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Crowd evacuating simulation of different personalities with floor field cellular automata

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Abstract: The floor field cellular automata (FFCA) model is employed for integrating the combined effects of crowd personalities and indoor environments on evacuation to simulate a crowd evacuation with different personalities. Herein, the space-time network diagrams of the environment in a crowd evacuation are constructed. A static floor field is established by computing the least travel cost path. According to their personalities, the evacuating crowd is divided into three categories. Each category is likely to use different strategies to find a balance between energy and time. Every pedestrian will choose a moving destination at each time step using the time-varying FFAC. Pedestrians continuously plan new routes or choose to wait until they reach the exits based on their decision-making mechanisms. Simulated studies are conducted in various complicated environments, including a multi-exit room, a classroom, and a subway. The evacuating crowd has a dense population of different personalities. Simulation results provide a novel tool for revealing the intrinsic connection between psychology, environment, and evacuation.

Key words: pedestrian behavior; crowd evacuation; space-time network; floor field cellular automata

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With the ongoing urbanization in China, all types of megastructures and public places have sprung up everywhere. However, this process inevitably leads to urban public security issues. The evacuation simulation is a useful tool for reducing potential risks and ensuring public safety in an emergency. Furthermore, it may be used for analyzing the feasibility of contingency plans and enhancing the evacuation capability. However, architectural design requires the study of crowd behavior characteristics and mobility norms in the evacuation process.

Evacuation is a group behavior in which people are affected by the combined effects of their surroundings, the behavior of others, and their psychology. The factors influencing an evacuation simulation mainly include architectural environment, pedestrian behaviors, and emergency situations. In evacuation events, each of the three factors overlaps. The characteristics of all three factors should be comprehensively considered for completing a safe evacuation in the shortest amount of time.

The architectural environment and emergency situation overlap in building structures that are directly related to evacuation, such as exits, escape routes, aisles, and stairs[1-2]. The facilities in a building, such as furniture, which will obstruct an evacuation, belong to this area. Pedestrian behaves abnormally in an emergency because of nervousness, fear, and a lack of information[3-6], which are then manifested in congestion avoidance, guiding or following behavior, etc. Evacuation factors related to the building environment and human behavior include path planning, walking habits, familiarity with the environment, and human visual range. Fire, stampedes, terrorist attacks, floods, and earthquakes are typical emergencies[7-8]. Density, distribution, age, and even the race of the crowd are primary factors affecting evacuation in emergencies.

In this paper, we consider three main components of these cross-cutting factors: personality, exit, and path selection. Evacuation crowds with different personalities—radical, conservative, or steady—will choose different evacuation routes and exits because of their different strategies for congestion expectations. The crowd evacuation environment and its corresponding static floor field are established using cellular automata. Simulation experiments in different scenarios show that the evacuation model proposed in this paper can realistically simulate crowd evacuation behavior with high credibility.

1 Related Works

Macroscopic and microscopic evacuation models can be distinguished based on modeling scales. Fluid dynamics is used to describe the trend of crowd velocity and density with time as partial differential equations in the macroscopic model[9]. The microscopic model takes a single pedestrian as the research object and generates complex population dynamics through personalized descriptions of individual pedestrians. Compared with the macroscopic

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model, individuals in the microscopic model can interact with each other, which more realistically reflects the behavior patterns among evacuating people. Social force, agent-based, and cellular automata models exemplify traditional microscopic models.

Cellular automata (CA) is a dynamic system built on a cellular space composed of discrete and finite state cells and evolves in a discrete-time dimension. In the cellular automaton model, space is divided into certain regular grid cells. The status of a cell at the current time step is determined by the status of its neighbors at the previous time step. The CA model has the advantages of lesser calculations and higher efficiency than traditional models, and it is more suitable for simulating massive crowd evacuations. In 2001, Blue and Adler[10] modeled bidirectional pedestrian walkways using CA and proved that a small rule set may accurately estimate pedestrian behaviors at the microlevel while attaining realistic macrolevel activity. The floor field cellular automata (FFCA) model was proposed by Burstedde et al.[11] in 2001; its main feature includes the transformation of long-range interactions into neighboring cells by importing a floor field. Alizadeh[12] proposed a dynamic CA model for depicting the evacuation process within a building while accounting for the effects of obstacles and crowd distribution. By improving CA models, Zheng et al.[8] proposed an extended floor field model to investigate pedestrian evacuation dynamics under the influence of fire and smoke spreading. A continuous FFCA (CFFCA) model was proposed by Zhao et al.[13], in which pedestrians do not occupy cells anymore but are treated as particles in continuous space.

