{ij}^{t}\end{pmatrix} \quad (9)$$

In the formula, $(\alpha_{ij}^t, \beta_{ij}^t)^T$ is the probability amplitude of the pheromone on the path from client i to client j in the tth iteration; θ represents the rotation angle of the qubit from path i to j, which is used to control the convergence speed of the software.

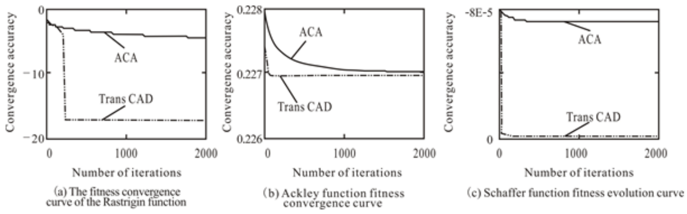

Figure 1. Comparison of convergence performance between Trans CAD and ACA software.

3.4. Solving steps of logistics distribution route optimization

Using Trans CAD software to solve the problem of vehicle distribution route optimization is to use artificial ants instead of vehicles to serve customer points. After multiple cycles, some ants choose the same path or Find an optimal path, then the solution is completed. The specific steps are as follows:

1) Initialize the parameters, read the customer data to be served, and generate the global initial solution.

2) Place m ants in the logistics distribution center; the initial time t=0 and the number of iterations Nc=0, establish an ant colony taboo table.

3) For each ant i, find the nodes that have not been passed from the node list, and select the next customer node j of the ant from these nodes

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according to the transition probability formula.

4) Calculate the total freight volume q of the path (i, j), if q>Q, where Q represents the maximum capacity of the vehicle, then jump to step 5), otherwise add node j to the feasible point set A, and jump to step 6).

5) Calculate the waiting time at customer demand point j. If the time window requirements are met, add point j to the taboo table, and at the same time, jump to step 3) for the path length and cost from node i to node j, otherwise add node j again In the feasible point set A, skip to the next step 6).

6) Update the line local pheromone and pheromone increment of the path traveled by each ant.

8) Search for the shortest path length and the shortest path of k ants, calculate the minimum cost and the corresponding minimum cost path, and update the pheromone on the path. When the cycle starts, if all the ants cruise once, then the k ants The pheromone of the searched edge is updated, otherwise the optimal path of this cycle is updated.

Step 1: Set the values of the parameters α, β, ρ, γ, the number of ants is m, the maximum number of iterations is NMAX, the current number of iterations t=0, and the pheromone τij(0)=1, in order to make the software initial search The state appears with the same probability, and all αij and βij in the ant quantum pheromone code are $1/\sqrt{2}$.

Step 2: Put m ants in the logistics distribution center, and each ant independently constructs a solution. According to the constraint conditions of the logistics distribution of equation (3), select the next customer according to equation (10), and repeatedly apply the state transfer rule, Until Ant K completes the logistics and distribution of all customers.

$$j=\begin{cases}\arg\max\limits_{l\in N_i^k}\left\{\tau_{il}\left(\eta_{il}\right)^{\delta}\right\}, q\le q_0\\ J, otherwise\end{cases} \tag{10}$$

In the formula, τil is the pheromone concentration on the delivery path (i,l); ηil=1/Cil, represents the self-inspired amount of the delivery path (i,l); δ is the weight of the self-enlightened amount; N_i^k represents the location in the customer The set of adjacent customers that ant k of i can reach directly, that is, the set of all customers that have not been visited by ant k.

Customer j is a random variable generated by roulette based on the probability distribution given by equation (10).

$$p_{ij}^k=\frac{\left[\tau_{ij}\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum\limits_{l\in N_i^k}\left[\tau_{il}\right]^{\alpha}\left[\eta_{il}\right]^{\beta}}\left(j\in N_i^k\right) \tag{11}$$

In the formula, α and β are two parameters, which respectively represent the relative influence of pheromone and heuristic information; p_{ij}^k refers to the probability that ant k at customer i chooses customer j as the next customer to visit.

Step 3: If m ants have constructed their respective solutions, go to step 4, otherwise go to step 2.

Step 4: According to the current optimal solution, apply the quantum revolving door rule to update the quantum information probability amplitude of the ants in each delivery route, and update the pheromone according to formula (7) and formula (8).

Step 5: If the end condition is met, that is, t>Nmax, output the optimal solution to obtain the optimal path plan for logistics distribution, otherwise t=t+1, go to step 2, and continue.

