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Human Behavior Based Evacuation in A Large Room Using Cellular Automata Model For Pedestrian Dynamics

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Abstract

Comfort and safety of the public service space for pedestrians is determined by the availability of facilities and infrastructure based on established quality standards. One important factor for this condition is the existence of a supporting infrastructure for pedestrian evacuation, including information related to evacuation systems; maps; access to the exit from the chamber. Regarding to the evacuation process, in this paper, a cellular automaton model is presented to simulate the evacuation process in a room. This model defines the behavior of pedestrians in three characters, namely: partially of them behave as agents; the other ones as diligent; and the rest have the character of panic. Some simulation results show the model description of the pedestrian dynamics. Total evacuation time is considered as an indicator of the progress of the evacuation and its efficiency. By considering three pedestrian behavior, obtained evacuation time getting down in a certain density with increasing number of agents, this condition also occurs at the time of percentage diligent increasing. Contrary to the above situation, the evacuation time will increase with the increase in the percentage of pedestrians who have the character of panic

Keywords: cellular automata, evacuation time, pedestrian behavior: agent, diligent, panic.

1. Introduction

Pedestrian flow based on the three methods, namely: continuum model, social force model, and cellular automata (CA) model. Modeling and analysis of the macroscopic of pedestrian flow uses a continuum model. Three of the macroscopic variables of pedestrian are speed, density, and flow. Some published papers of the macroscopic of pedestrian flow discussed about the continuum model [1][2][3]. A concept of continuum model for the flow of pedestrians including the equilibrium system was presented by [1], he compared the stability of disturbances in subcritical flows and that in supercritical flows. Revisit of Hughes's dynamics continuum model for pedestrian flow was performed by [2] and they developed an efficient solution algorithm. In their algorithm is used time-varying for the pedestrian generation, the interaction of each variables: pedestrian density, flux, and walking speed is performed by the conservation equation. An algorithm for an extended reactive dynamic user equilibrium model of pedestrian counterflow as a continuum is developed by [3]. It is based on a cell-centered high-resolution finite volume scheme with a fast sweeping method for an Eikonal-type equation on an orthogonal grid. The numerical results demonstrate the rationality of the model and efficiency of the algorithm.

On the other hand, method of social force model is microscopic pedestrian simulation model. The motion of the pedestrians defined by the social force is based on a measure for the internal motivation of the individuals including the panic behavior to perform certain actions (movements) [4][5]. When describing the experimental data of pedestrian flows in normal conditions, The Social Force Model has some limitations [6]. They modified it that consists of a self-stopping mechanism to prevent a simulated pedestrian from continuously pushing over other pedestrians. By this sample change, the modified model have been able to reproduce the specific flow rates and fundamental diagram of pedestrian flows for normal conditions. The basic theory of the Social Force Model has been combined with the Gaussian Puff Model [7]. They have applied a Combined Social Force Model for a real situation where there is a sudden toxic gas event. The model can be used to demonstrate some individual behaviors in evacuation, such as competitive, grouping and herding.

The other method of pedestrian flow is cellular automata (CA) model. CA has very high simulation speed due to the simple rules of it. When be compared with the social force model for the pedestrian flow, CA model has the calculation efficiency is higher than that the social force model. A CA model is a microscopic discrete model, in case of the evacuation model for pedestrians, characteristics that have been used as parameters related to individual behaviors. A two-

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dimensional cellular automaton model to simulate pedestrian traffic has been proposed by [8]. They focused on the long-range interactions between the pedestrians that mediated by floor field which modifies the transition rates to neighbouring cells. The floor field is sufficient to model collective effects and self-organization encountered in pedestrian dynamics, e.g. lane formation in counterflow through a large corridor. As an application they presented simulations of the evacuation of a large room with reduced visibility. To simulate the evacuation process in a closed square with partition wall, [9] used a cellular automaton model. They defined a floor field and considered the selection of an exit and effect of social forces. Based on some simulation results, they showed the model's correct description of the pedestrian dynamics. The total evacuation time and the degree of pedestrians jamming in a certain area are regarded as the indicators of the evacuation progress and the measure of evacuation efficiency. In contrast to [9], the locations used in the simulation of evacuation process proposed by [10] was in a large classroom by considering the different exit choosing and movement rules. The numerical simulations showed that the model could better reproduce realistic evacuation phenomena, such as route-choice behaviors and bottleneck effects at the exits. When the distance to exit and the local density distribution of pedestrians were considered synthetically, the evacuation time could be reduced apparently.

