Evacuation Simulation in Floor Field by Real-Coded Cellular Automata

Kazuhiro Yamamoto

Dep. Mechanical Science and Engineering, Nagoya University, Japan
`kazuhiro@mech.nagoya-u.ac.jp`

1 Introduction

So far, Cellular Automata (CA) have been applied in a variety of scientific fields, including traffic problems and biological researches. Especially, as one of the excellent achievements, CA models for pedestrian dynamics have been developed. Since the pedestrian flows are caused by collective crowd behavior, it is difficult to model the pedestrian dynamics based on differential equations. Although the social force model has been proposed [1], CA approach could be more appropriate to describe pedestrian dynamics, because pedestrian flows are naturally emerged in a collective behavior of pedestrians [2-5].

In our previous study, we have proposed a new approach for pedestrian dynamics. We call it a Real-coded Cellular Automata (RCA) [6,7]. The idea is based on the Real-coded Lattice Gas (RLG) developed for fluid simulation [8]. We applied this scheme to the CA model for pedestrian dynamics. The numerical procedure is not explained here. Similar to RLG, the position and velocity of the pedestrian can be freely given, independent of grid points. It has been confirmed that the movement of pedestrians in an oblique direction is successfully described by RCA, which was not taken into account in the former CA models. Some benchmark simulations including room evacuation and lane formation in the street have been conducted.

2 Numerical Model

In this study, we present simulations in room evacuation using a floor field model. We consider the evacuation from a large room with one exit. Examples of the floor field are shown in Fig. 1. It is the static floor field describing the shortest distance to the exit. In both cases (room A and room B), the room size is the same, and there is one exit. Only in room B, there is an obstacle located in the center. The room size is 16m×16m, and the exit width, W, is varied from 0.4 to 2.8 m. The obstacle size in room B is 8.8m×8.8m. The time step of $\varDelta_t$ is 0.5 s, and the spatial grid of $\varDelta$ is 0.4 m [6,7]. In the simulation, the number of people in the room, N, is changed, but the evacuee velocity is constant of 2.2 m/s. By comparing results in both rooms, we discuss the evacuation route and the total evacuation time.

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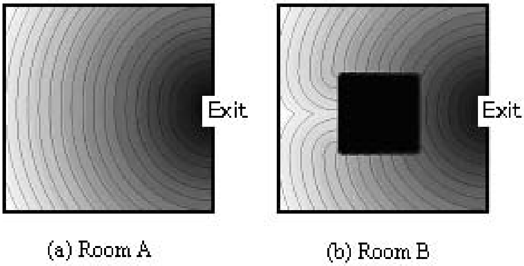

Fig. 1. Floor field in room with one exit;(a) room without obstacle, and (b) room with obstacle

3 Simulation Results

Figures 2 and 3 show the motion of evacuees in rooms A and B. For both cases, initial number of people in the room (N) is 100. The exit width of W is 1.2 m. Three results at t = 0.5, 5.0, and 9.0 s are shown. In room A, all evacuees can move directly toward the exit. It should be noted that, depending on the exit width, the bottleneck is observed at the exit [7]. On the other hand, in room B, most of people in the room can not pass through the obstacle, and take the longer route. Therefore, there are two places where the bottleneck is observed; one is at the corner of the obstacle, and the other is the exit.

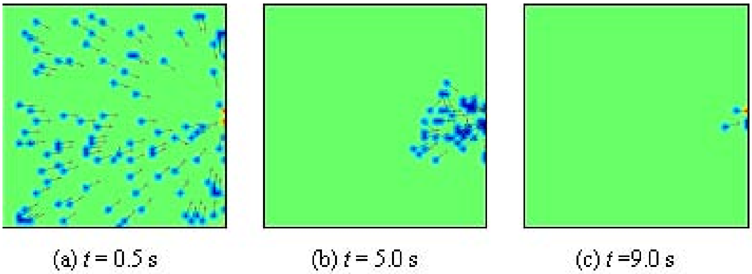

Fig. 2. Evacuation simulation in room A; N = 100, W = 1.2 m

Next, we change the exit width. Figure 4 shows the examples of room evacuation for W = 0.4 and 2.0 m, respectively. The room type is A, and the number of people in the room is 100. These are the results at t = 8.0 s. Expectedly, as the exit width is smaller, there are more people clogging at the exit, because there is the limitation people can go out from the exit.

