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Layout Optimization Method of Railway Transportation Route Based on Deep Convolution Neural Network

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Abstract
To improve the railway transportation capacity and maximize the benefits of railway transportation, a method for layout optimization of railway transportation route based on deep convolution neural network is proposed in this study. Considering the transportation cost of railway transportation and other factors, the layout model of railway transportation route is constructed. Based on improved ant colony algorithm, the layout model of railway transportation route was optimized, and multiple candidate railway transportation routes were output. Taking into account external information such as regional information, weather conditions and actual information of railway transportation routes, optimization of the candidate railway transportation routes obtained by the improved ant colony algorithm was performed based on deep convolution neural network, and the optimal railway transportation routes were output, and finally layout optimization of railway transportation routes was realized. The experimental results show that the proposed method can obtain the optimal railway transportation route, the shortest transportation length, and the least transportation time, maximizing the interests of railway transportation enterprises.

Keywords
Ant Colony, Convolutional Neural Network, Layout Optimization, Railway, Transportation, Transportation Route

1. Introduction

With the rapid development of smart economy, the increase in the number of traffic vehicles, and the advancement of automation and urbanization, the problems such as urban environment pollution, unbalanced supply-demand for taxis, overcrowded vehicle flow, and road congestion have become increasingly intensified [1]. The survey shows that billions of dollars are spent on urban traffic planning every year. In order to alleviate the increasingly tense road conditions, the route planning system emerges as the times require. It transforms the existing road flow system by providing users with the optimal travel plan, thereby improving the traffic capacity and service quality of urban roads. Railway is an important part of China's transportation. With the rapid development of China's social economy, China's railway transportation has achieved considerable development, and people have put forward higher requirements for railway transportation safety. As the commander of railway transportation, the operational level of

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railway dispatchers [2] has an important impact on the safety of railway transportation.

In order to better adapt to the socio-economic development and meet people's travel needs, it is necessary to further improve the command ability of railway transportation dispatch. The layout optimization of railway transportation route is an important basis for railway dispatchers to make scheduling decisions [3]. Optimal route planning has attracted extensive attention from scholars and traffic management agencies at home and abroad [4]. If the railway traffic congestion can be predicted in advance, railway dispatchers can choose an optimal route for trains and reduce lost time in traffic. The route planning information not only provides railway dispatchers with the time required to reach a specific destination in a real-time manner [5], but also shows the possible congestion occurring at a specific road section. How to comprehensively use line information to provide railway dispatchers with optimal travel choices is the key for railway optimal line planning [6]. The optimal route planning scheme can reduce the cost of railway transportation and improve the efficiency of railway transportation [7,8].

At present, many researchers have made studies on path planning. Chen et al. [9] applied the distance measurement learning method to vehicle path planning. However, the planning effect of this method is not ideal. Bakach et al. [10] studied the vehicle route planning method by fully considering travel time, but this method involves too complex calculation and takes long time in route planning. However, the methods mentioned above cannot guarantee the maximization of railway transportation benefits. Convolutional neural network (CNN) is an important method in deep learning algorithm. Based on spatial relations, CNN shows advantages in the fields of time prediction, image recognition, semantic understanding, and so on [11]. Compared with traditional neural network, deep CNN has the following two advantages. First, it can capture the local spatial correlation in the characteristic matrix. Second, by sharing weights, the learning parameters are fewer and the model structure is more simple. In order to solve the above problems, improve the railway transportation capacity and maximize the railway transportation benefits, this paper introduces the deep convolution neural network into this field, and designs a layout optimization method of railway transportation route. By reviewing existing literatures, there are few methods to solve the path optimization and nonlinear problems by using deep learning, and traditional measurement methods and path planning involve a large amount of calculation. To this end, the deep CNN is used in this work to optimize the layout of railway transportation lines and improve the railway transportation performance.

2. Materials and Methods

2.1 Layout Model of Railway Transportation Route

Considering the transportation cost and reloading cost of railway transportation, this paper constructs a layout model of railway transportation route. The shipper on the demand side of railway transportation transports the goods to the consignee through the transportation supplier. There are pricing problems, railway transportation route planning problems and profit distribution problems between transportation demanders and transportation suppliers. The overall structure of the layout model for railway transportation route is shown in Fig. 1.

