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CROSS-BORDER E-COMMERCE LOGISTICS OPTIMIZATION ALGORITHM FOR COLLABORATION BETWEEN THE INTERNET OF THINGS AND LOGISTICS

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Abstract. This paper proposes the shortest path optimization algorithm for domestic and overseas e-commerce logistics based on a bilateral search method. This paper uses the logistics distribution route optimization algorithm based on the shortest path to set the collaborative parameters. Then, it builds an adaptive optimization model for the grid planning of domestic and overseas e-commerce logistics path. The route is optimized. Then, the PSO and genetic algorithm are integrated to establish the logistics path planning model of domestic and overseas e-commerce. The superiority of the proposed route optimization algorithm in domestic and overseas e-commerce logistics distribution is verified through simulation experiments. This algorithm has high spatial positioning efficiency and high transportation efficiency.

Key words: Internet of Things; Bilateral search method; Logistics collaboration; Domestic and overseas e-commerce; Transport route; Path planning algorithm

1. Introduction. With the rapid development of domestic and overseas e-commerce, consumers have an increasingly high demand for e-commerce at both the economic and real-time levels. Whether goods can be delivered to users on time and economically is essential for consumers to obtain satisfaction. Under the premise of meeting customer needs, delivering goods to the specific location required by customers with the lowest cost and shortest time has been the essential requirement of transnational e-commerce business. Logistics distribution has higher cost efficiency and better real-time performance. Customers want to know the status of their goods in real-time with minimal cost. At the same time, the customer expects the goods to be delivered within the expected delivery time. How to meet the customer's time demand for products to reduce the logistics and distribution costs is an essential topic in the current international research. But the cost of international trade is also increasing, making it difficult for e-commerce companies to bring high-quality services to customers. With the deepening of domestic and overseas e-commerce business and the broad application of the Internet, a diversified global logistics system has developed rapidly. This has led to diverse options for how goods move around the world. Currently, China is in a dilemma of mutual penetration of domestic and overseas e-commerce and logistics, and it is urgent to find countermeasures and optimization ways for their mutual integration and mutual development.

Literature [1] studies the cooperation decision of domestic and overseas e-commerce and transnational logistics enterprises. However, there is no in-depth research on how to improve customer satisfaction. Literature [2] analyzes the growth process of international trade and cross-border business from the supply chain perspective. Then, based on the "alienation law," this paper discusses how to enhance the competitiveness and profitability of transnational e-commerce enterprises. However, this method does not establish the relevant mathematical model or have the relevant mathematical theory support. Literature [3] takes refrigerated container transportation as the research object and establishes a mathematical modeling method for the comprehensive cost minimization of cold chain logistics to minimize freezing, transportation and transit costs. The path planning is solved as a parameter. It is calculated that there are differences in the optimal routes between cold storage and conventional containers under different conditions. However, optimizing the optimal route is not included because of the cost. This results in the inefficiency of the whole system. From shipper route selection, literature [4] established freight organization optimization methods in the port area of the upper reaches of the Yangtze

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River. However, this distribution route optimization method is based on a genetic algorithm. Its poor adaptive optimization ability leads to poor effect of transportation path planning. Therefore, this paper proposes the bilateral search method for domestic and overseas e-commerce logistics route planning. Firstly, the path characteristics of transnational e-commerce logistics are optimized using path information clustering. The model is solved by particle swarm optimization [5]. The simulation results are verified and analyzed. The simulation results show that this method can effectively improve the traffic route planning ability of transnational e-commerce systems.

2. Design of domestic and overseas e-commerce logistics management system . This paper builds a domestic and overseas e-commerce logistics service system under the mobile Internet [6]. The aim is to effectively control and monitor it through the mobile Internet to achieve satisfactory information management.

