A Summary of Research on Passenger Flow Simulation Technology in Rail Transit Station

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Abstract. From macroscopic and microscopic aspects, the research status on passenger flow simulation technologies are summarized. The macro-model mainly contains the system dynamics model and the hydrodynamic model. And the macro-model mainly introduces the magnetic model, the queuing theory model, the cellular automaton model and the social force model. Through comparative analysing the simulation models mentioned, this paper proposes the model suitable for the station simulation in peak hours.

1. Research Status of Pedestrian Movement Macro-model
The main idea of the pedestrian movement macro-model is to treat the crowd as a whole with the same nature. The dynamic characteristics of the whole are described by its flow, speed, density, location and time. The characteristic of the macro model is that it can grasp the whole movement characteristics of pedestrians from the whole point of view. Compared to the micro model, it requires less calculation and low performance of computer. In addition, when it comes to a large number of pedestrians, macro-model can control the whole characteristic better, the results are also more realistic. Common macro models include system dynamics model and fluid dynamics model.

1.1. System Dynamics Model
System Dynamics Method is built by Professor Jay Forrester from Massachusetts Institute of Technology (MIT). In the context of scientific engineering, Professor Forrester make use of laws of Physics to describe and study the dynamic changes of various complex systems in life. As a very common model, system dynamics model has long-term, strategic and macroscopic characteristics. The assumption has a higher level of abstraction, representing people, products, events, and other discrete things expressed in quantity. It can be seen that system dynamics is a typical theory to study the macro-properties of a system from the micro-characteristics.

In the 1990s, based on the research of Ever and Abbas, system dynamics began to be applied in the field of transportation. System dynamics takes large-scale complex systems as the research object, uses the internal feedback theory to enable the users to understand the structure and dynamics of complex systems. Systematic dynamics is also a rigorous modelling method, making users to build formal computer simulations of complex systems and use them to design more effective policies and organizations. In recent years, more and more scholars have begun to apply system dynamics to the complex large-scale urban traffic system, which is helpful to planning, construction, management and other aspects, and has played a great role in promoting the development of urban traffic theory and practice.

The essence of system dynamics is a set of first-order differential equations about time, which are based on the flow chart of the system when establishing the model. The main foundation of system dynamics is the causality among the elements in the system and the whole structure of the system.
System dynamics takes complex systems as research objects, and draws corresponding system structure diagrams, element causality diagrams, flow charts and so on. The system must have certain structure and corresponding functions. After separating the structure of a complex system and analysing the relationship between each part, the corresponding equation is compiled by computer software, and then the actual data are fitted. The computer simulation experiment can be carried out, and the results change with time can be obtained.

1.2. Hydrodynamic Model

Hydrodynamic model is one of the typical representative models of macroscopic pedestrian motion theory model. Its basic principle is to take pedestrians as the research object, regard crowd flow as the flow medium that accords with the law of fluid mechanics movement, and describe the law among the variables of crowd flow, density and speed with the aid of fluid mechanics theory.

In the 1880s, Henderson first proposed two macroscopic model ideas of gas dynamics and fluid dynamics, obtained the corresponding models and applied them to the actual pedestrian movement through the actual statistical data of the crowd. Coscia and Canavesio reanalysed the human population flow macro-model, linking the local velocity and local density that were not considered into the macro-model, and considering some relatively microscopic aspects, such as obstacles and crowds on the path. The influence of factors such as the degree of panic. People who use fluid dynamics and gas dynamics in stations include Guo, Asano and so on.

2. Research Status of Pedestrian Motion Micro-model

The main idea of the micro-model of pedestrian movement is to study the individual. The behaviour characteristics of the individual are described by the interaction between the individuals in the movement and the individual characteristics. The characteristic of micro-model is that it can grasp the behaviour and motion characteristics of micro-individuals. It has a large amount of calculation and a high requirement for computer performance in simulation. Compared with the macro-description methods of crowd movement, the methods of micro-models are more diverse, such as magnetic model, queuing theory model, cellular automata model and social force model, which are the mainstream micro-models nowadays.

