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A behavior-based model for pedestrian counter flow

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Abstract

A behavior-based lattice-gas model for pedestrian dynamics is presented. This model adopts the behaviorism for mobile robot, and the walk task of pedestrian can be divided into three basic behaviors, i.e., "move", "avoid", and "swirl" basic behaviors. The walk direction is determined from the walk weight, which is the sum of the product of each vector of basic behavior multiplied by the weight in the corresponding direction. This model can simulate pedestrian movement with different walk velocities through the update at different time-step intervals. The periodic boundary for pedestrian counter flow with six simulation conditions in the channel is considered, and the dynamical characteristics are discussed. Simulation results show this presented behavior-based model can simulate some characteristics of pedestrian counter flow, e.g., lane formation and jammed configuration, etc. In addition, the different simulation conditions result in the different numbers of phases and their different critical total densities. In general, the mean flow $\langle J \rangle$ is always high if the corresponding mean velocity $\langle V \rangle$ is high, and their phases also turn at the same critical total density.

Keywords: Pedestrian dynamics; Counter flow; Behavior-based

1. Introduction

Recently, traffic and pedestrian flows have attracted considerable attention from physicists [1–6]. The reason for pedestrian study is that pedestrian movement is an important component in the analysis and design of transportation facilities, pedestrian walkways, traffic intersections, markets, and other public buildings. For the design of walking infrastructure, a working knowledge of the characteristics of pedestrian flows is required in order to design the infrastructure as well as to assess its efficiency and safety. In particular, a good understanding of the emergent patterns is required to predict how the flow will behave under different circumstances. It is also important to avoid the jammed state of pedestrian in the channel of the walkways such as the subways, etc.

Pedestrian flow is a kind of many-body system of strongly interacting persons. The pedestrian flow dynamics is closely connected with the driven many particle systems. Many observed self-organization phenomena in pedestrian flows have been successfully reproduced with physical methods [7,8]: the lattice-gas model of biased-random walkers [9–11], the molecular dynamic model of active walkers [6,12,13], and the

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mean-field rate-equation model [10]. Henderson [14] has conjectured that pedestrian crowds behave similarly to gases or fluids. Helbing and Mulnar [6] has shown that human trail formation is interpreted as self-organization effect due to nonlinear interactions among persons. The escape panic [12,13,15,16], counter channel flow [9], and bottleneck flow [11,17,18] have been studied numerically. Muramatsu and Nagatani [19,20] have found that the jamming transition occurs in the pedestrian counter flow within a channel when the density is higher than the threshold [9]. Tajima et al. have shown that the clogging transition occurs in the unidirectional channel flow with a bottleneck if the density is higher than the threshold [10]. The clogging transition is similar to that of the simple asymmetric exclusion model with a barrier. Schadschneider and others [21,22] also presented a 2-dimensional cellular automaton model introducing a so-called floor field to collective effects and self-organization encountered in pedestrian dynamics. Maniccam has studied the effects of back step and update rule on the traffic congestion properties of mobile objects [23], and a 2-dimensional traffic system using simple congestion-avoiding traffic rules [24].

The purpose of this paper is to present a behavior-based model for pedestrian flow. The idea of behavior-based model is from Brooks' behaviorism for mobile robot. Based on behavior-based view, Brooks [25] developed subsumption architecture and Arkin [26] presented motor schemas. In behaviorism, individual primitive behaviors express separate goals or constrains for a task, and a high-level behavior (task) may subsume many low-level behaviors, which run concurrently. As an example, important behaviors for a navigational task would include "move", "avoid", and "swirl" behaviors. Pedestrian behaves in the channel like mobile robot's navigation. So, this paper adopts the idea of behaviorism for the simulation of pedestrian counter flow. Weng et al. [27] have presented ideas of behavior-based model and given a simulation of evacuation from a hall. And here pedestrian counter flow using the behavior-based model will be studied to check the effects of weights of some basic behaviors.

This paper proposes a behavior-based lattice-gas model for pedestrian dynamics. This model can simulate pedestrian movement with different walk velocities through update at different time-step intervals. The periodic boundary condition for pedestrian counter flow is considered, and the dynamical characteristics are discussed. In the following section, model is presented in detail. Section 3 gives simulation results and discussions, followed by conclusions.

2. Behavior-based model

We concentrate on the simplest case, which seems to be sufficient for most purposes. We will simulate the pedestrian flow by use of a lattice-gas model. Each pedestrian is represented by a walker on a lattice with $L \times W$ sites reflecting the channel. We choose the lattice spacing as 0.4 m, since the typical space occupied by a pedestrian is about $0.4 \times 0.4\,\mathrm{m}^2$. For simulating the pedestrian movement with different walk velocities, we introduce an idea for the model, i.e., pedestrians' update at different time-step intervals. For example, for the pedestrians with walk velocities of 1.0 and 1.5 m/s, the former ones update at every 3 time steps, and the latter ones are at every 2 time steps, if the lattice spacing corresponds to approximately $0.4 \times 0.4\,\mathrm{m}^2$ and one time step is approximately 2/15 s.

In the lattice-gas model, a rule defines the state of a site in dependence of the neighbor of the site. In this model, the neighbor setup shown in Fig. 1 is used. Thus, the state of the core site at the next update time step depends on the states of the sites in the neighbor including the site above, below, right, and left, also the core site itself of this update time step. Each pedestrian is only allowed to move to a neighbor site in the directions of east, west, south, and north at a given time step. In each update time step, for each pedestrian a desired move is chosen according to the walk weights of four directions. The walk weights are determined based on the behavior described below.

In this model, pedestrian counter flow is considered, and there are four types of walkers including the right walker with the walk velocities of 1.0 and 1.5 m/s moving from the left to the right boundary, and the left walkers with walk velocities of 1.0 and 1.5 m/s moving from the right to the left boundary. And so the walk task can be divided into three basic behaviors, i.e., "move" (moves to the given direction), "avoid" (avoids other pedestrians), and "swirl" (swirls other pedestrians) basic behaviors. Fig. 2 gives the schematic illustration of three basic behaviors. For simplicity, the magnitudes of all three basic behaviors are set as 1, i.e., $|\vec{S}_{\mathrm{mo}}| = |\vec{S}_{\mathrm{av}}| = |\vec{S}_{\mathrm{sw}}| = 1$.