Dynamic Tracking Method for Train Number of Rail Transit Signal System

Liwen Liu[1](✉), Chao Cai[2], Yulong Wang[2], and Zhiwen Chen[3]

[1] Wuhan Railway Vocational College of Technology, Wuhan 430205, China
LiwenLiu613@126.com
[2] Wuhan Metro Operation Co., Ltd., Wuhan 430205, China
[3] Department of Mechanics and Electronics, Wuhan Railway Vocational College of Technology, Wuhan 430205, China

Abstract. The conventional dynamic tracking method of train number of rail transit signal system mainly uses the ZG (Zone Controller) regional controller to report the train position, which is vulnerable to the influence of the occupation of the logical section, resulting in the mismatch of the tracking display position. Therefore, a new dynamic tracking method of train number of rail transit signal system needs to be designed. Namely, the GPRS train number dynamic tracking server is installed, the dynamic tracking module of this number on the side of the rail transit signal system is developed, and the dynamic tracking algorithm of the train number of the rail transit signal system is designed combined with the artificial neural network, thus realizing the dynamic tracking of the train number. The experimental results show that the designed dynamic tracking method for train number of rail transit signal system has good tracking effect, and the matching between the tracking display position and the actual position is reliable and has certain application value, which has made certain contributions to improving the safety of rail transit.

Keywords: Rail Transit Signal · System · Train Number · Dynamic Tracking · Method

1 Introduction

With the rapid development of national economy and the acceleration of urbanization process, the number of urban population and vehicles are increasing [1], and the huge flow of people and vehicles often lead to traffic congestion on urban roads [2–4]. In order to alleviate the pressure of urban traffic, rail transit has been built [5–7]. With the continuous progress of science and technology and the large-scale development of urban rail transit, the urban rail transit network will certainly become more developed [8]. From manual driving under the supervision of ATP to semi-automatic driving in ATO mode [9], and then to fully automatic driverless driving with the highest level of automation, the automation level of urban rail transit system has gradually improved. In

L. Yun et al. (Eds.): ADHIP 2023, LNICST 549, pp. 360–376, 2024.
https://doi.org/10.1007/978-3-031-50549-2_25

a fully automated driving system, the work of the train driver is transferred to a highly integrated automated control system, which enables fully automated operation from the depot to the main track. For the safety of vehicle operation, it is necessary to track the train number, but the recognition effect is not good at this stage, and relevant scholars have carried out research.

For example, literature [10] puts forward the design method of neural network PID controller for high-speed train speed tracking, which introduces neural network and builds a PID controller based on it to track trains. But the tracking effect of this method is not good. Literature [11] proposes a fault tolerant tracking control method for high-speed trains that considers actuator performance constraints. Based on the auxiliary system constructed by hyperbolic tangent function, this method constructs an augmented speed tracking control model for high-speed trains. In order to avoid the first derivative of virtual control signal in the controller, a fault tolerant tracking controller for high-speed train is designed by using dynamic surface method and adaptive control technology. The stability of the controller is analyzed based on Lyapunov function, and the train tracking is realized. However, the error between the tracking position and the actual position is large and the fitting is poor.

Under the above background, in order to improve the dynamic tracking effect of rail transit signal system, this paper designs a new dynamic tracking method of rail transit signal system based on the operation characteristics of rail transit signal system, which makes a certain contribution to improving the operational reliability of rail transit.

2 Design of Dynamic Tracking Method for Train Number of Rail Transit Signal System

2.1 Installing GPRS Train Number Dynamic Tracking Server

In order to solve the problem of tracking display position mismatch caused by the occupation effect of logic section[9]when the ZG regional controller reports the train position, this paper applies GPRS technology to install a GPRS train number dynamic tracking server. GPRS network adds GPRS service support node and GPRS gateway support node, two functional entities, on the basis of GSM-R network. The actual installed network structure is shown in Fig. 1 below.

