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https://doi.org/10.1007/s11277-018-5319-z

Logistics Terminal Distribution Mode and Path Optimization Based on Ant Colony Algorithm

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Abstract In order to discuss the logistics distribution that directly affects the satisfaction of consumers for the entire online shopping activities, this article mainly studies the logistics terminal distribution mode and path optimization, and combined with the application of ant colony algorithm in the traveling salesman problem, analyses the basic principle and implementation process of ant colony algorithm. In addition, through reference to map and field research, we consider the route length and road conditions (slope and congestion) of the the regional distribution point, and collect and draw the geographic information surrounding area A. Moreover, some key parameters in ant colony algorithm in value are chosen, and with the collected information as a concrete example, MATLAB simulation is carried out for the logistics terminal distribution path optimization based on ant colony algorithm, and its scientific nature and feasibility are verified. The simulation results showed that the ant colony algorithm has good feasibility so that it can be widely applied. As a result, it is concluded that the application of ant colony algorithm has great significance in the exploration of the logistics terminal distribution path optimization.

Keywords Logistics terminal distribution · Ant colony algorithm · Path optimization

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Published online: 22 January 2018

1 Introduction

With the development and progress of society, the society has entered the era of Internet, Tmall, Jingdong and other large B2C e-commerce platforms are gradually complete, Tmall November 11th and December 12th shopping festivals are rather hot. In the daily consumption process, people can feel convenience and benefits brought by online shopping whenever and wherever, and they trust more on the online shopping. Therefore, Chinese online shopping transaction has expanded rapidly. China network shopping market data released by iResearch showed that, in 2016, Chinese online shopping market transactions was 2.8 trillion yuan, an increase of 48.7%, equivalent to 10.7% of total retail sales of consumer goods, and annual line penetration exceeding 10% for the first time. In the first quarter of 2017, the scale of online shopping market in China was 757.410 billion yuan, an increase of 45.2% over the same period. In the second quarter, the scale of China's online shopping market was 872.410 billion yuan, an increase of 39.6% over the same period. The proportion of it in the total retail sales of social consumer goods is 12.3%, and the permeability is further improved.

In the context of the supply side reform, as the "last kilometer" of e-commerce, the logistics link needs to further improve the quality and level of service. The terminal distribution, as the "last mile" of logistics, only contacts by the end user, which is a key part of the logistics. How to send the purchased goods to consumers safely, quickly, and conveniently directly affects the satisfaction of consumers for the entire logistics and even the whole online shopping. As a result, it is necessary to do a good job in the whole logistics scheduling and improve the efficiency of logistics. At the same time, the logistics terminal link also needs to take the corresponding methods and measures to adapt to consumer requirements on the delivery mode and efficiency, so as to further enhance the consumer satisfaction for online shopping activities [1].

In the paper, we mainly study the logistics terminal distribution mode and path optimization, and combined with the application of ant colony algorithm in the TSP, analyse the basic principle and implementation process of ant colony algorithm. In addition, through reference to map and field research, we consider the route length and road conditions (slope and congestion) of the the regional distribution point, and collect and draw the geographic information surrounding area A. Moreover, some key parameters in ant colony algorithm in value are chosen, and with the collected information as a concrete example, MATLAB simulation is carried out for the logistics terminal distribution path optimization based on ant colony algorithm, and its scientific nature and feasibility are verified.

2 Path Optimization Principles of Ant Colony Algorithm

The ant nest can always find the optimal path to the food source, which compared to a single ant, is more intelligent. For every ant in the entire colony, when he begins to search for food, the selection path is random. And in the path of searching for food, the information pheromone is released, and the information pheromone will continue to volatilize with the passing of time. For the path close to food, in a certain period of time, there will be more ants passing from the path, so as to form a parallel mechanism of positive feedback. The shortest path pheromone concentration will become increasingly larger, which will result in that more ants choose this path to foraging. Finally, all ants will get gathered in

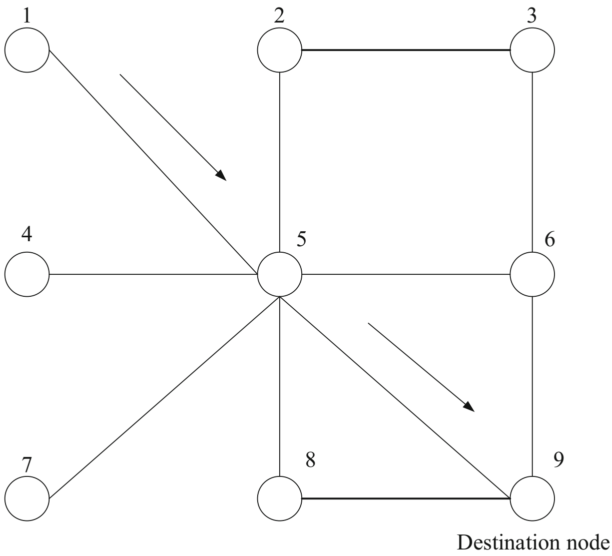

Fig. 1 Path optimization diagram

this path, and eventually find an optimal path from the nest to food [2, 3]. While the artificial ant in the ant colony algorithm will, based on this, add the heuristic factor, and bring into the "visual" effect. The path length is added as the influence factor of path selection to allow ants to find the optimal path faster.

