Prediction and Prevention of Metro Station Congestion Based on LSTM Neural Network and AnyLogic

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Abstract. Metro is one of the most important public transportation tools in large cities. Periodic congestion easily occurs in certain areas of metro stations because of the periodic peak of travel demand. Congestion will bring inconvenience to passenger's travel and increase the risk of accidents such as trampling. In this paper, a method based on LSTM neural network and AnyLogic is proposed to predict and prevent the occurrence of congestion in specific areas in metro stations in advance. Firstly, the congestion is predicted by LSTM and historical data, and then a reasonable way to solve the congestion is discovered based on AnyLogic simulations. The proposed method is expected to provide general suggestions for metro station managers. According to the simulation results, the proposed method can effectively alleviate the congestion in metro stations and reduce the probability of high passenger density areas.

Keywords: Simulation · Passenger flow management · Congestion avoidance

1 Introduction

With the rapid development of urban transportation, rail public transportation has gradually become one of the primary travel modes and played a crucial role in daily life. Nowadays, in rush hour or some transfer stations, crowd congestion jams are prevalent in the megalopolis. Scientists try to simulate and analyze the process to alleviate the above problem. Zhu et al. [1] based on the analysis of the traffic flow characteristics of the surrounding areas in 2009, the land use strategies of high-speed railway stations are found. This study improves the utilization rate of station land.

In order to simulate the evacuation and queuing of passengers, Shigeyuki Okazaki et al. [2] simulated the pedestrian movement in buildings and urban spaces by using the pedestrian movement model with evacuation and queuing in 2012, which provided an effective method to manage the passenger flow in public places such as metro stations. However, the generalizability is not tested in both papers. Bohari et al. [3] simulated the passenger moment pattern to reduce the congestion and improve the accessibility of passengers. However, it requires a large number of employees to implement this method, which is challenging to be deployed in different conditions in 2014. In order to provide guidance for the passenger flow, Li et al. [4] quality analyzed the short-term traffic flow prediction method of the dynamic highway traffic model. The simulation results show that the method is effective also feasible, which provides strong support

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for the traffic management department. However, this method has not been studied in traffic information optimization, so there may be some deficiencies in the actual road problems. The paper written by Hualan Wang et al. is based on AnyLogic, which analyzes the ways to improve the operation capacity of Zhongchuan High-speed Railway Station by optimizing passenger flow lines [5]. Although the walking distance of passengers entering the ticket hall has increased after the optimization, the effective separation of the crowd has become clearer. By doing this, the cross interference is reduced and station capacity is increased. However, in some special or novel structure stations, the simulation may not play such a good effect.

Wang and Xu et al. [6] established a model on an island platform. The model is used to simulate the process of passengers getting on and off the bus under different conditions. According to the calculation results, the main factors affecting the average time of getting on and off the bus and their influencing trends are obtained. Jiang and Yan et al. analyzed the train dispatch scheme and carrying capacity of Changsha South Railway Station [7]. By analyzing several aspects like the train headway, the station layout, and the utilization of tracks. In order to give effective suggestions for these limiting factors. But this paper only analyzes a few specific factors; This is not enough for all stations. Tian and Chen et al. analyzed the passenger flow conflict under the different layouts of service facilities [8]. On the basis of AnyLogic, constructive suggestions for alleviating station congestion are put forward. In future research, passengers' micro-behaviors can be included in the selection model to make the research more in-depth and detailed. According to the literature review, there are few scholars to make combined passenger flow prediction and simulation for passenger guidance research. This research proposes a method, which uses the historical traffic data and LSTM neural network to predict the upcoming congestion and uses AnyLogic simulation method to explore the strategy of relieving congestion. Finally, the prediction and simulation are combined to alleviate congestion. The contributions of this study are as follows:

1. Through the prediction model, the time of daily congestion can be analyzed in order to inform the metro station managers in advance and prevent the upcoming congestion.
2. By using simulation, the location and deployment time of the deployment staff are proposed.
3. The data obtained from the model analysis can provide data for the optimization of metro stations in the future.

2 Methodology

Figure 1 shows the control framework of this project design. The passenger flow management of the station is realized through the cooperation between an automation management platform and the managers.