It can be seen from Fig. 1 that GPRS shares the base station of the GSM-R system, but the BSC needs to add a packet control unit for processing packet data and wireless packet channel management, as well as SGSN and GGSN.Functions of the PCU: This function entity can be set up with the BSC or used as a separate network element [10]. The Gb interface between the PCU and the SGSN is a standard interface defined in the specification, and the interface between the PCU and the BSC is an internal interface. It is responsible for processing the data service of the wireless channel Y As shown in (1) below.

$$Y = \frac{DLTBFPEDCH + DLTBFPBDCH}{TRAFFCI, GPRSSCAN} \tag{1}$$

Where, $DLTBFPEDCH$ Represents the number of allocated businesses, $DLTBFPBDCH$ Represents the amount of contribution data, $TRAFFCI$ Represents the degree of reuse,

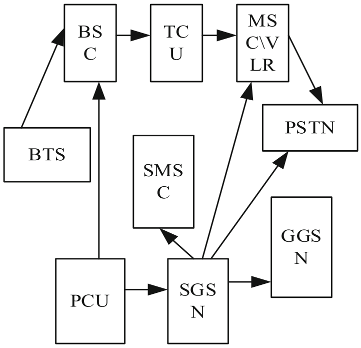

Fig. 1. Dynamic Tracking Server Installation Network Structure

GPRSSCAN It represents the total amount of services. When managing and allocating the wireless data channel, the above processing mode allows multiple users to access the same wireless resource, compress, encrypt and forward user data, and also has the functions of power control, quality control and channel coding scheme selection.

SGSN is an important part of GPRS backbone network and the core part of packet switching. It is connected to PCU through frame relay. The function is similar to the MSC/NLR function of the GSM system. The SGSN not only processes signaling transmission in packet switching, but also processes and transmits data packets. The number of channels at this time *PS* As shown in (2) below.

$$PS = TOTAL - ERLANG \tag{2}$$

Where, *TOTAL* Represents the data rate, *ERLANG* Representing the share of coding services, SGSN can perform mobility management, security management, access control and routing functions for MS. That is to record the relevant information of the mobile data user currently active in the SGSN area, such as location information, which can be modified, deleted, etc., and is responsible for the attach and detach, location update, paging, authentication, encryption, etc. of the data user; Be responsible for the establishment, maintenance and release of the logical link between MS and SGSN; The selection of negative expensive routes and the storage and forwarding of information; Generate original billing data *TBF* As shown in (3) below.

$$TBF = (TOTAL - ERLANG) \times TBFD \tag{3}$$

Where, *ERLANG* Represents the maximum value of data service, *TBFD* It represents the tracking loss rate. GGSN maintains the GPRS backbone network internally, and can connect multiple data networks externally, such as Internet, Enterprise Network, X.25 Network, etc. It is the gateway between the GPRS backbone network and the external data network; Its position in GPRS data network is similar to that of GMSC in traditional GSM network; Be responsible for generating the original billing data of data services.

The GPRS interface server can complete the data protocol conversion between the vehicle application entity and the ground application entity, as well as the data storage and forwarding service, which plays a key role. The structure of GPRS interface server is shown in Fig. 2 below.

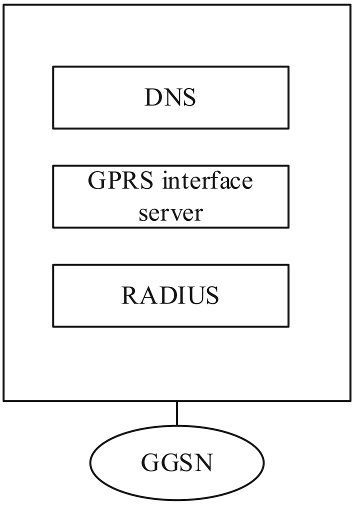

Fig. 2. Structure of GPRS interface server

As shown in Fig. 2, the GPRS interface server is composed of data forwarding unit, data recording unit, external DNS unit, Radius unit, disk array unit, three-layer Ethernet switch and management and maintenance terminal in hardware. The GPRS interface server is functionally composed of the following logical units: GGSN interface unit, CTC/TDCS interface unit, TCDS interface unit, GIS information service interface unit, mobile ticket system interface unit, data forwarding unit, etc. By connecting the above logical units, the tracking logical path can be effectively run to improve the sensitivity of dynamic tracking.

2.2 Develop Dynamic Tracking Module for Train Number of Rail Transit Signal System

For an urban rail transit [14, 15], it is composed of many stations. According to the deployment of CI, these stations can be divided into different interlocking areas. In the train identification and tracking module, an interlocking area and a station in the interlocking area adjacent to the interlocking area are regarded as a tracking area. In each tracking area, a set of train identification and tracking module processes can be placed on the ATS extension in the interlocking area, and each interlocking area can have one or more stations, so a tracking process can be responsible for tracking one or more stations, and the processes are connected through the communication platform, so as to realize the identification and tracking of trains in different areas and between different interlocking areas, the dynamic tracking process of train number of rail transit signal system is shown in Fig. 3 below.

