Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (14): 2705-2709, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.2705.2709

Simulation of Emergency Evacuation Considering the Strong Movement Ability for Some Students

Xingli Li and Kai Sun
School of Applied Science, Taiyuan University of Science and Technology,
Taiyuan, 030024, China

Abstract: A modified cellular automata model is proposed to simulate the students emergency process by considering the students' emergency behavior characteristics, especially the strong movement ability for some students. The evacuation time it takes for students to escape out a classroom under the influence of strong ability students' ratio and position are investigated, respectively. When the ratio of strong ability students is about 25% and they are far away from the exits, the evacuation efficiency can be improved apparently.

Key words: Students emergency evacuation, cellular automata model, strong movement ability, evacuation time

INTRODUCTION

With the increase of various accidents caused by pedestrian jams and trample of crowd, how to reduce casualties in emergency evacuation has been an important research topic. Especially, the safety evacuation of students in classroom has attracted considerable attention. The prime models to simulate evacuation process are social force model (Helbing and Molnar, 1995), hydrodynamic model (Jiang *et al*., 2010), lattice gas model (Muramatsu *et al*., 1999; Kuang *et al*., 2008) and cellular automata model (Varas *et al*., 2007; Mrowinski and Kosinski, 2011; Zhang *et al*., 2012). As a microscopic model, the cellular automata model can better characterize the different behaviors of pedestrian. Applying the cellular automata model, Varas *et al*. (2007) simulated an evacuation process from a room and found that the optimum position of a double exit door is at the back of the room. Liu *et al*. (2009) investigated the effect of exit density on students' evacuation through experiment. Chen *et al*. (2011) investigated the effect of internal layout in classroom on students' evacuation.

However, in above models, the students' behavior and psychological factors has not been fully referred. For example, some students with strong ability have higher speed to exceed others. How this typical factor influence the evacuation process is still a open problem. For this consideration, we presented an improved cellular automaton model to simulate students' evacuation from a classroom and focused on studying the effect of strong students' ratio and position on evacuation time.

MODEL

The length of the ordinary classroom is 12 m and the width is 5 m. The classroom is described by a two-dimensional grid.

The cellular automata model is defined on a square lattice of 23×11 cells, where each cell can be empty or occupied by an obstacle (or a pedestrian). Suppose one exit can only let one person in or out. As is shown in Fig. 1, according to the conventional Moore two fields, the individuals can move toward 8 directions and arrive to an adjacent empty cell in one time step and the size of the

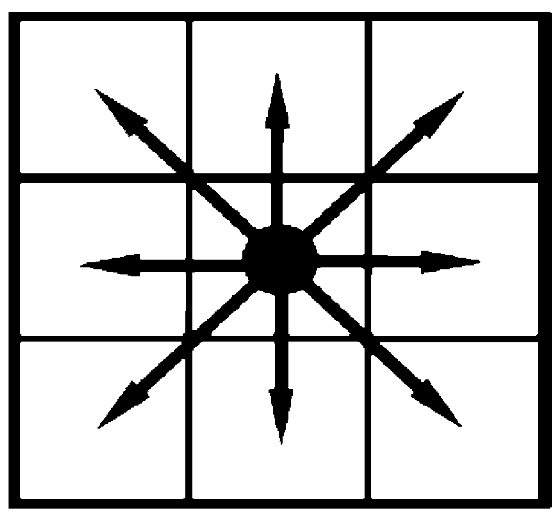

Fig. 1: Moore two fields

Corresponding Author: Xingli Li, School of Applied Science, Taiyuan University of Science and Technology, Taiyuan, 030024, China