Transportation time and transportation mileage of different railway transportation routes are different. The railway transportation and distribution of goods should be considered integratedly, and the goods cannot be studied separately when they are transported or transshipped by railway transportation. The transit of goods d by rail should occur at the node rather than in the process of transportation. The same goods can only be transported by rail transportation mode between two nodes. Goods are transferred in real time at railway transit nodes without stagnation.

For the mathematical layout model of the railway transportation route, it is assumed that m describes all feasible routes in the railway transportation network, r_{ab} represents the transportation distance from railway transportation node a to node b; Γ_{ab} describes the unit transportation cost from railway transportation node a to node b when using railway transportation mode n; ∂_{ab} indicates the transportation volume from the railway transportation node a to node b; ε_a^{12} denotes the unit transfer cost of using railway transportation node a from transportation mode 1 to 2.

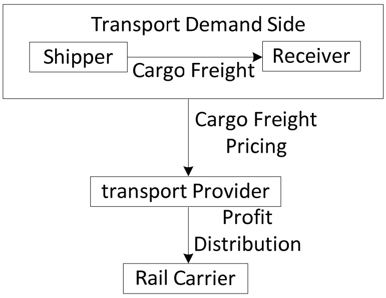

Fig. 1. Overall structure of the layout model of railway transportation routes.

Then the decision variables of railway transportation are:

$$y_a^{12} = \begin{cases} 1, & n \\ 0, & other \end{cases} \tag{1}$$

$$x_a^{12} = \begin{cases} 1, & a \\ 0, & other \end{cases} \tag{2}$$

where y_a^{12} means that the transportation mode used by the railway transportation node a to the railway transportation node b does not belong to n; x_a^{12} is the possibility of transshipment.

If the minimum total transportation cost is taken as the planning goal of the railway transportation route, the mathematical model for constructing the railway transportation route layout model is:

$$min(O) = \sum_{a-1}^{m}\sum_{b-1}^{n} \Gamma_{ab}^{n}\, y_{a,b}^{n} + \sum_{a-1}^{m}\sum_{b-1}^{n} \partial_{ab} r_{ab} \varepsilon_a^{12} \tag{3}$$

In formula (3), O represents the total transportation cost.

2.2 Improved ant Colony Algorithm to Solve the Layout Model of Railway Transportation Route

Ant colony algorithm proposed by Dorigo et al. [12] simulates the behaviors of biological ants looking for the best path. The essence of the algorithm is to find the best path in the graph, which is a new simulated evolution method. Ant colony algorithm has many excellent characteristics and high application value, but it may fall into the dilemma of partial optimal solution and long convergence time. Therefore, this paper improves ant colony algorithm and constructs a layout model of railway transportation routes according to the actual railway transportation situation.

By using the improved ant colony algorithm to select the destination of line planning under the railway transportation line topology, so that the selected line can meet the optimal or sub optimal requirements of users. When choosing railway transportation routes, people have different requirements. Some people require the shortest time, some require the shortest route [13], some require the lowest cost, and some require passing through a certain large urban agglomeration. On this basis, planning a reasonable route should meet all requirements as much as possible, or a reasonable route that only meets some of the requirements of passengers is formed. Obviously, the factors that people may consider for reasonable railway travel include: the shortest route, the minimum cost, the minimum time, and a city or a city group must be passed through.

The given algorithm is not only different from the greedy algorithm such as Dijkstra's algorithm, but also solves two problems that cannot be solved by the classical ant colony algorithm. (1) Comprehensive planning of customers with multiple conditions, that is, the optimization problem of multiple conditions. (2) The search direction is limited, so that each step of the algorithm's convergence direction directly points to the end point, which speeds up the algorithm's convergence speed [14]. The given algorithm involves more cost matrices to represent the possible cost of customers as compared with the traditional ant colony algorithm. These cost matrices should be given by the expert system, which can be in the form of a knowledge base or a pure cost matrix, but the knowledge base is better, and the execution speed of the algorithm will be greatly improved. This issue is not within the scope of discussion. The improved ant colony algorithm is used to construct the layout model of railway transportation routes, and multiple candidate railway transportation routes are output.