It can be seen from Fig. 3 that in the same station in the same tracking area, trains are identified and tracked according to the status and relationship of equipment in the station; For different stations in the agreed tracking area and between different stations in different tracking areas, the train shall be identified and tracked according to the

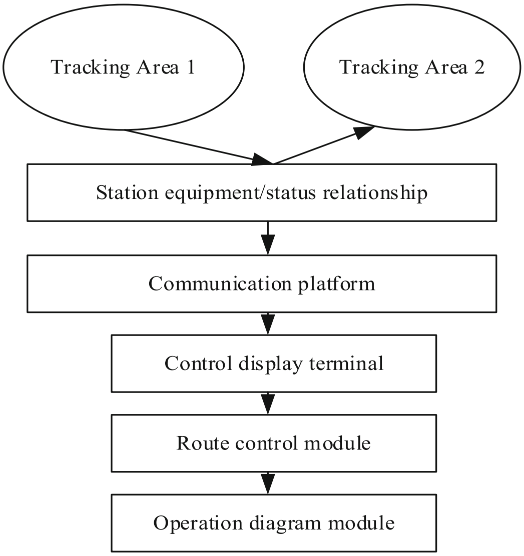

Fig. 3. Dynamic Tracking Process of Train No

equipment relationship between stations. The relationship between the station equipment and the inter station equipment is configured in the ATS system data according to the interlocking table information, and the dynamic tracking module of train number can be designed according to the dynamic tracking process of train number.

The first is the train identification module. In the ATS system, the train identification number plays a very important role. It is not only the unique identification of the train, but also the premise for the ATS system to realize its train route arrangement, automatic operation adjustment, train tracking and other functions. Therefore, the design of the train identification number is particularly important. The data structure of train identification module is shown in Fig. 4.

It can be seen from Fig. 4 that the change identification of train number is the mark for adding, deleting, modifying and moving the train identification number. The train ID is the number of the train, the table number, the number of the running line in the running chart, the train number and the train operation; Train set number is the train number; Destination number is the number of the destination where the train will arrive; The office code/line number is the number of the line to which the current train belongs; Station code, the number of the station where the train is located; Train number window number, the number of train number window where the train is located; Train number refers to the number of trains to distinguish multiple trains in the same train number window.

The train information maintenance module mainly includes adding, deleting, modifying and moving the train identification number. Its information processing structure is shown in Fig. 5.

It can be seen from Fig. 5 that the train information maintenance module receives the commands from the ATS control and display terminal to add, delete, modify and

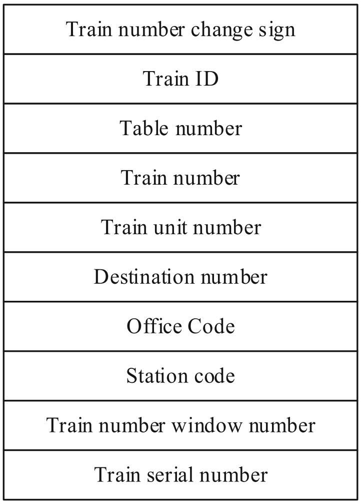

Fig. 4. Data Structure of Train Identification Module

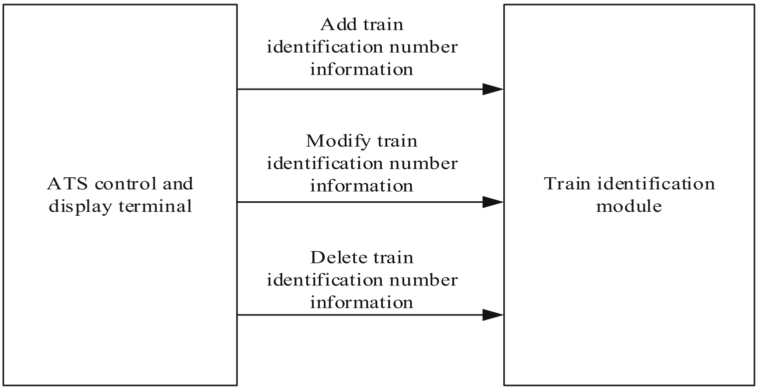

Fig. 5. Information processing structure of train information maintenance module

move the train identification number, then compares and judges the train identification number in the whole ATS system, finally maintains the train identification number, and then feeds back the modified train identification number information to the control and display terminal, and gets the correct display. When the train position is updated. This module can check the information C As shown in (4) below.

$$C = \sum_{i=1}^{N} R_i - d \tag{4}$$

Where, R_i The representative modifies the information group number, d It represents the standard information group number, i stands for field number. After information verification, subsequent information processing can be carried out.