2.1. Domestic and overseas e-commerce integrated service architecture . The overall structure of the domestic and overseas e-commerce logistics service system based on the mobile Internet can be divided into a logistics monitoring system, mobile Internet system and mobile user terminal system. Its core is to use B/S architecture to manage each module [7]. The monitoring center of the logistics service system is mainly composed of the database, GPS server, mobile communication server, etc. It can monitor and collect each networked mobile terminal in real-time and pass the corresponding information to logistics transportation and distribution employees. At the same time, it can also pass the instant message of the logistics business to the management so that all aspects of the logistics activity become an organism. Mobile communication network uses radio as a data transmission medium to build a bridge between the monitoring center and mobile phone users. Due to the continuous development of domestic mobile communication technology, the 5G communication network has been quite popular [8]. The distance used and the speed of transmission have been greatly improved. The wireless network can provide stable and reliable transmission service for the logistics support system. Mobile terminal equipment is also a critical link in the logistics service system. Most mobile phones and tablet computers currently have GPS positioning and wireless networking functions. It can collect and transmit logistical information.

2.2. Functions of domestic and overseas e-commerce logistics service system. Figure 2.1 shows the functional architecture of the domestic and overseas e-commerce logistics service system. The system collects the task order, scans the items, sends and signs for receipt, and deals with anomalies and service statistics [9]. The task command extraction function is to transmit the distribution information to the mobile phone operation platform through the mobile phone network to improve employees' work efficiency. The function of item scanning is to encode and scan the item so that the item corresponds to the number one by one. The scanned data is transmitted to the monitoring center, which is convenient for managers to search and deploy. The delivery signature of the Courier company is to facilitate the inspection of the cargo information between the Courier and the recipient. Abnormal processing refers to various abnormal conditions (such as loss and damage to items) that occur in the logistics process and are stored in the system's database [10]. The business statistics function can calculate transport-related business information in the logistics process, such as the number of delivery employees, transportation plans, etc. Logistics supervision and operation systems are essential data management functions, logistics distribution management functions, distribution management functions, and operation report database management functions [11]. Database management realizes the functions of customer information management, goods distribution management, transportation route planning, logistics information collection and statistics. Among them, the logistics distribution monitoring system can realize the functions of GPS position and navigation for the mobile terminal equipment and collect and upload relevant information, such as the traffic status and route of the goods, in real time. This is convenient for operators and customers to inquire. Enterprise report database management realizes the summary of various types of reports of various types of enterprises and stores them in a dedicated database.

The mobile Internet module uses mobile phone communication technology. It can interact with the Internet and has a wide range of uses. It can achieve seamless connections in fast motion [12]. At present, the main communication networks, such as 4G and 5G, are relatively mature, which can ensure the efficient and stable data transmission of mobile terminals. It has laid the foundation for upgrading and transforming China's domestic and overseas e-commerce logistics management system.

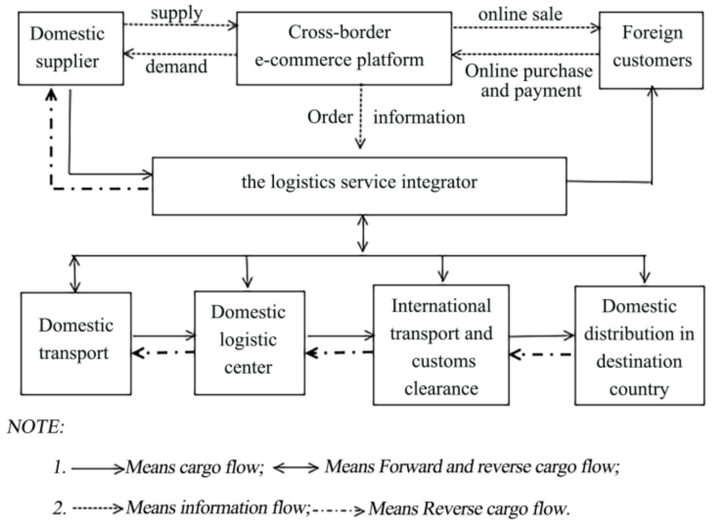

Fig. 2.1: *Functional architecture of domestic and overseas e-commerce logistics service system.*

A modern logistics management mode system based on mobile Internet is proposed. It gives full play to the advantages of mobile Internet, real-time collection and processing of logistics information, which is helpful to alleviate the problem of poor real-time logistics information in our country [13]. It points out a new way for the informatization development of our logistics industry to enhance the core competitiveness of our logistics enterprises.