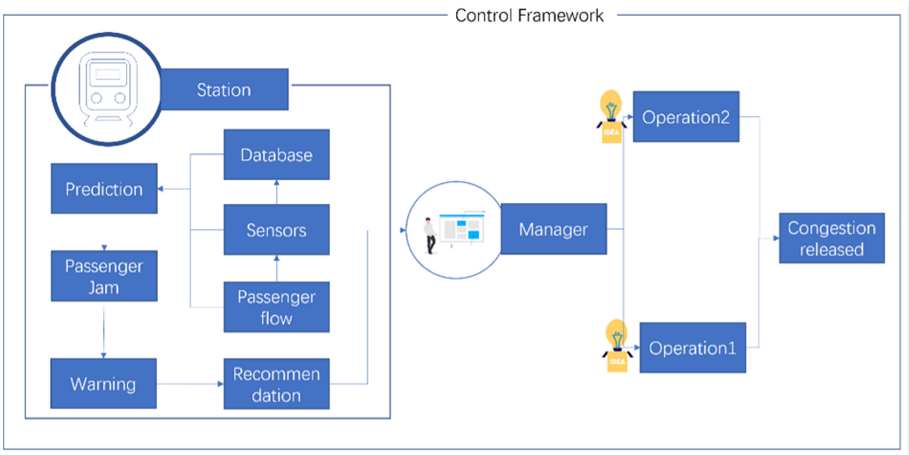


Fig. 1. Demonstration of the control framework

The three functions of the automatic management platform are to predict passenger flow, to provide early warning of congestion, and to provide suggestions for passenger flow guidance when congestion is predicted. The passenger flow prediction function is based on a trained Long Short-Term Memory (LSTM) neural network. The network is trained based on the historical data of card swiping, and a well-trained LSTM network is able to support accurate prediction. The adopted input and target data for training the LSTM is shown in Fig. 2. The input for the first LSTM is the observed predictor feature, but for all future LSTM, the input is the expected deviation term for time and the output value of the previous LSTM. In this figure, the variable names are explained as follows: $D(t(n))$: passenger density in key areas, $D(\widehat{t(n)})$: the prediction of key area's passenger flow density, $CP(t(n))$: the number of passengers who swiped the card into the station within the corresponding time. $TH1(t(n))$: the headway for trains in direction 1. $TH2(t(n))$ the headway for trains in direction 2. The prediction can be obtained by setting up the LSTM network and input $CP(t(1))$, $TH1(t(1))$, $TH2(t(1))$.

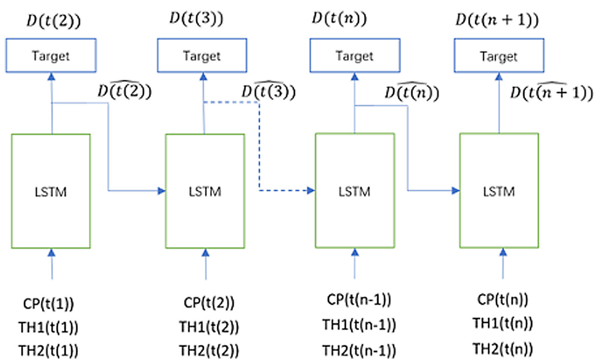


Fig. 2. Adopted LSTM model

The proposed system will send a warning to the station managers when it detects the impending congestion. The early warning part of congestion needs to provide the staff with the predicted areas where congestion will occur and the congestion degree. It is difficult to collect such data in practice. For a specific station, the direction of passengers' travel during peak hours is often periodic. Thus AnyLogic can be used to simulate and explore mitigation strategies in advance. Therefore, the AnyLogic is employed to obtain the demand data through simulation. A three-dimensional model of the corresponding station is established in AnyLogic, and the passengers entering and leaving each station could be controlled in the simulation. By changing the frequency and speed of passengers entering the station, the high-density areas in different scenarios can be obtained. The passenger density in some areas of the station will exceed the safety standard in some scenarios, and the corresponding input parameters and areas where congestion occurs are recorded. The simulated data can be used as the preliminary data for realizing congestion area prediction in the platform with the continuous accumulation of recorded data. The data obtained from the simulation can be compared and adjusted according to the real data collected by the sensors when congestion occurs, in reality, to continuously improve the accuracy of early warning.

The third function is to provide suggestions for preventing congestion. Guiding passenger flow in advance is a way to avoid congestion. In the model, engineers test the guidance modes in different scenarios and carry out verification tests in the AnyLogic model. Each solution is numbered and then stored in the database. The platform first seeks solutions to similar congestion in the database when the intelligent prediction platform predicts that congestion is about to happen, and it gives suggestions to the staff and if similar solutions are found. If it is not found, however, the early warning information will be recorded, and the engineer will conduct a new solution modeling test according to the marked early warning information in the short future.