Aiming at the requirement of ATO train number information verification in the train identification [16, 17] requirement, the ATO train number information processing plug-in is designed. The basic functions of the plug-in include: identifying new trains according to ATO train number information, checking logical train number and generating alarm. In CBTC mode, track and check the train according to the CBTC train position information. When a track is occupied by a train, but there is no train identification number in the train number window corresponding to the track, and the track is not represented by a red light band, an alarm will be sent and the alarm information will be sent to the control and display terminal.

When the train arrives at the platform, compare the train set number of the train in the ATS system and the ATO system. If the number is the same, update the train start, stop, door status and other information. If different, the ATS system needs to send an alarm, and the dispatcher can modify it according to the actual situation. When a track is occupied by a train, and there is no train identification number in the train number window corresponding to the track, but the track is indicated by a red light band, an alarm will be given, and ATO train number information will be used to generate logic tracking train number, and the train identification number will be displayed in the train number window corresponding to the track. According to ATO stop stability information, set the stop stability status of the train at the platform, and the structure diagram of the processing plug-in of this module is shown in Fig. 6 below.

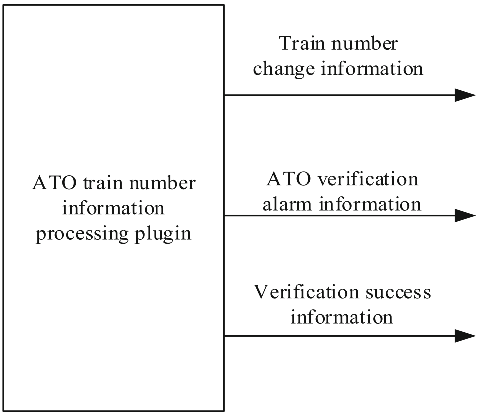

Fig. 6. Structure of processing plug-in

It can be seen from Fig. 6 that the above plug-in can obtain the position and change information of the train for dynamic tracking. The process of tracking train number according to ATO information generation logic is: search train information in the plan according to train set number, if the corresponding operation line is found, update train information according to the operation line; otherwise, generate the first train with only train set number and destination number of 0, and send an alarm.

The plan information management module mainly aims at the plan information management requirements in the train tracking requirements, and designs the plan management plug-in and the automatic point reporting plug-in. The basic functions of the plan management plug-in include: receiving and analyzing the train operation plan from the train diagram; Operation adjustment mode and its changes received from train diagram; Find the operation line information for the train according to the train set information; Provide turn back information for trains requiring turn back according to the plan and adjustment mode, and use the above functional modules to effectively track and report points and determine the train number of the rail transit signal system.

2.3 Design Dynamic Tracking Algorithm of Train Number

In the process of train number dynamic tracking, the influence of actual tracking environment changes on the tracking results is often ignored. Therefore, this paper uses artificial neural network to design an effective train number dynamic tracking method for rail transit signal system. Artificial neural network (ANN) is a mathematical model of information processing using a structure similar to the synaptic connection of brain nerves. It is a nonlinear system composed of a large number of simple computing units. The steepest descent method can be used to continuously adjust the weighted value and threshold of the neural network, so that the sum of squares of the network errors can be minimized.

BP neural network [18–20] consists of a large number of simple basic elements, namely neurons, which are interconnected to form a nonlinear dynamic system. Although the structure and function of each neuron are relatively simple, the dynamic system behavior generated by a large number of neuron combinations is very complex. In the process of calculation, the use of artificial neural network can greatly improve the speed of calculation.

Train number tracking refers to the automatic calculation of the train number of the running or stopped train at a certain time and place according to the adjustment plan information and actual operation of the train. Train number tracking technology mainly includes three aspects: acquisition of original train number, logical tracking processing of train number, and train number verification. The original train number is generally obtained according to the train adjustment plan. The verification of train number is to check the calculated train number with the planned train number, wireless train number, etc., and judge whether the calculated train number is correct according to certain rules to improve the accuracy of the output train number. Among them, the logic tracking is the most complex, including the tracking of the train in the station and the tracking of the section. The essence of logic tracking train number is that only one train can run or stop at the same time in the same block section, and the dynamic tracking strategy function generated at this time a_t, as shown in (5) below.

