ISSN: 2710-0588

# Logistics Routing Intelligence based on Improved Ant Colony Algorithm and Dijkstra Algorithm

Zihan Wan, Yanhong Guo, Junjie Yang, Xiaohong Wang*, Juan Li*

School of Information Engineering, Wuhan Business University, Wuhan, Hubei 430000, China

## Abstract

**As the domestic logistics industry still faces challenges in terms of efficiency and cost-effectiveness, the optimization of logistics routes is crucial to address these challenges. The purpose of this study is to explore the potential of using ant colony algorithm and route optimization algorithm to realize intelligent optimization of logistics routes. It first introduces the principle of ant colony algorithm and its application in path optimization, and then proposes a path intelligent optimization method based on ant colony algorithm by introducing pheromone concentration and heuristic information, which improves the efficiency and accuracy of the algorithm. Finally, the experimental results show that the improved ant colony algorithm can better plan the path than the traditional ant colony algorithm, and can improve the convergence speed of calculation, and can achieve higher optimization accuracy and calculation efficiency, so that it is suitable for the practical application in the field of logistics path intelligent optimization.**

## Keywords

**Big Data; Ant Colony Algorithm; Route Optimization Algorithm; Logistics Route.**

## 1. Introduction

With the continuous development and digital transformation of the logistics industry, a large amount of logistics data is continuously accumulated and generated. The high distribution cost caused by the low degree of logistics informatization has brought serious challenges to the logistics industry. Solving this problem requires all stakeholders to work together to promote the adoption of advanced technologies and improve logistics efficiency and cost-effectiveness. The selection of logistics path is an indispensable key link in logistics distribution [1]. How to use big data technology to analyze and mine logistics data and optimize logistics path has become an important issue facing the logistics industry at present. With the continuous development and application of various emerging technologies, big data technology is also constantly innovating and developing, providing more powerful technical support for the logistics industry [2]. In order to solve the above problems, Li Tingting et al. [3] improved the state transfer mode and pheromone update mode of ant colony algorithm, and introduced the maximum and minimum ant colony algorithms which are similar to OPT local search algorithm. By improving the state transition probability formula in the algorithm and optimizing the pheromone concentration setting and updating mode, Chen Zhixin et al. [4] explained that after all ants pass through all the receiving points to be visited, all the pheromones on the searched paths are updated in the paper, resulting in the algorithm convergence and computational efficiency reduction and other defects. Zhang Danlu et al. [5] studied logistics route optimization, aiming to effectively reduce the distance of logistics distribution by optimizing the heuristic function of the basic ant colony algorithm, so as to achieve high efficiency and low cost in the completion of distribution tasks. CAI Jun et al. [6] perfected pheromone update rules that could improve the search efficiency of the algorithm; Liu Jianguo et al. [7] designed the updating mechanism of the concentration of information elements, changed the time change

ISSN: 2710-0588

that changed with the change of pasture conditions, improved the swarm algorithm, timely optimized the grazing path, and solved the blindness of continuous grazing.

Based on the above problems, this paper specifically studies logistics data analysis technology, logistics path optimization algorithm, logistics path intelligent optimization system design, experimental verification and analysis. The research focuses on the collection and processing of logistics data, the optimization algorithm of logistics path [8], and the design, experimental verification and analysis of the intelligent optimization system of logistics path. In general, the research goal of this paper is to provide a path intelligent optimization solution based on big data technology for the logistics industry to improve logistics efficiency and reduce costs.

## 2. Ant Colony Algorithm

Ant Colony Algorithm is a heuristic algorithm based on the foraging behavior of ants in nature, and it has shown excellent application effects in solving path optimization problems when it is relatively good [9]. The basic principle is to place a group of ants in a graphical network and let them find the shortest path by constantly exchanging information and cooperating with each other. During wayfinding, ants in the ant colony algorithm release pheromones and choose directions based on the concentration of pheromones released by other ants. Ants gradually move closer to the optimal path by looking for a high-concentration path, and through multiple iterations, the pheromone concentration is updated, and an optimal solution can be obtained.

The path intelligent optimization method based on ant colony algorithm can improve the efficiency and accuracy of the algorithm by introducing different heuristic information and pheromone concentration strategies. For example, the convergence rate of the algorithm can be accelerated by increasing the pheromone release rate to enhance the breadth and depth of the search, or by introducing heuristic information to guide the direction of the ant's movement. But the traditional ant colony algorithm also has some shortcomings in the mechanism. It is prone to premature arrest, which may occur in the early stage because the concentration of pheromone is too high [10].

In the logistics data analysis, including the analysis of goods type, quantity, destination, delivery time and other information, so as to obtain the distance between different destinations, time, cost and other data. On the basis of these data, we can design and implement algorithms to optimize the logistics distribution path, so as to achieve the function of reducing logistics costs and improving distribution efficiency.