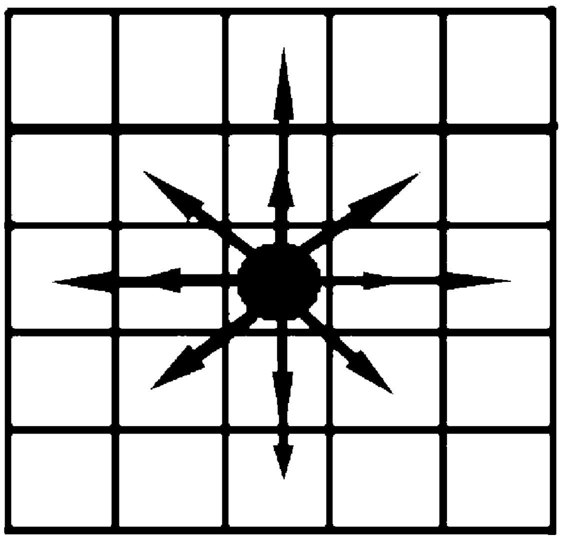

Fig. 2: Extended Moore two fields

arrow indicates the speed magnitude is 1 m sec (move up or down or left or right), 1.5 m sec (move to diagonal), respectively.

Generally, in the process of emergency evacuation, students have the following behavior and psychological characteristics:

- **Panic phenomenon:** Students usually cause panic at a time when emergency occurs immediately, which makes students at a loss and stay still at this time
- **Going first for the students in the front row:** Students near the exit will leave the classroom firstly
- To exceed the others: the individual hopes to escape the classroom faster than others instinctively due to the intense fear and escape expectation. They belong to strong ability individual
- **Conformity:** In the confused scene, the individual will follow the majority subconsciously
- **Intelligent choice:** The individual will choose the exit with fewer persons after he/she calms down

Here, we consider some students with strong movement ability. According to our experience, the biggest difference between the ordinary students and the strong ability students is that the strong ability students have higher maximum speed.

Based on the above consideration, we give the extended Moore two fields (Fig. 2) to describe the different movement, where the individual can go toward the adjacent 12 empty grid points of his/her location, the maximum speed is 2 m sec and can exceed the others. The speed magnitude is 1 m sec (move one cell up or down or left or right), 1.5 m sec (move to diagonal), 2 m sec (move two cells up or down or left or right), respectively. The ordinary students only can go toward the adjacent 8 empty grid points (Fig. 1)We define the average density p and average velocity v as follows:

$$\rho = \frac{1}{T}\sum_{j=1}^{T}\frac{N_n}{N_c} \tag{1}$$

$$v = \frac{1}{T}\sum_{j=1}^{T}\frac{\sum_{i=1}^{N_n} v_i\ (t)}{N_n} \tag{2}$$

where, N_n denotes the number of students in classroom at one moment; N_c denotes the number of students that classroom can contain; v_i (t) is the velocity of ith student at time t; T is the time of simulation.

Then we introduce the concept of location risk of each grid point:

$$PD(i,\ j) = \begin{cases} 0 \quad \text{(the cell at the exit)} \\ \inf \quad \text{(the cell is occupied)} \\ \min\left(\sqrt{(x_i - x_1)2 + (y_i - y_1)^2}, \sqrt{(x_i - x_1)2 + (y_i - y_1)^2}\right) \\ \text{(the cell is empty)} \end{cases} \tag{3}$$

where, (i, j) and (x_i, y_i) denote the cell's location and coordinates, respectively; (x_1, y_1) and (x_2, y_2) are two exits' coordinates, respectively.

In addition, the location risk is also related to students' psychological factors and some objective factors in the process of evacuation. We expand its definition to make location risk can comprehensively reflect the distance, psychological and some objective factors. The specific rules are as follows:

- Firstly, according to (3), the location risk of all the cells is determined
- When the student is in a panic state, the location risk of his location is 0 at that time
- When the student follows the leaders, he/she only selects the adjacent or close cell as the next step moving target and the location risk of other directions are infinity
- When the student intelligently chooses the left exit as the ultimate goal, the location risk of student's right area is infinity and vice versa

The updating rules of the model are as follows:

- Determine each cell's location risk
- According to the principle of going first for the front row, students choose the cell with the minimum

location risk as the goal grid at the next moment. If the students reach the exit, they are removed from the system

- After every person has updated in each time step, each cell's location risk is recounted
- Cycle calculation until all the students have walked out of the classroom

SIMULATIONS AND DISCUSSION

Considering the evacuation efficiency is higher when the distance from the corridor to the exit wall is farther (Chen *et al*., 2011), we set the desks arrangements as shown in Fig. 3, where ▶ and ♦ denote desk and student, respectively. The total number of students is 55.