2.1. Magnetic Model

The magnetic model is a model that describes the movement of pedestrians by using Coulomb's theorem. It was proposed by Okazaki. Its core idea is to endow pedestrians, obstacles and other magnetic fields with positive poles, and destinations with negative poles. After that, people can show the attraction relationship between pedestrians and destinations like magnetic poles, and show the exclusion relationship with obstacles and so on. The pedestrian motion is adjusted appropriately according to the magnitude of the force obtained by the magnetic model. The basic mathematical model is as follows:

$$F = \frac{k \cdot Q_1 \cdot Q_2}{r^2}$$

Where, $Q_1$ denotes the magnetic quantity of the positive pole, $Q_2$ denotes the magnetic quantity of the negative pole, $k$ denotes the coefficient related to human motion, and $r$ denotes the distance between pedestrians and other parts.

2.2. Queuing Theory Model

Queuing theory model divides the region into uniform meshes, uses nodes to represent small regions, and wires to connect nodes. After each pedestrian leaves the node, he will queue up in the connection, and select one of all the connections according to the size of the probability value, then move to another node. Queuing theory is a branch of operations research in mathematics. Like queuing theory model, queuing theory has three basic elements, including pedestrian input process, queuing rules and service mechanism. In 2012, Xinyue Xu and others analysed the relationship between passenger travel...
characteristics and channel service capacity, and established a channel capacity calculation model based on M/G/C/C state-dependent queuing model. The relationship between channel width, length and maximum throughput is also analysed. On the basis of queuing theory, Xueping Rao studied and analysed the queuing situation of passengers at stairs and escalators in subway stations, and established the corresponding delay model. In 2016, Kunwar and others analysed the pedestrian behaviour characteristics and used queuing network model to predict the total evacuation time of pedestrians.

2.3. Cellular Automaton Model

Cellular automata (CA) is a non-linear pedestrian simulation technology. Its model is a discrete space, time and state dynamic system composed of finite state cells on a uniform grid. The moving plane space is divided into several small square cells, which are occupied or empty at any time. At this time, the spatial position of the individual and obstacle is represented by the number of the cell in which it is located. In the simulation process, time is divided into equal-sized time segments. In any time segment, the individual considers his own behaviour rules and environment and judges the next movement based on Monte Carlo method, that is, to maintain in the original cell or move to one of the eight adjacent cells. Koster and others proposed a cellular automaton model for pedestrian simulation, which can be used to better simulate pedestrians. Wei Zhang and others used cellular automata model to study the impact of the surrounding environment on pedestrian behaviour. Hao Yue and Chunfu Shao studied the impact of dynamic rules on pedestrian movement in different areas of cellular automata model, and analysed the impact of exit interference on pedestrian emergency evacuation time. Tang and others used cellular automata model to explore the behaviour characteristics of pedestrians in high-speed railway stations. Zhou and others used cellular automata model and added guidance factors to study the impact of pedestrian movement at this time.

2.4. Social Force Model

The basic principle of the social force model is Newton mechanics, which regards the moving pedestrian as a particle and is influenced by his own motive, external environment and surrounding pedestrians. In this way, the three forces he receives are deduced: self-driving force, interaction force between people and buildings and obstacles, then the acceleration of the pedestrian is formed and the corresponding physical motion is carried out. In 1995, Helbing and others established a social force model based on Newtonian mechanics. Five years later, Helbing once again improved and revised his social force model, making it more accurate to describe pedestrians. Qingyan Ding and others improved the parameters and algorithms of the social force model, and evaluated the improvement through the study of model simulation. In 2017, Han and Liu added information transmission mechanism to the social force model to simulate a scenario: when most pedestrians are unfamiliar with the evacuation environment, they studied the impact of adding information transmission mechanism. Weiguo Song used the social force model to study the pedestrian emergency evacuation time and change the factors of the export situation, so as to explore its impact.

3. Comparative Analysis of Station Simulation Models

Due to the different principles of the above models, there will be some differences in their application. The advantages and disadvantages of these models are summarized by comparing and analysing them, as shown below.