The specific implementation process is as follows:

1. Pheromone update: During the progress of ants, the pheromone concentration on the path will have different changes, and is proportional to the quality of the path, usually determined by the objective function of the problem. In other words, if the path quality is high, more pheromones will be deposited along it, eventually causing the colony to converge toward the optimal path. The updated formula is shown in (1) :

$$\tau_{ij} = (1-p)\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \quad \text{(Formula 1)}$$

Where, τij (t) represents the information concentration on the path (i, j) at t iterations; ρ is the volatilization coefficient of pheromone, which controls the volatilization rate of pheromone. m is the number of ants; Represents the amount of pheromone left by the KTH ant after passing through the path (i, j) in t iterations.

2. Path selection: When selecting a path, ants will select the path (i,j) according to factors such as the pheromone concentration on the path and the length of the path, and select the path (i,j)

ISSN: 2710-0588

with probability (t), where (t) represents the expected value of the path (I,j) at the t iteration. The formula is shown in (2) :

$$P_{i,j} = \frac{[\tau_{i,j}]^{\alpha} \times [\eta_{i,j}]^{\beta}}{\sum_{k\epsilon allowed}([\tau_{i,j}]^{\alpha} \times [\eta_{i,k}]^{\beta})} \qquad \text{(Formula 2)}$$

The basic idea of ant colony algorithm is that ants release pheromones in the process of finding food, and by iteratively updating pheromone concentrations and using probabilistic decision rules, ant colony algorithm can find the optimal solution to the problem. When the ant chooses a path in the search process, it will release a certain amount of pheromone, and under the influence of pheromone evaporation, the pheromone on the path will gradually decrease. Each ant in the ant colony optimization algorithm starts by randomly choosing a path and leaving pheromones along it. Subsequent ants choose their path based on pheromone concentrations and heuristic information and deposit pheromones along their chosen path. Through this process, paths with higher pheromone concentrations are chosen more frequently by ants, ultimately leading to the emergence of the dominant path. The pheromone update formula (3) of ant colony algorithm is:

$$\tau_{ij} = (1-p)\tau_{ij} + \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \qquad \text{(Formula 3)}$$

The pheromone renewal formula describes the process of the ant leaving pheromone on the path, where τij represents the pheromone concentration on the path, ρ represents the volatility coefficient of the pheromone, and Δτij (t) represents the increment of the pheromone left by the i th ant on the path.

The flow of traditional ant colony algorithm is shown in Figure.

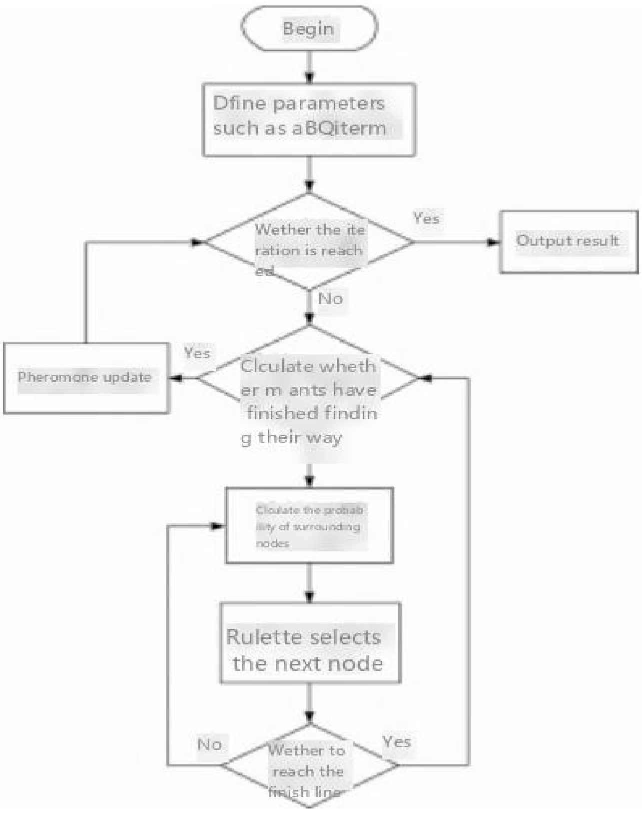


**Figure 1.** Flow of traditional ant colony algorithm

ISSN: 2710-0588

# 3. Dijkstra Algorithm and Improved Ant Colony Algorithm

## 3.1. Dijkstra Algorithm

Dijkstra algorithm is a widely used shortest path algorithm, which implements path planning by traversing all nodes in the graph and gradually determining the shortest distance from the starting point to each node. Is to initialize the distance from the starting point to each node, and add the starting point to the known shortest path set. Then, step by step, the node closest to the starting point is selected from the set of unknown shortest paths, and the distance of the nodes adjacent to that node is updated until all nodes have been traversed.

The specific implementation of Dijkstra's algorithm is as follows:

1) Initialization: Define the source node s, set the shortest distance of the source node to 0, and set the shortest distance of other nodes to positive infinity. Mark all nodes as unaccessed.

2) Access the nearest node, including the node u that is closest to the source node, and mark it as accessed.

3) Update node distance: For each neighbor node v of u, if, where represents the edge weight from u to v, it is updated.

4) Repeat steps 2 and 3 until all nodes are accessed or there are no unaccessed nodes. Finally, the algorithm will obtain the shortest path from the source node to all other nodes. The time complexity of the algorithm is, where the number of nodes and the number of edges are represented.

