

Research on the application of cellular automata and improved BP neural network in road design of logistics park

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Abstract. With large-scale construction of the Logistics Parks, it has become an urgent problem to quantitatively analyze, evaluate and optimize the logistics park designing, which needs to be solved scientifically. At present, more of the domestic logistics park planning of a part of the qualitative analysis, the lack of quantitative and overall study, resulting in internal structure disjointed. Based on cellular automata theory, this paper presents a hybrid traffic flow model which is more suitable for the traffic characteristics of the logistics park, and analyzes the complexity of the collection and evacuation system in the logistics park, combined with BP neural network and its improved algorithm, the method of road design in Logistics Park is studied and the feasibility and validity of the model and algorithm are verified by an example. The train of thought is expected to provide for the planning and construction of the internal road in the logistics park.

1 Introduction

In the study of logistics parks transportation system, in generally, Considering form the internal transportation and the external connection of logistics parks. The collecting and distributing system of logistics parks is closely connected with the function area inside the park. Responsible for the distribution of goods, When the volume of business is increased, it is easy to cause blockage. Therefore, in order to avoid the situation of "unable to get out or go in" in the logistics park, we must have a good traffic system. Road design is an important part of logistics park planning, but the research on road design of logistics park is in initial stage. From the purposes of the study, the existing research on logistics park planning mainly focuses on the site selection research, functional area layout research or traffic impact analysis of the logistics park, while the research on internal road design is less. In this paper, the cell automata theory and the improved BP neural network are applied to the design of the internal road design in the Logistics Park: according to the traffic characteristics of the Logistics Park, a model of Complex Cell is established. The relationship among traffic flow, density and average speed in different lanes is analysed. The new characteristics of the multi-speed mixed traffic flow of road in the Logistics Park is summarized. According to the model statistics, a road design function model based on Levenberg-Marquardt Algorithm is established, and the training process of the model is realized through the programming of MATLAB. It is concluded that the improved BP neural network model based on Levenberg-Marquardt Algorithm can effectively

predict the number of internal road lanes in the logistics park.

2 Literature review

In the existing literature, there is a limited number of papers researching on the Interior Road Design Platform of the Logistics Park. Many researchers have focused on the layout of logistics or the traffic analysis of logistics park. Yong Chen (2012) studied the SLP Method Based on Low-Carbon Logistics in Professional Agricultural Logistics Park Layout [1]. Jianxun Tang, Lixin Tang, Xianpeng Wang (2013) studied a logistics park location planning problem in which the capacity of the logistics park is determined by the sectors used to establish it in an open site [2]. Lele Qin and Xiaoxia Zhu (2013) studied the Information Management Platform of Logistics Parks Based on Cloud Computing [3]. Karl F. Doerner, Dennis Huisman, Leena Suhl (2014) studied the relationship of Logistics, traffic and transportation [4]. Yanru Chen, Yangsheng Jiang, M.I.M. Wahab, Xiaoqiang Long (2015) proposes two mathematical programming models to obtain competitive solutions to the facility layout problem in a logistics park [5]. Rodrigo Rezende Amaral, El-Houssaine Aghezzaf (2015) discuss and model one of the effective management strategies for city logistics and traffic management in a metropolitan area [6]. Jiuhe Wang (2019) used the improved SLP method to quantitatively analyze the various factors affecting the layout and designed a particle swarm algorithm and simulated annealing algorithm are combined [7]. Jinhui Zhang (2021) used the simulation modeling method to build the park traffic simulation model to get the park traffic design optimization scheme [8]. Huaiyuan Liu (2022)

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improves the BPR function from three factors: road grade mixed flow characteristic factor and traffic flow time distribution imbalance, and designs the road resistance function in line with the characteristics of the logistics park [9]. Yuxuan Li (2022) combined SLP method and landscape design thought to carry on the comprehensive relation analysis to each functional area, and used Flexsim simulation software to verify the feasibility of the scheme [10].

Therefore, the empirical method is often used in the internal road design of logistics park, but it lacks Quantitative analysis, The paper studies from two aspects:

First: Based on cellular automata theory, the characteristics of traffic flow in logistics park were analyzed through simulation modeling.

Second: the improved BP neural network algorithm is applied to calculate the internal road of Logistics Park, and the simulation data is used to verify the accuracy of the algorithm.

