Research on Ant Colony Algorithm for Location Planning of Distribution Center

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Abstract: The location of logistics center is affected by many factors. And it is an urgent problem to optimize the location selection and obtain the accurate location selection. Based on fully considering the actual distribution center planning problems, this paper introduces the problem of distribution center location planning model building and the steps of ant colony algorithm implementation. Then a large number of experimental simulations are used for instance verification to prove the rationality and effectiveness of the proposed ant colony algorithm to solve the distribution center allocation problem.

1. Introduction

With the continuous development of the economy and e-commerce platforms, the logistics industry has ushered in new developments. The logistics industry plays a vital role in our country's economic development. Development of the logistics industry will be not only conducive to optimizing the regional industrial structure and reducing the cost of the logistics industry, but also conducive to the expansion of regional employability. Modern logistics industry has become an important part of modern service industry. At present, one of the main directions of academic research in the logistics industry is how to integrate the problems that may arise in the logistics and transportation links. [1]-[3] According to the development trend of the logistics industry, the distribution center is an important link between distributors, retailers and customers. Therefore, it is particularly important to comprehensively consider various factors to plan the location of the distribution center. The location planning of the logistics distribution center has received extensive attention from academia.

Logistics is the process of transporting goods from the warehouse to the place of demand, including a variety of basic functions such as loading and unloading, handling, transportation, circulation, and processing. In the process of transporting the goods from the place of production to the place of demand, it is necessary to establish a central site for the centralized distribution of goods. The purpose of establishing a central site is to make goods reach the demand site efficiently and quickly, and which is called as the logistics distribution center. The logistics distribution center location selection often has been influenced by many factors, such as the distribution of materials and transportation conditions. Therefore, considering various factors to reasonably plan the specific location of the
distribution center plays a vital role in the development of the logistics industry. The focus of the paper is to use intelligent software to scientifically plan the location of the logistics distribution center by constructing a mathematical model.

Domestic and foreign scholars have carried out relevant researches on location selection. Weber and Alfred first proposed the theory of site selection. It mainly studied how to choose a warehouse location so that the distance between the warehouse location and the scattered demand points was the shortest. Our country's research on location selection started a litter late. In 1985, Cai Xixian and Xia Shizhi made a systematic introduction to foreign site selection models. Li Shuang and Pan Xiu proposed to use DEA and AHP to solve the problem of the logistics distribution location. It used DEA to calculate the relative coefficients between the projects and constructed the corresponding matrix. Then it used AHP to sort and finally established the logistics distribution center. Zhao Qin divided areas of the Hanyun Logistics Group logistics operation from the perspective of fuzzy clustering method and considered various factors in location selection. Then the literature combined the center of gravity method to solve the problem of distribution center location, so that the location selection model had practical significance. Huang Xin used the BP neural network to determine the specific location of the agricultural product logistics distribution center in Province A. It used the specific data in the studied area to train the neural network and got the point with the highest evaluation value from the candidate area. Finally, the specific location of the distribution center was obtained through calculation. However, the algorithm of BP neural network is more complicated and there is a certain degree of difficulty in practical application.

In conclusion, there have been many optimization methods applied to the problem of location selection planning, but there are fewer optimization methods involving intelligent optimization algorithms. On the basis of establishing the mathematical model of the distribution center location planning, the paper uses ant colony algorithm to optimize the model, so as to obtain a more accurate distribution center location planning scheme. According to the simulation experiments, the ant colony algorithm is effective in solving the problem of the distribution center location planning.

2. Location Planning of Distribution Center
The premise of location planning of distribution center is that demand points are known, and distribution centers are set in these demand points, so as to realize the minimum transportation cost between the selected distribution center and its demand points.

Assume that the supply of the distribution center can always meet the demand of the demand point, and the supply of the distribution center is determined by the demand of the distribution range. Each demand point only allows one distribution center to carry out distribution. In the process of model building, only the cost from the distribution center to the demand point is considered, and the cost of the upper-level transportation network is not considered. In other words, the cost from the factory to the distribution center is not considered.

\[
\min F = \sum_{j=1}^{m} \sum_{k=1}^{n} D_{jk}d_{jk}y_{jk}
\]

\[
\sum_{j=1}^{m} y_{jk} = 1, \ j \in J, \ k \in K
\]

\[
y_{jk} \leq f_{j}, \ j \in J, \ k \in K
\]

\[
\sum_{j=1}^{m} f_{j} = P, \ j \in J
\]

\[
y_{jk} \in \{0, 1\}, \ j \in J, \ k \in K
\]
3. Ant Colony Algorithm for Location Planning of Distribution Center

3.1. Basic Ant Colony Algorithm

Since ants release pheromones on their walking routes, ants in nature will show a group of intelligent behaviors when foraging. And they usually choose the path with the highest pheromone concentration to move. It is through this positive feedback mechanism that the ant colony can quickly find food. Ant colony algorithm includes two steps: path selection and pheromone update. In the process of path selection, each ant chooses the forward direction according to the pheromone concentration of the surrounding environment through a probability function (a function related to the pheromone concentration); In the process of pheromone renewal, each ant will leave a new pheromone on the path it passes. At the same time, in order to avoid excessively high pheromone concentration, which affects the path selection of subsequent ants, the pheromone on all paths in the space will undergo a volatilization process.