3 Case Study

The case study uses AnyLogic to verify the efficiency of the proposed system. The created model includes two floors. Each floor has an area of around 512 m^2. The B1 floor mainly simulates a series of processes, such as passengers buying tickets at the station, security check, taking the escalator to the platform, and getting out of the station. During the simulation, the number of passengers entering each metro entrance to the B1 floor is 100 person-times per hour. On the B2 floor, the metro arrives at the station every 120 s. This floor mainly simulates the passengers boarding and alighting the metro, leaving the platform, and entering the station by escalator. During the study, the B1 floor and B2 floor are separate from imposing different conditions of constraints so that the flow of passengers into and out of the station will be congested on different floors. After the congestion has formed, there are two ways to change the congestion and relieved the passenger flow.

Two congestion scenarios are created and alleviated in the simulation. Passengers jam at the entrance, security check, and ticket gate in the first scenario. The solution for this scenario is to arrange staff members in a certain area to guide the passenger flow (as shown in Fig. 3).

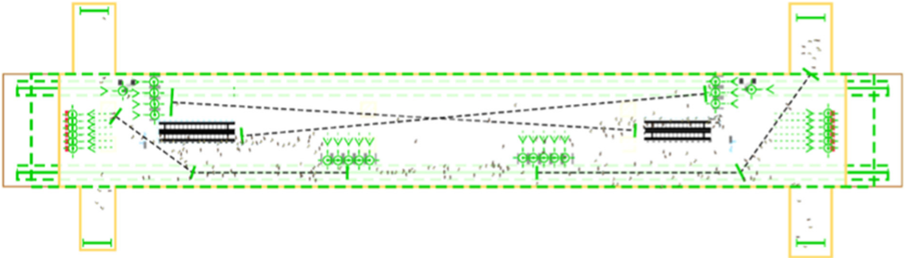
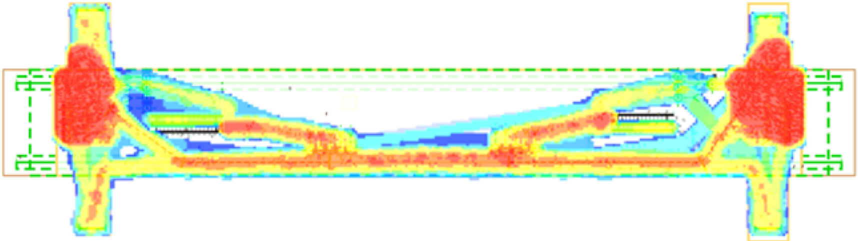
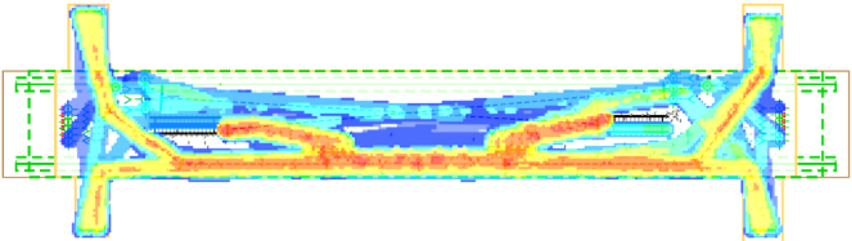


Fig. 3. Solution for the first scenario



(a). Passenger Density without Guidance



(b). Passenger Density with Guidance

Fig. 4. Passenger density distribution comparison of the first scenario

Figure 4 shows the passenger density distribution comparison between with and without the guidance within the station, and Fig. 5 shows the highest density comparison. As shown in the figure, density decreased significantly and dropped.

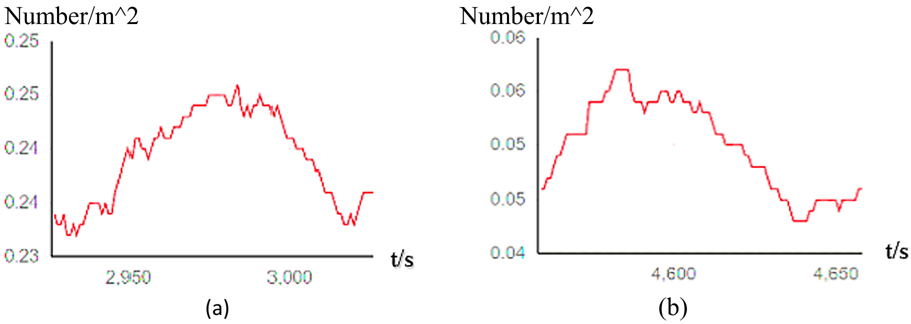
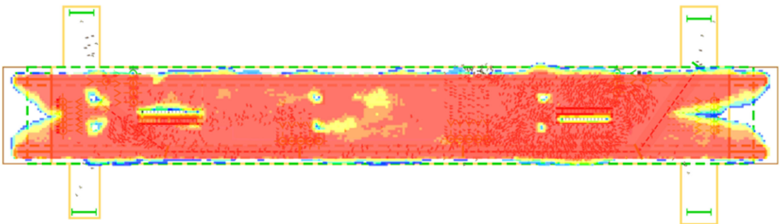