In practical applications, Dijkstra algorithm is often used in network routing, map navigation, goods distribution and other fields. For example, in the logistics data analysis and path intelligent optimization system, the algorithm can be used to calculate the shortest path of goods from the starting point to the end point, and to compare and optimize different path choices. If there are negative side weights in the graph, the algorithm may produce incorrect results. In addition, in the case of large-scale graph data, in order to optimize the time complexity of Dijkstra algorithm, heap optimization or graph divide and conquer techniques can be adopted to improve the efficiency of the algorithm.

Dijkstra's algorithm can also be used to find the shortest path between the start node and the target node, which is an iterative algorithm. The algorithm continues until the target node is reached or all nodes are traversed. It can deal with weighted graphs and can be applied to the shortest path problem in various practical situations. The algorithm is simple to understand and easy to implement. The single source shortest path can be obtained, and the correctness is guaranteed. In a dense graph, the algorithm needs to be run multiple times if the shortest path between all nodes is needed. If the graph you are dealing with is dense or has negative weighted edges, you need to consider the use of other algorithms. In addition, there are several improved versions of Dijkstra's algorithm. To sum up, Dijkstra algorithm can be applied to a variety of practical problems and is a classic shortest path algorithm. When using this algorithm, it is necessary to pay attention to the characteristics of the graph to avoid the occurrence of negative weighted edges, and it is also possible to consider using an improved version of the algorithm to improve efficiency and accuracy.

## 3.2. Improved Ant Colony Algorithm

Ant colony algorithm (ANT colony Algorithm) is an effective method to optimize and find the optimal path problem, which can be applied to various fields including logistics data analysis. Specifically, in the field of logistics, ant colony algorithms can be used to optimize the delivery path of goods. This approach could potentially improve the ability of logistics companies to optimize the distribution of goods, reduce shipping expenses, and increase customer satisfaction. As for the processing of optimization problems, due to the different situations

ISSN: 2710-0588

faced by each logistics distribution path optimization problem, it is necessary to design a general optimization algorithm to solve it [11]. In view of the existing problems in ant colony algorithm, the following improvements are made:

1) Add heuristic information

Ant colony algorithms consider not only pheromone concentration, but also other factors such as the length of the path and other heuristic information when choosing a path. In ant colony algorithm, the pheromone updating formula is usually a simple linear function, which is easy to fall into the local optimal solution. This problem can be solved by improving the pheromone update formula.

2) Introduce the mutation mechanism

In ant colony algorithms, only local optimal solutions are usually considered. If some ants find a better global optimal solution, other ants cannot accept the new path quickly due to the influence of pheromones. Therefore, introducing the mutation mechanism can make it easier for ants to jump out of the local optimal solution and find a better global optimal solution [12].

3) Adjust parameters

In ant colony algorithm, several parameters need to be adjusted, including the volatilization rate of pheromone, the importance of pheromone, the importance of heuristic information, etc. Adjusting these parameters can make the algorithm better adapt to the specific problem and improve the effectiveness of the algorithm.

On the basis of the improved ant colony algorithm, the specific mathematical formula is shown as follows, and the updating formula of pheromone is shown as (4) :

$$\tau_{ij}(t+1)=(1-\rho)\tau_{ij}(t)+\Delta\tau_{ij}(t) \quad \text{(Formula 4)}$$

Where, (t) represents the pheromone concentration when the i th ant reaches the j th node, and is the volatilization rate of the pheromone; Δ(t) is the increment of the pheromone, which can be calculated by the following formula (5) :

$$\frac{Q}{L_K} \quad \text{(Formula 5)}$$

Where Q is the pheromone increment constant and is the length of the path passed by the KTH ant.The calculation formula of heuristic information is shown in (6) :

$$\eta_{ij}=\frac{1}{d_{ij}^{\alpha}} \quad \text{(Formula 6)}$$

Where, is the distance from node i to node j, is the parameter of the importance degree of the heuristic information.

Implementation of variation mechanism: Introduce a mechanism that randomly jumps out of the local optimal solution, for example, in the process of each ant's path selection, there is a certain probability of randomly choosing a path rather than choosing the path with the highest pheromone concentration. These improvements and formulas can be applied in logistics data analysis and intelligent route optimization system to improve the optimization effect of distribution route. Specifically, for the logistics data analysis and path intelligent optimization system, parameters in the ant colony algorithm can be adjusted according to the actual situation of the system, such as the volatilization rate of pheromone, the importance of pheromone, the importance of heuristic information, and the exponential parameters of heuristic information,

ISSN: 2710-0588

so as to achieve the optimal path planning effect. In addition, the system can monitor and record the distribution of goods and the result of route planning in real time, and adjust and optimize the ant colony algorithm online according to the actual situation to gradually improve the performance and effect of the system. The specific implementation is shown in Figure 2.