2.3 Deep CNNs

Deep CNN is mainly composed of four parts: model input, feature extraction, prediction, and model output. The deep CNN inputs the data captured by the detector into the model according to the characteristics of the mask matrix and the space-time matrix. Usually, the input data of the model are represented as a traffic time series matrix in time t. The following represents the model input matrix X_t, as shown below:

$$X_t = [x_t, m_t] \tag{4}$$

The range of railway traffic flow series data is from $t - L + 1$ to t. The time series are integrated in the form of space-time matrix x_t and mask matrix m_t. Secondly, the traffic state features are extracted through convolution layer and pool layer. Before model training, the convolution core of the convolution layer and output layer, namely weight and bias, must be initialized. The parameters of the convolution layer are basically a set of filters, which can extract multiple traffic flow features, and can also be regarded as the output of neurons. By reducing the number of parameters through weight sharing, higher-level and more abstract flow features are extracted. Convolution operation can be expressed as:

$$y_{conv} = \sigma\left(\sum_{1}^{m}\sum_{1}^{n} x_l^r w_l^r + b_l\right) \tag{5}$$

where σ is the activation function to perform the convolution operation, x_l^r is the railway traffic state of the detector r in the l-th time unit, $r \in [1, m]$, $l \in [1, n]$, w_l^r is the weight, and b_l is the deviation of the convolution layer.

Next is the pooling layer. The purpose of the pooling layer is to simplify the output of the convolutional layer and reduce the spatial size of the data volume. The pooling operation can be expressed as follows:

$$y_{pool} = pool\left(\sigma\left(\sum_{1}^{m}\sum_{1}^{n} x_l^r w_l^r + b_l\right)\right) \tag{6}$$

After the pool operation through formula (6), the vector is converted into model output through a fully connected layer. Therefore, the output of the model can be expressed as:

$$\hat{y} = w_f\left(flatten\left(pool\left(\sigma\left(\sum_{1}^{m}\sum_{1}^{n} x_l^r w_l^r + b_l\right)\right)\right) + b\right) \tag{7}$$

where w_f and b_f are the weights of the fully connected layer and the bias $\hat{y}$, respectively, which are the predicted rail traffic flow.

The goal of a deep convolutional neural model is to find a mapping function that satisfies the conversion from y_{pool} to $\hat{y}$ and outputs the predicted result.

2.4 Layout Optimization of Railway Transportation Routes by Deep CNNs

The candidate railway transportation route layout results are optimized by based on deep CNN. Build a travel time prediction model for railway transportation, use CNN to capture external factors such as weather, regional location, etc., that affect railway transportation, and obtain the optimal transportation route.

3. Results

The effectiveness of the proposed railway transportation route optimization method is verified based on the actual process of freight transportation in a railway transportation enterprise. The layout optimization effect of railway transportation routes determines the benefits of railway transportation enterprises. The shorter the route of railway transportation is, the shorter the time required is, and the higher economic benefits, the railway transportation enterprise can obtain. This article uses Microsoft Windows XP, system model of all series, and Intel Pentium 4 processor. The experimental data are collected from an enterprise.

The start and end points of the railway transportation process are set as 1 and 60, respectively. The goods are transported from point A to point B, and there are 59 nodes in the middle. The proposed method is used to construct a railway transportation route layout model based on improved ant colony algorithm. The obtained 10 candidate route layout results are shown in Table 1.

Table 1. Layout results of candidate routes for railway transportation

Path layout No.	First station	Second stop	Third station	Fourth stop	Fifth stop
1	1	5	9	38	60
2	1	11	16	57	60
3	1	12	35	59	60
4	1	11	46	57	60
5	1	7	28	51	60
6	1	9	29	49	60
7	1	13	31	58	60
8	1	18	32	42	60
9	1	21	27	43	60
10	1	17	36	57	60

In order to prove the effectiveness of the proposed method, the prediction accuracy of the proposed method and the methods in [9] and [10] was comparatively analyzed. The statistical results are shown in Fig. 2.

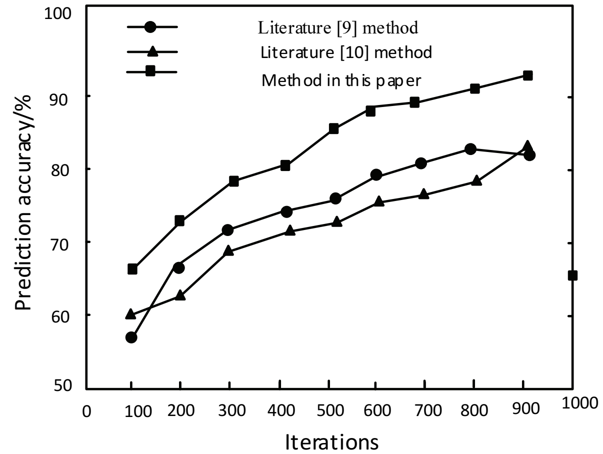

Fig. 2. Prediction accuracy of different methods.