Ant colony algorithm is, based on the study of ant foraging behavior, to form a bionic algorithm. Figure 1 is a schematic diagram of logistics terminal distribution path optimization. Nine terminal distribution nodes are distributed on a two dimensional plane, and the coordinates of all nodes on a plane constitute a 9×2 matrix Place. According to the position (line number) of the node coordinates in the matrix Place, they are numbered, No. 1 distribution node, No. 2 node distribution…… No. 9 distribution node, respectively. The distance between the distribution nodes is expressed by the Euclidean distance. n ants are randomly put into any one node of 9 distribution nodes, the node visited by ants is put into the search tabu list $tabu_k$ table. Except for the distribution nodes having been visited in the search tabu list, the remaining nodes, as node set hasn't been visited, are put into No_Visited table. Each ant can only move to the distribution nodes haven't been visited, so as to avoid that the ants being trapped in loop distribution between several nodes in the place. Before each ant moving to the new node, according to a certain probability formula P, we decide the next distribution node. When the ant search tabu list is full, the paths have passed through are recorded, and according to the pheromone updating rule, the information pheromone is updated. When the algorithm operates until it meets the maximum number of cycles required for satisfying the termination conditions, the optimal path found by ants is output.

3 Application of Ant Colony Algorithm in TSP

The traveling salesman problem (TSP) is the the most basic vehicle routing solution problem. It takes the minimum transportation cost as the primary factor for the consideration. Without considering the vehicle capacity and time window constraints, the traveling salesman, from the starting point, visits all the destination points one by one, and then returns to the original starting point [4]. Of course, there is a strong similarity between the traveling salesman problem and the logistics terminal distribution studied in this paper. Therefore, we can learn from the idea to the solution of traveling salesman problem to solve this problem by taking full consideration of the specific requirements of the logistics terminal distribution routing optimization problem. The ant colony algorithm solves the TSP problem. A simple description of TSP is that a traveling salesman has to finish n cities, and each city can only be visited once and it needs to return to the city where it starts after the visit is finished. The key to the problem is the optimization search of the path, and how to choose the path to allow the traveler to walk the shortest distance to visit all the cities. The idea of ant colony algorithm is applied. First of all, all the cities are numbered 1, 2, 3…n. Assuming that there are m ants, the meaning of the symbol in the algorithm is shown in Table 1.

At the beginning of solving the TSP problem, firstly, m ants are randomly placed in a different cities, and m initial cities are put into the search tabu list $tabu_k$. We calculate the probability $P_{i,j}^{k}(t)$ of ants being transferred from the current city to all the cities in non search tabu list. The city with the largest probability value will become the next destination city, and continue to update the search tabu list $tabu_k$. $P_{i,j}^{k}(t)$ indicate the probability of the k-th ant being transferred from node i to node j at the moment of t, and the specific expression is shown as (1).

$$P_{i,j}^{k}(t) = \begin{cases} \dfrac{\left[\tau_{i,j}(t)\right]^{\alpha}\left[\eta_{i,j}(t)\right]^{\beta}}{\sum\left[\tau_{i,s}(t)\right]^{\alpha}\left[\eta_{i,s}(t)\right]^{\beta}}, \ j \notin tabu_k \\ s \subset No, \ -\text{Visited} \\ 0, \ j \in tabu_k \end{cases} \tag{1}$$

We can see from Table 1 that, $\tau_{i,j}(t)$ suggests the information pheromone concentration from the city i to the city j. It is a key factor for probability decision when the ant chooses the path. Nowadays, there are three main calculation methods of pheromone updating, namely, ant density model, ant quantity model and ant perimeter model [5]. Three models are basically the same in the update method, and the main difference lies in the renewal mode of the pheromone. Ant density model and ant quantity model make continuous pheromone update in the process of find the optimal path, which has the continuity of time. That is, when the ants walk an edge, i.e. from one node to another node, the synchronous

Table 1 Symbolic meaning table of ant colony algorithm in TSP problem

Symbol	Meaning
$d_{i,j}$	Represents the distance between city i and city j
$\tau_{i,j}(t)$	Represents the pheromone concentration left between cities i, j at time t
$\eta_{i,j}$	The expected value of city i to city j is also called the visibility function
α	Information heuristic factor, reflect the role of pheromone path in the path selection
β	The heuristic factor of expectation value reflects the extent to which the expectation value plays a role in path selection
ρ	Which indicates the degree of pheromone volatilization in the path, ranging from [0, 1]
$tabu_k$	Search tabu list, said k (k = 1,2, …, m) only the ants have visited the city
$P_{i,j}^{k}(t)$	The probability of the kth ant moving from city i to city j at time t

update process of the pheromone is conducted for the path in accordance with the ant density model and ant quantity model. It uses a partial update mode, and ant cycle model is the overall pheromone update of each edge when all the ants walk all the cities, which is a global pheromone update method. In addition, the concentration of pheromone left on the path between the three is also slightly different. For ant density model, the quantity of pheromone released on the path of ants is a constant Q. While the pheromone released in the routing search process of ant quantity model is Q/dij, in which Q represents the total pheromone released in ant routing search process, which is constant [6]. The holistic updating methods of three pheromone are shown as (2) and (3), and the concentration of pheromone released by ants in the ant perimeter model is as shown in (4).