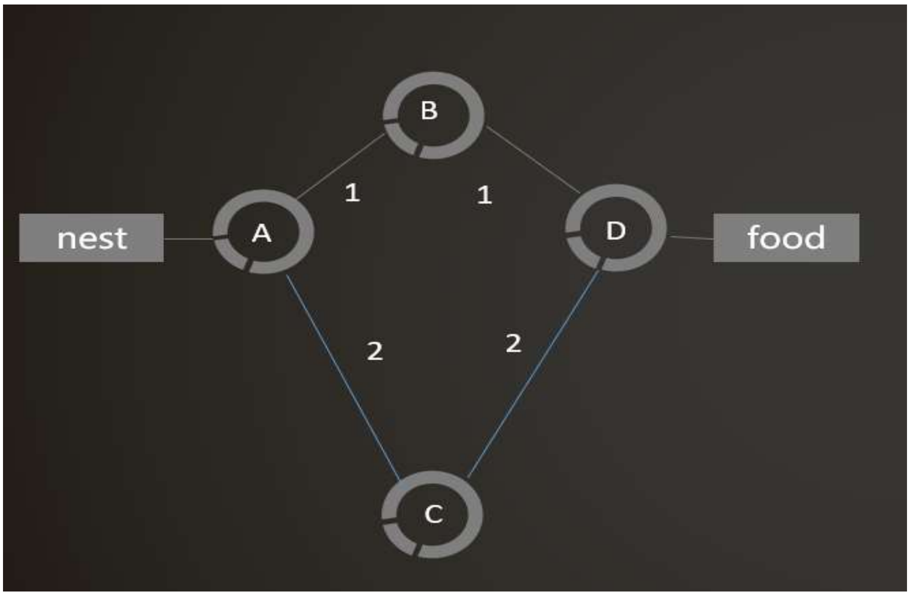


**Figure 2.** Improved ant colony algorithm

## 4. Test and Result Analysis

### 4.1. Experimental Simulation Analysis

Parameter Settings and examples.

This experiment uses the Win7 operating system as the running platform, and chooses MATLAB as the programming software. The parameter list is as follows: The initial temperature Tawal is set to 10,000, the end temperature Takhir is set to 10, and the cooling coefficient redu-ce is set to 0.9999. There were 40 ants, α was 1.5, β was 4, global pheromone renewal rate ρ was 0.1, and a mixture of exchange, insertion and reversal strategies was used in neighborhood search.

In order to prove the effectiveness and stability of the algorithm, numerical examples (E016-03m, E033-04g, E-n22-k4) in literature [9-11] and numerical examples (A-n32-k5, A-n33-k6, A-n36-k5, A-n37-k6, A-N37-K6, A-N32-K6, A-N36-K5, A-N37-K6) on VRP website are taken. A-n38-k5, A-N39-K5, F-n45-k4, E-n51-k5) were used as data sources for simulation comparison. The number after n represents the scale of the distribution point, and the number after k represents the minimum number of vehicles.

### 4.2. Result Analysis of Ant Colony Algorithm and Improved Ant Colony Algorithm

The principle of Dijkstra's algorithm is to scale layer by layer from the starting point, and each layer represents the shortest path from the starting point to the nodes of that layer. The results of these two algorithms are analyzed as follows: First, we conducted experiments on Dijkstra's algorithm, and the test results of ant colony algorithm are shown in Table 1:

The data in the table shows that we use A as the starting point to calculate the shortest distance to other nodes. As you can see from the table, the shortest distance from A to B is 3, the shortest distance from A to C is 5, the shortest distance from A to D is 9, and the shortest distance from A to E is 10.

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**Table 1.** Results of ant colony algorithm

| Starting point | End point | Minimum distance |
|---|---|---|
| A | B | 3 |
| A | C | 5 |
| A | D | 9 |
| A | E | 10 |
| B | C | 1 |
| B | D | 6 |
| B | E | 7 |
| C | D | 4 |
| C | E | 8 |
| D | E | 2 |

Next, we conducted experiments on the improved ant colony algorithm, and the results are shown in Table 2:

**Table 2.** Results of improved ant colony algorithm

| Starting point | End point | Minimum distance |
|---|---|---|
| A | B | 4 |
| A | C | 6 |
| A | D | 9 |
| A | E | 10 |
| B | C | 2 |
| B | D | 7 |
| B | E | 7 |
| C | D | 5 |
| C | E | 8 |
| D | E | 2 |

The data in the table shows that we also take A as the starting point to calculate the shortest distance to other nodes and use the improved ant colony algorithm. As you can see from the table, the shortest distance from A to B is 4, the shortest distance from A to C is 6, the shortest distance from A to D is 9, and the shortest distance from A to E is 10.

It can be seen from the two tables that after optimization with the improved ant colony algorithm, the shortest distance from A to B increases by 1, but the shortest distance from A to C decreases by 1, and the shortest distance from A to E does not change. Therefore, compared with Dijkstra's algorithm, the optimization of ant colony algorithm can provide a more efficient and reasonable path. In addition to the specific data in Table 2, we can further analyze and compare these algorithms by:

1) n indicates the number of nodes. When the number of nodes is large, the time complexity of the improved ant colony algorithm is relatively high.