From the experimental results in Fig. 2, it can be seen that when the number of iterations is different, the prediction error of different methods is very different, indicating that the number of iterations has a significant impact on the prediction error. The analysis of the experimental results in Fig. 2 shows that the more iterations, the better the prediction effect of different methods. The proposed method has higher prediction accuracy than the other two methods. When the iteration number is 900, the prediction accuracy of the proposed method can reach more than 90%.

To verify that the CNN optimized by ant colony algorithm has an effective application value for railway transportation optimization, MATLAB software platform was used to carry out simulation experiments.

The data samples provided by the railway transportation enterprises were collected and analyzed, and the test data set was constructed. At the same time, the ant colony optimization CNN (ACO-CNN) and the particle swarm optimization CNN (PSO-CNN) proposed in this study were comparatively analyzed. The experimental results are shown in Fig. 3.

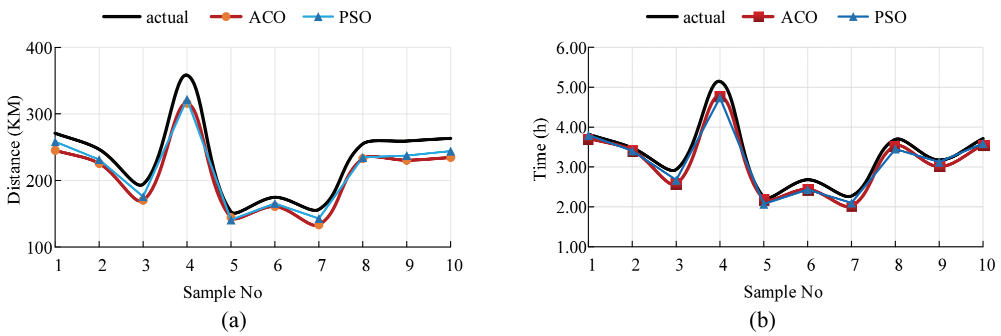

Fig. 3. Comparison of path optimization by using ACO-CNN and PSO-CNN: (a) transportation distance and (b) transportation time.

It can be seen from Fig. 3 that the PSO algorithm and ACO algorithm can both optimize the transportation distance and transportation time of 10 railway transportation routes. As a whole, ACO-CNN algorithm is better than PSO algorithm in optimization of transportation distance length and time consumption. In Fig. 3(a), the average distance of 10 sample data is 233.17 km, and the average distance after ACO optimization and PSO optimization is 209.36 km and 215.28 km, respectively. As shown in Fig. 3(b), the average time of 10 sample data is 3.314 hours, and the average time after ACO optimization and PSO optimization is 3.124 hours and 3.137 hours, respectively.

4. Discussion

The deep CNN is used to optimize the layout of railway transportation routes, and the experimental results show that this method can effectively optimize the railway transportation line layout and obtain the optimal railway transportation line. However, at present, there are the following problems in China's railway transportation scheduling: in the railway transportation scheduling and command work, the dispatcher plays an important role in the scheduling work. In order to achieve efficient and safe transportation dispatching and command, dispatchers must master comprehensive and professional dispatching knowledge, understand the personnel, equipment and all aspects of the area under their jurisdiction, and do a good job in command. However, due to high working pressure, dispatchers usually lack of energy and do not seriously study the basic rules and regulations, which leads to the accumulation and stagnation of working capacity with the passage of time and the lack of necessary operators in the layout of railway transportation lines, resulting in the difficulty in maximizing the economic benefits.

5. Conclusion

This paper focuses on the layout optimization of railway transportation, applies deep CNN to the layout optimization of railway transportation routes, and evaluates its performance. The test results show that the proposed method can realize layout optimization of the railway transportation routes, and obtain optimal railway transportation route with high efficiency. Using this method to optimize the layout of railway transportation routes, the route with the shortest distance and the least time consumption can be obtained, which can maximize the economic benefits of railway transportation enterprises. Therefore, the proposed method has certain application value in the field of railway transportation route planning.

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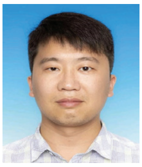

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