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Simulation of pedestrian flow based on cellular automata: A case of pedestrian crossing street at section in China

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HIGHLIGHTS

- A novel CA model is built to simulate the process of pedestrians crossing street.
- Attraction of pedestrians who are in the same direction is considered in this model.
- The simulation results are similar to the results of our investigation in China.
- Capital densities of pedestrians crossing street in various conditions are analyzed.
- This simulation model can help city designers to evaluate pedestrian facilities.

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ABSTRACT

One of the purposes of pedestrian studies is to evaluate the effects of a proposed program on the pedestrian facilities before its implementation. In order to evaluate the level of service (LOS) of a pedestrian facility, a microscopic model is built to simulate the process of pedestrian crossing street. Most of the existing models focus on the occupant evacuation flow in buildings; however, they are not appropriate for pedestrians in the traffic. According to the characteristics of pedestrian crossing street at signalized crosswalks, we build a model based on cellular automata. Both of the system size and cell size are coordinate with the reality. Depending on the contrast of three parameters of pedestrian flow between simulation data and the reality data, we found that this model is analogous to the real process of pedestrian crossing street at signalized sections. Finally, simulation and its results can provide guidance for evaluating the effects of pedestrian facilities before their implementation.

1. Introduction

Recently, more and more concerns have been focused on how to evaluate the effects of pedestrian facility before its implementation. Unfortunately, most of the facilities have not been studied or discussed before implementation which lead to a very costly trial and error (e.g., jam, dangerous, time cost, etc.). The problem is how to evaluate the effect of pedestrian facilities before their use. Computer simulation can be used as a good way to evaluate the service level of pedestrian facility.

Pedestrian simulation models can be divided into two categories: continuous models and discrete models. Continuous simulation models include gravity model, gas-kinetic model [1,2] and social force model [3]. For the discrete model, Muramatsu applied discrete cellular automata model into the pedestrian dynamics and proposed a lattice gas model with biased random walkers [4]. According to the cellular automata theory, Dijkstra built a multi-agent cellular automata model of pedestrians' movement [5]. Perez established a real-time behavior model based on cellular automata [6]. Kong and Yue did

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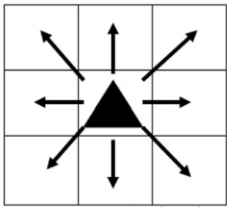

Fig. 1. Schematic illustration of pedestrian moving direction (Moore neighborhood).

$P_{1,1}$	$P_{1,0}$	$P_{1,-1}$
$P_{0,1}$	$P_{0,0}$	$P_{0,-1}$
$P_{-1,-1}$	$P_{-1,0}$	$P_{-1,-1}$

Fig. 2. Movement matrix of pedestrian.

the research on vehicle traffic flow and four-way pedestrian flow respectively [7,8]. Gotoh et al. built a self-evasive model to simulate the high crowd pedestrian contra-flow at a crossing; this model show satisfactory agreement with the observation. And it can describe either collision avoidance or an alignment behavior between adjacent pedestrians [9]. Airault developed a behavioral traffic simulation model named ARCHISIM, and this model is used to simulate the interactions between vehicles and pedestrians when pedestrians crossing a road [10]. In this paper, simulations of pedestrian crossing street flow on the square lattice will be introduced based on cellular automata (CA).

To begin with, the decision-making process of pedestrians is complex and stochastic. They will seek and choose an optimum route according to the dynamic conditions [11]. Moreover, in order to avoid obstacles and other people, pedestrians may change their current direction and choose another feasible route [12,13]. As a result, all the necessary human-specific factors need to be taken into account in studying pedestrian flow (i.e., avoid behavior and follow behavior). Some researchers introduce pheromone, which is inspired by the experiment and observation of ants, to simulate human behaviors (i.e., ants will leave pheromone to his companions in order to let others follow him and pedestrians will also follow others when they move in a building or cross street) [14]. Teknomo developed a microscopic agent-based model to evaluate the effects of pedestrian facilities. The model is simple, but it shows lane formation and self-organization phenomena as seen in reality [15]. ALHAJYASEEN has already obtained good results according to his simulation model at signalized crosswalk, and this model is a macroscopic model which is focused on the pedestrians at intersections [16]. However, the macroscopic model is not good at simulating the interactions among pedestrians. The problem of our work is to build a microscopic model to simulate the pedestrian flow at signalized sections considering human behaviors and interactions among pedestrians.

Nowadays, in some pedestrian flow studies based on CA, the probability of pedestrian's route-choice is given in two options: (a) static, which means the probability is fixed. In other words, the value of this probability is a constant during the whole process of simulation [4,12,13,17]; (b) dynamic, the probability is not fixed and the value of it is a variable according to the conditions around a certain pedestrian [6,18,19].

In the following sections, we make a pedestrian crossing signalized sections model based on cellular automata (CSSCA model). The probability of pedestrians' moving is given by a dynamic way; all the pedestrians will choose their route based on the transforming environment.

2. Model description

Pedestrians in traffic will influence each other during their movement. They need to follow, avoid or overtake others to be able to maintain their walking speed. As a result, changing direction and waiting are the basic behaviors of them. In the CA model, each pedestrian can move to eight directions or stop according to their destination and interaction with others at one step.

Pedestrians at crosswalk will make their movement at next step according to their surrounding environment, and they can choose to wait or move to one of the eight cells around them (Moore neighborhood is used as is shown in Fig. 1). In our model, movement matrix P is used to describe the will of pedestrians selecting positions (Fig. 2). The element in P is probability P_{ij}, where $i, j = -1, 0, 1$. The higher the P_{ij} in the movement matrix, the stronger the corresponding position attracting pedestrians and pedestrians will choose the cell based on the probability. If there are several same probabilities in the movement matrix, only one of them will be chosen as the target cell at random.

The average width and thickness of people are different from different countries. The average width of pedestrians is 0.426 m in China, and it is much wider when a pedestrian take a bag with him/her. In this paper, we decide 0.6 m as the width of a pedestrian. According to HCM [20], the static thickness is 0.3 m and the dynamic space is 0.6 m–0.8 m. When people cross street, they will follow the one in the front of him closely to keep conformity with others [21]. So we choose 0.6 m as the dynamic space in our model.