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Pedestrian simulations in hexagonal cell local field model

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HIGHLIGHTS

- A conception of local field is put forward to direct pedestrian.
- Four moving-preferences and the effect on balance state were discussed in detail.
- The fundamental graphs were used to verify the practicability of this model.
- We proposed a method to detect the press effect near the bottleneck.

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ABSTRACT

Pedestrian dynamics have caused wide concern over the recent years. This paper presents a local field (LF) model based on regular hexagonal cells to simulate pedestrian dynamics in scenarios such as corridors and bottlenecks. In this model, the simulation scenarios are discretized into regular hexagonal cells. The local field is a small region around pedestrian. Each pedestrian will choose his/her target cell according to the situation in his/her local field. Different walking strategies are considered in the simulation in corridor scenario and the fundamental graphs are used to verify this model. Different shapes of exit are also discussed in the bottleneck scenario. The statistics of push effect show that the smooth bottleneck exit may be more safe.

1. Introduction

As the rapid development of the society and buildings, the crowd stampede leading people crushed or trampled is a serious threat to the public security. Pedestrian dynamics have caused wide concern by many researchers in many fields. In the recent years, many ingenious models have been proposed to simulate the pedestrian dynamics in a variety of situations.

Generally, these models can be classified into macroscopic models [1–3] and microscopic models [4–7]. The former class treated the pedestrians as a fluid. However, the models in this class are oversimplification and not accordance with the reality. The latter class is more exquisite in describing pedestrian and each pedestrian will be treated individually. The most representative microscopic models are social force (SF) models [8–11] and cellular automata (CA) models [12–15]. The SF models are continuum models, considering the effect from other pedestrians and obstacles surrounding. The moving direction of each pedestrian is calculated by social force effects [8]. The CA models decompose the whole walking space into small cells [15]. The movement of pedestrians are depend on several simple rules according to the cells. These models often have high efficiency and have been adopted in many commercial softwares. Many researchers work are based on CA models [16–19]. Schadschneider et al. [20] and Nowak et al. [21] calibrated the floor field model in single-file and counterflow

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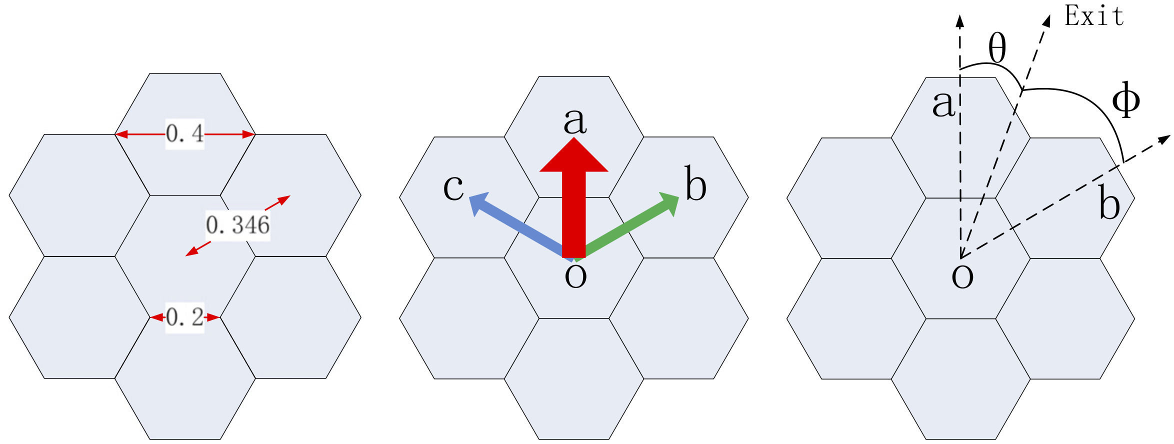

(a) Basic size. (b) Moving directions. (c) Forward direction.

