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Pedestrian Evacuation Modeling and Simulation on Metro Platforms Considering Panic Impacts

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Abstract

A pedestrian evacuation model is presented, in which the social force model and a mathematical model are incorporated. The social force model is capable of describing the pedestrian behavior realistically under the non-panic evacuation situations. However, a series of catastrophes make us reasonably think about crowd dynamics under stress and panic. In order to forecast the catastrophe point of pedestrian mood changes in a real emergency situation, a mathematical model is proposed by considering residence time, crowd density and exit distance. This paper follows the implementation of the system simulation modeling environment written in Java program language on AnyLogic simulation software to facilitate studying the panic spread mechanisms of passengers. Furthermore, different simulation scenarios on passenger evacuation from the platform of the Xizhimen Metro station in Beijing are carried out to validate the feasibility of the proposed method and to further evaluate the influence of evacuees' number and pedestrian distribution on evacuation efficiency when passenger panic is spreading.

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Keywords: Metro station; Passenger evacuation time; Panic evacuation model; Panic spread time; Panic rate

1. Introduction

Pedestrians are generally confined to the limited space due to its airtight, independence and other characteristics during the evacuation processes from metro stations. Trapped people are the largest uncertainties because their motives and actions are dynamic and the panic behavior which may occur is basically maladaptive. In short, panic is

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a focus of attention because it is thought to be a major potential human problem in most situations of sudden extreme stress. Therefore, it is an urgent issue for crisis management to study the characteristics of panic spreading in unconventional emergencies of metro stations.

The layouts of metro station and their impacts on evacuation considering the change of human behavior incurred by panic should be paid attention to when an emergency event occurs. The existing studies on simulation technology of emergency evacuation mainly incorporated with accident investigation (Yang et al., 2010), controllable experiments (Ge et al., 2011), mathematical-physical modeling (Helbing et al., 2006; Chen et al., 2008 & 2012) and animal-based crowed experiments (Nirajan et al., 2011) to recur evacuation processes. Moreover, some literatures have been given on the study of the impacts of inner emotional on evacuation behavior (Fruin, 1971; Helbing et al., 2005; Zhang et al., 2005; Tetsuya et al., 2012; Wang et al., 2012).

Fruin (1971) introduced the concept of the panic parameter to study the panic evacuation and found that occupant density has a great impact on the evacuation speed when the panic parameter is low and congestion is more prone to occur at the bottleneck while the panic parameter is high. Helbing et al. (2005) established a mathematical function which implied that desired speed changes with the panic degree and verified the effects of “faster-is-slower” and “freezing-by-heating” under the panic state. Zhang et al. (2005) analyzed pedestrian’s velocity while the road condition is changing under time pressure and proposed the concept of partial decreasing coefficient of speed on curvilinear road and downstairs. Tetsuya et al. (2012) established an aircraft emergency evacuation model to reflect the resulting selfish behavior of those panic passengers and to further evaluate the performance of the proposed model by comparing the simulation results and an actual aircraft accident. Wang et al. (2012) established a qualitative simulation model of a large-scale evacuation system based on the qualitative knowledge to study the influence of some factors on panic spreading. This model confirmed that the severity of disaster exponentially positively correlates with the panic spreading and the effectiveness of rescue guidance is influenced by the leading emotion in the crowds as a whole.

Insufficient research has focused on modeling the characteristics of panic spreading. In this study, a model is proposed to further describe panic spread phenomena and its influence on evacuation efficiency. Its unique features and advantages over the existing models are twofold: (1) Passengers' critical psychical characteristics, e.g. residence time, crowd density and exit distance, are taken into account to distinguish whether the passenger is panic or not. (2) Improvements are made to enhance the accuracy of the simulation model from two aspects. First, the proposed model together with the agent-based approach is utilized to simulate movements of individual passengers in an emergency evacuation process. Second, for normal (non-panic) conditions, each individual passenger is able to change his/her desired speed according to the density within a circle with one-meter radius from the current position in a real-time manner. For panic conditions, each individual passenger changes his/her desired speed with the critical level. The proposed model in this paper is used to simulate panic evacuation processes based on the AnyLogic software.

2. Model formulation

2.1 Evacuation model for non-panic situation

Non-panic behavior rules strictly obey the social force model (Helbing et al., 2005), which is defined by the following equation of motion.

$$f_i = m_i \frac{d\vec{v_i}(t)}{dt} + \sum_{(i\neq j)} f_{ij} + \sum_w f_{iw} + \varepsilon_i(t), \tag{1}$$

where f_i is the sum of the social forces influencing pedestrian i.

$m_i \frac{d\vec{v_i}(t)}{dt}$ is the driving force when pedestrians keep desired speeds.

$\sum_{(i\neq j)} f_{ij}$ and $\sum_w f_{iw}$ are the repulsive forces describing attempts to keep a certain safety distance to other pedestrians j and obstacles w, respectively.

$\varepsilon_i(t)$ is the individual fluctuations force reflecting unsystematic behavioral variations.