3. Grid division and feature matching of e-commerce logistics distribution routes.

3.1. Rasterization of traffic routes . The optimization method of domestic and overseas e-commerce logistics distribution routes based on linear programming is established.

$$\min K = \sum_{m=1}^{M}\sum_{i=1}^{l} u_{i,i+1}^{m} K_{i,i+1}^{m} + \sum_{m=1}^{M}\sum_{n=1}^{M}\sum_{i=1}^{l} f_i^{m,n} K_i^{m,n}$$
$$\min Z = \sum_{m=1}^{M}\sum_{i=1}^{l} u_{i,i+1}^{m} Z_{i,i+1}^{m} + \sum_{m=1}^{M}\sum_{n=1}^{M}\sum_{i=1}^{l} f_i^{m,n} Z_i^{m,n}$$

K represents the total time spent in the entire delivery process. Z is the total expense. $u_{i,i+1}^{m}, f_i^{m,n}$ is the determining variable. $u_{i,i+1}^{m} = 1$ is the choice of the transport mode of m between i and $i+1.f_i^{m,n} = 1$ is the transport mode from node i mode m to another transport mode $n.l = (l_i)$ is the transport mode, which is the set of alternative paths of all traffic nodes [14]. Where M is the distribution characteristic of the transport vehicle set. From this, the number of global circulation paths of goods in transnational n commerce is obtained. The time and space parameters $N_1,$ L$, N_n$ and $Q_1^{\min},$L$, Q_n^{\min}$ of road flow are obtained by linear fusion of road flow characteristics. An optimization algorithm based on the network topology structure is proposed to obtain the weighted coefficient $S^K = [s_1, S_2,$ L$, S_n]$. The optimal route parameter set of the node is obtained by block-matching the traffic distribution on each node.

$$u_i^m + u_{i+1}^n \geq 2f_i^{mn}$$
$$Z_{i,i+1}^m, Z_i^{mn}, K_{i,i+1}^m, K_i^{mn}, \sigma \geq 0$$

$[0,\sigma]$ is the delivery time limit suggested by the customer. The shortest path optimization method is used to design domestic and overseas e-commerce logistics route parameters [15]. An adaptive optimization model

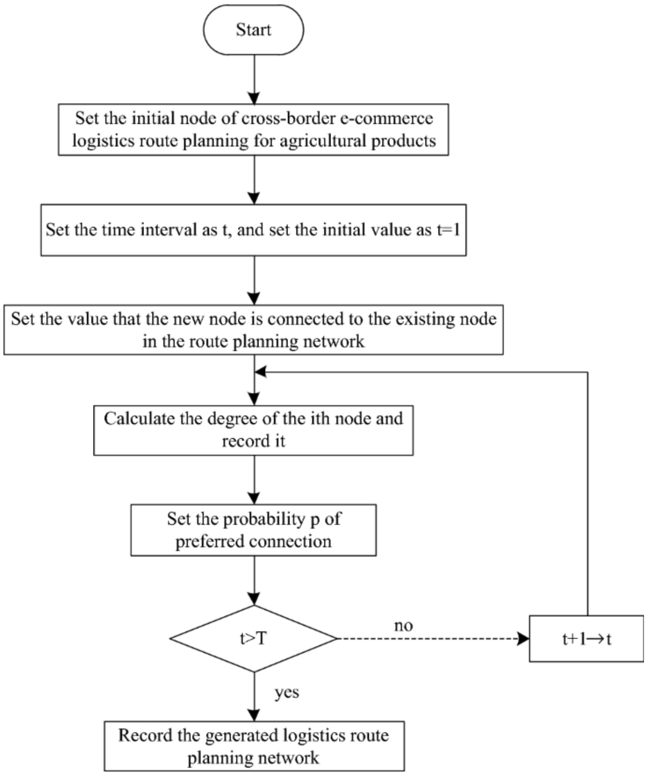

Fig. 3.1: *Grid planning of domestic and overseas e-commerce logistics transportation paths.*

based on a grid is established. The uniform rectangular grid obtained by grid planning of the domestic and overseas e-commerce logistics transportation path is shown in Figure 3.1.