$$\tau_{i,j}(t+n) = (1-\rho)\tau_{i,j}(t) + \Delta\tau_{i,j}(t) \tag{2}$$

$$\Delta\tau_{i,j}(t) = \sum_{k=1}^{m} \Delta\tau_{i,j}^{k}(t) \tag{3}$$

$$\Delta\tau_{i,j}^{k}(t)\begin{cases} Q/L_k & \text{The pheromone released by ants at time t} \\ 0, & \textit{otherwise} \end{cases} \tag{4}$$

Table 1 shows that, ρ refers to the volatile degree of pheromone in the path, range of [0,1], and $\Delta\tau_{i,j}^{k}(t)$ represents the concentration of pheromone left between cities i and j by the k-th ant. Q indicates the total amount of pheromone released by the ant during the whole path optimization, and L_k suggests the line length of the ant in the entire process of the current iteration. In the research of ant colony algorithm, the ant circle model is used to update pheromone, which is more common. Its operation process is more simple, the computation in the process of operation will be further simplified, and the effect will be better. To sum up, in this paper, ant colony algorithm is applied to solve the logistics terminal distribution routing optimization problem. The ant circle model such kind of global pheromone updating rule is adopted to update pheromone in ant routing process [7].

4 Solution of the Optimal Path of Logistics Terminal Distribution Based On Ant Colony Algorithm

4.1 Principle of Logistics Terminal Path Choice

Through the questionnaire, a total of 120 copies of questionnaires are issued to the courier and takeaway delivery personnel, and 100 valid questionnaires recovered are analyzed. There are 82% couriers, in the logistics terminal distribution process, in the selection of distribution nodes, tend to choose the distribution point closest to the distribution point where it locates for the one step distribution. Especially for the young couriers, who are unfamiliar to the route, are easy to make such a choice. Among them, the factors influencing the path, the path length, road capacity, path quality, traffic flow, road slope, weather factors, vehicle speed, and vehicle tail number limit, path length, road capacity, traffic flow, and road slope these factors are ranked in the top four. What selected by more than 74% of the couriers are the important factors needed to be considered in the process of path selection, far more than the influence degree of other factors. The concept of path length is easy to understand, namely the total length of each section of the candidate path. But due to the rugged road, the low road capacity and the congestion problems, in the distribution, they may use more cost and more time to complete the delivery. The path capacity is an important factor of congestion. Path capacity refers to the number of vehicles contained in the sections in the path, which can be understood as the number of lanes in our daily life. For instance, the sections in the path A are basically two-lane path, and sections in path B are mostly four-lane path. Then, the path capacity of path B is greater than that of path A. In the case of other conditions basically the same, we should try to choose the path with the highest capacity. Traffic flow is also an important factor of congestion. When the path is chosen and other conditions are almost the same, we are more willing to choose the path with small traffic volume. At this time, our terminal delivery process will be more smooth. The road slope is also an important influencing factor in the path selection, and slope road will affect our travel speed. As a result, in the road, we will be more careful, and more cost will be consumed than that in the flat road. In the same candidate paths under other conditions, we tend to choose a relatively flat path.

Through the above analysis, we should give full consideration to the factors, such as the path length, road capacity, traffic volume and road slope in the logistics terminal distribution route optimization. Only in this way can we really find a more reasonable delivery route. Therefore, when we use ant colony algorithm to solve the logistics terminal distribution optimal path, we will comprehensively consider the above four factors. For the path length, road capacity, and traffic flow, we will use the analytic hierarchy process (AHP) method to set the weight and translate them into the flat road length. Moreover, road capacity and traffic flow are the two major indexes of road congestion. In addition, we consider the road slope factor by transforming the slope road to the flat road. These factors and distribution waiting time are added to the expectation factor selected by probability in the ant path selection, which influences the choice of the path. And eventually, we find a more highly-qualified and reasonable distribution route.

4.2 Basic Implementation Steps for Solving the Optimal Path of Logistics Terminal Distribution

Initialize the parameters, such as m, n, α, β and cyclic parameter NC and so on, and set the initial pheromone concentration C (C is a constant);

Randomly place M ants at n distribution points, and write each ant's starting point to the ant's search tabu table;

Then, ants select the next distribution point j according to the probability formula and puts j into their own tabu table;

If an ant's taboo list is full, then the ant has completed the entire path. We preserve the ant's searching path and update the pheromone for the ant's searching path in accordance with the pheromone update model;

If the number of cycles NC does not meet the end condition, then $NC = NC + 1$. Otherwise, the optimal path is output. The specific algorithm flow of the process is shown in Fig. 2.