Here, to examine the effect of obstacle in the room, we compare results in room A and room B. Figure 5 shows the total evacuation time (T_E) estimated from both simulations. The total evacuation time is the time when the last evacuee passes through the exit. The exit width is systematically varied. The

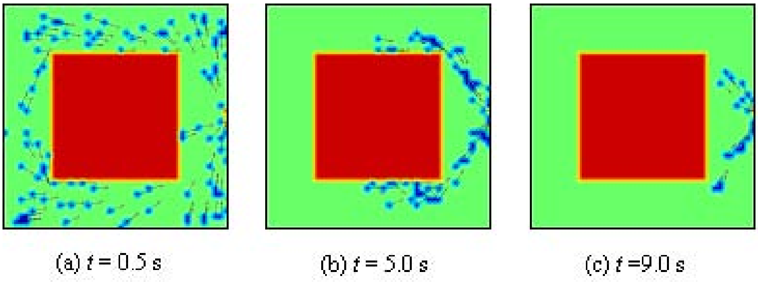

Fig. 3. Evacuation simulation in room B; $N = 100$, $W = 1.2$ m

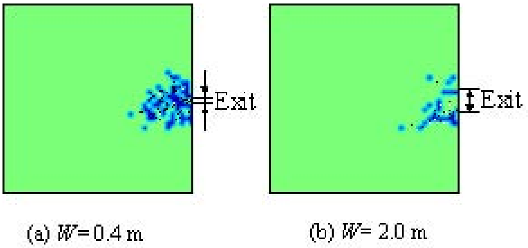

Fig. 4. Evacuation simulation in room A at $t = 8.0$ s; $N = 100$

initial number of people in the room is 100. It should be noted that the total evacuation time is changed when the different initial position of evacuees is given. Thus, we obtained the averaged evacuation time based on 5 simulations at random position of evacuees.

As seen in Fig. 4 in room A, as the exit width is larger, more people can pass through the exit. Then, the total evacuation time is decreased, as the exit width is larger. However, it is found that the total evacuation time is saturated when the exit width is larger than 1.6 m. The same tendency is observed for simulation in room B. Comparing both results, the total evacuation time in room B is always longer. This is because the evacuation route is longer when the obstacle is placed in the room. Additionally, as seen in Fig. 3(b), the bottleneck is observed at the corner of the obstacle. Due to the above two reasons, the total evacuation time is longer in room B. Since the oblique motion of the evacuee is correctly described in RCA model, more precise time can be estimated in room evacuation. We conclude that simulation by RCA model can be a good tool to validate the safety planning for evacuation route and time in advance.

4 Summary and Future Work

This paper presented the simulation of room evacuation by the real-coded cellular automata (RCA). The motion of each evacuee was determined by the floor field. Only static floor field was used, corresponding to the shortest distance to

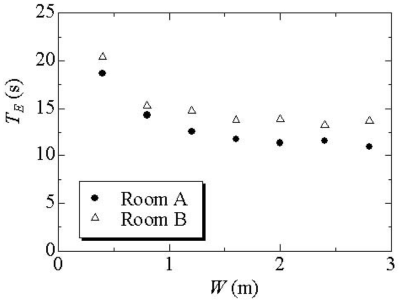

Fig. 5. Variation of T_E at different value of W

the exit. We considered two cases with and without obstacle. We changed the initial number of people in the room and the exit width. We concluded that RCA can be a good tool to discuss the total evacuation time and the evacuation route. Future work will be conducted for fire evacuation.

Acknowledgement

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