Crowded treading warning system for urban rail transit stations based on video detection technology

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ABSTRACT

Based on the rapid development of rail transit and the large crowded treading dangers of rail transit stations, this paper constructs a crowded treading warning system for urban rail transit stations based on video detection technology, which uses video detection technology to collect passenger flow, velocity and density data of the bottleneck channel in rail transit stations, then builds and trains a neural network model to predict the next time passenger flow density combined with the three-parameter relationship of the traffic flow, and uses the SPSS software to fit and analyze the passenger flow parameters, so the limit value of the flow-density polynomial model is predicted by pedestrian flow mutation model and used to realize the definition of the critical passenger flow density model based on catastrophe theory. On this basis, the real-time predicted value of the passenger flow density is compared with it and get the analysis result, then set the corresponding early warning coefficient, early warning level and early warning measures, so truly realize the real-time warning of crowding and trampling of rail transit stations based on passenger flow density prediction.

KEYWORDS: Video detection; crowded stepping; passenger flow; warning level

1 INTRODUCTION

Urban rail transit has many advantages such as large volume and rapid punctuality. It has been put into operation in many cities as an important means to solve traffic congestion. By the end of 2018, there were 32 places in Hefei, Nanjing, Chongqing, Beijing, Tianjin and Chengdu. The city has opened 155 urban rail transit lines with a total operating mileage of more than 5,000 kilometers and 3,245 stations, of which 15 cities have a mileage of more than 100 kilometers. The operation of urban rail transit has entered a networked era. At the same time, the contradiction between supply and demand between the increasingly long urban rail transit passenger flow and the urban rail transit station with limited capacity has become more prominent, which in turn has increased the risk of crowded stampede accidents among passengers in urban rail transit stations. In order to prevent the occurrence of such crowded stampede accidents and to ensure the safety of passengers, it is necessary to implement a passenger flow congestion stamping warning for urban rail transit stations.

A large number of research scholars have carried out many researches on subway passenger flow early warning. Wang Wei studied the daily large passenger flow detection and early warning system of Shanghai rail transit according to the daily large passenger flow characteristics of urban rail transit, and proposed large passenger flow detection at different levels of network, line and station. Early warning requirements and applicable detection

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techniques; Li Dewei proposed the concept and framework of passenger flow warning for rail transit stations, studied the classification and classification basis of passenger flow early warning, and analyzed the applicable conditions and scope of use of different passenger flow early warning indicators to construct corresponding indicator systems. And suggesting the passenger traffic warning threshold; Ding Lei selects the ticket checking ability, the channel space load degree, the passenger boarding time and so on as the basic indicators, and on the basis of analyzing the passenger flow characteristics, proposes a passenger flow warning level division. The method also sets the countermeasures corresponding to different levels; Yang Jufen designed the early warning system under the large passenger flow of the station, analyzed the influence degree of the crowd under different passenger flow and divided the corresponding early warning level and proposed related preventive measures; Ma Chengzheng analyzed the passenger flow of the urban rail transit station. Based on the related characteristics, a passenger flow early warning model based on GRNN algorithm is proposed, which realizes the early warning and countermeasure implementation under sudden large passenger flow; Li Guanggang selects Nanjing subway as a reference example, based on its video detection and analysis technology. Passenger flow forecasting research, summed up the relevant ideas and difficulties of the construction of subway passenger flow early warning system; Zhang Wei selected a number of orbital rail traffic safety early warning indicators, carried out dimensionless and determined their respective weights, and pre-emptive rail transit safety. The single early warning indicator is comprehensively obtained from the comprehensive evaluation and early warning indicators, and the early warning method is determined on this basis; Yang Anan refers to the relevant research conclusions of the human flow current limit threshold, and studies the passenger flow threshold of the subway platform, based on which the passenger flow early warning model is constructed. And set the conditions for the corresponding current limit start; Jiang Yanzhen takes the Xi'an subway as an example. The paper analyzes the risks in its passenger flow organization, and on the basis of analyzing the existing various passenger flow early warning systems, it proposes a passenger flow early warning system that can intelligently measure the passenger flow density and respond to the intelligent start of passenger flow control.

In the above research, it is mainly aimed at macroscopic comprehensive evaluation and early warning of the overall safety of large passenger flow or rail transit stations. The microscopic level lacks detailed research on the complex characteristics of pedestrians in specific spaces within rail transit stations and predicts short-term traffic conditions is rarely studied. This paper studies the passenger flow information collection, passenger flow state prediction, crowded stampede accident risk assessment and early warning, and builds a crowded stepping warning system for urban rail transit stations based on video detection technology to realize real-time dynamic monitoring early warning of rail transit station passenger flow.