Because the FFCA model can discretize the interior structures of buildings, it is often used to simulate indoor crowd evacuation. The internal structure of a building, such as stairs, aisles, intersection areas, and columns, and the facilities placed in it, such as furniture, greatly influence an evacuation. Using a floor field enables analyzing how easy it is to reach the nearest exit from any building position. Huang and Guo[14] simulated pedestrian evacuation in rooms with internal obstacles and multiple exits. Peng and Chou[15] reported a study of the conformation of congestion in a "T" intersection using a cellular automata procedure with multi-floor fields. Yue et al.[16] considered the effects of pedestrian jams around exits and the width of exits on evacuation path selection to reduce the evacuation imbalance caused by exit layout asymmetry. Using an extended floor field model to consider the effect of aisles, Zhu et al.[17] found that congestion often occurs at the intersections of the main aisles rather than the area near the exits. The fine discrete FFCA model is modified by integrating the fatigue function to explore the influence of fatigue on the crowd ascending evacuation[1].

Individual behaviors and habits lead to different evacuation results. The leader-follower (L-F) relationship and the herding effect are basic collective behaviors in crowd simulations. However, L-F behavior may expedite an evacuation, while the herding effect may cause congestion[18]. Hesitation—the other universal behavior during an evacuation—decreases the probability of pedestrian movement and even results in falls and stampedes[19]. However, few studies focus on the cause of these behaviors—personality, which considerably influences the evacuation of a crowd. Burstedde et al.[11] divided the people involved in an evacuation into two modes: "happy" and "unhappy." "Happy" pedestrians try to move in a preferred direction, whereas "unhappy" pedestrians move more randomly. In the proposed methodology of Hsu and Chu[20], two types of pedestrians are defined: congestion-averse and congestion-neutral. Congestion-neutral pedestrians will always follow the least cost paths to their destination, regardless of the congestion situation. Conversely, congestion-averse pedestrians identify congestion locations as obstacles and avoid them. An anticipation effect, the ability of pedestrians to avoid collisions by forecasting other pedestrians' movements, is introduced by Suma et al.[21]. Many researchers[22-23] have developed models for investigating emotional contagion. Three aspects of emotional contagion are discussed in this study[24]: intra-group contagion, inter-group contagion, and third-party authority-based emotional contagion. Zhan et al.[25] focuses on the potential relationship between the pedestrians' choice of evacuating route and final exit and their personality traits.

The combined effect of multiple factors—pedestrian behaviors, architectural environment, and emergency properties—has not been adequately studied. In this paper, we explore the path and exit options chosen by different personalities under various indoor evacuation circumstances. We first use CA to discretize the evacuation environment. Subsequently, the least travel cost (LTC) path algorithm is employed to calculate the static floor field. Finally, when different personality crowds are imported, pedestrians will change paths and exits based on their congestion prediction. Different scenarios are selected to implement evacuation simulations. Simulation results show that the model conforms to crowd flow rules and could realistically simulate the evacuation processes in megastructures and public places.

2 Crowd Evacuation Modeling

The overall framework of our simulation is shown in Fig. 1. First, we employ the floor field CA model to simulate indoor evacuation. We study the evacuated scene model and obtain the relevant space-time network based on the architectural plan and facility layout. The LTC path in the space-time network is calculated to create the static flood field. Second, we categorize pedestrians into conservative, steady, and radical types and build behavior models for each personality. Different pedestrians will choose to move to a neighbor cell or remain put based on their movement conditions. Finally, we update the position and time and start a new time step.