Related to the research of the simulation of evacuation process for pedestrian dynamics, the study on microscopic model of pedestrian traffic has grown and improved. This paper discusses the proposed characteristics for pedestrian behavior, namely: pedestrians as agent, diligent, and panic in case of evacuation process. A CA model is used to simulate the evacuation from the large room. This experimental study is focused on the evacuation time as well as the dynamic performance of the experiment program. By changing number of agent, percentage of diligent, and panic, the simulation results are obtained related to the evacuation time.

2. Model of pedestrian behavior

In this paper, human behaviors in question is the behavior of pedestrians in the room in the context of evacuation. The pedestrian behavior can be divided into three, namely: partially of the pedestrians behave as agents, the others as diligent, and the rest as pedestrians that have the character of panic.

An agent has a character that he is very understanding about the environmental conditions; knows the position of the exit; very conscious to move toward the exit by calm, and affect other pedestrians to walk toward the exit. A diligent pedestrian has a character that he always tries to understand the surrounding environment; trying to figure out the position of the exit by following the direction of motion of an agent; moving toward the exit by calm. Pedestrians who have character of panic tends to move in random directions because they are experiencing confusion determining the direction of moving.

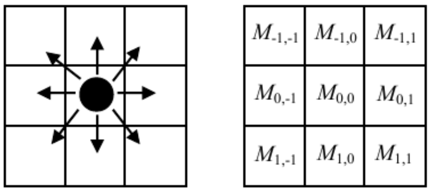

Figure 1. A particle, its possible transitions and the associated matrix of preference $M = (M_{ij})$ [8].

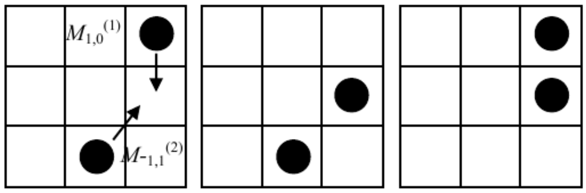

Figure 2. Solving conflict according to the relative probabilities for the case of two particles with matrices of preference $M^{(1)}$ and $M^{(2)}$ [8].

Basic rules in this paper is based on [8], they stated that each particle is given a direction of preference. Related to this direction, a 3×3 matrix of preferences is constructed which contains the probabilities for a move of the particle. Element is devided into two types: (1) the central element, the probability for the particle not to move at all; (2) the remaining 8 elements that can move to the neighbouring cells. The probabilities of each cell can be related to the velocity, the longitudinal, and transversal standard deviations. In practice, all particles of the same species share the values of these parameters and in consequence the same matrix. In the simplest case the pedestrian is allowed to move in one direction only without fluctuations and in the corresponding matrix of preference only one element is one and all others are zero (see Figure 1).

According to the update step, [8] stated that for each particle moves in accordance with its probability. All particles update in parallel. Particle does not move if the target cell is occupied. The move is executed if a target cell is not occupied and the other particles have no target

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with the same cell. Relative probabilities is used as references for chose one particle when more than one particle share the same target cell. The elected particle moves while the other (its rivals for the same target) keep their position (see Figure 2). Based on Figure 2, the relative probabilities is counted by Eq. (1).

$$p_i = \frac{M_{k,l}^{(i)}}{M_{k,l}^{(i)} + M_{m,n}^{(j)}} \qquad (1)$$

3. Simulation of evacuation in a large room

In this section discusses the specification of simulation, evacuation time with respect to the density, the agent pedestrian, the pedestrian diligent, and the panic pedestrian, and also shows the snapshot of simulation related to pedestrian behavior.