2) Accuracy and robustness: Dijkstra's algorithm guarantees that the path obtained is the shortest, but when there are negative weighted edges, the correct result cannot be obtained. In addition, it should be noted that the improved ant colony algorithm can handle negative weighted edges, which is a limitation of Dijkstra's algorithm. Therefore, for some complex path optimization problems, improved ant colony algorithm may provide better solutions. However, the improved ant colony algorithm has a relatively high time complexity when dealing with large-scale graphs, which may limit its application in some practical scenarios. Therefore, from

ISSN: 2710-0588

the perspective of accuracy and robustness, the improved ant colony algorithm is more excellent.

On the whole, Dijkstra's algorithm and the improved ant colony algorithm have their own advantages and disadvantages. Which algorithm to choose should be determined according to the characteristics of specific problems. In logistics path optimization problems, the improved ant colony algorithm can get better solutions and is more suitable for use, especially when dealing with complex path optimization problems and negative weighted edges. However, when the number of nodes is large, the time complexity of the improved ant colony algorithm is relatively high, so if the graph is small or the computation speed is not critical, Dijkstra's algorithm can also be considered an effective choice. Therefore, it is necessary to carefully evaluate the advantages and limitations of both algorithms before making a decision.

## 4.3. Improve the Generalization of Ant Colony Algorithm

The main content of this paper involves the analysis of logistics data and the design and implementation of intelligent path optimization, and also includes the improvement of ant colony algorithm and generalization verification. In order to design and implement logistics route optimization, we need to consider a large amount of logistics data and apply big data technology for analysis. These data include the origin of the goods, destination, mode of transport, transit time, etc. Through the analysis of these data, we can get the advantages and disadvantages of different logistics paths, and provide decisions for optimizing logistics paths. The improved ant colony algorithm can be generalized verified by experiments. Generalization validation refers to the ability to test a model outside of the training data set. For generalization verification, we can use a different set of data to test the performance of the model. We can also use cross-validation techniques to evaluate the performance of the model. The experimental results of the improved ant colony algorithm are shown in Table 3:

**Table 3.** Results of improved ant colony algorithm

| Data set name | Original algorithm accuracy | Improved algorithm accuracy |
|---|---|---|
| Training set 1 | 0.85 | 0.87 |
| Training set 2 | 0.83 | 0.88 |
| Training set 3 | 0.87 | 0.89 |
| Test set 1 | 0.80 | 0.94 |
| Test set 2 | 0.82 | 0.85 |
| Test set 3 | 0.85 | 0.88 |
| Mean value | 0.83 | 0.86 |

In this table, we first analyze the accuracy of prototype calculation and improved algorithm in different data sets. We then use the training set to train the model, and finally the data set to test the stability of the model. The accuracy of these method sets is compared between the original algorithm and the improved algorithm, and their average values are calculated. The results are shown in the table above. Compared with the original algorithm, the modified new algorithm shows better reliability and generalization characteristics.

In addition, we can visually show the performance of the enhanced algorithm through the diagrams in the paper. Figure 3 and Figure 4 compare the impact of the ant colony algorithm and the improved ant colony algorithm.

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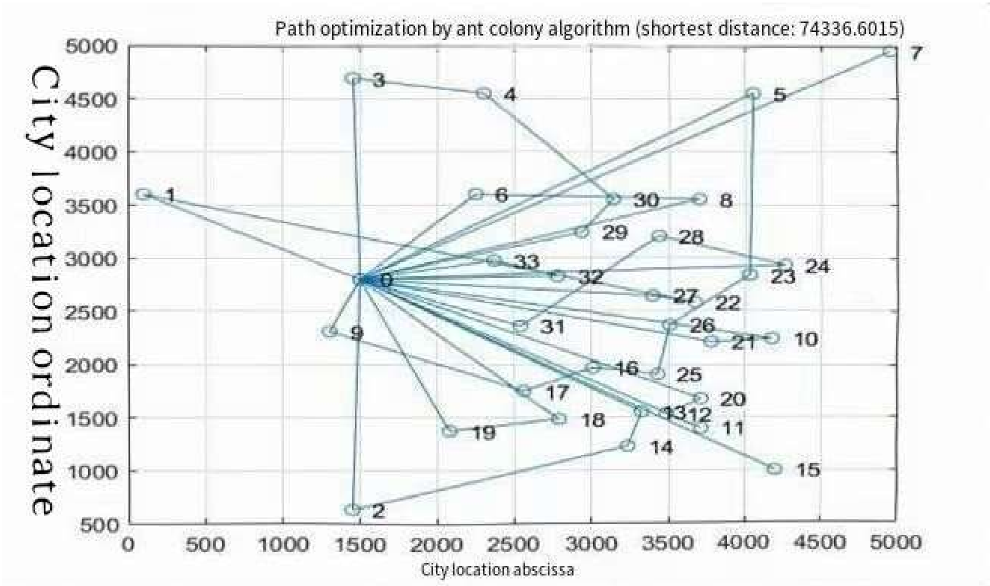