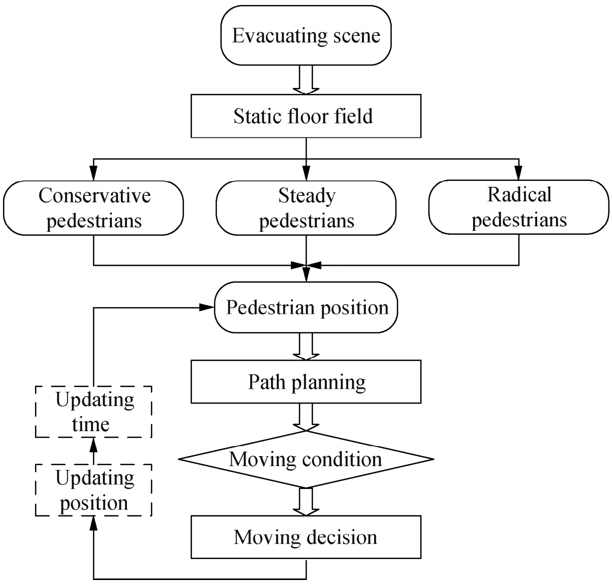


Fig. 1 Overall framework of the simulation model

2.1 Space-time discretization

We employ a CA model to discretize the evacuating environment and time for simulating the evacuation of pressing crowds in a confined location. Grids of uniform size are used to partition the simulation space. The size of each grid is determined by estimating how much space each individual occupies. The size of the grid used in our simulation is 0.4 m × 0.4 m, in accordance with human body dimensions. Each cell can only accommodate one pedestrian at a time, and each pedestrian can only occupy one cell at a time. These regions are categorized as obstacle cells based on their size if any inaccessible items are in the evacuated space, such as walls, pillars, or furniture.

The state of each cell affects the status of its neighbors. In our research, we use the Moore CA model, in which each cell, except edge cells, has eight neighbors. Every cell has one of three states: obstacle, occupied, or unoccupied. In addition to the spatial discretization of the evacuation environment, time is discretized into steps. The position of the pedestrian is updated at each time step. A pedestrian can move to an unoccupied neighboring cells or remain put when there is congestion.

In this paper, all pedestrians take the same time to reach their neighbors. Consequently, conservative, radical, and steady pedestrians take the same time. The floor field of each cell can be determined by discretizing time and space.

2.2 LTC path

In our model, we adopt the decreasing order of time algorithm (DOT algorithm) proposed by Chanibi[26] for computing the shortest path. At every time step, the DOT algorithm updates the travel cost to reach the destination in chronological order. A pedestrian usually chooses the LTC path rather than the shortest path. Based on the DOT algorithm, the arc cost for horizontal and vertical movements is one unit. Additionally, the cost for a diagonal movement is 1.4 units, while that for waiting is 0.8 units[20].

Travel costs are used to estimate pedestrian expense during the evacuation process. If a cell is an obstacle (a wall or column), a pedestrian cannot pass through it; hence, the travel cost to that cell is specified as ∞. Moreover, the travel cost at the exits is specified as 0.

The travel cost of a path is the sum of the cost at each time step. The LTC is the minimum of all costs of all possible paths and is usually obtained by searching for the minimum consumption of nodes from the starting point.

As depicted in Fig. 2(a), a building has 16 available cells numbered 1 to 16 (white grids) and four unavailable cells (black grids). The exit (destination) is cell 15. Fig. 2(b) depicts the node-linking diagram. Every cell is considered a node. The lines between two nodes show that a pedestrian can move between cells in a single step. Notably, the line between cells 3 and 8 is allowed, although an obstacle cell lies between them. People can incrementally advance from the initial to the ending cell over time.

