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Interaction between vehicle and pedestrians in a narrow channel

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Abstract

In this paper, the interaction between vehicle and pedestrians in the narrow channel is studied. Comparing with our previous work, here the vehicle is allowed to move with different maximum velocity. The pedestrians are stilled modelled by the lattice gas model and they are regarded as biased random walkers. The dependence of the average speed of the vehicle on its maximum velocity and the pedestrian density is investigated. The simulations show that for a given pedestrian number, there exists a critical maximum velocity $v_{max,c}$ above which the vehicle can move freely. Moreover, an interesting phenomenon, i.e., the alternating behavior of vehicle between free moving state and slow moving state is observed. The dependence of the average velocity of the vehicle on its position as well as its moving direction is also investigated.

Keywords: Pedestrian flow; Lattice gas model; Biased random walkers

1. Introduction

Nowadays in cities, traffic consists of vehicular flow, pedestrian flow, bicycle flow and etc. Vehicular flow theory has a history of about 80 years and pedestrian crowds have been empirically studied for more than four decades now [1–14]. Usually these flows are investigated separately. However, in developing countries and even some developed countries, traffic is usually characterized by a mixture of vehicles, pedestrians, and bicycles. Therefore, the investigation on the interaction between different transportation mode is necessary.

There are different kinds of interaction between vehicles and pedestrians. Some typical examples are: (i) pedestrians cross the street without traffic light; (ii) a vehicle moves in a crowd street (which may be simplified as vehicle moving in the counter flow of pedestrians); (iii) a fire engine drives toward the building on fire and people run away from the building (which may be simplified as vehicle moving opposite to pedestrian flow); (iv) fans leave the stadium, some drive car and some walk (which may be simplified as vehicle moving in the same direction of pedestrian flow).

The case of (i) was discussed in Ref. [15]. Case (ii) is different from cases (iii) and (iv) in that the jam will occur in the counter flow when the pedestrian density exceeds some threshold. Therefore, we study case (ii) in future work and concentrate on cases (iii) and (iv) in this paper.

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In a previous paper [16], we have carried out a preliminary simulation on this interaction. In that paper, pedestrians are simulated as biased random walkers, vehicle or bicycle is treated as large moving object and is supposed to move at most one site per timestep. The dependence of the average speed of the large object on the density of the pedestrians, the size of the large object, and the position of the large object is investigated. It is found that when the large object is moving opposite to the pedestrians, generally it will move fast in the middle of the channel. However, if it moves the same direction as the pedestrians, then it will move fast when it is along the wall.

In this paper, a more realistic interaction between pedestrians and vehicle is studied. Here the vehicle is allowed to move with velocity larger than one site per timestep. We have studied the dependence of the vehicle behavior on its maximum velocity. An interesting phenomenon, i.e., the alternating behavior of vehicle between free moving state and slow moving state, is observed.

The paper is organized as follows. In Section 2, the simulation model for the interaction between pedestrians and vehicle is presented. In Section 3, the simulations are carried out. In Section 4, the conclusion is given.

2. Model

The model is defined on the square lattice of $W \times L$ sites where W is the width of the channel and L is the length of the channel. Pedestrians go to the right and the vehicle goes either to the left (case 1) or to the right (case 2). Each site contains only a single walker. The walker is inhibited from overlapping on the site. The excluded-volume effect is taken into account. The vehicle occupies $W_1 \times L_1$ sites where W_1 is its width and L_1 is its length. When the walker arrives at the wall of channel, it is reflected by the wall and never goes out through the wall.

In case 1, the effect of the vehicle on the pedestrians is simulated as follows. We suppose that pedestrians in areas A, B, C, and D as shown in Fig. 1(a) are affected by the vehicle. Here L_2 is determined by $L_2 = 1 + v^2/(2a)$, where v is velocity of the vehicle and a is the preferred deceleration of the vehicle.

For the walkers outside the areas, they move to the nearest neighbors according to the following configurations as defined in Ref. [10]. Fig. 2 shows all the possible configurations of the right walker. The cross point indicates the site occupied by the other walkers or the wall. The transition probabilities $p_{t;x}; p_{t;y}; p_{t;-y}$ of the right walker corresponding to each configuration are given by the following: $p_{t;x} = D + (1 - D)/3$; $p_{t;y} = (1 - D)/3$; $p_{t;-y} = (1 - D)/3$ for configuration (a), $p_{t;x} = D + (1 - D)/2$; $p_{t;-y} = (1 - D)/2$ for configuration (b), $p_{t;x} = D + (1 - D)/2$; $p_{t;y} = (1 - D)/2$ for configuration (c), $p_{t;y} = \frac{1}{2}$; $p_{t;-y} = \frac{1}{2}$ for configuration (d), $p_{t;x} = 1$ for configuration (e), $p_{t;y} = 1$ for configuration (f), $p_{t;-y} = 1$ for configuration (g), and $p_{t;x} = p_{t;y} = p_{t;-y} = 0$ for configuration (h), where D indicates the strength of the drift.

For a walker in area A (which has the length L_2 and width $W_1/2$),[1] he moves one site up provided his upper neighbor is empty. Otherwise, he stays motionless. For a walker in area B (which also has the length L_2 and width $W_1/2$), he moves one site down provided the neighbor below is empty. Otherwise, he stays motionless.

For the walkers in area C (which has the length $L_1 + L_2$ and width 1), they move either forward or upward. Fig. 3 shows all the possible configurations of the right walker. The transition probabilities $p_{t;x}; p_{t;y}$ of the right walker corresponding to each configuration are given by the following: $p_{t;x} = D + (1 - D)/2$; $p_{t;y} = (1 - D)/2$ for configuration (a), $p_{t;x} = 1$ for configuration (b), $p_{t;y} = 1$ for configuration (c), and $p_{t;x} = p_{t;y} = 0$ for configuration (d).

For the walkers in area D (which also has the length $L_1 + L_2$ and width 1), they move either forward or downward. Fig. 4 shows all the possible configurations of the right walker. The transition probabilities $p_{t;x}; p_{t;-y}$ of the right walker corresponding to each configuration are given by the following: $p_{t;x} = D + (1 - D)/2$; $p_{t;-y} = (1 - D)/2$ for configuration (a), $p_{t;x} = 1$ for configuration (b), $p_{t;-y} = 1$ for configuration (c), and $p_{t;x} = p_{t;-y} = 0$ for configuration (d).

As for the vehicle, it moves forward according to the following rule. Suppose the minimum distance from the pedestrians in areas A and B to the vehicle is L_3, then the velocity of the vehicle is determined as $v = \min(\lfloor L_3/T \rfloor, v_{max})$. Here T is the preferred time headway of the vehicle, v_{max} is maximum velocity of

[1]In this paper, only even number of W_1 is studied.