3.2. Transport path feature matching. The path of domestic and overseas e-commerce logistics transportation is optimized using the path information cluster analysis based on raster data. It is assumed that the block characteristic matching matrix of the network node can be expressed as:

$$Q(u) = \begin{pmatrix} \frac{\partial r_1(u)}{\partial u_1} & \mathrm{L} & \frac{\partial r_1(u)}{\partial u_n} \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ \frac{\partial r_M(u)}{\partial u_1} & \mathrm{L} & \frac{\partial r_M(u)}{\partial u_n} \end{pmatrix}$$

$\frac{\partial r_M(u)}{\partial u_n}$ represents the balanced distribution of domestic and overseas ecommerce transport routes in the road network. The quadratic gradient method $\nabla^2 Q(u)$ is used to describe the problem of cargo traffic route planning in domestic and overseas e-commerce [16]. Suppose that the number of nodes E of the associated properties of each path is constant. In state $t < \eta$, the matching of the traffic route characteristics of domestic and overseas e-commerce is expressed as follows:

$$S_i = \int_{1 \leq i \leq E} \frac{1}{r(t) K_{i,j+1}^{m} - d(t) K_i^{mn}} dt Q(u)$$

t is the time of the planned international freight route. $r(t)$ and $d(t)$ represent the volume and density of goods along the transit route of domestic and overseas ecommerce.

4. Dual-path query optimization of goods distribution routes in domestic and overseas e-commerce.

4.1. Dual-path optimization Query. The bidirectional search optimization algorithm is used to realize the shortest route planning of domestic and overseas e-commerce logistics distribution routes [17]. Different road network structures are constructed by optimizing input, output, and intermediate layers. At this time, the compressed output of traffic flow characteristics is expressed as

$$H = \sum_{m=1}^{M} \sum_{n=1}^{M} \sum_{i=1}^{l} u_{i,i+1}^{m} f_i^{m,n} Z_i^{m,n} + \min \sum_{m}^{M} \sum_{i=1}^{l} \left(K_{i,i+1}^{m} - ES_i \right)$$

$M = \{m_1, m_2, \ \mathrm{K}, m_N\}$ is a parameterized distribution scheme for transnational e-commerce distribution routes. N is the metric distance. Where l is the number of routes that goods in domestic and overseas e-commerce travel on the road. Assume that the optimal control is between each solution and the ideal solution. The traffic flow set of the whole road network is built based on the discrete sampling of group n with various traffic flows. The expressions of tensor dimension and output tensor obtained during path optimization are as follows:

$$\phi(i,t) = \sum_{i \in E} \nabla^2 Q(u) H + Z_{i,i+1}^{m} K_{i,i+1}^{m}$$

Node i has n adjacent nodes j. The following fuzzy iterative formula can be obtained by optimizing the cargo transportation routes in transnational e-commerce:

$$S^* = \frac{(z_1 - z_2)\, u_{i,i+1}^{m} - d(t)\delta_i}{K_{i,i+1}^{m} \phi(i,t)}$$

z_1 and z_2 are the learning coefficients of the sections. The optimal logistics transportation path of transnational e-commerce is $(X_1(0), X_2(0), \mathrm{L}, X_N(0))$. The distribution route planning and route allocation of domestic and overseas ecommerce is expressed in the diagonal matrix.

$$G = \begin{pmatrix} u_{i,i+1}^{m} Z_{i,i+1}^{m} & \mathrm{L} & 0 \\ \mathrm{M} & \mathrm{O} & \mathrm{M} \\ 0 & \mathrm{L} & u_{i,i+1}^{m} K_{i,i+1}^{m} \end{pmatrix}$$