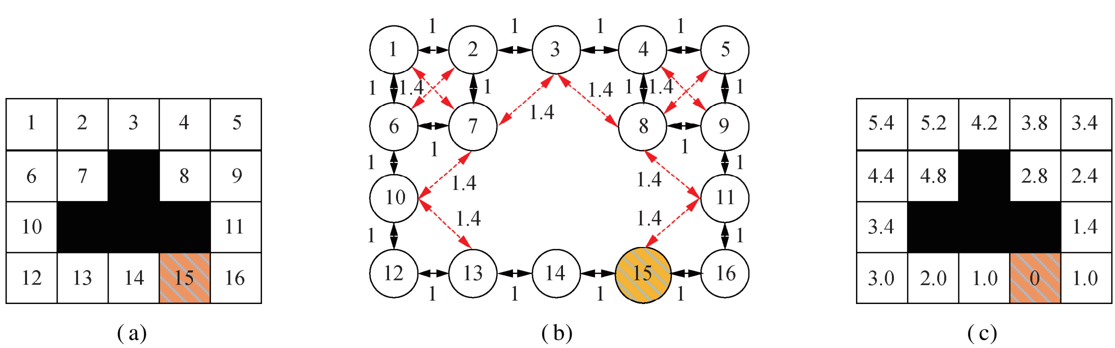


Fig. 2 Least travel cost and static floor field. (a) Cell numbering of a building; (b) Node-linking diagram of (a); (c) Cost to exit using available cells

Several routes with possibly varying travel costs are available for getting from one place to another. Taking cell 4 as an example, if we choose the path 4→3→7→10→13→14→15, the consumption is 7.2. The corresponding consumption of the path 4→9→11→15 is only 3.8, the minimum consumption of all paths. For one cell, more than one LTC path may exist. For example, the path 4→8→11→15 is another LTC path for cell 4. Fig. 2(c) depicts the travel cost of available cells.

2.3 Static and dynamic floor field

Using the concept of a gravity floor field, we extend the idea of the static floor field to an evacuation space. The static floor of each cell is defined as the minimum trip cost spent by a pedestrian to move to one of the multiple exits. The floor field of each cell is determined by calculating the LTC. According to the above algorithm, there is only one exit in Fig. 2(c), and the static floor of cell 4 is 3.8.

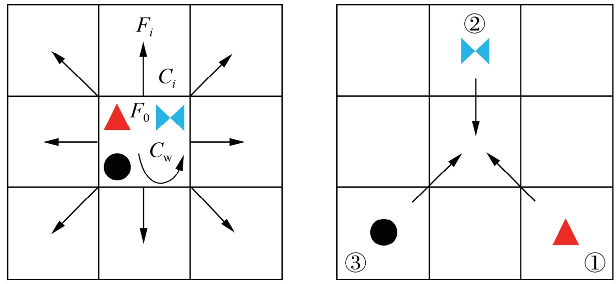
Because many people have frequently raced toward the evacuation exit(s), the next nodes on the LTC path are likely to be occupied by other people. Hence, pedestrians will have to either wait or skip at certain time steps. Therefore, the actual travel expenses from their starting points to respective exits equal or exceed the value of the static floor field. The dynamic floor is the actual motion consumption. This time-related consumption is challenging to define in the static floor field but is straightforward to indicate in the space-time network. We will update the floor field at every time step to make the model more realistic.

Cell node 8 or 9 is the next cell on the LTC path of cell 4 in Fig. 2(c). If they are both occupied at a given time step, the person in cell 4 must wait one extra time step. The actual path 4→4→8→11→15 is chosen, and the dynamic floor changes from 3.8 to 4.6. In contrast, the pedestrian in cell 4 may have a different option that costs less: 4→5→9→11→15 (cost is 4.4).

2.4 Path planning of different-type crowds

Whether or not pedestrians change their routine is determined by their behavior. Individuals are likely to take different measures to deal with congestion in a particular floor field. All pedestrians will initially attempt to evacuate along the LTC path. However, they must wait occasionally or reroute sometimes because the front nodes are already occupied by other people.

Our model categorizes pedestrians into three personality types: conservative pedestrians (labeled as circles), radical pedestrians (labeled as triangles), and steady pedestrians (labeled as bowknots) (see Fig. 3). They take different approaches to deal with the congestion ahead. Conservative pedestrians do not mind traffic delays and prefer to wait when congestion occurs. Therefore, they always follow the LTC path, irrespective of the level of crowding. Radical pedestrians despise congestion and avoid it at all costs. They will predict traffic congestion nodes and choose to avoid them. The steady pedestrians weigh the costs of waiting vs. bypassing and select the optimal option.