4.3 Weight Analysis of Influence Factors of Terminal Distribution Based on AHP

Analytic hierarchy process (AHP) classifies all factors that influence research questions, determines the relationship between factors, and constructs a set of multi-level influence factors structure models. The model is divided into target class, rule class and program class, and then the weight of each influence factor on the final target is obtained. The

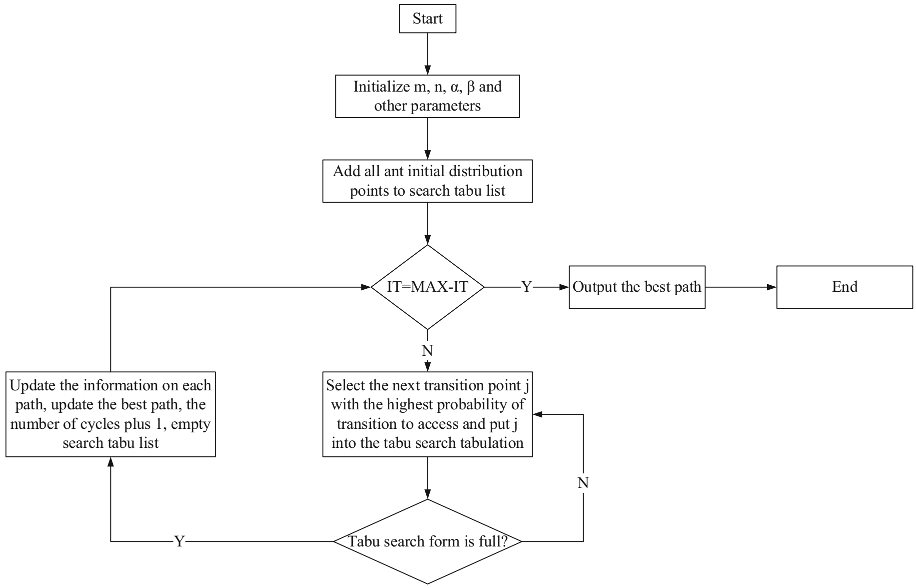

Fig. 2 Ant colony algorithm flow chart

weight of the selected plan for the evaluation criteria and the final goal is obtained, and finally, the selection result of the alternatives is determined. This paper divides the structure model into two layers: the target layer A and the standard layer B. The weight of the distribution path of the target layer is $W_{i,j}$, and the corresponding weights of the standard layer relative to the target layer are w_1, w_2, and w_3, respectively, as shown in Fig. 3.

The data in the judgment matrix derives from the comparison result of the importance between the elements of the standard layer. The scale of its importance is shown in Table 2.

The judgement matrix is determined by questionnaire, and the 5-scale survey is made to compare the importance of elements. The issued objects are mainly for the courier and the driver, a total of 100 questionnaires are issued, and 87 valid questionnaires are analyzed. The constructed judgement matrix as shown in Table 3.

The weight of standard layer will be solved by eigenvalue method. The specific method is: $BW = \lambda_{max}W$, where λ_{max} is the largest eigenvalue of matrix B, and W is the feature

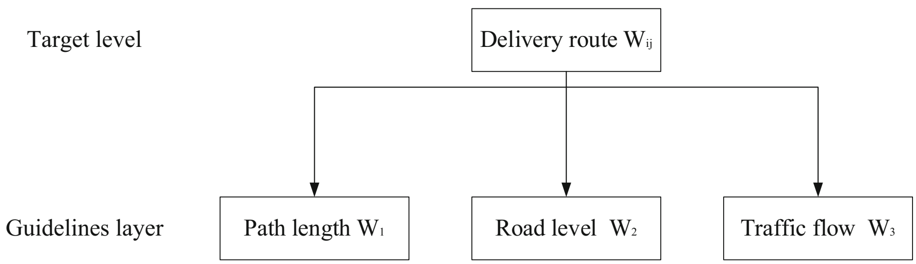

Fig. 3 Optimal path weight hierarchy diagram

Table 2 Importance scale

Importance scale	Meaning
1	That two elements are equally important
2	Said the two elements of comparison, the former slightly more important than the latter
3	Said the two elements of comparison, the former is more important than the latter
4	Said the two elements of comparison, the former is more important than the latter
5	Said the two elements of comparison, the former is extremely important than the latter
Fraction	If the ratio of the importance of element i to element j is a_{ij}, the ratio of element j to element i is $a_{ji} = 1/a_{ij}$

Table 3 Judgment matrix

Z	B_1	B_2	B_3
B_1	1	4	3
B_2	1/4	1	1
B_3	1/3	1	1

vector corresponding to the largest eigenvalue. The standard layer weight will eventually be obtained through normalization processing [8]. We calculate the eigenvalues and feature vectors of the judgement matrix based on the MATLAB function [x,y] = eig(B). The computation results show that the maximum eigenvalue is 3.0092, and the corresponding feature vector is (0.92550.25470.2803).

The consistency test is carried out, and the test standard is: CR = CI/RI. Among them, CR is a conformance ratio. When its value is less than 0.1, the judgment matrix passes the consistency test; otherwise, it needs to be corrected. $CI = (\lambda_{max} - n)/(n - 1)$ and RI is the average random consistency index, determined by the order of the judgement matrix. From Table 4, we can see that when n = 3, RI = 0.52; eventually, we calculate CR = 0.01769, and the judgement matrix passes the consistency test.

After normalization of the feature vector (0.92550.25470.2803) corresponding to the maximum eigenvalue, the feature vector is (0.63370.17440.1919). Therefore, the weight of the standard layer is $w_1 = 0.63$, $w_2 = 0.18$, and $w_3 = 0.19$.