$$a_t = u(s_t \big| \theta^n) + N_0 \tag{5}$$

Where, u Represents regression tracking noise, s_t Represents the tracking target weight, θ^n Represents the moving angle, N_0 Represents the tracking parameters. Under different tracking states, the dynamic tracking effect of train number will change. Therefore, updated follow-up review L, as shown in (6) below.

$$L = \frac{1}{n} \sum_{j} (y_i - Q(s_t, \theta^n))^2 \tag{6}$$

Where, y_i Represents the tracking gradient, n Represents the train number update parameters, $Q(s_t, \theta^n)$ Represents the update coordinate, and a reasonable tracking reward function can be obtained for the above update d, as shown in (7) below.

$$d = \sqrt{\sum_{j=1}^{6} (a_j - c_j)^2} \tag{7}$$

Where, a_j Represents the current train number of the traffic signal system, c_j Represents the actual train number, and the artificial neural network tracking model is constructed according to the above reward function x_i, as shown in (8) below.

$$x_i = f(t) = \begin{cases} 0, t = f_i \\ 1, t \neq f_i \end{cases} \tag{8}$$

Where, $f(t)$ Represents the tracking state information function, f_i Representing the condition function, the train number tracking objects are divided into four categories: station tracking objects, interval tracking objects, train number verification objects and original train number objects. First, these four elements are set as the first layer, and the tracking objects in the station and in the section are divided into the second layer, namely, a single object, including turnout object, track object, turnout free object, approach departure object, indicator object, block section object, section annunciator object, etc., as the input layer. The output of tracking hidden layer can be further generated according to the check relationship of train number z_k, as shown in (9) below.

$$z_k = f_i(\sum_{i=1}^{n} vk) \tag{9}$$

Where, vk It represents the check and matching parameters of the train number. At this time, train number dynamic tracking y_j can be obtained according to the above output, as shown in (10) below.

$$y_j = z_k f(t) \left(\sum_{i=1}^{n} w \right) \tag{10}$$

Where, w It represents the weighted value of the tracking transfer function. The above tracking algorithm can effectively determine the dynamic tracking position to ensure the accuracy of the final tracking display.

3 Experiment

In order to verify the tracking effect of the designed dynamic tracking method for train number of rail transit signal system, this paper builds a simulation tracking ATS topology structure, and compares it with the conventional dynamic tracking method for train number of rail transit signal system based on machine learning and the dynamic tracking method for train number of rail transit signal system based on reinforcement learning algorithm. Experiments are carried out as follows.

3.1 Experiment Preparation

In combination with the experimental requirements, this paper designs an effective ATS line topology based on a rail transit signal system and in combination with the characteristics of the station yard diagram. The topology is mainly composed of the starting point coordinates, the ending point coordinates, the specified logical direction, the length of the side and other parameters. The experimental ATS line topology is shown in Fig. 7 below.

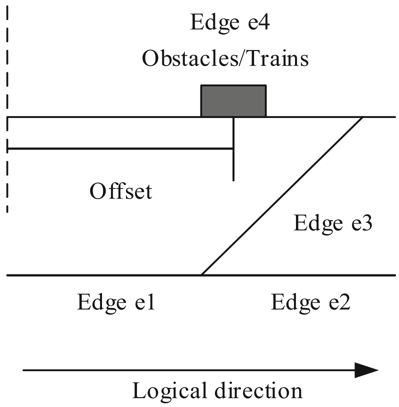

Fig. 7. Experimental ATS Topology

It can be seen from Fig. 7 that any point on the edge is uniquely determined by the ID value number of the edge plus the offset, that is, the offset relative to the starting point of the edge. In the ATS simulation system, it is not necessary to carry out absolute positioning for the train. By reading the train information data received by ATS, obtaining the train occupation ID value and the offset value, the specific position of the train in the station yard can be calculated, so as to achieve accurate positioning of the train. This paper determines the logical direction of the side from left to right according to the signal plane layout, as shown in Fig. 8 below.

It can be seen from Fig. 8 that in reading train information, the offset of the occupied section of the train relative to the logical direction is read in turn according to the logical direction of the side, and then the accurate position of the train is calculated.