(a) (b)

Fig. 3 CA model including human factors. (a) Moore's FFCA model; (b) Competition for vacant cells

Based on Moore's FFCA model, a particle in the central cell can either move to any of the eight neighboring cells or stay put, as shown in Fig. 3(a). Each particle is given a direction of preference at a certain moment [11]. We improve the CA model by considering different human personalities. The particle in the central cell can either be a radical, steady, or conservative pedestrian.

F_0 is the field of the current occupied cell, while F_i is that of the unoccupied neighboring cell i. C_i represents the cost of traveling from the current cell to nearby cell i. Its value is 1.0 (horizontal or vertical direction) or 1.4 (diagonal direction), as explained in Section 2.2. C_w is the cost of waiting in the current position. The value of C_w is 0.8. If $C_i = F_0 - F_i$, cell i is just on the minimum cost path.

Table 1 lists the moving conditions for the three types of pedestrians. Because $C_i > C_w > 0$, a radical person is more likely to move to a neighboring cell than a conservative person, consistent with the actual situation. In a real evacuation, impatient people are more likely to move rather than wait, although sometimes running blindly is not the best option. If two or more nearby cells satisfy the movement criterion, the cell with the lowest value is picked as the next cell; otherwise, people will wait.

Table 1 Moving conditions for different crowds

Type of people	Condition of moving	Probability of moving	Processing sequence
Conservative	$F_i = F_0 - C_i$	Small	Last
Steady	$F_i + C_i \leqslant F_0 + C_w$	Medium	Second
Radical	$F_i \leqslant F_0$	Large	First

As shown in Fig. 3(b), if multiple people want to occupy the same cell, the radical pedestrians are chosen to move to the next cell first, followed by the steady pedestrians and then the conservative pedestrians. The explanation is that people with more impatient personalities are likelier to make snap decisions, whereas conservative people are more likely to deliberate for a while before deciding.

Fig. 4 depicts a simple example of the three types of people making different decisions when faced with traffic congestion. The room has 3 × 3 cells, and every accessible cell is numbered, as shown in Fig. 4 (a). The middle cell is an impediment, while cells 4 and 7 are exits. The floor field of this room is depicted in Fig. 4(b). T represents the number of time steps since the evacuation began.

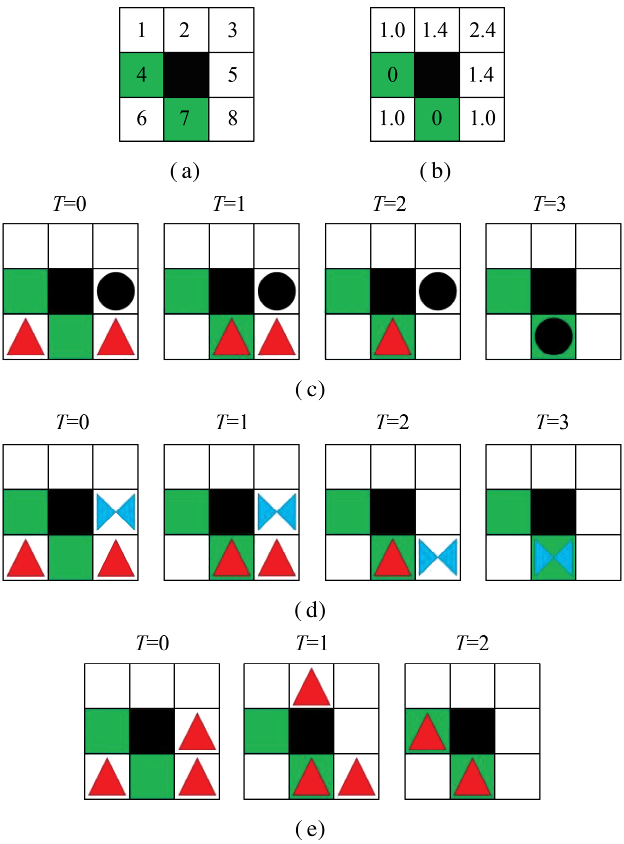


Fig. 4 Evacuating path for different types of pedestrians. (a) Cell numbering of a simple building; (b) Cost to exits of (a); (c) Evacuating paths of a conservative person; (d) Evacuating paths of a steady person; (e) Evacuating paths of a radical person