Fig. 5. Highest passenger density comparison of the first scenario.

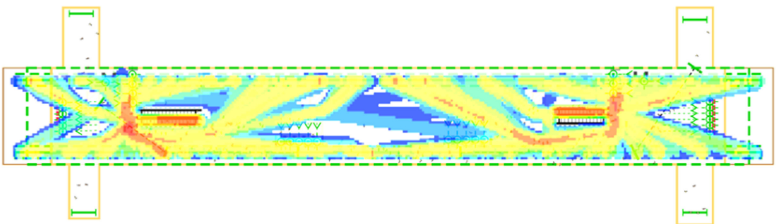
By comparing with Figs. 4 and 5, the congestion has been significantly reduced. So there is no doubt that this is a very feasible approach.

Congestion occurs at the B2 floor in the second scenario.

Congestion in the second scenario is caused by the headway. When the evening rush hour and other factors arrive, more passengers can be gathered in a short time on the B2 floor. So, at this point, the original headway cannot satisfy the requirement of that passenger flow. Thus, it caused congestion. It also leads to a gradual increase in the number of passengers waiting for the metro on the B2 floor, resulting in the congestion phenomenon, which is more obvious when the metro arrives at the station. When it comes to the solution, the flow can be relieved by shortening the metro's arrival time,



(a). Passenger Density of the Second Scenario without Headway Adjustment



(b). Passenger Density of the Second Scenario with Headway Adjustment

Fig. 6. Passenger density distribution comparison of the second scenario

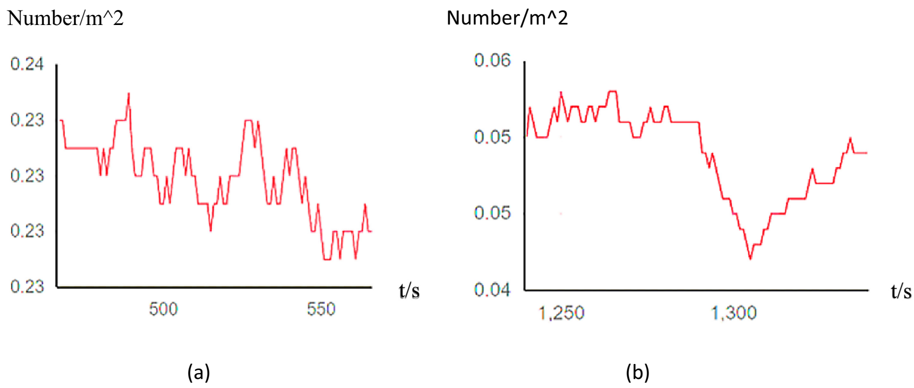


Fig. 7. Highest passenger density comparison of the second scenario

which is collected by a large amount of historical data to ensure that the operation of the metro will not cause unnecessary safety risks by shortening the headway. In the past, the metro arrives at the station every 120 s. But when the headway changes to every 45 min, the congestion has been greatly reduced (Fig 6).

Figure 7(a) shows without change the headway during the rush hour, the peak density of the B1 floor is very congested and even reaches 0.24. Figure 7(b) shows that the population density decreased significantly after shortening the headway and dropped even to 0.04. The test result of the two scenarios proves the proposed system is feasible and is able to reduce the congestion on the different floors effectively.

4 Conclusion

This paper proposes a system that is able to predict the congestion and provide guidance to alleviate it. The prediction is realized by the LSTM neural network, and the AnyLogic is adopted to test different solutions. By analyzing the data and improving the management measures of the metro station, the original congestion has been relieved significantly. Although the case study proves the system could relieve the congestion, there are some limitations. The prediction part is not tested in the case study due to lack of data. Consider the LSTM is well tested in many research areas, it is reasonable to assume the model could provide acceptable prediction accuracy. It is expected to further discover the proposed system and refine the method in the future.

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