The parameter $\alpha$ is the pheromone heuristic factor, which represents the relative importance of the motion trajectory between two nodes; $\beta$ is the expected heuristic factor, represents the relative importance of visibility. $\rho$ is the global pheromone volatilization factor, which represents the retention rate of pheromone, $\rho \in [0,1]$; $1 - \rho$ indicates the degree of volatilization of pheromone in order to avoid unlimited accumulation of pheromone; $Q$ is a constant, and its size setting will affect the convergence speed of the algorithm. $\eta_{ij}(t)$ indicates the degree of expectation between the city $i$ and the city $j$, $\tau_{ij}(t)$ is the pheromone residual from city $i$ to city $j$ at time $t$, $d_{ij}$ indicates the Euclidean distance between the city $i$ and the city $j$, $\Delta \tau_{ij}(t)$ represents the amount of information between city $i$ and city $j$ that the k-th ant stayed in this tour. $P^k_{ij}(t)$ represents the probability that ant $k$ moves from position $i$ to position $j$ at time $t$. Therefore, the mathematical expression of the basic ant colony algorithm is as follows:

$$P^k_{ij}(t) = \begin{cases} \frac{[\tau_{ij}(t)]^\alpha [\eta_{ij}(t)]^\beta}{\sum_{i \in \text{allowed}_k} [\tau_{ik}(t)]^\alpha [\eta_{ik}(t)]^\beta} & \text{if } j \in \text{allowed}_k \\ 0 & \text{other} \end{cases}$$

(7)

$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \Delta \tau_{ij}(t)$$

(8)

$$\Delta \tau_{ij}(t) = \sum_{k=1}^m \Delta \tau^k_{ij}(t)$$

(9)

Among them, formula (7) is the path selection process, the ants determine the direction of
movement according to the pheromone and heuristic function factors on each path. Formula (8) is to simulate the update process of pheromone, including the volatilization of pheromone and the superposition of pheromone on the ant's path. Formula (9) is to add new pheromone to the path that the ant walks.

3.2. Solving problem of ant colony algorithm

Step 1: Set the number of iterations $N_C = 0$, perform parameter initialization and pheromone initialization, and randomly place $m$ ants on $n$ demand points;

Step 2: Record the initial demand points of the ants, put them in the current solution set; select the next demand point $j$ for each ant according to formula (7), place $j$ in the current solution set, and repeat until all demand points are traversed;

Step 3: Record the transportation cost of each ant;

Step 4: Record the minimum value of the current transportation cost;

Step 5: Follow formula (8) to update the pheromone;

Step 6: Number of iterations $N_C = N_C + 1$;

Step 7: If $N_C < N_{C_{\text{max}}}$, clear the tabu list, and return to step 2; if $N_C = N_{C_{\text{max}}}$, output the minimum value of transportation cost, and end the program.

4. Example simulation

This paper uses the coordinate data of demand points in the literature [10], and the demand for demand points is shown in Table 1. Similarly, 4 distribution centers are set up according to the literature [10]. After many experiments, it is concluded that when $\alpha = 1$, $\beta = 5$ and $\rho = 0.6$, the calculation result is the best.

| Serial number | Demand | Serial number | Demand |
|---------------|--------|---------------|--------|
| 1             | 30     | 10            | 20     |
| 2             | 50     | 11            | 40     |
| 3             | 100    | 12            | 10     |
| 4             | 130    | 13            | 110    |
| 5             | 90     | 14            | 130    |
| 6             | 120    | 15            | 150    |
| 7             | 150    | 16            | 100    |
| 8             | 40     | 17            | 50     |
| 9             | 150    | 18            | 60     |

Table 2 shows the results of 10 runs using the ant colony algorithm to solve the distribution center location problem. Table 3 shows the specific plan of the basic ant colony algorithm for selecting distribution centers and distribution. And table 4 is the performance description table of the basic ant colony algorithm in the distribution center location allocation problem.

| Number of calculations | Cost     | Number of final iterations | Difference from minimum fee |
|------------------------|----------|-----------------------------|----------------------------|
| 1                      | 14120    | 40                          | 2400                       |
| 2                      | 11720    | 2                           | 0                          |
| 3                      | 13350    | 32                          | 1630                       |
| 4                      | 13140    | 45                          | 1420                       |
| 5                      | 13330    | 34                          | 1610                       |
| 6                      | 13980    | 52                          | 2260                       |
| 7                      | 11800    | 81                          | 80                         |
Table 3. Ant colony algorithm location selection scheme

| Selected distribution center | Delivery Area |
|-----------------------------|--------------|
| 5                           | 4, 13, 18, 2, 7, 16 |
| 3                           | 12, 1        |
| 6                           | 15, 17, 14   |
| 9                           | 8, 11, 10    |

Table 4. Performance description table

|                         | ACO       |
|-------------------------|-----------|
| Optimal value           | 11720     |
| Worst value             | 14120     |
| Average value           | 13025     |
| Standard deviation      | 911.6     |
| Average number of convergences | 36.5     |
| Mean value of difference| 1305      |

At the same time, we can get the location plan and optimization curve of the basic ant colony algorithm, as shown in Figure 1 and Figure 2 respectively.

![Figure 1. Location selection plan](image1.png)

![Figure 2. Optimization curve](image2.png)

5. Conclusions

Aiming at the problem of distribution center location planning, this paper constructs a mathematical model of distribution center location planning, and uses ant colony algorithm to optimize the model. The MATLAB simulation shows that the ant colony algorithm is effective in optimizing the location planning of distribution centers. However, the parameter setting of the ant colony algorithm and its theoretical proof are still in the initial stage, and further research is needed. This paper only initially studies the optimization of the distribution center location planning by the basic ant colony algorithm, and the subsequent improvement of the ant colony algorithm is also one of the research directions for the optimization of this problem. In addition, the location model of the distribution center is still in the ideal stage, and how to make the model closer to reality is an important direction for future research.
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