2 PASSENGER FLOW INFORMATION COLLECTION

The passenger flow information data of the rail transit station base is the decision-making basis for the crowded trampling warning of urban rail transit stations. The acquisition of passenger flow information data needs to be realized through certain acquisition and detection technologies. At present, the common passenger flow intelligent detection technologies at home and abroad mainly include video detection technology, photoelectric detection technology and pressure sensitive sensing technology three categories. Compared with the photoelectric detection technology and the pressure sensitive sensing technology, the video detection technology not only has a large single-camera imaging range, but the multi-machine system can basically achieve no dead angle coverage, and can overcome the shortcomings that it cannot comprehensively monitor and detect the passenger flow state of the station. Therefore, the video detection technology is more applicable to the comprehensive real-time collection and detection of passenger flow status information of urban rail transit stations.
The early warning system is based on real-time passenger flow data. The data monitoring of passenger flow operation status mainly includes passenger flow, passenger flow speed and passenger flow density. The monitoring method adopted in this project is set up video surveillance equipment at the bottleneck location to circulate the passenger flow data, then identify moving targets in video images by pedestrian detection, pedestrian tracking and pedestrian counting technology, establish data statistics principles, statistic and output the required data in the monitoring area. Among them, the bottleneck location of the passenger circulation line includes the horizontal channel of the confluence, the upstairs staircase, and the descending stairway.

3 PASSENGER FLOW STATE PREDICTION

In order to realize early-warning decision-making, urban rail transit stations need to accurately and accurately predict the passenger flow state at the subsequent time. The existing rail transit passenger flow state indicators mainly include pedestrian flow, pedestrian flow speed, pedestrian flow density and congestion degree. Some scholars have studied the degree of association between the bottleneck point and its associated points, and used the real-time pedestrian flow density information of the bottleneck point and the associated point to propose a space-based pedestrian flow parameter prediction model, which is more accurate in predicting the flow density. However, real-time and continuous prediction of the passenger flow state at the subsequent moments has not been made. In terms of short-term traffic flow prediction based on real-time prediction, scholars from various countries have proposed a variety of methods and models, including methods based on linear system theory, methods based on nonlinear system theory, intelligent prediction methods based on knowledge discovery, and combined prediction. Model method, traffic simulation based method, forecasting method based on traffic flow spatiotemporal characteristics and other methods, but mainly predicting passenger flow single state index, forecasting application in passenger flow speed, passenger flow density and congestion degree is rarely studied.

The important decision-making basis for the crowded treading warning of urban rail transit stations is based on the development forecast of the passenger flow state. The higher the passenger flow density, the more crowded, the higher the risk of crowded stampede accidents, the more reason to issue a crowded stamping warning. The indicators in the passenger flow information of urban rail transit include passenger flow, speed, density and flow direction. The passenger flow density can best characterize the congestion of passenger flow. The passenger flow state prediction of rail transit stations is actually the prediction of passenger flow density.

The macro pedestrian flow is similar to the macro traffic flow, and the traffic flow model can be used to analyze the macro pedestrian flow. The individual characteristics of different pedestrians, the traffic environment in which they are located, and the purpose of travel of the pedestrians all affect the free flow velocity of the pedestrian flow. As the pedestrian flow density increases, pedestrians will be restricted by other pedestrians. When the density reaches a certain value, there will be a similar blocking flow phenomenon in road traffic. There is obvious difference between speed, flow and density. affect each other. According to the model of road traffic flow, the passenger flow of the rail transit station can also establish a correlation model of three parameters of speed, flow and density, \( Q = K V \) (\( Q \) is the passenger flow, \( k \) is the passenger flow density, and \( v \) is the passenger flow speed).

Based on the passenger flow information collection subsystem, the passenger flow and passenger flow velocity information are collected for statistical analysis, and the time variation law is mastered. The neural network theory is used to set a reasonable short-term passenger flow prediction interval according to the start-up and emergency response time of the prediction system. The corresponding short-term passenger flow prediction model predicts the passenger flow and passenger flow velocity at the subsequent time, and combines the above three-parameter model of passenger flow to predict the corresponding passenger flow density, thus realizing the prediction of passenger flow state.
The establishment of the early warning mechanism and system of the rail transit station is of great significance for ensuring the operation of the rail transit system. The early generation of early warning theory was in the field of macroeconomics. The early French economist Fulily used the method of weather forecasting to forecast the economic crisis. The mature stage represented the prediction of economic warning theory by the composite index early warning model applied by Higgins. In recent years, the research hotspots of early warning at home and abroad are mainly reflected in the application research of early warning technologies, tools and models in various industries. The transportation system is no exception. It is often used in the operation management and safety analysis of rail transit, especially in the research with regularity of the development of rail transit from single-line to network.

To realize the reasonable release of the early warning information of the rail transit station and the reasonable implementation of the early warning measures, it is necessary to accurately evaluate the crowded stampede risk of the rail transit station based on the passenger flow density predicted by the passenger flow state prediction subsystem. The project is based on the traffic flow and passenger flow density data of different passenger flow bottlenecks collected in the passenger flow information collection subsystem (in the horizontal channel of the confluence, upstairs stairs, and descending stairs), and the SPSS software is used for fitting to obtain the bottleneck of the passenger flow. The relationship between passenger flow (ordinate) and density (abscissa), the corresponding maximum passenger flow is calculated, and the multimodality, unreachability, sudden jump, divergence and hysteresis of the pedestrian flow operation state of the rail transit station are analyzed. Based on the catastrophe theory, construct a sudden model of the pedestrian flow operation state of the rail transit station, and calculate the pedestrian flow state critical density of the sudden change, that is the critical passenger flow density of the crowded trampling warning of the passenger flow of the rail transit station.

