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Modeling the evacuation behavior considering the effect of dangerous source

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Abstract

Modeling the pedestrian's evacuation behaviour in danger is an interesting and challenging work. In this paper, pedestrian's microscopic psychological characteristics and movement characteristics of evacuation behaviour are discussed and analysed. A modified social force model is proposed to describe the movement behaviour affected by dangerous source. In this model, the concept of most possible detouring directions is proposed, and an algorithm of calculating the directions is introduced. The self-driven force and repulsive force are reformulated. The spreading dynamics of dangerous source and coefficient of risk are integrated into this model. Simulations in a room with a single exit have been implemented. According to simulations, the influence of the factors, such as exit width, risk coefficient, scale of crowd is discussed in detail. The simulation results show that our model can reproduce the 'fast-is-slow' effect in dangerous situation. A large risk coefficient may reduce the evacuation time in some extent.

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Keywords: evacuation behaivor; dangerous source; flow characteristics; social force model

1. Introduction

Large scale public places are very important in our daily lives. In recent years, security incidents occur constantly in these places. Fire, poison gas, power failure, or other hazards may threaten personal safety and disrupt individual

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behavior during evacuation. Scientific management and effective design are urgently needed to guarantee crowd in a normal and safety status. Understanding the characteristics of pedestrian dynamics during evacuation process in emergency is the key issues in crowd management (Fruin, 1971, Wood, 1972). In dangerous situation, pedestrians may be crowded, nervous or even panic. If pedestrians make some irrational behaviors, it may lead to fatalities or injuries of crowd. It is necessary to deeply discuss and model the evacuation behavior affected by dangerous source.

There are many models that describe the pedestrian's individual movement behavior (Hoogendoorn & Bovy, 2005). These models mainly consist of spatial-discrete models and spatial-continuous models. Cellular automation (CA) model (i.e., Okazaki & Matsushita, 1993, Blue & Adler, 1997, Kretz, 2007, Varas et al., 2007; Bandini et al, 2014; Leng et al, 2014) and lattice gas (LG) model (i.e., Hoogendoorn & Bovy, 2000) are widely used spatial-discrete models. In these models, the research area is divided into a series of homogeneous cells, and each pedestrian occupies one or several cells. Based on given movement rules, pedestrian can move to one of the neighbor unused cells by transition probability. The concept of floor field (FF), including static floor field and dynamic floor field, has been proposed to describe the movement (Schadschneider, 2001; Huang & Guo, 2008; Fu et al., 2013; González et al., 2013).

Compared with spatial-discrete model, pedestrian can discretionary move in a two-dimensional planar in spatial-continuous models. In the models, social force model is a well-known model, which precisely describes pedestrian movement (Helbing et al, 1995, 2000, 2002; Parisi & Dorso, 2005; Antonini et al, 2006; Seyfried et al., 2006; Johansson et al., 2008; Suzuno et al, 2013; Zeng et al., 2014). This model is based on the Newtonian's second law of motion, and pedestrian movement is driven by external forces, including self-driven force, non-contact social force, and contact force. It has been successfully applied to quantitatively reproduce the fundamental diagram in corridors, evaluate the flow characteristics through bottlenecks, and investigate self-organized phenomenon in evacuation process. Many researchers have improved the model to simulate pedestrian movement in different situations, such as normal condition, crowed condition, and panic situation (Moussaid et al. 2011, Kwak et al, 2013). In addition, route choice behavior has been included into the model to describe the pedestrian evacuation process in large scale places with many exits (Wagoum et al, 2012, Werberich et al., 2014). However, these models do not mention the hazard situation, and not consider the effect of the dangerous source.

In hazard situation, the dangerous source may impact pedestrian's behavior. For example, in fire, pedestrians always keep away from the fire to prevent themselves from being burnt (Guo et al., 2013). When pedestrians get closer to the fire source, they may get nervous and accelerate their desired velocities to leave from it as soon as possible. Pedestrians will make a tradeoff between minimization of walking time and persistence of personal safety. Nearby dangerous source, radical people may prefer to rush through it in a short time, while conservative people may prefer to make a detour from it in a safe status. In addition, pedestrian's behavior will also be influenced by the spreading features of dangerous source, such as fire smoke, poison gas. People may dynamically adjust their movements to adapt to the surrounding environment.

In this paper, an improved social force model is proposed to describe the movement behavior of evacuation process in dangerous situations. First of all, the features of pedestrian movement behavior are discussed in Section 2. Considering the influence of dangerous source on movement behavior and choice behavior, the modified formulations in social force model are introduced in Section 3. Simulations are implemented to investigate the evacuation dynamics and evaluate the egress time in Section 4. Section 5 is the conclusion.

2. Characteristics of movement behavior in dangerous situation

When walking in a street or evacuating from a room, a pedestrian will be influenced by other surrounding pedestrians and obstacles. If there are some dangerous sources, pedestrian's movement behavior will be also influenced by the dangerous sources. In face of danger, pedestrian may reflect some negative psychological activities (i.e., intension, fear, panic) or positive activities (i.e., unity, enthusiasm, humility). These activities may have a significant impact on the cognition and decision behavior. If pedestrians are in negative condition, they may not make their decisions by themselves, and congestion phenomenon and conformity behavior may occur.

The features of pedestrian behavior in danger are mainly embodied as: (1) pedestrian wants to leave dangerous area quickly with a higher desired velocity; (2) pedestrian behavior is with larger fluctuations; (3) pedestrian experiences a repulsive force from dangerous source; (4) pedestrian prefers to make a detour from dangerous source