Through the above analysis, after we obtain the weight of each factor in the standard layer, we calculate the weight of each path of the distribution network. With the actual path length as the base, through the weight relationship between path length, road capacity and traffic flow, we quantify the weight of road capacity and traffic flow (unit: m). The distribution path weight can be seen as the dynamic path length of each path in the whole distribution network. The length more than the actual distance can be seen as congestion degree w (unit: m), and the related formula is shown in (5):

Table 4 Average Random Conformance Index RI table

Matrix order	1	2	3	4	5	6	7	8
RI	0	0	0.52	0.89	1.12	1.26	1.36	1.41

$$W_{i,j} = s + s * n(w_2/w_1 + w_3/w_1)/m$$
$$w = s * n(w_2/w_1 + w_3/w_1)/m \tag{5}$$

In the above formula, w_1, w_2, and w_3 are the weights of each factor for the target layer in the standard layer. w_2/w_1 suggests the ratio of road capacity weight to path length weight, and w_3/w_1 indicates the ratio of the traffic flow weight to the path length weight. w_2/w_1 and w_3/w_1 are used as parameters of path length quantization of road capacity and weight of traffic flow. s indicates the path length of the path to be optimized, and m represents the road capacity. In accordance with the road traffic, road capacity and other indicators, it is divided into 5 levels from high to low (0.2, 0.4, 0.6, 0.8, and 1). According to the number of the car or the road width, we determine the grade value. n refers to the traffic flow, and combined with Baidu's real-time congestion, we predict and determined the value of the traffic flow, range of (0,1). w represents the road congestion degree (with path length quantifying the road capacity and traffic value). In addition, it is known from the above analysis that, $w_1 = 0.63$, $w_2 = 0.18$, and $w_3 = 0.19$.

4.4 Optimization of Logistics Terminal Distribution Path

In the process of the logistics terminal distribution path optimization, following the path (time) optimal principle, the slope road and congestion factors in the distribution path are considered. Because it will affect the progress of the entire distribution process, this paper mainly adopts the way of turning to the flat road to consider various kinds of influence factors, so as to improve the fine degree in the model calculation process and improve the path optimization effect. As a result, the whole logistics distribution terminal can deliver the goods within the time estimated by consumers or courier company, to improve customer satisfaction.

In the traveling salesman problem, the distance between distribution nodes use the Euclidean distance to represent. Because the route of logistics terminal distribution is not a simple line between two points, but the twists and turns. The distance between two distribution points cannot simply calculated by using the absolute distance between the coordinates. In the research of the logistics terminal distribution, the coordinates of each distribution point in a two dimensional plane just suggests the location information between the various distribution points. For the distance between each distribution node in the optimization of logistics terminal distribution route, we represent it through the path length between the distribution points. And because of the consideration of influence factors, in the path optimization process, we can use the specific influence factor turning to flat road to realize the transformation of slope road length to flat road length in the distribution process. And in the process of ant colony optimization path, the flat road length transformed is added to the expected value factor.

In the process of slope road turning to flat road, we mainly follow the consumption energy reciprocity principle. In the terminal distribution process, the slope road in a certain length is transformed into the flat road consuming the same energy. For example, there is a 30 m slope road consumption energy equivalent to a 60 m road consumption energy, then we will regard the 30 m slope road as a 60 m flat road. In the model construction, it will display the slope road in the form of flat road, to realize the process of transforming slope to flat.

The way to transform slope road to the flat road is: $Mgh_{\text{height difference}} = \mu Mgl_{\text{flat}}$. μ refers to the coefficient of friction with the ground, M = the weight of courier + the total weight of vehicles and goods, L_{flat} refers to the length of slope road turning to flat road in the distribution process, and $h_{height\ difference}$ indicates the altitude height overcome in the distribution process. We use ant colony algorithm to optimize the path in the logistics terminal distribution process. The basic process is similar to the traveling salesman problem. m ants are randomly put into each distribution point, and put into the tabu search list. Except for the nodes in the tabu list $tabu_k$ having been visited, when each ant moves to the new node, according to (1) in chapter 3, $\eta_{i,j}^{k}(t)$ in the formula suggests the expected value for the city i transferred to the city j, also known as the visibility function. Its expression i shown in (6):

$$\eta_{i,j}^{k}(1) = \frac{1}{d_{i,j}} \tag{6}$$

In the above formula, $d_{i,j}$ represents the distance between node i and node j after considering waiting time, slope and congestion degree, and their expression is $d_{i,j} = s + L_{flat} + w$.

In (6), s indicates the path length between the distribution point i to point j, L_{flat} refers to the path length after considering the slope, and w represents the flat road length of congestion degree (considering the road capacity and traffic flow factors).

In the terminal logistics distribution process, there will be some external factors that affect the efficiency of delivery. This article will mainly consider the slope road and congestion situation. We will add the slope road and congestion to the consideration factor of the path optimization, and optimize the path.

According to the slope road in the distribution process, we mainly consider through the way of turning slope road into flat road.

Congestion degree (considering the road capacity and traffic flow of logistics terminal distribution), through the formula, we obtain the length w after the congestion degree transforms to the flat road.

In the logistics terminal distribution, according to the probability in (1), we conduct the distribution. When all ants visit all the cities, we update the information on each path, and mainly use the ant cycle model. The update method and way of pheromone are shown in (2), (3), and (4) in chapter 3 in this paper.