4. Simulation experiment

4.1. Classic function test

Three classic multimodal functions were selected to test the performance of Trans CAD and simulation software. The three classic test functions are as follows:

(1) Rastrigin function

$$f\left(x\right)=\sum_{i=1}^{n}\left(x_i^2-10\cos\left(2\pi x_i\right)+10\right) \tag{12}$$

(2) Ackley function

$$f\left(x\right)=-20\exp\left(-0.2\sqrt{\frac{1}{30}\sum_{i=1}^{n}x_i^2}\right)-\exp\left(\frac{1}{30}\sum_{i=1}^{n}\cos 2\pi x_i\right)+20+e \tag{13}$$

(3) Schaffer function

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$$f(x)=\frac{\sin^2\sqrt{x_1^2+x_2^2}-0.5}{\left(1+0.001\left(x_1^2+x_2^2\right)\right)^2}-0.5 \qquad (14)$$

It can be seen from Figure 1 that for all functions, Trans CAD can quickly reach the theoretical minimum points of 0 and □1. The convergence speed of Trans CAD is significantly better than that of ACA software, mainly because Trans CAD uses qubits to encode pheromone. The revolving door updates the pheromone in the link to avoid the shortcomings of premature stagnation and local optimality of ACA.

4.2. Simulation test of logistics distribution route optimization

A company has a logistics distribution center with 5 cargo trucks (each truck has a load of 1 ton) and needs to deliver to 7 customer points. The coordinates and freight demand of each customer point are shown in Table 1 (0 means distribution center; 1~7 are customer points).

Table 1. Customer coordinates and demand for goods.

Customer Number	Coordinate	Goods demand/t
0	(40，40)	
1	(10，20)	1.0
2	(15，50)	1.6
3	(25，40)	1.3
4	(30，60)	2.4
5	(35，15)	1.5
6	(55，45)	1.1
7	(65，10)	1.6

The number of ants in Trans CAD is n=5, α=1, β=5, ρ=0.9, γ=2~4, prior knowledge q0=0.05, maximum evolution algebra NMAX=500, and the initial pheromone on each edge is 1. , Using ACA and Trans CAD respectively to solve the logistics distribution route optimization problem in Table 1, and the results are shown in Figure 2 and Figure 3.

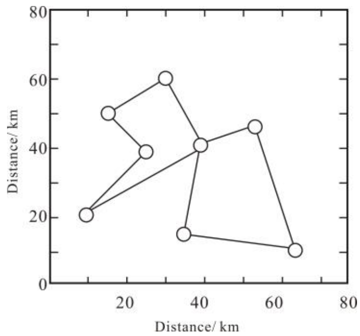

Figure 2. ACA's logistics distribution path.

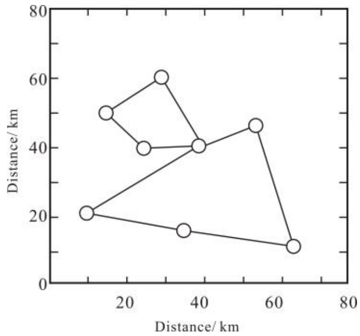

Figure 3. Trans CAD logistics distribution path.

It can be seen from Figure 2 that the ACA logistics distribution route is divided into 2 routes, route 1 is: 0→4→2→3→1→0, and the total length of the distribution route is 110.547km; route 2 is: 0→5→7→ 6→0, the total length of the distribution path is 108.121km, so the total path length under ACAO's logistics distribution path plan is 218.668km. As can be seen from Figure 3, the logistics distribution path optimized by Trans CAD is divided into

There are 2 routes, route 1 is: 0→4→2→3→0, the total length of the distribution path is 64.491km; route 2 is: 0→1→5→7→6→0, the total length of the distribution path is 144.177km, so the total length of the route under Trans CAD's logistics distribution route plan is 208.668km. The comparison results show that the logistics distribution route plan that Trans CAD can find is better than ACA's logistics distribution route plan.

In order to comprehensively compare the optimal performance of Trans CAD and ACA to solve the logistics distribution path, Trans CAD and ACA are used to solve the logistics distribution path problem in Table 1 for 50 consecutive times. The results obtained are shown in Table 2. It can be seen from

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Table 2 that the number of times and efficiency of Trans CAD search to the minimum are better than ACA, and the reliability of optimization is higher. This is mainly because Trans CAD uses qubits to encode pheromone on each delivery path, and quantum rotation The door updates the pheromone in the distribution route, improves the software's optimization ability, effectively avoids the software from falling into the local optimum and prevents premature convergence, and improves the search efficiency.

Table 2. Comprehensive performance comparison of Trans CAD and ACA.

Evaluation index	Trans CAD	ACA
Average path/km	219.023	230.750
Maximum path/km	220.912	235.230
Minimum path/km	208.668	218.668
50 calculations to find the optimal number of times	25	10
Average time/s	35	42

5. Conclusion

According to the characteristics of logistics distribution path optimization and the shortcomings of ant colony software, a Trans CAD logistics distribution path optimization strategy is proposed. The experimental results show that Trans CAD can quickly and effectively obtain the optimal solution for optimizing the logistics distribution path, which has certain reference value for the research of ant colony software and logistics distribution path problems.

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