In our example, three people are in the room, including two radicals. The third person in node 5 is different: a conservative person in Fig. 4(c), a stable person in Fig. 4(d), and a radical person in Fig. 4(e), respectively. They are in the same starting positions, as shown in Fig. 3 when $T = 0$. Because other people hold the unique target node 7, the conservative individual decides to wait for two time steps. However, when faced with the same situation, the radical person refuses to wait and takes the other exit. A steady person compares the expenses of staying to those of departing. At $T = 1$, the costs of remaining in node 5 vs. switching to node 2 are 2.2 and 2.8, respectively. Thus, the steady individual chooses to wait because the overall cost is lower. At $T = 2$, the expenses of staying at node 5 vs. going to node 8 are 2.2 and 2.0, so he chooses to travel to node 8 rather than wait at node 5. Conservative, steady, and radical individuals have total expenses of 3.0, 2.8, and 2.8 and take 3, 3, and 2 time steps, respectively.

3 Crowd-Evacuating Simulations of Different Personalities

The proposed model is used for simulating crowd evacuation in various scenarios, such as basic one- and two-exit rooms and a complex subway station. First, the virtual environment is constructed in accordance with the architectural design along with appropriate facility configurations. The evacuation space is discretized into the space-time network, where the position of walls, obstacles, and exits are marked. Information on pedestrians' numbers, types, and initial positions is provided at the beginning. Subsequently, the number of people who are still alive during a simulation is monitored and represented with figures. Finally, a flat channel scenario is developed to show the model's viability. Results demonstrate that our model can realistically simulate the evacuation process of a mixed crowd with different personalities.

3.1 Simple scenario simulation with one exit

For example, consider the room represented in Fig. 2. Two steady, one conservative, and three radical pedestrians are at various parts of this room. The evacuation has a total of eight time steps. Participants in the same category are numbered in Fig. 5 for clarity. The conservative, steady, and radical pedestrians travel to the same exit.

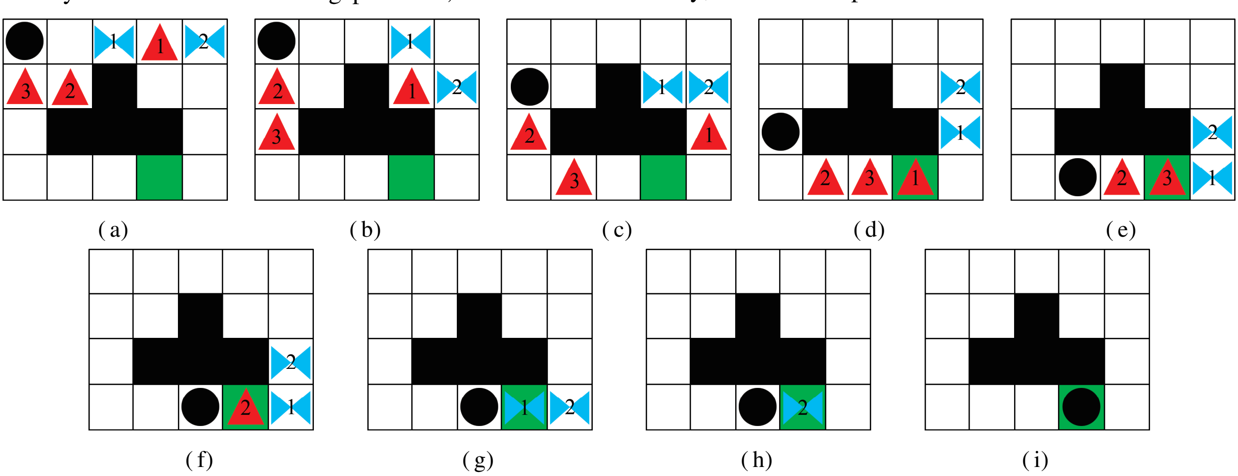


Fig. 5 Evacuation process in a simple scenario. (a) $T=0$; (b) $T=1$; (c) $T=2$; (d) $T=3$; (e) $T=4$; (f) $T=5$; (g) $T=6$; (h) $T=7$; (i) $T=8$