In a word, in the logistics distribution path optimization process, the road slope and the congestion degree are considered. Through the principle of energy consumption reciprocity, a section of slope road is transformed into the flat road in a certain length. Through the analytic hierarchy process, the congestion related factors are transformed into the corresponding path lengths, and then ant colony algorithm is applied to optimize the path of the total length of the road after transformation.

5 Simulation Verification and Result Analysis

5.1 MATLAB Simulation Analogue

Through the way of map search and field visits, we comprehensively consider the physical route distance and road condition between the distribution points in the area. In addition, we collect and draw the geographic information around the A area, select the 7 virtual distribution points, and do the related research work in this paper.

According to the collected data and information, we summarize and abstract the geographic information in the area. We also use the software PS to extract the key points of

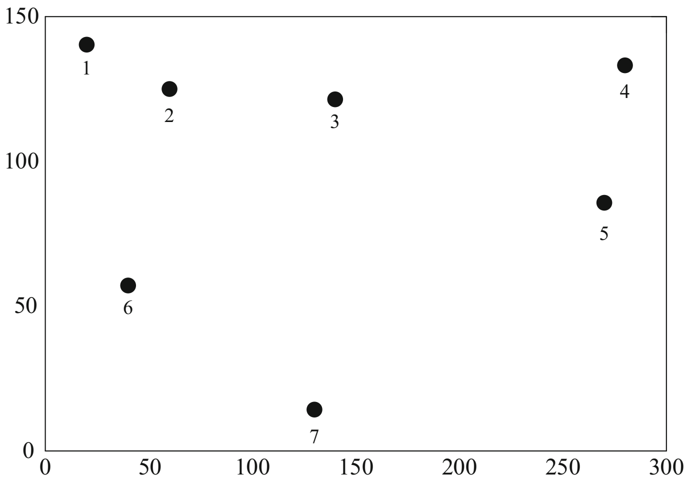

Fig. 4 The virtual distribution point coordinates

distribution, and form a simplified diagram, as shown in Fig. 4. Due to the complexity of geographical coordinates, this research adopts the self coordinate system, to reflect the relative position information of each distribution point. And the various distribution points are numbered. According to the way from the left to the right and from top to bottom, they are numbered as 1, 2, 3….

The simulation software used in the simulation process is MATLAB, and the version is MATLAB7.11.0 (R2010b). The simulation of logistics terminal distribution is conducted on 7 virtual distribution points around A area. The experimental data are derived from the collected and processed information around A area.

The parameter setting in the algorithm is shown in Table 5.

m represents the number of ants, and the setting of m has a great impact on the MATLAB simulation results. Through literature research and extensive simulation results, it is shown that when the number of ants is 0.6 to 0.9 times the number of nodes, the simulation effect is better. In this paper, the number of nodes when using ant colony algorithm is 7, so the number of artificial ants is set to 6.

n refers to the number of nodes. The number of nodes is the number of distribution nodes in the experimental data, $n = 7$.

α is a pheromone heuristic factor. It expresses the influence of the pheromone released by the ant on the path selection of ants during the path finding. Through literature study, it is known that the effect is better when α takes 0–5, and this article takes $\alpha = 1$.

β suggests the expected value heuristic factor. It shows the role degree of expectation in path selection. The greater the β value is, the easier it is to fall into the local optimal solution. The smaller the β value is, the less the role of expected value is, and the more difficult it finds the optimal solution. According to the experimental analysis, the effect is better when the β value is selected between 0–5, and $\beta = 2$ is selected here.

C represents the initial pheromone concentration on every line in distribution network. In order to make every ant have the same probability when taking different paths, so we set the same value for each line's initial pheromone concentration and set $C = 0.1$.

Q denotes the amount of information each ant carries. After research in the literature, Q usually takes the values between $10 \sim 10{,}000$, and for the small scale path optimization

Table 5 Ant colony algorithm parameter setting table

Parameter	m	n	α	β	C	Q	ρ	NC-MAX
Value	6	7	1	2	0.1	100	0.1	50

Table 6 Route length between each distribution point

Serial number	1	2	3	4	5	6	7
1	0	557	729	1298	1346	730	816
2	557	0	196	1095	1148	543	636
3	729	196	0	1298	971	391	475
4	1298	1095	1298	0	181	1299	507
5	1346	1148	971	181	0	1249	493
6	730	543	391	1299	1249	0	558
7	816	636	475	507	493	558	0

problem, when Q takes 100, the algorithm has a better optimization effect. The number of nodes in the simulation experiment is 7 and the number of path bars is 21. It belongs to a small scale problem, and Q = 100 is taken here.

ρ means the pheromone evaporation coefficient after every time loop is completed.

NC-MAX represents the terminating condition and the maximum cycle times.

The route length between the distribution points in Table 6 is input into the MATLAB ant colony algorithm program. After running, the simulation diagram of the route length optimal route between the distribution points is shown in Fig. 5.

The dynamic length between each distribution point in Table 7 is input into the program of MATLAB ant colony algorithm, and the simulation diagram of the dynamic length optimal path under the influence of multiple elements between the distribution points (considering the path length of slope road and congestion) is obtained, as shown in Fig. 6.