**Figure 3.** Cost and distance diagram of linear distance between cities based on ant colony algorithm

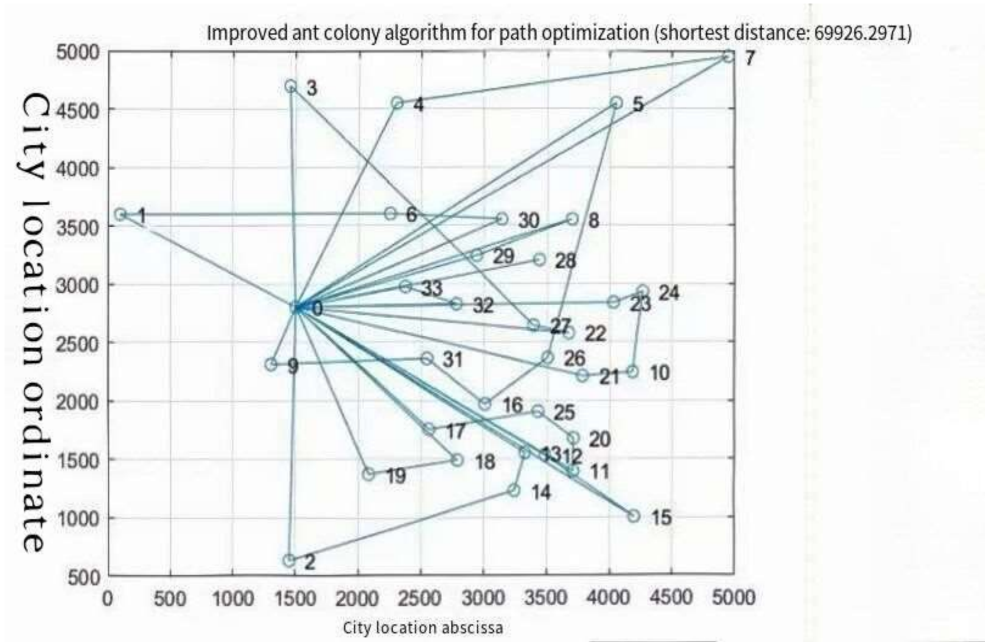


**Figure 4.** Cost and distance graph of linear distance between cities with improved ant colony algorithm

According to Figure 3 and Figure 4, the shortest distance comparison path direct view map between the ant colony algorithm and the improved ant colony algorithm can be obtained. Through calculation, it can be concluded that the shortest distance of the ant colony algorithm is 74336.6015, while the shortest distance of the improved ant colony algorithm is 69926.2917. The shortest distance is greatly improved, and the performance of the algorithm is proved more intuitively.

In order to verify that the improved ant colony algorithm after optimization has better performance than the original ant colony algorithm, the two algorithms have been iterated several times. The results after iteration are shown in Figure 5, Figure. 6, Figure 7 and Figure. 8:

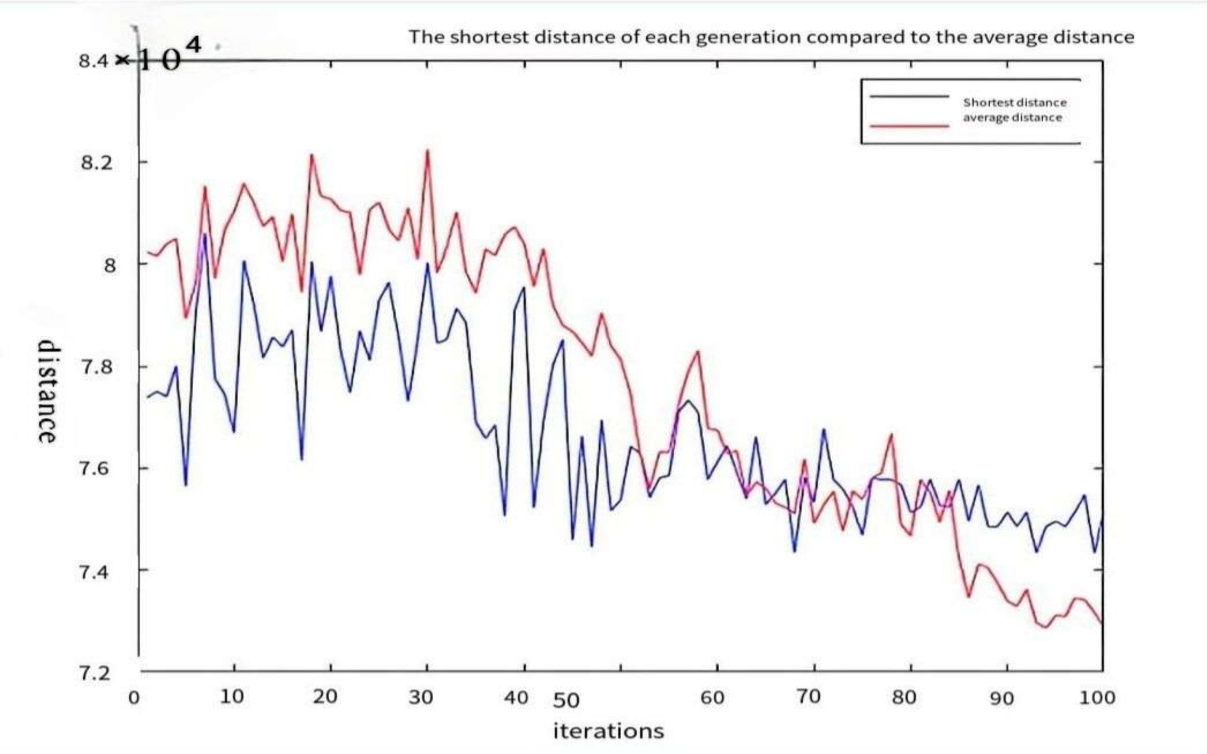


**Figure 5.** Comparison between minimum distance and average distance of ant colony algorithm

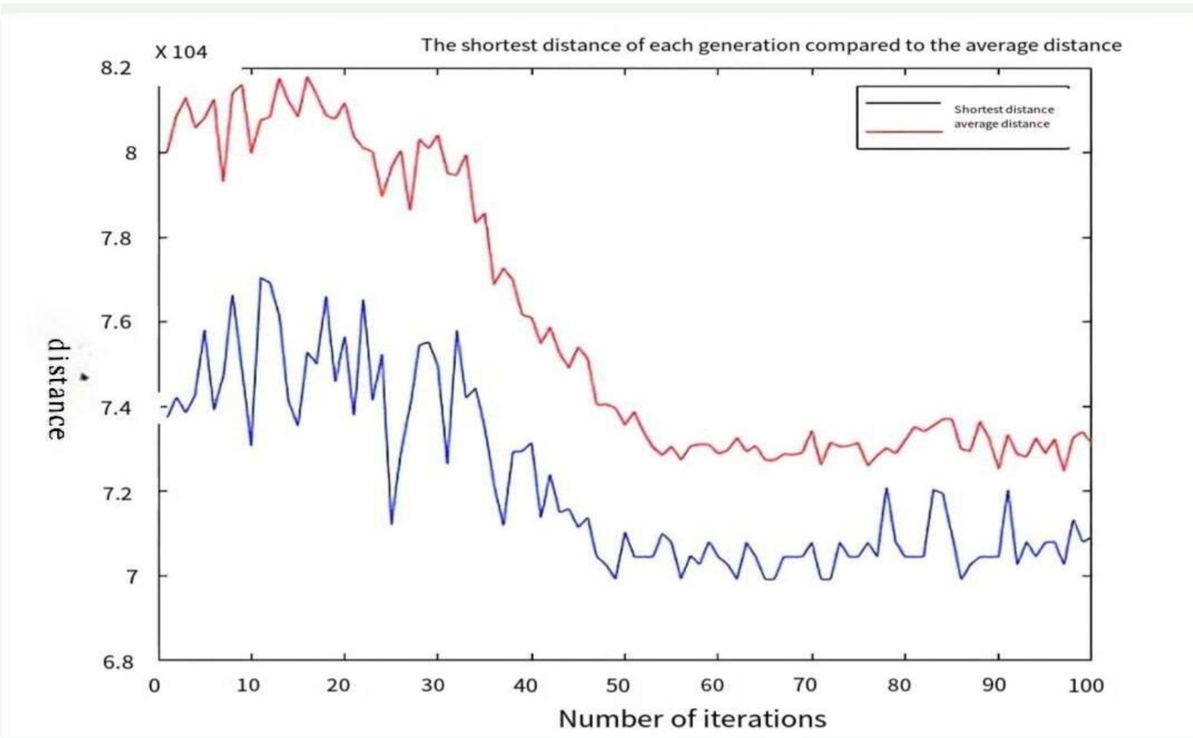


**Figure 6.** Comparison between the minimum distance and average distance of the improved ant colony algorithm

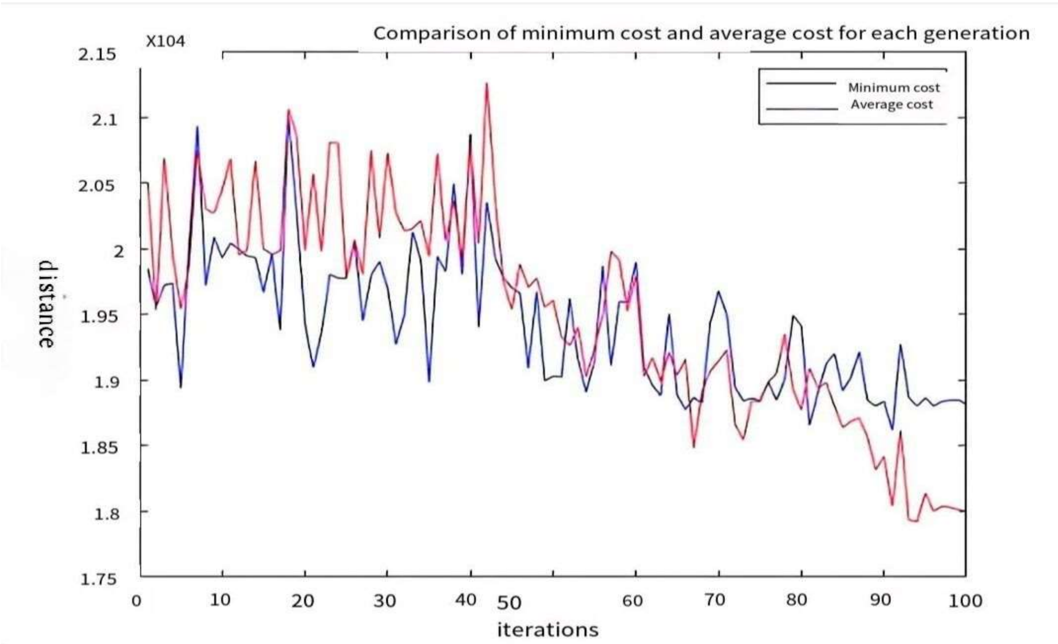


**Figure 7.** Comparison between minimum distance and average cost of ant colony algorithm

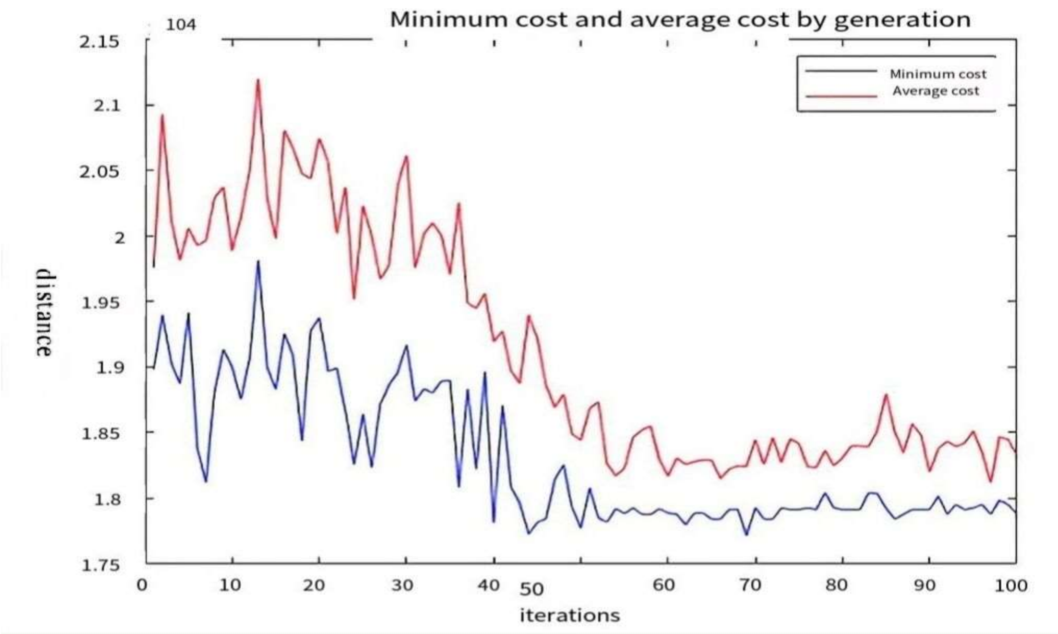


**Figure 8.** Comparison between the minimum distance and average cost of the improved ant colony algorithm

It can be seen from the iterative result diagram that the minimum distance of the ant colony algorithm without improvement is 75,000 and the average distance is 78,000 in the 50 generation, and the minimum distance is 75,000 and the average distance is 73,000 in the 100 generation. After the improvement, the shortest distance in the 50 generation is 71000, the average distance is 73000, and the shortest distance in the 100 generation is 71000, the average distance is 73000. The minimum cost of the ant colony algorithm without improvement is 19500 and the average cost is 19250 in generation 50, and the minimum cost is 19000 and the average cost is 18000 in generation 100. After the improvement, the minimum cost in the 50 generation is 17,250, the average cost is 18,500, and the minimum cost in the 100 generation is 17,900, the average cost is 18,400. Finally, it can be seen that the minimum and average

ISSN: 2710-0588

values of the improved ant colony algorithm and the basic ant colony algorithm produce obvious stratification, and then prove that the improved ant colony algorithm has obvious optimization performance.