The hesitating fuzzy set of intuitive duality is defined as d. The overall control factors of logistics distribution routes of transnational e-commerce based on unaffiliated metrics are proposed. Its expression is:

$$d_i^m = \frac{\bar{d}_i S^*}{\sum_{n=1}^{n} \bar{d}_n}$$

The loading information of node i, which is arranged by domestic and overseas e-commerce logistics and transportation modes at time t, is as follows:

$$\bar{d}_i = \left(\prod_{n=1}^{n} p_{in}^{m} \right)^{\frac{1}{n}}$$

p_{in}^{m} is the hesitation-ambiguity weighting of the intuitive dual. At this time, the formula for optimizing the distribution route of transnational e-commerce logistics can be obtained:

$$D = \sum_{m=1}^{n} G d_i^m \cdot \bar{d}$$

4.2. Path planning optimization model. A feature decomposition algorithm based on non-membership degree is proposed. The transportation path optimization node is $Q_M = (u_M, f_M)$. In this paper, a traffic flow density formula based on the direct dual hesitant fuzzy set model is proposed to solve this problem:

$$g_D(i) = \frac{|M_E Q_M| + |M_R D_i|}{M_D}$$

M_E, M_R and M_D are the number of nodes of international logistics transportation path planning under time conditions E, R and D. Assume that the maximum iteration time is $E_{\max}$ to increase the coverage of the entire network. The current iteration algebra is E_z. Then, an adaptive weight algorithm based on the local ant colony algorithm is proposed.

$$p_{ij}^m = \frac{\sum_{i=1}^n g_D(i) - \sum_{j=1}^n l_{nj}}{2n}$$

A domestic and overseas e-commerce distribution network model based on a spatial planning matrix is proposed. The error measurement parameters obtained in the road vertical coordinate system are:

$$y_i = \sum_{m=1}^{n} \sum_{i \in E} \nabla^2 Q(u) \frac{(z_1 - z_2)\, u_{i,i+1}^m - Z_{i,i+1}^m}{p_{ij}^m}$$

The double hesitation fuzzy unit describes the transport route of goods in domestic and overseas e-commerce.

$$J_i\left(g_i(j)\right) = \int_1^\infty \frac{g_d(i) y_i}{r(t) Z_{i,i+1}^m - d(t) Z_i^{mn}} dt$$

This paper proposes an optimization algorithm based on Hamming distance to optimize the transportation path of domestic and overseas e-commerce logistics. The fuzzy membership function of the traffic route planning problem of transnational ecommerce enterprises is expressed as follows:

$$\kappa = \sum_{m=1}^{M} \sum_{i=1,j=1}^{M} J_i\left(g_i(j)\right) p_{ij}^m$$

The optimization model of transnational e-commerce logistics distribution route based on particle swarm optimization algorithm is proposed:

$$\Phi(u) = \frac{\sqrt{2}\tau \left\| g_i(d) p_{ij}^m \right\| \kappa}{r(t) Z_{i,i+1}^m - d(t) Z_i^{mn}}$$

τ is the route planning method of domestic and overseas e-commerce logistics based on the geographical coordinate system. Where κ is the frequency characterization of freight route allocation of goods in transnational e-commerce.

5. Simulation test analysis. Finally, taking the goods purchased by a customer and the logistics distribution optimization model of the product as an example, the mathematical model and solution method are empirically studied. Table 5.1 shows the information on the goods purchased by this customer. Table 5.2 is the price information table for each logistics company to send the goods to the location specified by the customer. The customer's expected logistics distribution time is 3.5 working days. The ideal distribution of shipping costs is \$1354. In the objective function of logistics distribution optimization, the two weight values $\alpha\beta$ are respectively 0.5.ε is 0.000001 . The algorithm is iterated 100 times, and its optimal effects are listed in Table 5.3 below. The algorithm is optimized in this paper. The shipping cost of this order is \$1250.52. The transportation cycle of the entire cargo is 3.5 days. From the optimal effect, the transportation time of the whole goods is close to the customer's expectation of 3.5 days. But the cost of transporting the entire cargo was much lower than customers expected.

Through the analysis of Figure 5.1, we can see that the model established in this paper can plan the logistics route of transnational e-commerce. The resulting data is shown in Figure 5.2.

Through the analysis of Figure 5.2, we can see that the traffic predicted by the model established in this paper is consistent with the actual traffic. The model established in this paper has good optimization performance and higher accuracy in optimizing and determining domestic and overseas e-commerce logistics distribution routes, and its convergence is shown in Table 5.4. The method proposed in this paper has a good convergence performance for traffic route planning in transnational e-commerce.