5.2 Result Analysis

From the operational results of MATLAB, we can see that the 7 virtual distribution points around the area A, with 5 points for the distribution center, without considering the slope, the physical distance between the 7 points distribution is input to the MATLAB. After the optimization processing of ant colony algorithm, we obtain the optimal path of 5–4–1–2–3–6–7–5, and the route length is 3674 m. The optimal path refers to the final distance considering the slope and the congestion of distribution points, and calculates the dynamic length of the whole distribution (considering the length of the slope and the congestion) as 4934 m.

In the courier delivery process, if goods are delivered only by intuition and experience, especially for the novice courier, after they arrive at a distribution point, for the choice of the next distribution point, in most cases, they will consider the point closest to the current distribution point for the distribution services. If they have an objective judgment for the distance of the distribution point, the physical distance between each distribution point in Table 6 can be regarded as an objective judgment of a courier for the distance between the distribution points. In accordance with the principle of searching the shortest point, the courier delivers starting from the distribution point 5. We can see from Table 6 that, from

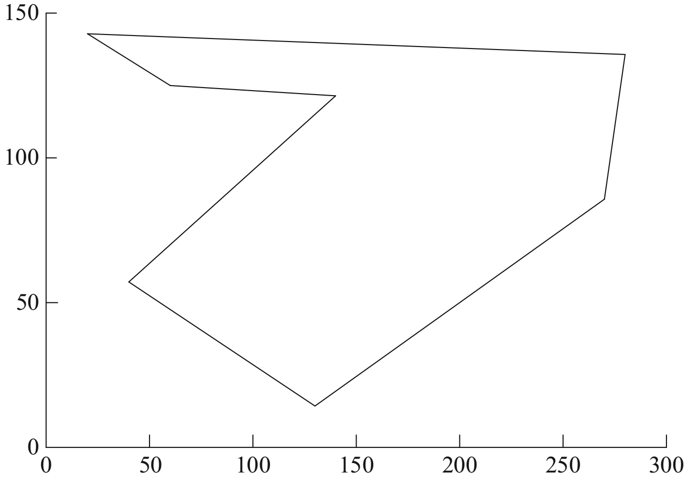

Fig. 5 The route length between the distribution point of the best path simulation diagram

Table 7 Route length between each distribution point

Serial number	1	2	3	4	5	6	7
1	0	850	1147	1428	1571	959	912
2	857	0	298	1621	1705	736	1012
3	1153	304	0	1721	1588	598	587
4	1432	1626	1689	0	298	1789	819
5	1575	1709	1549	286	0	1910	601
6	962	739	592	1819	1947	0	869
7	914	991	579	839	633	858	0

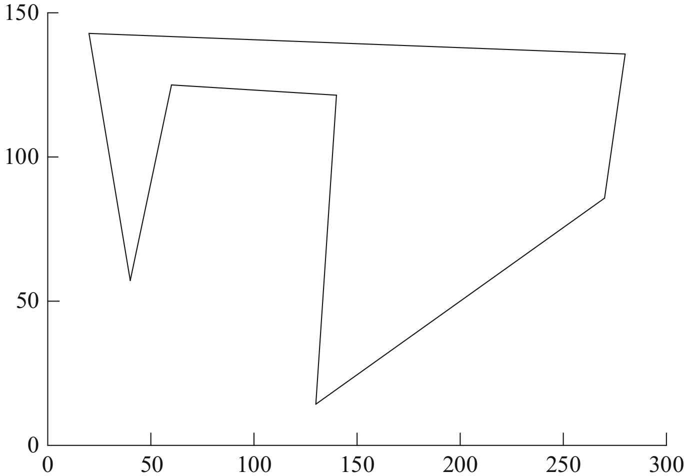

Fig. 6 The optimal path simulation diagram of dynamic length under the influence of multiple elements between distribution points

distribution point 5 to distribution point 4, the shortest distance is 181 m. When he arrives at the distribution point 4, after excluding the distribution point have been sent, he can search the distribution point closest to the distribution point 4 for delivery. According to the rules, we can determine the next distribution point 7. In turn, through this rule, the courier can find 5–4–7–3–2–6–1–5 this experience distribution path. Referring to the physical distance between the distribution point in Table 6, the route length of entire distribution is 3978 m. The comparison with the optimization path of ant colony is shown in Fig. 7. From Fig. 7, we can see that, relative to the experiential path, the distribution path of ant colony algorithm can save 304 m on route length, which validates the effectiveness of ant colony algorithm in path optimization. In addition, in accordance with Table 7, the dynamic length table, considering the slope and congestion between the distribution points, the dynamic distance of the whole distribution is 5269 m.

According to the data in Table 7, the length values under corresponding dynamic conditions between 7 distribution points are input to MATLAB. After the optimization processing of ant colony algorithm, the optimal path 5–7–3–2–6–1–4–5 is obtained, and the total length of the distribution route is 5081 m.