We assume the students with strong ability are distributed randomly. Let n represent the strong students' ratio, i.e., the proportion of the number of strong ability students to the number of total students. The process of students evacuation is simulated 50 times by the computer. The result is averaged over them.

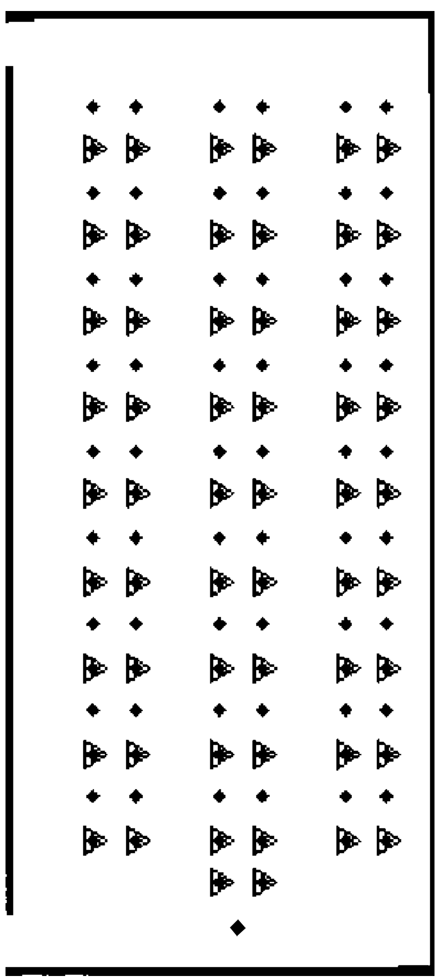

Fig. 3: Schematic diagram of classroom

The relationship between evacuation time and strong ability students' ratio is shown in Fig. 4. As the strong students' ratio n increases from 0-25%, the evacuation time decreases gradually; while as n increases from 25-100%, the evacuation time increases gradually and as n = 1, the evacuation time is longest. The ratio of strong ability students influences the evacuation time evidently.

The change curves of average density and average velocity with evacuation time under different strong ability students' ratio are shown in Fig. 5 and 6, respectively. We can see clearly: (1) The relationship between average density and evacuation time is nonlinear and students evacuate slowly within 5 sec for three curves. When an emergency suddenly happens, a great panic causes the evacuation efficiency to be slow, which is consistent with the actual situation, (2) The evacuation speed is faster when the evacuation time is about 5-20 sec. This may be caused by two facts: one is that those students close to the exits hardly have been affected by obstacles and can evacuate quickly; the other is that the number of the students in the classroom is large in the beginning stage and the students that can evacuate out are also more, (3) The evacuation speed decreases gradually when the evacuation time is more than 20 sec. With the increase of time, many students gather to the exits, which forms "jam" and thus declines the evacuation efficiency. In addition, at the last stage, the number of students in the room becomes fewer and this also will have a great influence on the evacuation speed, (4) Three curves have little difference within 15 sec, this means to a certain extent, too many students