Fig. 1. Basic settings. (a) The side length of hexagonal sell is 0.2 m. Thus the wide is 0.4 m, the area is about 0.103 m^2, and the distance of the center of two neighbor cells is approximately 0.346 m. (b) Supposing that a pedestrian is in cell o and that the exit is in oa direction, he/she will have three moving direction: oa, ob and oc, besides, oa direction is his/her first choice. (c) If the exit is in other directions, for example: the angles to oa, ob are θ and ϕ respectively, the pedestrian will have $\phi/60°$ chance to select oa and $\theta/60°$ chance to select ob as forward direction.

by quantitative analysis. Yang et al. [22], Yue et al. [23], Xu et al. [24] and Yanagisawa et al. [25] focused on the pedestrian moving preference. Fang et al. [26] considered the slow-to-start effect on pedestrian. Kirchner et al. [27], Weng et al. [28] and Guo et al. [29] adopted different pedestrian velocity by reducing the cell size. Zeng et al. [30] and Leng et al. [31] proposed two methods for scene segmentation, and established temporary goals to guide pedestrians through complex scenarios.

The discretization of the walking space is not limited to square cells. In this paper, we proposed an local field model based on the hexagonal cell. The hexagonal structure has been adopted by many researchers [32–35] in the situations where there is no preferred direction of motion. We found that this structure is also useful in simulating pedestrian dynamics in straight channel facilities. In our previous work [36], the hexagonal cell was proved to be practical. We hope to further study the characteristics of this model and focus on the interaction of pedestrians. Unlike the previous local models [30,31], the local field in this model is a small region around a pedestrian where the interaction always happens. Considering that the pedestrians in straight channels choose the moving direction mainly according to the situation of the local field around him/her. This local field model is more proper to simulate the pedestrian dynamic in such scenarios.

We conduct a detailed analysis of pedestrian dynamic features in hexagonal cells scenarios, including a corridor and a bottleneck. The simulations in a corridor consider four different strategies. A relationship among the different strategies, density and distribution of pedestrian is found. Fundamental graphs compared with practical experiments [37–39] are also used to verify this model. The bottleneck simulations reveals the effect of exit shape. We define the push effect between pedestrians, and the statistic results show that the smooth intersection angle bottleneck exits may be more safe.

The structure of this paper is as follows. In Section 2, we introduce the local field model in details. Section 3 shows the simulations in corridor and bottleneck scenarios. Finally, we come to the conclusion in Section 4.

2. Model description

2.1. Basic setting

In this model, the walking zone is divided into regular hexagonal cells with an edge length of 0.2 m in Fig. 1(a). Each pedestrian will occupy one cell about 0.103 m^2 in area. The maximal density is approximately 10 Ped./m^2, which is coherent with that in the literature [24] of 11 Ped./m^2. Pedestrians in this model only have three directions to move. That is forward, front-left and front-right. They can move to one of the neighbor cells in the three directions if the target cells are empty. Of course, the pedestrian has a highest probability to move forward in usual in Fig. 1(b). This model is appropriate to simulate pedestrian dynamics in straight scenarios such as corridors and bottlenecks. In other scenarios when the exit is in other directions, the pedestrian should select the forward direction firstly in Fig. 1(c).

Pedestrians in this model are updated asynchronously. Each second contains 24 update intervals and pedestrians will be updated every several intervals. Thus in each interval, only a small part of pedestrians need to be updated. This part of pedestrians are updated synchronously, the details of synchronous update works are elaborated in Section 2.3.

There are two advantages in this setting of update interval. Firstly the pedestrians in different update intervals can have different velocities. We call the different update intervals as pedestrian update interval. A pedestrian with an update interval of k means that the pedestrian will be updated every k intervals. Usually, the mean velocity of pedestrian ranges from 1.24 m/s [26] to 1.55 m/s [39]. So we initial the pedestrian update interval as 6 corresponding to a velocity of 1.38 m/s.