3 Analysis of the traffic impact of Cellular Automata Theory

In actual traffic, a road consists of multiple lanes and the vehicle on the road is made up of vehicles of different types, However, most of the cellular automata traffic models established at present only analyzed one component, and the results obtained through the model do not reflect the actual traffic condition. The traffic flow in the logistics park has its particularity. The freight vehicle is different from the coach. Which has the characteristics of large volume and low speed, if the simple use of the parameters of a single traffic can not objectively reflect the traffic characteristics of the logistics park. Therefore, on the basis of full understanding of the traffic characteristics in the logistics park, the length, running speed, the changing rules and the turning rules are reset according to the actual situation, the cellular Automata model of single-lane and multi-lane multi-speed mixed traffic flow in open boundary condition is established. The influence of mixed proportion of commercial vehicle and freight transport vehicle on traffic flow is studied.

3.1 Simulation Models

The road is divided into countless cells, each of which is occupied by a car or empty at any time. Based on the layout scheme of the logistics park and the application of cellular Automata model in road traffic flow, the internal road traffic model of the Logistics Park is established, Vehicles entering the park are mainly van, commercial vehicles and cars. The size of the cell is related to the length of vehicle and the speed of vehicle. commercial vehicles and cars do not have a clear distinction, so, in the study of this article, commercial vehicles and cars are unified as commercial vehicles. The cell size is fixed in the traffic system modeling process. One Lane is composed of multiple cells, and the number of cells is equal to the length of the road divided by the length of a single cell, In this model,

there are different vehicle types, cannot simply apply the single-cell traffic simulation model, which is different from the previous port wharf front structure modeling, In order to solve the above problems, the concept of " mixed " cell was put forward, and the model of mixed Cellular Path was established, the two different cells have common and special characteristics. They represent the same lane, but the rules of driving on different cells are different, and a virtual road is added to the model, that is, a real lane is represented in the model by two different cell sizes.

Each lane is made up of two different types of cells. the cells above may be occupied by the van or empty, and the cells below may be occupied by commercial vehicles or empty. However, there is no situation where the same set of cells is occupied by a van and the lower part is occupied by a commercial vehicle.

A single-lane, two-lane, three-lane simulation model is established according to the internal road of the Logistics Park. In the model, the input parameters are the arrival distribution of vans and commercial vehicles, and the output parameters are traffic volume of vehicles and the speed of vehicles. The maximum speed of the van is 20 m/S, the maximum speed of the commercial vehicle is 30 m/S, in the single lane, the vehicle cannot change lanes, the van reaches the maximum speed, and drives at a constant speed, commercial vehicles determine whether a deceleration or even speed is required according to the type of vehicle in front; in a two-lane or three-lane lane, the vehicle needs to be sufficiently safe to change lanes depending on the speed or destination of the vehicle in front, don't change the speed after the switch.

3.2 Car-following models

In 1992, Nagel and Schreckenberg proposed the famous NaSch model, In this model, the speed can be expressed as 0, 1, 2, ..., $v_{\max}$, $v_{\max}$ is the maximum of the speed. In the process of transformation, the rules of evolution are shown below.

Step 1: Speed Up, $v_n \rightarrow \min(v_{n+1}, v_{\max})$; The driver wants to be able to drive as fast as possible in the actual traffic.

Step 2: Slow Down, $v_n \rightarrow \min(v_n, d_n)$; Drivers are afraid of the speed bumps that can result in a collision with the vehicle in front of you or to reach your destination.

Step 3: deceleration probability, ρ , $v_n \rightarrow \max(v_n - 1, 0)$; Deceleration due to unexpected events such as weather impact, driver's temporary change of driving route, etc.

Step 4: driving, $x_n \rightarrow x_n + v_n$; The speed is determined by the commissioning.

When a cellular automata traffic flow model is established, there are two situations for the determination of boundary conditions: ①Periodic

boundary conditions: Once each update is completed, the vehicle will re-enter the system from the other end of the road, i.e. the number of vehicles in the road system will not be reduced. ② Opening boundary conditions: When vehicle updates on the road are completed, the vehicle leaves the road at the end of the road.

In this paper, because the vehicle in the park is constantly changing, the opening boundary condition is chosen. The NASCH model is modified slightly according to the characteristics of high efficiency of freight vehicle in the logistics park. In the single lane, the vehicle cannot be changed, and the goods transport vehicle reaches the maximum speed, even speed or deceleration, commercial vehicles decide whether to slow down or to drive at a constant speed depending on the type of vehicle in front.

3.3 Lane-changing models

When the vehicle meets the following conditions, the lane can be changed:

- (1) $d_n < l$;
- (2) $d_n, other > l_o$;
- (3) $d_n, back > l_{o, back}$;
- (4) $rand() < \rho_{change}$

In this paper, the vehicle determines whether to change lanes depending on the speed or destination of the vehicle in front, without changing the speed of the switch.

