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Medical Delivery Route Planning Using Adaptive Ant Colony Algorithm

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Abstract

Aiming at the need to reduce the cost of medical distribution logistics, a method of designing medical distribution routes with improved ant colony algorithm is proposed. The reasonable assumptions and constraints of the medical logistics mathematical model are put forward, and the objective function for the optimization of medical delivery routes is constructed. Use ant colony algorithm to avoid risks reasonably, strengthen the processing of information data, and use adaptive ant colony algorithm based on dynamic adjustment of pheromone volatilization coefficient to adjust data lines. The software is used for simulation design, and the experimental results show that the distribution route designed by the adaptive ant colony algorithm has practical application value.

Keywords

Medical distribution; Vehicle routing problem; Ant colony algorithm; Pheromone.

1. Introduction

The pharmaceutical logistics industry relies on certain logistics equipment, technology and logistics management information systems, integrates upstream and downstream resources of marketing channels, and optimizes the inspection, storage, sorting, and distribution processes in the drug supply, marketing and distribution links to improve order processing capabilities and reduce Incorrect sorting of goods reduces inventory and delivery time. Logistics distribution is a key link of pharmaceutical logistics, and medical distribution route planning is of great significance for reducing logistics costs, improving service levels and capital use efficiency [1].

Medical distribution route planning is a special vehicle routing problem (VRP) [2]. The methods for solving VRP mainly include precise algorithms and intelligent optimization algorithms [3], among which precise algorithms are rarely used because of the complexity and low efficiency of the solution. The heuristic intelligent optimization algorithm obtains the feasible solution of the problem through computer simulation, and it is widely used because of its strong referenceability [4]. For the intelligent optimization of medical distribution routes, there are still some problems [5-8], such as long search time, easy to fall into local optimal solutions, and insufficient description of cost issues and logistics processes.

In this paper, ant colony algorithm is used to optimize the design of medicine distribution route. Firstly, the mathematical model of medical distribution planning is established to determine the objective function of ant colony optimization; then, the design method of using adaptive ant colony algorithm to optimize medical distribution path planning is described; the dynamic adjustment of pheromone volatilization coefficient is realized. Finally, the method in this paper is used to carry out the simulation design of the medicine distribution route optimization, which proves that the proposed method can effectively realize the medicine distribution route planning.

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2. Analysis Method

2.1. Medicine Distribution Model

The medical logistics center distribution model is built around a medical logistics center between multiple cities. For a certain service provider to provide medical delivery, it is required to deliver the lowest cost in the shortest time. Because it is a service provider that provides medicine, it is necessary to minimize fixed costs during delivery and keep the delivery vehicles to a minimum. However, it is necessary to meet the needs of the demanders for medicine and control the number of vehicles within an appropriate range. The capacity is less than the carrying capacity, which can not only avoid the problem of excessive cost, but also save time and optimize the configuration.

The delivery vehicle in the pharmaceutical logistics distribution center is a single vehicle with a capacity of Q. In the distribution, according to the needs of different demanders, the responsibilities of all distribution vehicles are clearly divided to complete the total distribution service.

All shipping information is as follows:

(1) The needs of all demanders of medical logistics distribution are known, and the total amount of medical distribution is greater than the demand, and the delivery is completed regularly.

(2) In the process of starting the distribution, according to the known path planning, the medical distribution is carried out until the goods are delivered.

(3) The distribution environment is fixed, that is, the distance between the location of the demander and the location of the medical supply is fixed, and the two parties are in a cooperative and cooperative relationship.

(4) The delivery vehicle of the same model will start the delivery of goods in one place.

(5) The fixed path distance between the delivery vehicle from the departure place to the return place.

(6) According to the demand of the number and type of demanders, the cargo capacity in the car is fixed.

The distribution service should meet the following basic constraints:

(1) According to the path planning of medical delivery, the demand of the demander is less than the weight that a car can carry, which is one of the basic delivery conditions.

(2) Each vehicle has its own path plan. During the delivery process, all vehicles cannot stop, return, terminate, etc. from the starting point to the return point. After the goods are delivered, they will be based on the existing path. Plan to turn back.

(3) Each vehicle has its own time window constraint before the start of delivery, and the delivery of medicine must be completed within the specified time period for delivery. Too early or too late is not conducive to the established time window constraint.