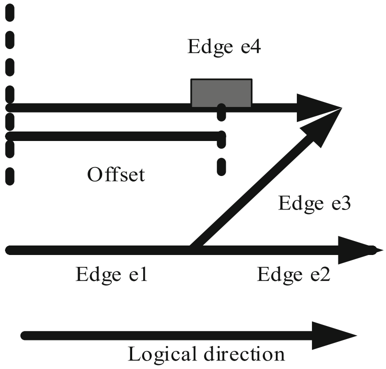

Fig. 8. Logical Direction of Side

The data in the station includes static data and dynamic data. Static data refers to the data that will not change with the change of signal equipment status or train position, that is, fixed data, which can only be modified when designing the station diagram.In this experiment, static data is configured and stored in the format of *. Xml file. By reading the *. Xml file, station entity instances are generated. Each instance corresponds to a signal equipment in the floor plan. The static data does not change with time. During the experiment initialization, the static data will be used as the line representation and basic data of train operation. After the experiment, the experimental platform will automatically save these data for future use. At this time, the data flow of signal equipment in the experimental station is shown in the following Fig. 9.

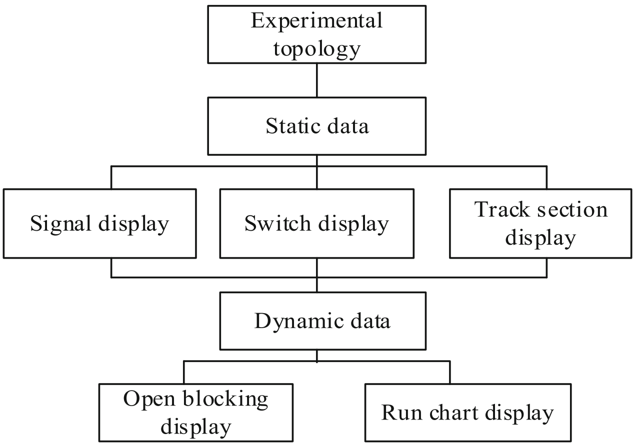

Fig. 9. Data Flow of Signal Equipment in Experimental Station

It can be seen from Fig. 9 that dynamic data refers to the data that changes in real time with the operation of the train. With the operation of the train, the status of the signal equipment changes constantly. Dynamic data is used to control the refresh of the dynamic status of the signal equipment. According to the above signal equipment data flow, the static data structure table of the experimental signal can be generated, as shown in Table 1 below.

Table 1. Static Data Structure of Experimental Signal

Data Attribute Name	Data type
Sig Name	String
Sig_ PointX	Int
Sig_ Pointy	Int
Sig_ Id	Int
Sig_Leftes QD Name	String
Sig_Right QD Name	String
Sig_DefaultStatus	Bit
Sig_ ProDir	Bit
Type	Int

It can be seen from Table 1 that the above static data structure meets the tracking experiment requirements, but it is difficult to track the dynamic attributes of train number using only the static data structure, so it is necessary to update the dynamic data structure table of the experiment, as shown in Table 2 below.

Table 2. Dynamic Data Structure of Experimental Signal

Data Attribute Name	Data type
Sig-G	TINYINT
Sig-H	TINYINT
Sig-U	TINYINT
Sig-HU	TINYINT
Sig-Broken	TINYINT
Sig-Off	TINYINT
Sig-AR	TINYINT
Sig-FS	TINYINT

It can be seen from Table 2 that the dynamic properties of dynamic signals mainly include the current light on state, route enabling state, blocking state, etc. of the annunciator. Obtain the dynamic data value of each annunciator through data interaction with the server, and update the display in real time. Five segment representation method is adopted for single turnout, as shown in Figs. 3 and 4 below. In order to facilitate the experimental division, this paper uses the five section method to distinguish, so that the train can be accurately positioned. The schematic diagram of experimental division is shown in Fig. 10 below.

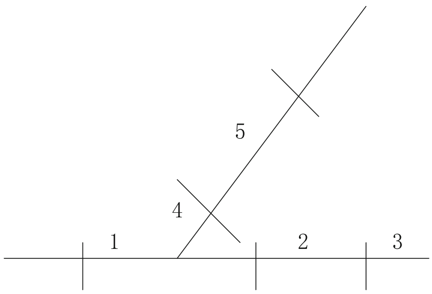

Fig. 10. Schematic Diagram of Experimental Section Division

It can be seen from Fig. 10 that during the design, the secondary number is set to 0 for the parking track and the section without turnout, and the secondary number is assigned to the section with turnout according to different sections. When positioning, accurate positioning can be achieved by using the primary number and secondary number.

In order to effectively carry out experiment interaction, this experiment uses the data information interaction between the area controller/on-board computer/computer interlocking/ATS system to enable ATS to complete train tracking identification and display, station diagram display, temporary speed limit control and other functions. All data interactions between the system and other subsystems are simulated and designed by the device simulation server. The browser only needs to communicate with the server to obtain relevant experimental data. At this time, the definition of experimental communication information is shown in Table 3 below.