Drawing on the research results of the risk assessment of crowded stampede accidents, the “General Emergency Plan for National Public Emergencies” issued by the State Council of the People's Republic of China in 2006\textsuperscript{[10]}, see Table 1, for the reasonable division of the early warning levels of rail transit stations, see Table 2. From high to low, it is divided into four levels: red, orange, yellow and blue. According to the risk level of each crowded stepping, it develops corresponding early warning measures and implements related measures of passenger flow guidance and emergency rescue.

| Alert level | Specific indicators |
|-------------|---------------------|
| IV blue warning | The number of people in the activity exceeds 10% of the approved safety capacity, and there are safety accidents. |
| III yellow warning | The number of people in the activity exceeds 20% of the approved safety capacity, and there are major safety accidents. |
| II orange warning | The number of people in the activity exceeds 30% of the approved safety capacity. The site has dangerous parts in the bottleneck section, the environment is complex, and there are major safety accidents. |
| I red warning | The number of people in the activity exceeds 50% of the authorized personnel capacity. There are many dangerous parts in the bottleneck of the site. The environment is very complicated and there are hidden dangers of serious safety accidents. |
| Alert level | Specific indicators |
|-------------|---------------------|
| IV blue warning | Passenger flow density prediction is greater than 10% of critical density, less than 20% |
| III yellow warning | Passenger flow density prediction is greater than 20% of critical density, less than 30% |
| II orange warning | Passenger flow density prediction is greater than 30% of critical density, less than 50% |
| I red warning | Passenger flow density prediction is greater than 50% of critical density |

Finally, based on the passenger flow state prediction subsystem, the passenger flow density at the subsequent time is compared with the critical density of the crowded trampling warning. The passenger flow state of the rail transit station is used to carry out the crowded stamping risk assessment to determine whether it reaches the respective warning levels. If the warning requirements are met, no early warning will be issued. If the warning requirements are met, an early warning will be issued, corresponding to the corresponding early warning levels and measures, and presented and alarmed in a multimedia manner such as graphics and sound, prompt and warn passengers, decision-making managers at rail transit stations, and station staff.

5 PASSENGER CROWDED STEPPING WARNING SYSTEM

On the basis of the above-mentioned subsystems, this paper proposes an early warning system for the support of the rail transit national station. Through the analysis of the spatial layout of the rail transit station and the pedestrian traffic organization scheme, the location of the bottleneck channel in the station is determined and video surveillance is arranged. The detection equipment collects the three-parameter data of passenger flow, velocity and density, trains the short-term passenger flow prediction neural network model, and combines the three-parameter relationship of traffic flow to predict the short-term passenger flow density at the subsequent time, and uses SPSS software to collect the collected passenger flow. The data is fitted and analyzed, the relationship between passenger flow and passenger flow density is determined, and the critical value of passenger flow is determined. Finally, based on the catastrophe theory, a pedestrian flow catastrophe model is established. The critical value of passenger flow is input to obtain the critical value of passenger flow catastrophe. Compare with the predicted value of passenger flow density, the early warning coefficient of rail traffic congestion is set, the early warning level is divided, and the early warning strategy and early warning measures are formulated. The specific technical process of the system is shown in Figure 1.
Figure 1 Passenger flow congestion stepping warning technology flow

It can be seen from the above technical flow chart that the execution flow of the passenger flow crowding and treading warning system starts from the video detection and collection of relevant short-term passenger flow information, and the relationship between each passenger flow parameter and the subsequent short-term passenger flow state prediction, and the corresponding early warning information is performed. The implementation of the release and early warning measures, real-time dynamic prediction of the passenger flow status of urban rail transit stations and congestion

6 CONCLUSION

This paper focuses on the crowded treading warning of urban rail transit stations, discusses the passenger flow information collection, passenger flow state prediction, passenger flow crowding risk level assessment and corresponding early warning, and establishes a crowded stepping warning system for urban rail transit stations based on video detection. Implement the following features: (1) Based on the video detection technology, the pedestrian flow, velocity and density data collection of the station is realized, and the real-time prediction of the passenger flow density of the bottleneck channel of the rail transit station is realized through the comprehensive application of the neural network model and the three-parameter relationship of the traffic flow; (2) Through the sudden change model of the pedestrian flow operation state of the bottleneck channel of the rail transit station, the maximum critical passenger flow density that may be crowded and stepped on is theoretically defined to obtain the early warning threshold value; (3) The passenger traffic congestion crowding stepping warning level is classified, and All levels of early warning measures and passenger flow diversion measures are implemented at the time of early warning. However, due to the certain error of the passenger flow data obtained by video detection, it is also necessary to combine the information collection methods such as the passenger ticket checking data system, and the
accuracy of the short-term passenger flow state prediction method needs to be improved. The subsequent research needs to be further deepened.

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