The evacuation data are shown in Table 2. The LTC is used by Radicals 1 and 3, while others chose to wait or take a detour. The maximum value of the total time steps is the evacuation time. A higher difference between the static and dynamic floors suggests increased travel costs due to waiting or detours.

Table 2 Evacuation paths and costs of different people

Type of person	LTC path	Real path	Static floor	Dynamic floor	Difference	Total time steps
Conservative	16-10-13-14-15	1-1-6-10-13-14-14-14-15	5.4	7.8	2.4	8
Steady1	3-8-11-15	3-4-8-11-16-16-15	4.2	6.2	2.0	6
Radical 1	4-8-11-15	4-8-11-15	3.8	3.8	0	3
Steady 2	5-9-11-15	5-9-9-9-11-11-16-15	3.4	6.4	3.0	7
Radical 3	6-10-13-14-15	6-10-13-14-15	4.4	4.4	0	4
Radical 2	7-10-13-14-15	7-6-10-13-14-15	4.8	5.4	0.6	5

3.2 A square room with a different number of exits

We establish a 20 × 20 cell area and execute four scenarios, each with a different number of exits, as seen in Figs. 6(a)-(d). The maximum floor gradually decreases with increasing number of exits. In Figs. 6(a)-(d), the maximum floors are 21.2, 20.4, 12.2, and 10.8, respectively. When the exit positions vary, the cell with the highest floor also changes. For instance, the maximum is at or near the corner on the opposite side in Figs. 6(a) and (b) but is located at the center of the back wall in Figs. 6(c) and (d).

In Fig. 6, 100 pedestrians, including 40 radicals, 30 steady individuals, and 30 steady people, are put in the space in randomly selected initial positions. As seen in Fig. 7, the number of exits influences evacuation speed

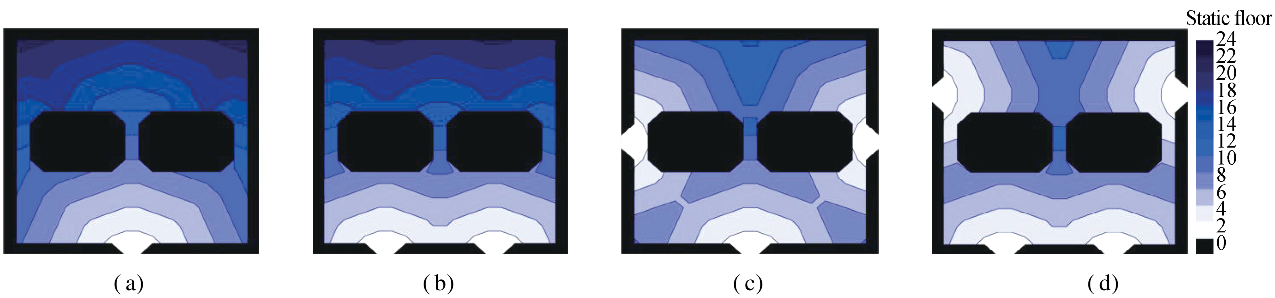


Fig. 6 Static floor of a square room with different numbers of exits. (a) One exit; (b) Two exits; (c) Three exits; (d) Four exits