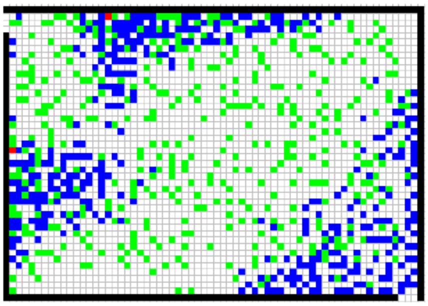

Figure 3. People leaving a room with two doors. Displayed is one typical stage of the dynamic with density $k = 30\%$, agent $a = 3$, and % diligent $d = 50\%$. The red point is an agent people; the blue one is a diligent people, and the green one is a panic people.

3.1. Specification of simulation

In this simulation of evacuation, we apply our model of pedestrian dynamics with the specification: a room is considered here 64 × 44 cells; a number of occupants are initially randomly distributed in that room. The room has two doors as way out (exits), a door located on the upper left side and the other on the bottom right side, the width of the each exit is 3 cells. The parameters including n, T are interpreted as follows: n is the number of occupants; T is the total evacuation time, that is, the total time for all pedestrians to leave the room, with second s as its unit. Given the above set of rules for pedestrian movement, simulations on the evacuation process in this room can be performed. Figure 3 shows a snapshot of a room and its simulation. It can be seen from the snapshot that the two exits modify the pedestrian trajectory.

In this discussion, the constant velocity for pedestrian movements v takes 1 m/s, which is empirically the mean velocity of pedestrians on common condition [11].

3.2. Evacuation time with respect to the density

In this section, experiments are carried out to find a relation between the density k and evacuation time T. Some experiments (simulations) have been done, one of which is done on the number of agents $a = 3$ persons for three different types of the diligent pedestrian (percentage) $d = 20\%$, 40%, and 80% respectively. The simulation results show that with increasing density of pedestrians in a room caused the evacuation time getting up on the percentage of diligent 20%, 40%, and 80%. This condition can be seen in Figure 4.

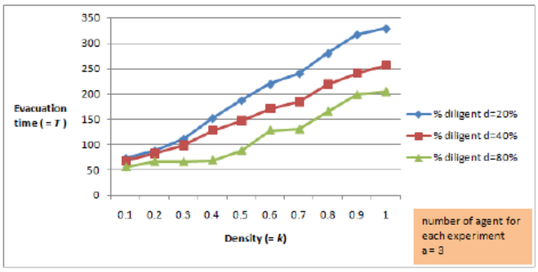

Figure 4. Relation between density k and evacuation time T on the different percentage of diligent (=d) and the same number of agent $a = 3$.

3.3. Evacuation time with respect to the agent pedestrian

The relation between number of agents a and the evacuation time T are obtained for several experiments (simulations). One of the simulation results obtained on the percentage of diligent $d = 50\%$ for the three different types of density, i.e. low density $k = 20\%$, middle density $k = 40\%$, and high density $k = 80\%$. The simulation results show that with increasing number of agents in a room, obtained the evacuation time getting down at the time of low density (20%), medium (40%), or high (80%). The results are shown in Figure 5.

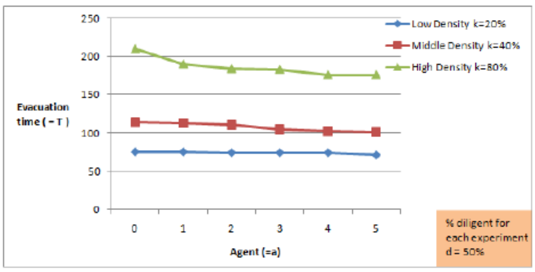

Figure 5. Relation between number of agent a and evacuation time T on the different densities (=k) and the same % diligent $d = 50\%$.

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3.4. Evacuation time with respect to the diligent pedestrian

The next simulation is done for the relationship between the percentage of diligent pedestrians *d* and evacuation time *T*. One of the simulation results for the number of agents *a* = 4 persons and density of pedestrians in a room for low density, medium, high *k* = 20%, 40%, and 80% respectively. The simulation results show that the evacuation time decreases with the increase of the percentage of diligent pedestrian, this condition can be seen in Figure 6.