3.4 Numerical Simulation and Analysis of Result

In the modelling process, if the total length of the lane is L , the total number of vehicles in the lane is N , the density of the vehicle is ρ ,

$$\rho = N / L \quad (1)$$

The average vehicle flow is the total number of vehicles divided by the model running time. The average speed of the t-hour is $\bar{V}_t$,

$$\bar{V}_t = \frac{\sum_{k=1}^N V_k(t)}{N} \quad (2)$$

Because the vehicle in the lane is composed of a mixture of vehicles, a mixed ratio n is set.

$$n = N_h / N_s \quad (3)$$

In this paper, the actual length of road is 1000 meters and the open boundary condition is adopted. At the beginning, the two vehicles are distributed into the road by non-negative exponential distribution, and the model runs 7200s at a time, record the speed at a certain point in the middle of a 500-metre vehicle, get the average speed of each vehicle and then do the vehicle average. In order to eliminate the influence of randomness on the model, the average value of multiple runs is obtained.

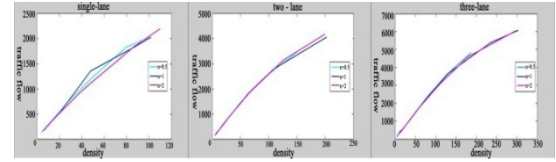


Fig. 1. Traffic flow-density relationship diagrams of multiple hybrid ratios in different lanes

According to the graph, when the average density of the vehicle on the road increases, so does the traffic flow, until it reaches its maximum, the conversion factor for a standard vehicle is 2,1, respectively, as the length of the van is twice the length of the commercial vehicle. In the single lane, the relationship between traffic flow and density varies linearly with the increase of the freight vehicle, while in the two-lane and three-lane, the relationship between them is close to the same, is less affected by the cargo vehicle. In any lane, when traffic is low, they have the same linear relationship, and when traffic increases, they have different linear relationships. The smaller the proportion of van, the smaller the maximum amount of traffic that can be reached in the lane.

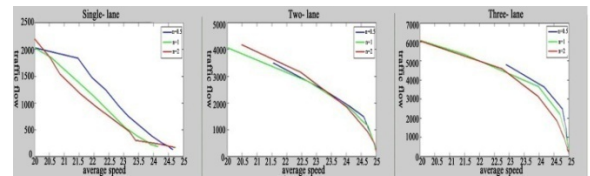


Fig. 2. Traffic flow-average speed diagram

As you can see from the diagram, when the vehicle occupancy rate is low, the road is more smooth, the traffic on the road can be driven at a large speed, and when the lane occupancy rate becomes larger, the traffic on the road becomes congested, the viscosity becomes larger between the moving vehicles and the average speed of the vehicle becomes smaller. In a single lane, commercial vehicles are more affected by van and the average speed varies considerably. As traffic in the lanes increases, the average speed of the vehicle slows down and then decreases. The reason for this is that when there is less traffic in the lane, the distance between the two vehicles is large and the vehicles are able to move freely, not being affected by the surrounding vehicles, and as the traffic volume increases to a certain extent, the distance between the two vehicles becomes smaller and the vehicle is more affected by the surrounding vehicle while driving, and the speed of the vehicle is affected by the surrounding traffic, it's slower.

4 Research on the Interior Road Design Platform of the Logistics Park

After the internal functional layout of the Logistics Park has been preliminarily determined, its road design needs to be designed. Because of the characteristics of the traffic flow in the logistics park, we can not simply apply the road capacity manual to get the road design scheme, in the past, most of them have been based on experience in determining the number of lanes and the

lack of quantitative analysis, which may have a significant impact on the future development of the Logistics Park, the data is obtained (table 1) by the established simulation model, combined with the improvement of BP Neural Network Algorithm to get the road design method.

Table 1. Sample data collected by the simulation model (Due to limited space, only part of the data is shown)

input (Veh/h)		output
van	commercial vehicles	Number of lanes
61	61	1
125	124	1
184	182	1
381	381	2
310	616	2
369	734	2
882	441	3
925	938	3
620	1245	2
876	1748	4
1209	628	4
1657	873	4

4.1 Improved BP neural network model

The traditional BP neural network is of great importance in artificial neural network because of its perfect in theory and wide practicability, but because of the characteristics of Network Training Algorithm, it has some shortcomings in the application process. Therefore, the improved algorithm is studied in this paper, the aim is to improve the speed of network training, improve the training precision and avoid falling into the local minimum.

