JOURNAL OF TRANSPORTATION
SYSTEMS ENGINEERING AND INFORMATION TECHNOLOGY
Volume 11, Issue 5, October 2011
Online English edition of the Chinese language journal

Available online at www.sciencedirect.com
ScienceDirect

Cite this article as: J Transpn Sys Eng & IT, 2011, 11(5), 99−106.

RESEARCH PAPER

Modeling and Simulation of Rail Transit Pedestrian Flow

DING Qingyan[1,2], WANG Xifu[1,*], SHAN Qingchao[1], ZHANG Xiuyuan[1]

1 School of Traffic and Transportation, Beijing Jiaotong University, Beijing 100044, China
2 Shandong Provincial Key Laboratory of Computer Network, Shandong Computer Science Center, Jinan 250014, China

Abstract: The law and basic characteristics of rail transit pedestrian flow movement are closely related to rail transit construction and operation. Under the background of China's large-scale rail transit construction and the expansion of operation ground, as a key factor, the safety and organization of mass and high-density pedestrian flow in rail transit has received wide attention. This paper reports an excessive overlap avoided behavior rule model based on the existing social force model, through improving the driving force, attractiveness and direction influence in the model parameters, and rectangular scope was also introduced in model calculation to reduce the computing time. This paper examines the conditions for which the model can be beneficial to the human behavior reflection in terms of automatic drainage phenomenon appearance and the arch formed in the station of exit in rail transit pedestrian flow motion. Finally, this paper uses Visual C++ 6.0 to create the SubPeds pedestrian flow simulation experiment platform, by setting the one-way virtual pedestrian flow scenarios, the model is simulated and the simulation data is analyzed. The results show that the proposed model accurately simulates pedestrian movement .

Key Words: traffic engineering; rail transit; pedestrian flow; social force model; microscopic simulation

1 Introduction

The movement of pedestrians is an important research direction in traffic science and engineering field, and has attracted many scholars' attentions. Early pedestrian movement research was built on the basis of direct observation. Fruin[1] used statistical methods to have obtained the relationship curve between the average travel speed and pedestrian density, and the "level of service" concept of road traffic theory was introduced to pedestrian movement research. Fruin's study laid the foundation for the development of pedestrian traffic flow, but this method cannot effectively predict the large-scale pedestrian flow. Many scholars have improved ideas and proposed relatively improved models[2–5]. However these improved models did not take into account the interaction between crowded pedestrians, which were limited in practical terms. For this reason, crowding pedestrian flow was similar to gas or fluid in the study of Henderson[2]. Henderson's study proposed the modeling method which was appropriate for single individual's behavior, but for pedestrian flow, to obtain the solution of the hydromechanics equations was difficult, so this method was not practical. So far, the primary focus of studies in the field of pedestrian movement has been on the microscopic simulation model of crowd behavior.

In the sight of system, pedestrian flow is a multi-agent system which is constituted of interaction pedestrians, and the dynamic characteristics of pedestrian flow are similar to traffic flow. Local interaction exists between people. In human traffic behavior, these local, regular interactions between individuals affect the complex and integral behavior of pedestrian flow, such as generating congestion, jam etc. To reflect these characteristics of pedestrian movement, a social force model was introduced by Helbing and Molnar[6,7]. They think that the driving force generated by the pedestrian desired speed, the repulsion generated by other pedestrian (obstacles) to pedestrians and the attraction force generated by the around things to pedestrians are the important driven factors for pedestrian behavior, and it is subjective mobility generated by pedestrian traffic behavior, that is social forces. In the following study[13–16], according to social force model, Helbing made a simulation to pedestrian flow motion and simulated the jammed phenomenon in the evacuation process. The results show that the cluster effect in the pedestrian flow

Received date: Mar 9, 2011; Revised date: May 2, 2011; Accepted date: Jun 2, 2011
*Corresponding author. E-mail: wangxifu@jtys.bjtu.edu.cn

DOI: 10.1016/S1570-6672(10)60145-6

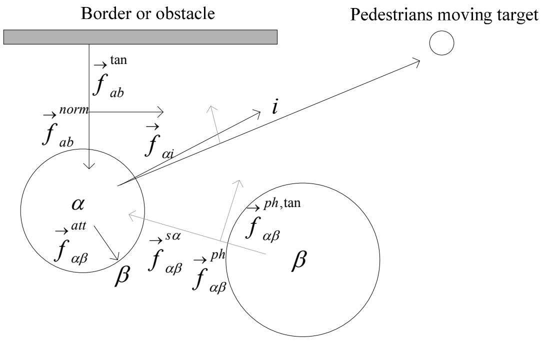

Fig. 1 Force of the social model

movement process is caused by the nonlinear interactions between individual pedestrians.

Social force model is a continuous microscopic simulation model, and it focuses on using the interaction between the pedestrians to study the relation between pedestrian psychology and behavior, and the relation represented by equations, simultaneously the randomness of pedestrian activity was emphasized in the model. For comparison with discrete simulation model, social force model can be used to describe the special phenomenon in pedestrian flow movement, like congestion, jam etc. But compared to the actual pedestrian movement, social force mode is still not real enough. Based on the above understanding, this paper proposes an improvement to the parameters in the model, so that the model can more closely reflect human behavior. And using Visual C++6.0 as a programming tool to create the SubPeds pedestrian flow simulation experiment platform, the virtual track by setting the one-way pedestrian flow of traffic scenarios, the model was simulated and simulation data was analyzed. The results show that the improved model can more accurately simulate pedestrian movement.