To sum up, under the static condition that does not consider the influence of other factors, the experience route of the courier is: 5–4–7–3–2–6–1–5. The optimal route after the optimization of ant colony path is: 5–4–1–2–3–6–7–5. Under the dynamic conditions considering the slope and congestion, the optimal route after the optimization of ant colony path is: 5–7–3–2–6–1–4. According to the data in Table 7, the path dynamic lengths of the three lines (refer to Table 7) is 5269, 4934, and 4895 m, respectively. As shown in Fig. 8, 1 represents the dynamic length of experience route, 2 represents the dynamic length of ant colony optimization under static condition without considering slope and congestion, and 3 represents the dynamic length of ant colony optimization under the dynamic conditions considering slope and traffic congestion, referring to Table 7).

From Fig. 8, we can clearly see that, in the case of considering the slope and congestion, the path is obtained through the ant colony algorithm calculation. The cost in the whole process of distribution is the lowest, and the time is the shortest, and case 3, compare with case 2, saves 39 m dynamic path length. It suggests that when we use the ant colony

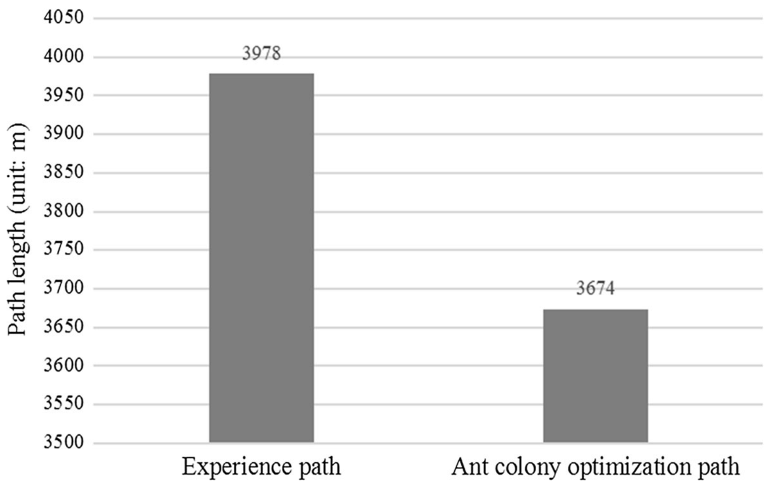

Fig. 7 Comparison chart of end-delivery experience path and ant colony optimization path length

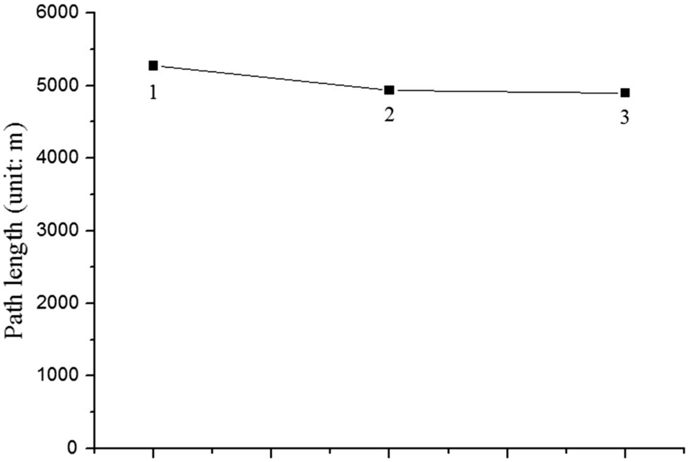

Fig. 8 Three cases of delivery path length comparison chart

algorithm for the path optimization, by considering the slope and congestion, we can save the dynamic path cost. At the same time, case 3, compared with case 1, saves 5269–4895 = 374 dynamic length cost. It shows that the route after ant colony algorithm optimization, compared with experience route, can save 374 m dynamic length cost, saving cost ratio up to 7.1%. Therefore, in the case of considering the waiting time, the slope and the congestion situation, the path optimization processing is conducted for the logistics terminal distribution process by ant colony algorithm. In this way, we can save more cost and improve the distribution efficiency. Then, we can apply ant algorithm in the information process of the logistics terminal distribution path optimization. In addition, we adopt the information technology to serve the logistics terminal distribution, so as to provide customers with more highly-qualified and efficient delivery service and to increase customer satisfaction.

6 Conclusion

The logistics terminal distribution, as the "last mile" of the logistics link, whether the delivery service model is appropriate or whether the efficiency of delivery can meet customer expectations, will directly affect the consumers' satisfaction for the entire online shopping activities. And it has become an important factor affecting the rapid development of electronic commerce. Through the analysis of the successful case (TSP) of ant colony algorithm, the basic principle and the implementation process of the ant colony algorithm are expounded. In the process of path optimization, slope and congestion are considered, and the MATLAB experiment simulation is carried out on the logistics terminal distribution path optimization algorithm. With map search and field visits research methods, we comprehensively consider the physical route distance and road condition between each distribution point in the area. Moreover, we collect and draw the geographic information around the area A. We select 7 virtual distribution points, and choose some key parameters of ant colony algorithm. MATLAB simulation is carried out on optimization of e-commerce logistics terminal distribution path based on ant colony algorithm with specific examples, which verifies the feasibility and scientific nature.

Acknowledgements The authors acknowledge "Basic Tasks of Technical forecasting" commissioned by CASTED, College Scientific Research Project of China University of Political Science and Law (Grant No. 17ZFG63001), Training and Supporting Project for Young or Middle-aged Teachers of China University of Political Science and Law, and NSF of China (Grant No. L1422009).

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