3.1. System Dynamics Model

The advantages: Simple and convenient, low requirement for computer performance, convenient debugging, low simulation cost and fast simulation speed; The station state can be predicted quickly in the near future according to the real-time situation; The internal mechanism of the system is clearer and clearer; It can reflect the key macro passenger flow information such as speed, density and flow.

The disadvantages: The interaction between individuals and individual habits are neglected. It is not suitable for describing specific and complex pedestrian movement characteristics. There is no visual effect of micro-model simulation.
3.2. **Hydrodynamic Model**  
The advantages: Master the overall movement characteristics of pedestrian flow; It can realize the fast calculation of the model; Simple and convenient, low requirement for computer performance and fast simulation speed.  
The disadvantages: The interaction between individuals and individual habits are neglected. It is not suitable for describing specific and complex pedestrian movement characteristics.

3.3. **Cellular Automata Model**  
The advantages: Pedestrian motion rules are relatively simple, computational complexity is relatively low, and engineering application can be realized. It can realize the basic characteristics of human mobility and has fast calculation speed.  
The disadvantages: It is difficult to realize the complex relationship between pedestrians, which cannot reflect the real behaviour of pedestrians. The direction of pedestrian movement is defined by ‘lane change’ and ‘travel’, which has limitations. Unable to capture the real motion characteristics of pedestrian flow.

3.4. **Magnetic Force Model**  
The advantages: Considering the requirement of avoiding collision between pedestrians; Pedestrian state can be controlled.  
The disadvantages: Fixed pedestrian route; The specific dynamic characteristics of pedestrian movement are not considered.

3.5. **Queuing Theory Model**  
The advantages: It has good visual effect; The bottleneck effect in queuing system can be simulated.  
The disadvantages: Individual behavioural characteristics are not clearly described; The conflict between pedestrians has not been fully considered; Service rules and arrival rules are not necessarily suitable for describing pedestrian movements.

3.6. **Social Force Model**  
The advantages: Pedestrian behaviour is based on pedestrian self-drive; It conforms to the behaviour of pedestrians and can simulate the walking process of pedestrians consistently. It can accurately describe the interaction between pedestrians when the crowd is congested. The pedestrian model is set as an elliptical cylinder, which is more accurate.  
The disadvantages: Lack of space demand for pedestrians; When the number of pedestrians increases, the computational complexity is too large, which leads to slow computational speed and high-performance requirements of the computer.  
Through the above comparative analysis, each pedestrian motion simulation model has its own audience situation, and each model is proposed for the actual situation of a certain pedestrian. In order to better meet the reality, various simulation models have been produced. However, each model has its own advantages and disadvantages and characteristics. From the macro and micro perspectives, it is analysed that the macro-pedestrian simulation model can well show the macro-traffic characteristics of pedestrian flow as a whole. In the simulation, the amount of calculation is small, but the characteristics of individual pedestrians will be neglected, which is not suitable for the small total amount and individual characteristics. The micro-simulation can better represent the interaction between individual pedestrians, equipment and facilities, and other pedestrians. The simulation of each pedestrian will require a lot of debugging work, which is more complex and has a huge amount of simulation calculation.

4. **Conclusion**  
According to the specific movement and characteristics of passenger flow in urban rail transit station, the passenger flow during the peak period of transfer station is simulated. At this time, the density of passenger flow is high and the macroscopic characteristics of passenger groups are obvious. The
model is simulated under the condition of high density. What we need to get is the overall passenger flow situation of the station, when the model is simulated in high density, it needs to get the overall passenger flow situation of the station, and the individual characteristics are not the factors that need special consideration at this time. Therefore, the macro model is chosen for analysis, and the system dynamics model in the macro model can relatively accurately analyse the internal structure and causality of a complex transfer station system in the above model, and grasp the macro characteristics of a station. Reasonable analysis of the station, reasonable simplification and modelling of the station, so that its macro characteristics are basically in line with the actual situation.

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