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Modified social force model based on information transmission toward crowd evacuation simulation[☆]

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HIGHLIGHTS

- Information transmission is introduced into social force mode in this paper.
- The reliability of evacuation information is used for choosing exits.
- A collision avoidance strategy is proposed and adopted in our model.
- The results show our model can help to design and optimize evacuation scheme.

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ABSTRACT

In this paper, the information transmission mechanism is introduced into the social force model to simulate pedestrian behavior in an emergency, especially when most pedestrians are unfamiliar with the evacuation environment. This modified model includes a collision avoidance strategy and an information transmission model that considers information loss. The former is used to avoid collision among pedestrians in a simulation, whereas the latter mainly describes how pedestrians obtain and choose directions appropriate to them. Simulation results show that pedestrians can obtain the correct moving direction through information transmission mechanism and that the modified model can simulate actual pedestrian behavior during an emergency evacuation. Moreover, we have drawn four conclusions to improve evacuation based on the simulation results; and these conclusions greatly contribute in optimizing a number of efficient emergency evacuation schemes for large public places.

1. Introduction

The research on pedestrian dynamics for emergency evacuation has attracted increasing attention from scholars recently. Many remarkable models simulating the complex behavior of pedestrians have been proposed to analyze evacuation processes in different situations [1–3]. These evacuation models can help create an efficient emergency evacuation scheme to minimize damage and avoid loss of life. The models can be divided into two categories: discrete and continuous, which include the cellular automata [4–6] and lattices models [7–9], and the social force (SF) model [10,11], respectively.

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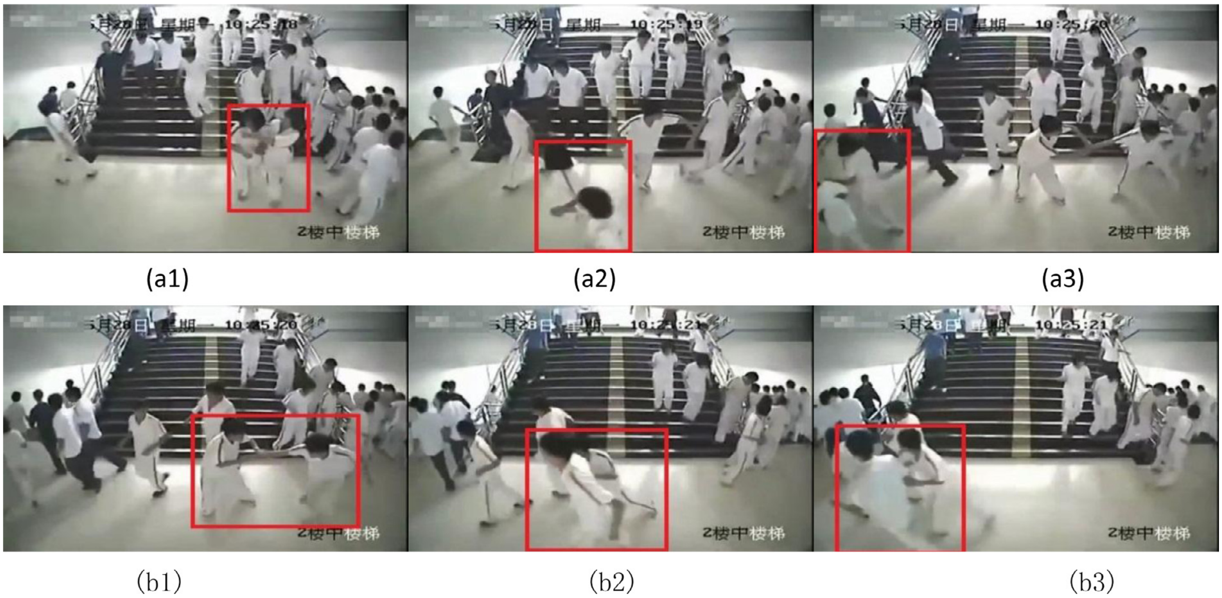

Fig. 1. Group shots from the earthquake evacuation in Tang Shan, China on May 28, 2012.

An important criterion for an evaluation model is self-organization, which reflects the non-linear interactions among different objects or subjects and refers to the spontaneous establishment of qualitatively new behavior [12]. Six types of crowd self-organization phenomena are analyzed in literature, among them, the SF model, proposed by Helbing, can simulate five of those phenomena better than other models [2]. Moreover, the SF model can also represent a whole range of realistic motion-base cases. Thus, it is often chosen and modified to simulate various evacuation types [13–16]. The current research is also based on the SF model.

According to Ref. [17], evacuation is not only an individual action, but a group behavior, such that its entire efficiency is affected by individual capability and group cooperation [18,19]. Cooperation is based on information exchanges realized through information transmissions. However, the original SF model does not describe this phenomenon. To refine the cooperation mechanism and increase evaluation safety, evacuation leader [20], guided pedestrian [21], and mutual information [22], are applied to the original SF model. In the guided pedestrian model, common individuals are guided to escape from the scenario by their choosing a nearest guider [21], and which is only standard. Leadership effect can assist ordinary pedestrians to move according to the position and moving direction of the chosen leader [20], however, cooperation is absent among common pedestrians. Mutual information highlights the influence of the location and velocity direction of pedestrians, as well as considers the environment density during evacuation [22]; however, the driving force is calculated only according to the position of the chosen exit. In conclusion, the modifications for the SF model mostly have focused on introducing a new force according to specific applications, with less attention paid on pedestrians' perception on the evacuation environment and the cooperation among individuals.

In actual evacuations, pedestrians can learn evacuation information in numerous means, including learning from themselves, other pedestrians (cooperation), and signs. Thus, information transmission is important during evacuation and worthy of focused attention. In this paper, information transmission mechanism is presented to simulate the dissemination of evacuation information, including exit's position, distance, and density, among the crowd by modifying the original SF model. Fig. 1 shows that information transmission exists in the actual evacuation.

The pictures in Fig. 1 are from an earthquake evacuation video from a school in Tang Shan, China on May 28, 2012. We chose two examples to explain information transmission in an evacuation process. One is shown in Fig. 1(a1–a3), and the other is presented in Fig. 1(b1–b3). In the first example, one student found that the right staircase was free (Fig. 1(a1)), and she informed her classmate to choose the right direction as the escape path. In the second example, another student found the same situation (Fig. 1(b1)), pulled his classmate, and chose the right direction to escape. Thus, information transmission is constant in the evacuation process, and it reflects the cooperation among pedestrians.

When pedestrians aim to escape from a scenario as quickly as possible under an emergency evacuation, they face two critical problems: how to obtain all the exit information, and how to choose the proper exit as their escape path [23]. The two problems are especially important for pedestrians who are unfamiliar with the evacuation environment. To find an appropriate path, pedestrians collect information, such as the exit's distance and evacuation capacity, from their neighbors, which refers to the information transmission and analysis process. In this paper, a novel evacuation model, which includes the information transmission mechanism, is presented to simulate this process by modifying the original SF model. Simulation results show that this modified model can reproduce the evacuation process, as well as effectively