Table 3. Definition of Experimental Communication Information

Name	Mess Type	Sending direction	Period or not
ATO control command	0 x 0201	Browser ~ Server	Aperiodic
ATO status information	0 x 0202	Server ~ Browser	Cycle
Train information	0 x 0204	Server ~ Browser	Cycle
Vehicle mounted equipment alarm information	0 x 0206	Server ~ Browser	Aperiodic

It can be seen from Table 3 that the train information is tracked and identified by using the train information sent by the server. Control commands can send dispatching control commands to the server according to operation requirements. ATS system monitors all trains in the station through ATO status information sent by the server. On board equipment alarm information is the fault alarm information of train equipment sent by the server to ATS system. Since all data interactions in the experiment are conducted with the server, the browser client only needs to send command related data, and the server sends the processed data to the device simulation server after logical processing, so all data formats involved in this paper are interactions with the server rather than real signal subsystems.

In order to effectively improve the network transmission efficiency of data, this paper defines the data format between the Web Socket server and the browser client as JSON format. The command information in the browser client is in JS information format, while the command information transmitted in the network must be in JSON string format; So first, you need to use the JSON function to convert the JS object into a JSON object for transmission in the network, that is, to serialize the JS object. Similarly, the JSON string information sent by the server must also be deserialized. That is, the front end can analyze the data only after you use the JSON function to convert the JSON string transmitted from the back end into a JS object. After the above experiment preparation is completed, the dynamic tracking experiment of train number of rail transit signal system can be carried out.

3.2 Experimental Results and Discussion

On the basis of the above experimental preparation, the preset train number dynamic tracking command is used for tracking experiments, that is, the train number dynamic tracking method of rail transit signal system designed in this paper, the train number dynamic tracking method of rail transit signal system based on machine learning, and the train number dynamic tracking method of rail transit signal system based on reinforcement learning algorithm are used for tracking. Record the dynamic tracking results of the three methods under different train positions, as shown in Table 4 below.

Table 4. Experimental Results

This paper			
Train position	Running direction	Actual train number	Track and display train number
1G	←	D1	D1
2G\3G	→	D2	D2
4G	←	D3	D3
5G	→	D4	D4
6G	←	D5	D5
A Dynamic Tracking Method for Train Number in Rail Transit Signal System Based on Machine Learning			
1G	←	D1	D1
2G\3G	←	D2	D1
4G	→	D3	D2

(*continued*)

Table 4. (*continued*)

This paper			
Train position	Running direction	Actual train number	Track and display train number
5G	←	D4	D2
6G	→	D5	D3
A Dynamic Tracking Method for Train Number in Rail Transit Signal System Based on Reinforcement Learning Algorithm			
1G	←	D1	D1
2G\3G	←	D2	D2
4G	→	D3	D2
5G	←	D4	D2
6G	→	D5	D3

It can be seen from Table 4 that under the preset operating environment, the dynamic tracking position of the train number dynamic tracking method of the rail transit signal system designed in this paper is matched with the actual train position, and the train number dynamic tracking method of the rail transit signal system based on machine learning. The dynamic tracking position of the train number dynamic tracking method of the rail transit signal system based on the reinforcement learning algorithm is quite different from the actual train position. The above experimental results prove that the train number dynamic tracking method of the rail transit signal system designed in this paper has good tracking effect, reliability and certain application value.

4 Conclusion

The development of rail transit technology has put forward higher demands on passenger volume, efficiency, comfort, energy conservation, etc. In areas with mature subway development, many cities consider upgrading existing lines to fully automated lines to improve operation efficiency and automation level. In the metro project, ATS system can obtain the occupation and clearing information of all physical tracks and logical tracks beside the line through the main line interlocking, and obtain the occupation and clearing information of physical axle counters or track circuits in the depot/parking lot through the depot interlocking, respectively realizing the tracking of train number based on the interlocking occupation information of the main line. Tracking of train set number based on interlocking occupancy information in depot.In the tram project, the operation dispatching system can only obtain the occupancy and clearing information of the section with turnout through the main line turnout controller, and the occupancy and clearing information of the trackside section without turnout can not be obtained, which makes it impossible to track the train number completely according to the occupancy and clearing information reported by the turnout controller. According to the characteristics of the rail transit signal system. An effective train number dynamic tracking method is designed, and experiments are carried out. The results show that the designed dynamic tracking method has good tracking effect, reliability and certain application value, and has made certain contributions to improving the operation reliability of the rail transit signal system.