According to the above requirements, the following mathematical model of distribution planning is established:

$$\min \sum_{i=0}^{n} \sum_{j=0}^{n} \sum_{k=1}^{K} c_{ij} y_{ijk} \tag{1}$$

$$\sum_{j=1}^{n} y_{0jk} \leq 1 \tag{2}$$

$$\sum_{i=0}^{n} y_{i0k} \leq 1 \tag{3}$$

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$$\sum_{k=1}^{K}\sum_{i=0}^{n} y_{ijk} = 1 \quad 1 \le i \le n \tag{4}$$

$$\sum_{k=1}^{K}\sum_{j=0}^{n} y_{ijk} = 1 \quad 1 \le j \le n \tag{5}$$

$$\sum_{i=0}^{n} m_i \sum_{j=0}^{n} y_{ijk} \le q \quad 1 \le k \le K \tag{6}$$

The relevant parameters in the model are defined as follows:

$$y_{ijk} = \begin{cases} 1, & \text{if Vehicle k drives from node i to j, } i \neq j,\ i,j \in \{0, 1, \ldots, n\} \\ 0, & \text{else} \end{cases} \tag{7}$$

Among them, k is the vehicle model. K is the total number of delivery vehicles. n is the sum of the demand of the demander, it is 0 in the distribution center. Cij is the distribution cost of two demand points, where $i \neq j$ and $i, j \in \{0, 1, \cdots, n\}$. m_i is the number and type of demanders. q is the maximum carrying capacity of the vehicle, each vehicle has its own carrying capacity, and the number of customer needs should be controlled within the maximum carrying capacity.

In the model, equation (1) is the objective function, which refers to controlling the distribution cost to a minimum. Equations (2) and (3) are closed-loop constraints. Each route has a specified delivery vehicle model, and the shortest distance from the origin to the destination in the delivery. Equations (4) and (5) are traversal constraints. In each delivery process of the vehicle, each customer point is the destination. Equation (6) is the capacity constraint of the vehicle, which means that the goods carried in the delivery path must be within the carrying capacity.

2.2. The Structure of Ant Route

Medical distribution path planning belongs to the capacity-constrained vehicle path planning problem (CVRP). When ants walk through the path between cities, the demand of the demander becomes the main reference object for the ant to expand the service; in the prescribed path, the demander's capacity If the limit is within the specified range, the ant can start the delivery service; and if the capacity limit is exceeded, the ant cannot deliver, and returns according to the original route. In order to avoid repeating the delivery to a customer during the delivery, the route that the ant has traveled needs to be calibrated and recorded.

Ants start distribution according to the prescribed route, and in this process, it is necessary to mark the demanders who have been distributed by the ant. After completing the entire target delivery, the ants return to the starting point. In the entire path, the function value of the demand is solved, and the maximum limit of the capacity is given. If the customer's delivery demand is greater than the actual carrying capacity, Ants will return to the distribution center to re-deliver. If the demand is less than the actual carrying capacity, the ants will continue to deliver until all demand points are visited, and the function is solvable. The following formula calculates the probability of access points:

$$P_{ij}^{k}(t) = \begin{cases} \dfrac{[\tau(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}}{\sum_{j \in allowed_k} [\tau(t)]^{\alpha} \cdot [\eta_{ij}]^{\beta}} & \text{if } j \in allowed_k \\ 0 & \text{otherwise} \end{cases} \tag{8}$$

Wherein, $\tau_{ij}(t)$ represents the pheromone concentration of (i, j). $allowed_k$ indicates a collection of cities not visited by the ant collection k. To avoid repeated visits to a single city, if a city is selected, it should be deleted from the collection In the formula, α and β are used to represent pheromone concentration parameters and heuristic parameters, which are important

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parameters that affect the selection probability. At the same time, it is necessary to establish a list of visited cities. In order to avoid repeated visits, in the running process of the ant colony algorithm, the visited cities will be deleted from the city set after each traversal.

2.3. Pheromone Update Rule

The pheromone of the ant colony algorithm is in the process of continuous updating, and the key for ants to complete the task is to strengthen the communication ability. Pheromone update is divided into local and global pheromone update. Partial pheromone update refers to the local information update after ant's demand distribution in the city according to the customer's demand point. When starting the next stage of the delivery task, the pheromone is continuously updated internally to help the ants adjust their routes in the delivery at any time. Global pheromone update means that all ants dispatched to deliver goods will optimize and adjust all routes after completing the first round of goods delivery.

When ants start distribution in different cities, the pheromone update rule for the next city is:

$$\tau_{ij} \leftarrow (1-\rho)\tau_{ij} + \rho\tau_o \tag{9}$$

Among them, ρ represents the coefficient of pheromone change with time; τ_o is the amount of pheromone at the initial moment.

After the ant colony completes all the urban distribution tasks, according to the optimal distribution route obtained by the solution algorithm, the pheromone update is carried out. The calculation formula is as follows:

$$\tau_{ij} \leftarrow (1-\rho)\tau_{ij} + \rho\Delta\tau_{ij} \tag{10}$$

$$\Delta\tau_{ij} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \tag{11}$$

$$\Delta\tau_{ij}^{k}(t+n) = \begin{cases} Q/L_k & \text{if ant k through path (i, j)} \\ 0 & \text{otherwise} \end{cases} \tag{12}$$

Equation (12) represents the global pheromone update condition. $\triangle\tau_{ij}$ is all pheromone increments. L_k represents the distribution line The shortest distance.