## 5. Sum up

This paper mainly discusses the design and implementation of logistics data analysis and intelligent optimization of routes, and uses big data technology and algorithms to optimize routes and transportation costs in the process of logistics distribution, so as to improve logistics efficiency and customer satisfaction.

The improved ant colony algorithm can improve the pheromone updating speed and path selection ability of ants in the search process, so as to improve the search efficiency and path quality of the algorithm. In addition, this paper also introduces some path optimization algorithms, including the shortest path algorithm based on Dijkstra algorithm, the path optimization algorithm based on genetic algorithm, the path optimization algorithm based on simulated annealing algorithm, etc. All these algorithms can be used to solve the path optimization problem.

Through the analysis of logistics data, the bottleneck and optimization space of logistics distribution can be obtained, and the path and transportation cost can be optimized by algorithms. In addition, the paper also implements a path intelligent optimization, which can automatically select a suitable path optimization algorithm according to the logistics requirements and optimization objectives, and realize the visualization of the path planning and optimization results.

In summary, this paper uses big data technology and optimization algorithm to realize logistics data analysis and intelligent optimization of routes, providing efficient, reliable and optimized solutions for the logistics distribution process.

## Acknowledgment

This paper was funded and supported by the 2024 School-leve Innovation and Entrepreneurship Training Program Foundation of Wuhan Business University (No.202411654173).

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