References

1. Hu, J., Ma, T., Ma, K., et al.: Three-dimensional discrete element simulation on degradation of air voids in double-layer porous asphalt pavement under traffic loading. Constr. Build. Mater. **313**(5), 570–582 (2021)
2. Guan, L., Wang, D., Shao, H., et al.: Understanding the topology of the road network and identifying key bayonet nodes to avoid traffic congestion. Int. J. Mod. Phys. C **34**(03), 316–328 (2023)
3. Wei, K., Vaze, V., Alexandre, J.: Transit planning optimization under ride-hailing competition and traffic congestion. Transp. Sci. **56**(3), 725–749 (2022)
4. Li, J., Ma, M., Xia, X., et al.: The spatial effect of shared mobility on urban traffic congestion: evidence from Chinese cities. Sustainability **13**(24), 1–10 (2021)
5. Suryakala, V., Rajalakshmi, T., Kolangiammal, S., et al.: A novel vision based embedded framework system to detect and track dynamic vehicles. IOP Conf. Ser. Mater. Sci. Eng. **1130**(1), 51–60 (2021)
6. Wen, Y., Wu, R., Zhou, Z., et al.: A data-driven method of traffic emissions mapping with land use random forest models. Appl. Energy **305** (2022)
7. Lee, S., Jain, S., Ginsbach, K.: Dynamic-data-driven agent-based modeling for the prediction of evacuation behavior during hurricanes. Simul. Model. Pract. Theor. Int. J. Fed. Euro. Simul. Soc. **106**(1), 193–207 (2021)
8. Hu, J., Xiao, F., Mei, B., et al.: Optimal energy efficient control of pure electric vehicle power system based on dynamic traffic information flow. IEEE Trans. Transp. Elec. **8**(1), 510–526 (2021)
9. Xu, D., Zhou, D., Wang, Y., et al.: Temporal and spatial heterogeneity research of urban anthropogenic heat emissions based on multi-source spatial big data fusion for Xi'an, China. Energy Build. **240**(4), 110–123 (2021)
10. Liang, X., Xiao, L., Wang, X., et al.: Design of neural network PID controller for high-speed train speed tracking. Comput. Eng. Appl. **57**(10), 252–258 (2021)
11. Xu, C., Gu, X., Wang, L.: Fault tolerant tracking control of high speed train considering actuator performance constraints. J. Chin. Inertial Technol. **30**(4), 545–552 (2022)
12. Wu, Q., Cheng, S., Li, L., et al.: A fuzzy-inference-based reinforcement learning method of overtaking decision making for automated vehicles. Proc. Inst. Mech. Eng. Part D. J. Automobile Eng. **236**(1), 75–83 (2022)
13. Wang, Z., Zhao, X., Chen, Z.: A dynamic cooperative lane-changing model for connected and autonomous vehicles with possible accelerations of a preceding vehicle. Expert Syst. Appl. **173**(2), 1–18 (2021)
14. Afrin, T., Yodo, N.: A probabilistic estimation of traffic congestion using Bayesian network – ScienceDirect. Measurement **174**(1), 1–13 (2021)
15. Jiang, P., Liu, Z., Zhang, L., et al.: Advanced traffic congestion early warning system based on traffic flow forecasting and extenics evaluation. Appl. Soft Comput. **118**(8), 108544–108570 (2022)
16. Zhang, X., Nie, X., Sun, Z., et al.: Re-ranking vehicle re-identification with orientation-guide query expansion. Int. J. Distrib. Sens. Netw. **18**(3), 205–214 (2022)

17. Yang, Z., Zhu, Y., Zhang, H., et al.: Moving-vehicle identification based on hierarchical detection algorithm. Sustainability **14**(1), 211–224 (2021)
18. Luo, Q., Li, J., Zhang, H.: Drag coefficient modeling of heterogeneous connected platooning vehicles via BP neural network and PSO algorithm. Neurocomputing **18**(1), 484–896 (2022)
19. Song, S., Xiong, X., Wu, X., et al.: Modeling the SOFC by BP neural network algorithm. Int. J. Hydro. Energy **46**(38), 65–77 (2021)
20. Liu, L.: Lute acoustic quality evaluation and note recognition based on the softmax regression BP neural network. Math. Prob. Eng. **22**(7), 46–59 (2022)