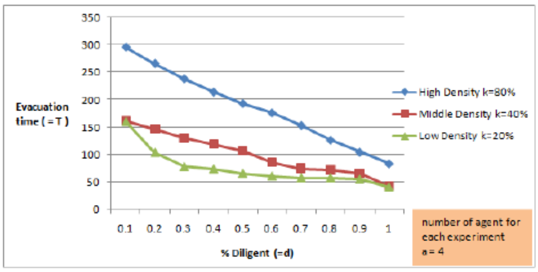

Figure 6. Relation between % diligent *d* and evacuation time *T* on the different densities (=*k*) and the same agent *a* = 4.

3.5. Evacuation time with respect to the panic pedestrian

In this section, experiments are conducted to obtain a relation between the percentage of pedestrians who have the character of panic p and evacuation time T. Some experiments (simulations) have been done, one of which is done on the number of agents a = 4 persons for three different types of the pedestrian density k = 20%, 40%, and 80% respectively. The simulation results show that with increasing the percentage of panic in a room caused the evacuation time getting up consecutively on the pedestrian density 20%, 40%, and 80%. This condition can be seen in Figure 7.

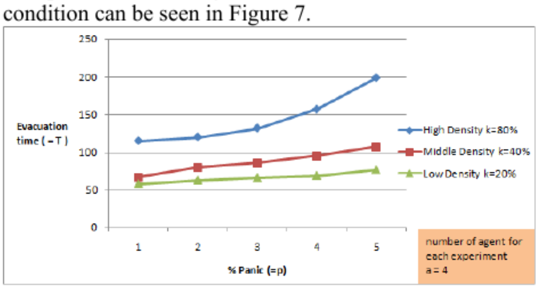

Figure 7. Relation between % panic *p* and evacuation time *T* on the different densities (=*k*) and the same agent *a* = 4.

3.6. Snapshot of simulation related to pedestrian behavior

As stated above that the pedestrians are divided into three classifications: pedestrians as agents, the others as diligent, and the rest as pedestrians have the character of panic. In this section, taking snapshot is conducted when the simulation is running. This condition is performed in order to observe the behavior of pedestrians who are in the room.

On the composition of density *k* = 20%, the number of agents *a* = 3 persons, percentage of diligent pedestrian *d* = 20%, and the rest (nearly 80%) is panic pedestrians, obtained pedestrian dispersal patterns that the diligent pedestrians tend to gather and following the pedestrian who behave as agents. While pedestrians who have the character of panic have tendency to spread, this situation in accordance with their character that have a tendency to move with direction uncertain (random) because of confusion determining the direction of moving. The pattern of movement of all types of pedestrians can be seen in Figure 8 (a).

Other movement patterns, by the composition of density k and number of agents a equal to the previous composition, i.e. k = 20 % and a = 3, but the percentage of diligent pedestrians about the same as the percentage of panic pedestrians (each almost 50 %). When the percentage of diligent almost same with the percentage panic, pedestrian movement patterns of diligent and panic equal to the previous movement patterns, i.e. the diligent pedestrians tend to gather and following the pedestrian who behave as agents, while pedestrians who have the character of panic have tendency to spread. This condition is shown in Figure 8 (b).

The next composition, the percentage of density *k* and the number of agents *a* is equal to the previous composition, i.e. *k* = 20% and *a* = 3, but the percentage of diligent pedestrians is dominant (*d* = 80%) and conversely the percentage of panic pedestrians is small, almost 20%. Pedestrian movement patterns generated is similar to the previous movement patterns, in which the diligent pedestrians tend to gather and following the pedestrian who behave as agents, while pedestrians who have the character of panic have tendency to spread. This condition is shown in Figure 8 (c).