2 Rail transit pedestrian flow social force model

2.1 Description of social force model

We consider that the motion of a pedestrian in pedestrian flows can be described by means of three different components: the internal driving forces, the interaction effects, the effects and the random forces of obstacle on this pedestrian, the interaction between various forces shown in Fig. 1. According to Ref. [6], the dynamic equation of social force model can be expressed as:

$$m_\alpha \frac{\mathrm{d}\overrightarrow{\omega_\alpha}}{\mathrm{d}t} = \overrightarrow{F_a}(t) + \text{fluctuations} \tag{1}$$

where $\vec{F}_\alpha(t)$ can be expressed as:

$$\begin{aligned}\overrightarrow{F_a}(t) = {} & \overrightarrow{F}^0_\alpha(\vec{v}_a, v^0_a\overrightarrow{e_a}) + \sum_\beta \overrightarrow{F}_{\alpha\beta}(\vec{e}_\alpha, \vec{r}_a - \vec{r}^{\,a}_\beta) \\ & + \sum_B \vec{F}_{\alpha B}(\vec{e}_\alpha, \vec{r}_a - \vec{r}_B) + \sum_i \vec{F}_{\alpha i}(\vec{e}_\alpha, \vec{r}_a - \vec{r}_{i,}t)\end{aligned} \tag{2}$$

In Eq. (1), α is pedestrian, m_α is the quality of pedestrian α, $\vec{\omega}_\alpha$ is the current velocity of pedestrian α, $\vec{F}_a(t)$ is the resultant of various forces in traffic behavior, fluctuations is the random variable. In Eq. (2), the first term is the driving forces of pedestrian, the second term is the resultant of the interaction effects between the pedestrians, the third term is the resultant of the interaction effects of obstacle on this pedestrian, and the fourth term is the resultant of attractive forces.

In the Fig. 1, $\vec{f}^{\,0}_\alpha$ is the internal driving force in the pedestrian's motivation, $\vec{f}^{\,s\alpha}_{\alpha\beta}$ is α feeling the interaction effect between pedestrian α and β (psychological force), direction is pointing to the pedestrian α; $\vec{f}^{\,ph}_{\alpha\beta}$ and $\vec{f}^{\,ph,\tan}_{\alpha\beta}$ are the contact force, they will occur only pedestrian contact with each other; $\vec{f}^{\,ph}_{\alpha\beta}$ and $\vec{f}^{\,s\alpha}_{\alpha\beta}$ have same direction, $\vec{f}^{\,ph}_{\alpha\beta}$ and $\vec{f}^{\,ph,\tan}_{\alpha\beta}$ are perpendicular to one another; $\vec{f}_{ai}$ is the attractiveness between the location to the pedestrian; $\vec{f}^{\,att}_{\alpha\beta}$ is the attractiveness between pedestrians; $\vec{f}^{\,norm}_{ab}$ and $\vec{f}^{\,\tan}_{ab}$ is the force between pedestrian and obstacle, $\vec{f}^{\,norm}_{ab}$ and obstacle are perpendicular to one another, $\vec{f}^{\,\tan}_{ab}$ and obstacle are parallel.

2.2 Model improvement

Although some social force models of pedestrian flow movement were established in literatures[8−10], those models have the following problems: firstly, there is no clear mechanism to ensure the pedestrian have not any excessive contact; secondly, they used great flexibility coefficient to avoid the duplication between pedestrians; at the same time the pedestrian was absolutely affected by the resultant of various forces in the model and the algorithm was complex. The above problems have directly affected the accuracy and practicality of the model. Based on the above understanding, this paper improved the model through the following respects: improve the model parameters, optimize algorithms and draft rules, and make the social force model better reflect the characteristics of rail transit pedestrian flow, and improve the simulation speed and authenticity in the hope of ensuring simulation accuracy.

2.2.1 Model parameters improvement

(1) Driving force improvement

The driving force is the most important force in the model, and it determines the pedestrian moving to the destination with the desired speed. If the pedestrian is not affected by the outside in the traffic behavior, the pedestrian will have the ideal speed $\vec{v}^{\,0}_a$ to the desired direction $\vec{e_a}(t)$. But in actual pedestrian movement, the pedestrian must accelerate/ decelerate or avoid other people, so the actual speed $\vec{v}_a(t)$ and desired speed have some differences. In this paper, we use "relaxation time" τ_α to correct the differences, and make it close to the ideal speed $\vec{v}^{\,0}_a(t)$, the specific form of acceleration term can be expressed as:

$$\overrightarrow{F}^0_a(\vec{v}_a, v^0_a\overrightarrow{e_a}) = m_\alpha \frac{1}{\tau_a}(v^0_a\vec{e}_a - \vec{v}_a) \tag{3}$$

In traffic behavior, the pedestrian can choose safe and