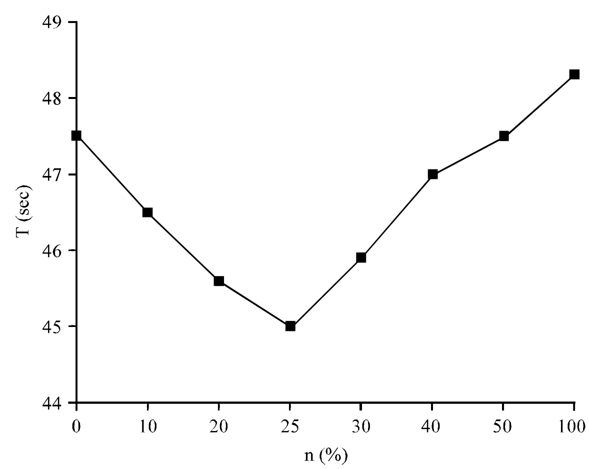

Fig. 4: Relationship between evacuation time and strong ability students' ratio

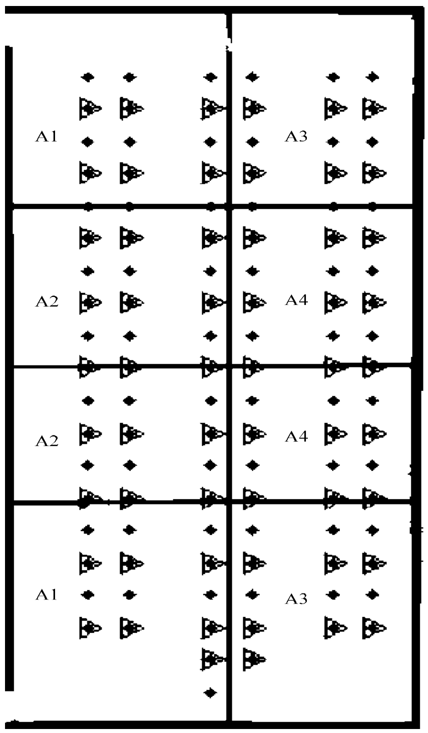

Fig. 5: Curves of average density with evacuation time as n is 0, 25, 40%

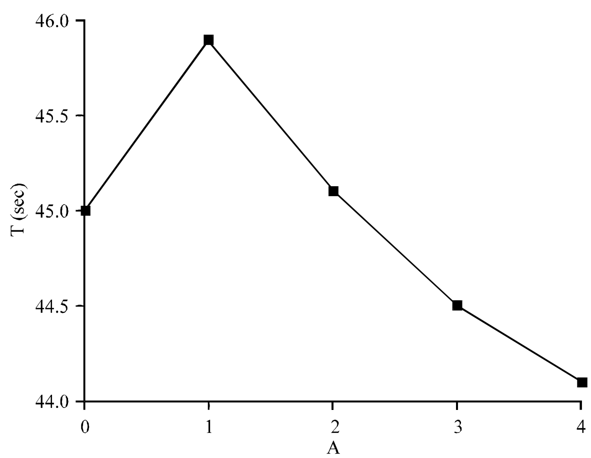

Fig. 6: Curves of average velocity with evacuation time as n is 0, 25, 40%

at the beginning stage limits the movement ability of the strong students. And after about one third students have left from the classroom, this strong ability can display; (5) After 15 sec, when n = 25%, the average density (velocity) is lower (more) than that other two situations. This implies under the two cases of no or too many strong ability

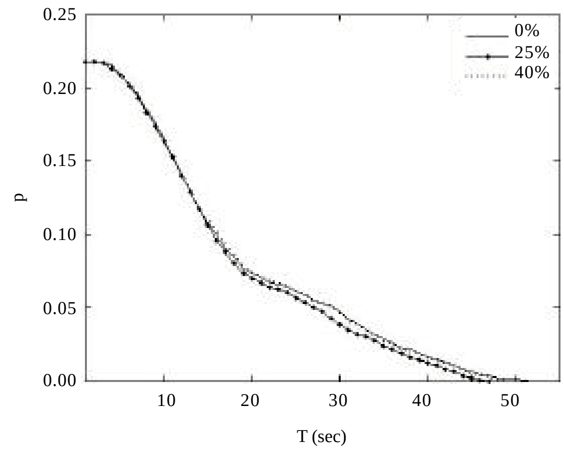

Fig. 7: Schematic diagram of 4 areas for the classroom

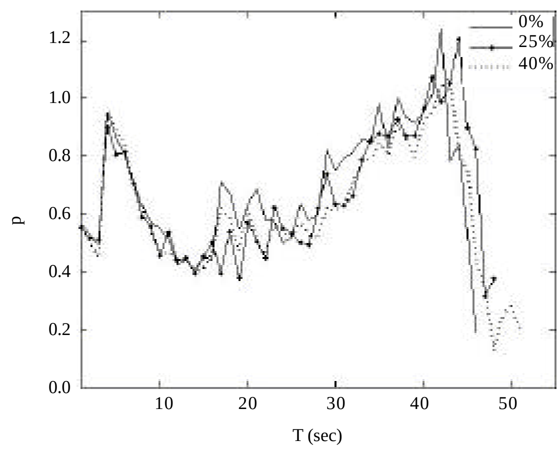

Fig. 8: Relationship between evacuation time and strong ability students' position