The Levenberg-Marquardt Algorithm is established to improve the model of BP Neural Network, The implicit layer transfer function uses "Tansig", Network Training Algorithm uses "trainlm", error is 0.00001; Training Steps is 1000; The initial value of μ is 0.005; Reduction coefficient is 0.01; increases coefficient is 5; The remaining arguments take the default value.

The contrast between the predicted and actual values is shown in Table 2. The comparison of the forecast results is shown in figure 3, and the training process is shown in figure 4 and the fitting degree is as shown in figure 5.

Table 2. The prediction results of improved BP Neural Network Algorithm (Due to limited space, only part of the data is shown)

Actual values	Predicted values	Absolute error	Relative error
1	1.00	0.00	0.00%
1	1.00	0.00	0.00%
2	2.00	0.00	0.00%
2	2.00	0.00	0.00%
2	2.00	0.00	0.00%
1	1.00	0.00	0.00%
1	1.00	0.00	0.00%
2	2.00	0.00	0.00%
3	3.00	0.00	0.00%
3	3.00	0.00	0.00%
2	2.00	0.00	0.00%
4	4.00	0.00	0.00%
4	4.00	0.00	0.00%
4	4.00	0.00	0.00%
4	4.00	0.00	0.00%
4	4.00	0.00	0.00%
4	4.00	0.00	0.00%

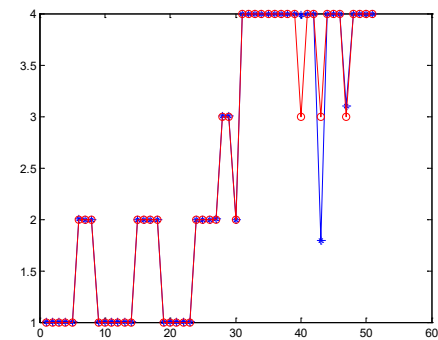


Fig. 3. The comparison of the forecast results

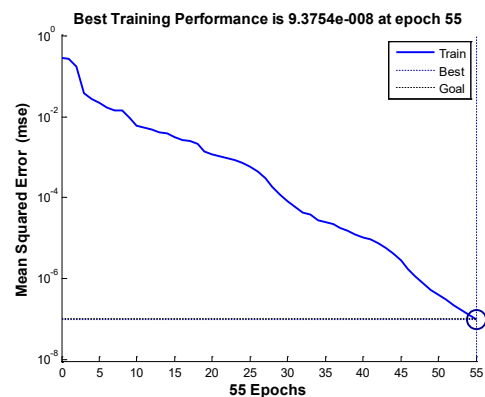


Fig. 4. The training process

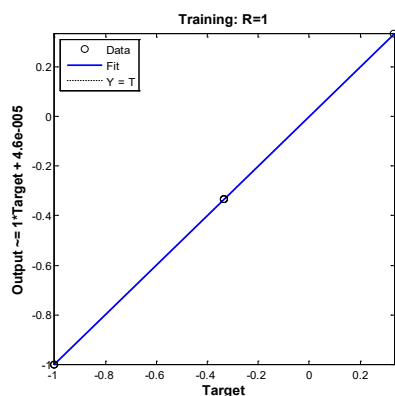


Fig. 5. The fitting degree

From the table and diagram: When the model is trained with LM Algorithm, both the prediction accuracy and the network training time have a better effect. The relative error is at least 0% and the fitting degree is 1. In this model, only 3 errors are predicted, which may be related to the inaccuracy of input factors. From the prediction results, the training error can reach the expected error, the curve after training is very similar to the original curve, the results show that the model can effectively predict the number of internal road lanes in the logistics park, which will provide convenience for the interior road design in logistics park.

5 Conclusion

Firstly, Based on the traffic characteristics of the logistics park, the NASCH model is improved, and a hybrid traffic flow model, which is more in line with the traffic situation in the Logistics Park, is established, this paper analyses the relationship among traffic flow, density and average speed in different lanes, and obtains the new characteristics of the multi-speed mixed traffic flow in the inner road of the Logistics Park, it provides an important reference value for the research of the internal traffic system in the logistics park.

Secondly, a road design function model based on Levenberg-Marquardt Algorithm is established. The training process of the model is realized through the programming of MATLAB and the results of the training are analyzed, it is concluded that the improved BP neural network model based on Levenberg-Marquardt Algorithm can effectively predict the number of internal road lanes in the logistics park. It has laid a good foundation for the design of internal road design in the Logistics Park.

Thirdly, the paper makes a deep study on the Interior Road Design of the Logistics Park, but the research work is still in the initial stage, considering the complexity and changeability of layout planning in Logistics Park, the theoretical methods and technical problems need to be further studied and summarized in future.

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