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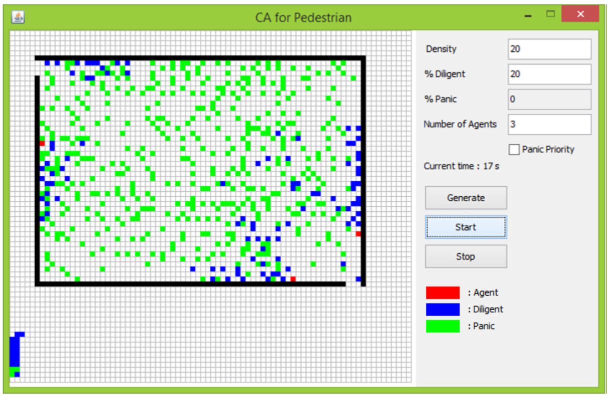
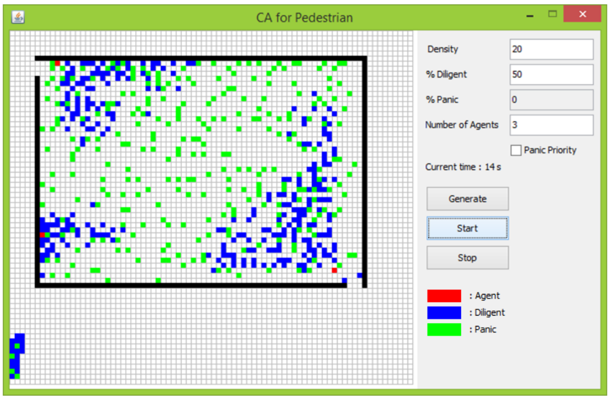
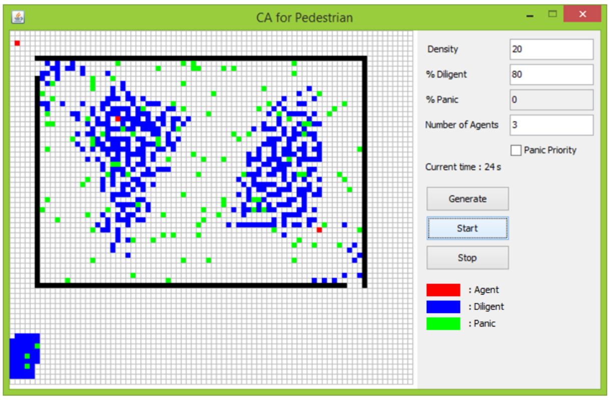


(a)



(b)



(c)

Figure 8. Behavior of the people leaving a room with two doors at the time t. Displayed are three typical stages of the dynamics with density k = 20% and number of agent a = 3, for (a) % diligent d = 20% (% panic around 80%); (b) % diligent d = 50% (% panic around 50%); and (c) % diligent = 80% (% panic around 20%).

4. Conclusion

In this paper, a CA model is presented to simulate the evacuation process in a large room. Characteristics of pedestrian classified into three, namely pedestrians behave as agents, the others behave as diligent pedestrians, and the rest are the panic pedestrians. Experimental simulation carried out with the specific composition of the density, the number of agents, percentage of diligent, and percentages of panic.

By considering three pedestrian behavior, obtained evacuation time getting down in a certain density with increasing number of agents, this condition also occurs at the time of percentage diligent increasing. Contrary to the above situation, the evacuation time will increase with the increase in the percentage of pedestrians who have the character of panic.

By using a certain composition of the density, number of agents, percentage of diligent, and panic, obtained pedestrian movement patterns that the diligent pedestrians tend to gather and following the pedestrian who behave as agents. While pedestrians who have the character of panic have tendency to spread, this situation in accordance with their character that have a tendency to move with direction uncertain (random) because of confusion determining the direction of moving

5. Future Works

Future studies related to the modeling and simulation of the pedestrian behavior in the room in case of an evacuation due to a disaster are:

a. Creating the intelligent agent from some pedestrians that can affect and lead the other pedestrians walk towards the exit by calm.
b. Determining the type of disaster that happened in the room, such as fires, earthquakes, and other. The behavior of pedestrian in a room is depend on type of disaster that occurs.
c. Determining the structure of the room or building used in this study to obtain the modeling and simulation more realistic.

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