2.4. Adaptive Ant Colony Algorithm

Ant colony algorithm has the advantages of globality, good performance, time optimization and path adjustment. The basic ant colony algorithm is too cumbersome to calculate the urban distribution links of all ants, and it is more suitable for the optimization of the local urban distribution process. Because the update factor of pheromone has a substantial impact on the search for the best route, the speed of factor update determines the choice of the best route. The adaptive ant colony algorithm used in this paper focuses on improving the update method of pheromone. The factor of setting pheromone increases as the number of iterations N_C increases.

$$\rho = \begin{cases} 0.2 & N_C \le 1/4\, N_{CMAX} \\ 0.3 & 1/4\, N_{CMAX} < N_C \le 3/4\, N_{CMAX} \\ 0.5 & N_C > 3/4\, N_{CMAX} \end{cases} \tag{13}$$

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According to the setting of formula (13), the optimized ant colony algorithm is updated based on the iterative update of pheromone, and it is easier to give a reasonable distribution route; and the adjustment of the parameter ρ in the iterative process enhances the ant's global search performance , Solve the algorithm premature phenomenon.

3. Calculation and Analysis

A certain manufacturer that implements medical logistics management is set up to distribute to hospitals and retail pharmacies in the region through a medical distribution center. A single delivery service needs to deliver medicines to 31 demand addresses in the jurisdiction. As shown in Table 1, the number of the delivery point is 1, and the number of the demand address is 2 to 32. The abscissa, ordinate and demand of the customer point are given in the table. The maximum vehicle capacity is set to 100.

Table 1. Customer information

Serial number	Abscissa	Ordinate	Cargo demand
1	0	0	0
2	3639	1315	12
3	4177	2244	13
4	3712	1399	14
5	3488	1535	53
6	3326	1556	45
7	3238	1229	22
8	4196	1004	11
9	4312	790	11
10	4386	570	56
11	3007	1970	43
12	2562	1756	24
13	2788	1491	65
14	2381	1676	32
15	1332	695	56
16	3715	1678	67
17	3718	2179	67
18	4061	2370	22
19	3780	2212	34
20	3676	2578	56
21	4029	2838	24
22	4263	2931	25
23	3429	1908	26
24	3507	2367	46
25	3394	2643	87
26	3439	3201	33
27	2935	3240	22
28	3140	3550	24
29	2545	2357	56
30	2778	2826	24
31	2370	2975	43
32	1304	2312	12

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The basic ant colony algorithm and the adaptive ant colony algorithm are used to solve this path optimization problem. In the calculation, the number of initial ants m is set to 50, the pheromone importance parameter α is 1, the heuristic factor importance parameter β is 5, the pheromone evaporation coefficient ρ is 0.1, the number of iterations N_{CMAX} is 200, and the pheromone increase intensity coefficient Q is 100. The basic ant colony algorithm took 28.5 seconds, and the adaptive ant colony algorithm took 27.7 seconds. It can be seen that the two algorithms have little difference in computing resource requirements.

The specific route obtained after optimization is shown in Table 2. Figure 1 and Figure 2 respectively show the distribution plan of the distribution center to 31 pharmaceutical retail points based on the basic ant colony algorithm and the adaptive ant colony algorithm, where different colors indicate different paths. The basic ant colony algorithm requires 13 vehicles to complete the delivery, while the adaptive ant colony algorithm only requires 12 vehicles to complete the delivery. The adaptive algorithm shortens the total delivery distance from 107084.7 to 102776.6. This shows that the ant colony algorithm can meet the needs of the medical delivery route optimization problem and give a reasonable delivery route, especially the adaptive ant colony algorithm can obtain more optimized results.

The change of the optimal path length with the number of iterations is shown in Figure 3. As the iteration progresses, the optimal path length continues to decrease. Due to the randomness of the initial ant colony establishment, the adaptive ant colony algorithm has a longer initial optimal path, but as the iteration progresses, the adaptive ant colony algorithm reaches convergence within 50 times, while the basic ant colony algorithm requires iteration Convergence can only be reached after 150 times. It can be seen that the adaptive ant colony algorithm can effectively improve the convergence characteristics of the basic ant colony algorithm.