students, the evacuation speed will not be so fast relatively. Comparing the changes curves under n = 0 and n = 40% within 15-20 sec, the average density value under n = 40% is higher than that under n = 0. The strong ability students may hinder each other and thus can't evacuate normally, i.e., more haste, less speed. This is why the evacuation time is longest when n = 1.

Secondly, we investigate the influence of strong ability students' position on the evacuation time. As n = 25%, the number of strong ability students is 14. Here, the classroom is divided into 4 regions denoted by A1, A2, A3, A4, respectively (Fig. 7) and the strong ability students can be in these 4 different regions.

The relationship between evacuation time and strong ability students' position is shown in Fig. 8, where A0 denotes the strong ability students are distributed randomly in the classroom. From A1 to A4, the evacuation time decreases gradually and the evacuation time of A1 is more than that of A0, A2 and A0 are almost, A4 is least. When the strong ability students are farther away from the exits, the evacuation efficiency is higher.

CONCLUSION

To explore the influence of some special emergency behavior characteristics on students evacuation processes, we presented a modified cellular automaton model to investigate students evacuation in a classroom with obstacles. The simulation results give the appropriate strong ability students' ratio and position. When the ratio of strong ability students is about 25% and they are farther away from the exits, the evacuation efficiency becomes higher. We hope the presented model in this study can be extended to explore students' emergency evacuation rules and mechanisms in other common buildings with obstacles, such as canteen, students' dormitory and teachering buliding.

ACKNOWLEDGMENT

This study was financially supported by the National Natural Science Foundation of China (10902076, 60904068, 10962002 and 11047003), the Top Young Academic Leaders of Higher Learning Institutions of Shanxi and the Natural Science Foundation of Shanxi Province (2010011004).

REFERENCES

Chen, Y.Q., K.Z. Bai, H. Kuang, L.J. Kong and M.R. Liu, 2011. Effect of classroom arrangement on student's evacuation. J. Guangxi Normal Univ.: Nat. Sci. Ed., 29: 1-4.

Helbing, D. and P. Molnar, 1995. Social force model for pedestrian dynamics. Phys. Rev. E. Stat. Phys. Plasmas Fluids Relat. Interdiscip. Topics, 51: 4282-4286.

Jiang, Y.Q., P. Zhang, S.C. Wong and R.X. Liu, 2010. A higher-order macroscopic model for pedestrian flows. Phys. A: Stat. Mechan. Appl., 389: 4623-4635.

Kuang, H., T. Song, X.L. Li and S.Q. Dai, 2008. Subconscious effect on pedestrian counter flow. Chin. Phys. Lett., 25: 1498-1501.

Liu, S., L. Yang, T. Fang and J. Li, 2009. Evacuation from a classroom considering the occupant density around exits. Phys. A: Stat. Mech. Appl., 388: 1921-1928.

Mrowinski, M.J. and R.A. Kosinski, 2011. Cellular automata models of evacuation on staircase-like geometries. Int. J. Modern Phy. C, 22: 71-84.

Muramatsu, M., T. Irie and T. Nagatani, 1999. Jamming transition in pedestrian counter flow. Phys. A: Stat. Mechan. Appl., 267: 487-498.

Varas, A., M.D. Cornejo, D. Mainemer, B. Toledo, J. Rogan, V. Munoz and J.A. Valdivia, 2007. Cellular automaton model for evacuation process with obstacles. Phys. A: Stat. Mechan. Appl., 382: 631-642.

Zhang, P., X.X. Jian, S.C. Wong and K. Choi, 2012. Potential field cellular automata model for pedestrian flow. Phys. Rev. E, Vol. 85. 10.1103/PhysRevE. 85.021119.