Table 5.1: *Commodity information table.*

Product	Quantity	Weight per piece (kg)
1	21	0.10
2	5	6.77
3	13	1.56
4	17	0.52
5	6	8.33
6	8	7.81
7	16	0.52
8	9	1.04
9	3	9.90
10	16	1.82

Table 5.2: *Logistics distribution unit price quotation information table ($).*

Logistics company	m 1kg	1kg m 5kg	5kg m 10kg	Time (d)
1	5.21	9.90	26.56	3.13
2	5.73	10.16	27.86	3.65
3	6.25	10.42	31.25	2.60
4	5.16	9.11	30.21	4.17
5	5.36	10.05	33.33	4.69
6	5.47	9.74	31.51	2.60
7	4.95	11.20	30.99	3.13
8	5.89	9.53	31.25	3.65
9	5.78	10.26	32.29	3.65
10	5.99	10.57	34.38	2.08

Table 5.3: *Results of logistics distribution optimization.*

Product	Logistics distribution company	Logistics distribution cost	Logistics Delivery time (d)
1	2	114.58	3.65
2	1	132.81	3.13
3	1	118.75	3.13
4	9	92.50	3.65
5	1	159.38	3.13
6	5	266.67	4.69
7	10	89.84	2.08
8	5	90.47	4.69
9	2	83.59	3.65
10	5	101.93	4.69

Table 5.4: *Convergence performance test of model path planning.*

Model	Minimum capacity	Maximum capacity	Mean value
ARMA	2.900	6.026	3.633
PC	0.566	2.653	2.024
ANN	2.558	5.783	3.575
MB	3.586	4.571	3.463
ALR	2.580	3.578	2.860
Road network TS	1.502	4.732	3.586

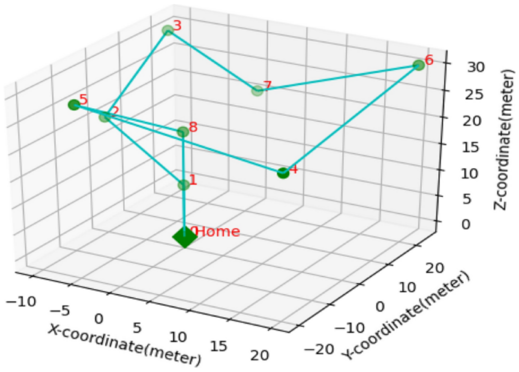

Fig. 5.1: *Optimal path planning results.*

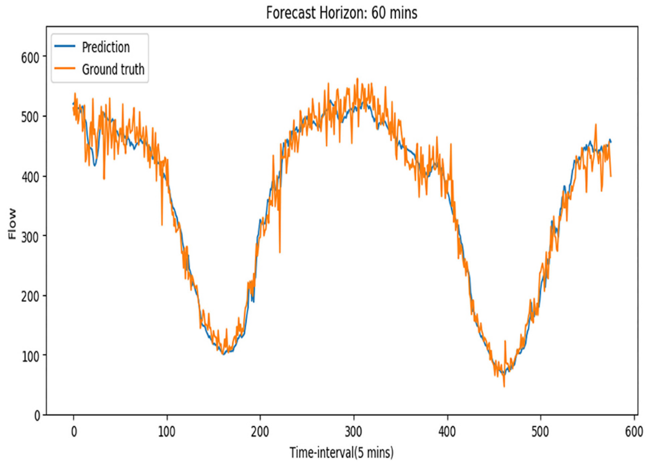

Fig. 5.2: *Forecast results of logistics transportation traffic flow.*

6. Conclusion. This paper first establishes the grid-parameterized model of domestic and overseas e-commerce logistics distribution trajectory. Then this paper analyzes the linear programming of traffic flow data. The shortest path in the domestic and overseas e-commerce logistics transportation path planning is planned. Finally, this paper uses a standardized Hamming distance measurement algorithm to optimize domestic and overseas e-commerce logistics networks. The simulation results show that the method established in this paper has achieved good results in optimization.

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