Table 2. Vehicle specific route

Vehicle serial number	Basic Ant Colony Algorithm	Adaptive Ant Colony Algorithm
1	1-15-1	1-15-14-1
2	1-10-9-8-1	1-12-13-1
3	1-20-26-1	1-6-5-1
4	1-21-22-28-27-1	1-7-8-9-10-1
5	1-30-31-32-1	1-25-1
6	1-24-11-1	1-20-11-1
7	1-6-5-1	1-2-4-16-1
8	1-7-16-1	1-3-19-24-1
9	1-13-12-1	1-26-28-27-32-1
10	1-14-29-1	1-29-31-1
11	1-25-1	1-30-21-22-18-1
12	1-17-4-2-1	1-17-23-1
13	1-3-18-19-23-1	

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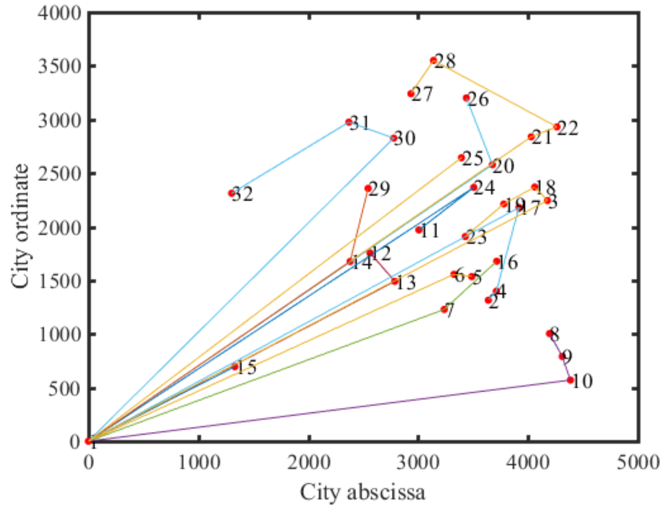

Fig 1. The best distribution plan of basic ant colony algorithm

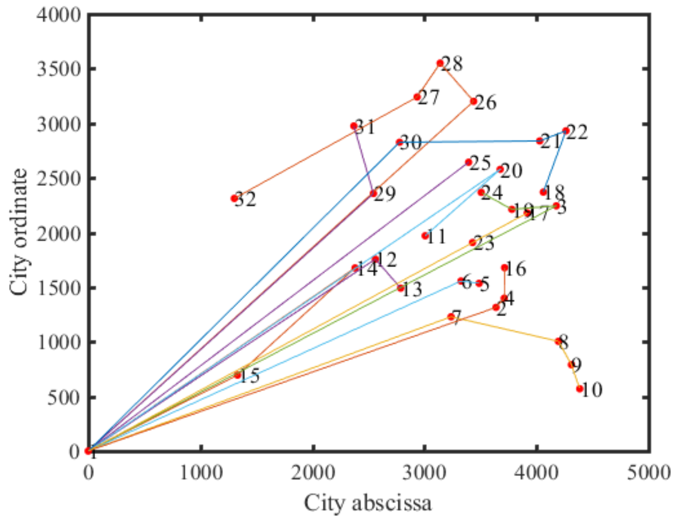

Fig 2. Optimal delivery plan of adaptive ant colony algorithm

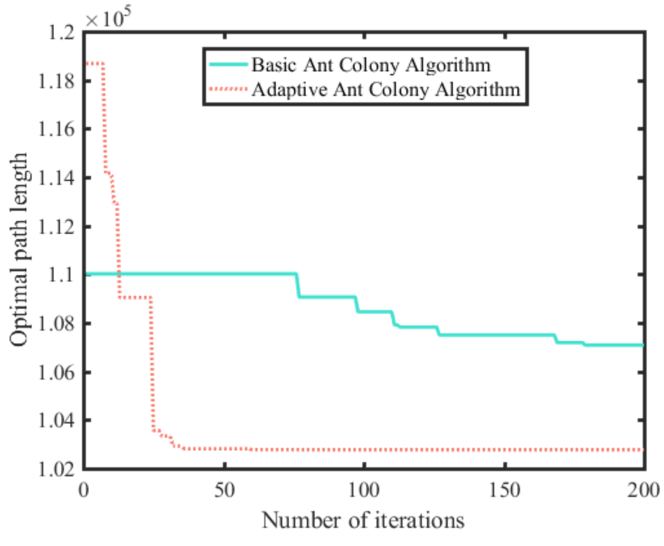

Fig 3. Variation curve of optimal path length in iteration

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4. Conclusion

Against the background of epidemic prevention and control, the author conducts online teaching practice on the course "Electromagnetic Fields and Electromagnetic Waves". By analyzing students' classroom participation and course performance, it fully shows that online teaching can fully guarantee the teaching quality and learning effect. After the epidemic is over, how to fully integrate the learning video resources of online teaching construction with the offline teaching process [9] [10], further improving the quality of teaching is a question that the author needs to ponder.

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