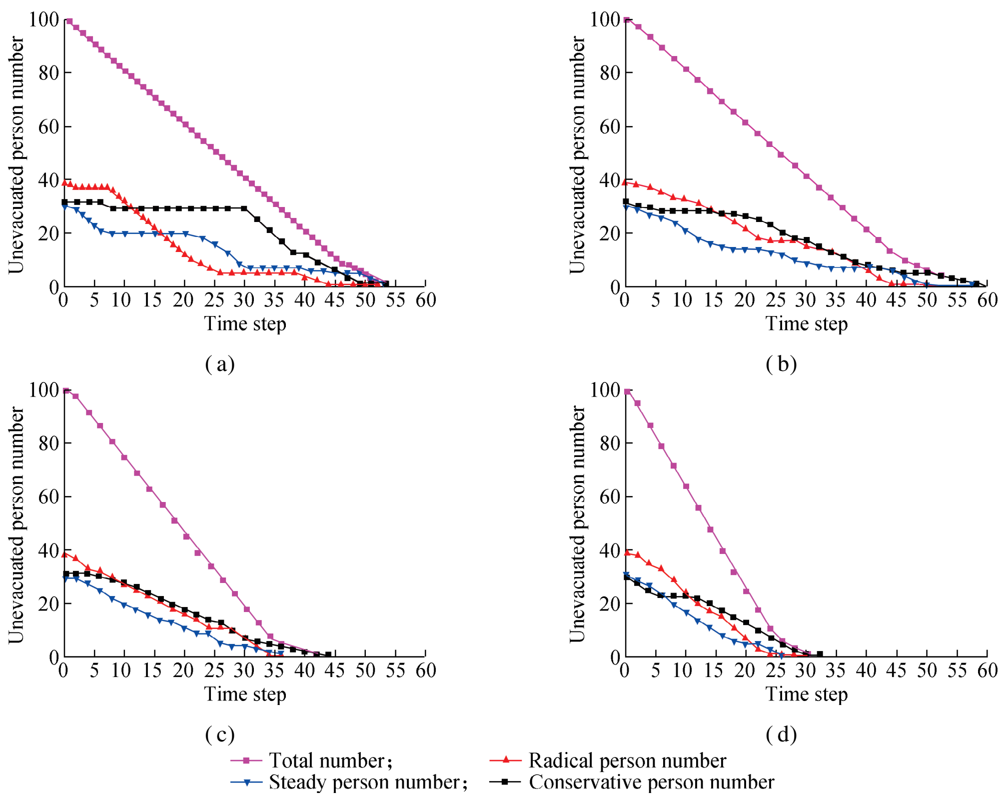


Fig. 7 Evacuations corresponding to different exit numbers. (a) One exit; (b) Two exits; (c) Three exits; (d) Four exits

considerably. Doubling the number of exits saves approximately half the evacuation time. Conservative people, probably mostly the elderly, may slow down evacuation times, particularly if fewer exits are available. When there are more exits, radical people, probably mostly young people, may choose other exits due to fear of waiting. The delay in total evacuation time will be minor.

Fig. 8 depicts an evacuation for mixed groups starting from a fixed place. Initially, 40 people are present in this space. This group is composed of seven radicals, seven moderates, and twenty-six conservatives. The total number of time steps in the two-exit room evacuation scenario is 25. Although it is not their LTC route, three radicals choose the middle lane. One of them even reselects a different exit. Four groups of conservatives are traveling along the LTC path. Moreover, all steady people use the same evacuation exits and choose the same path on the right side.

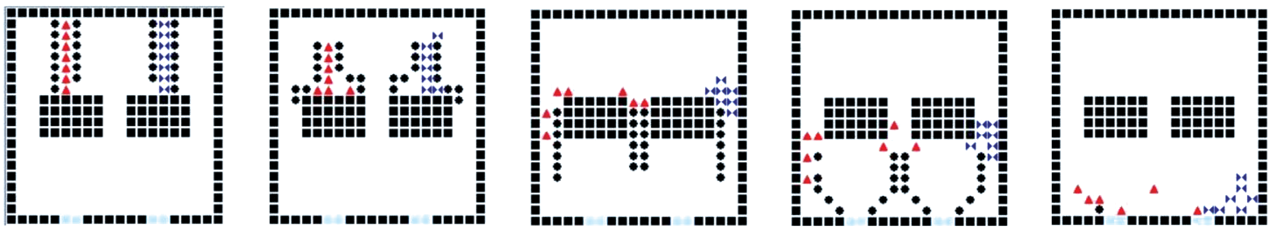
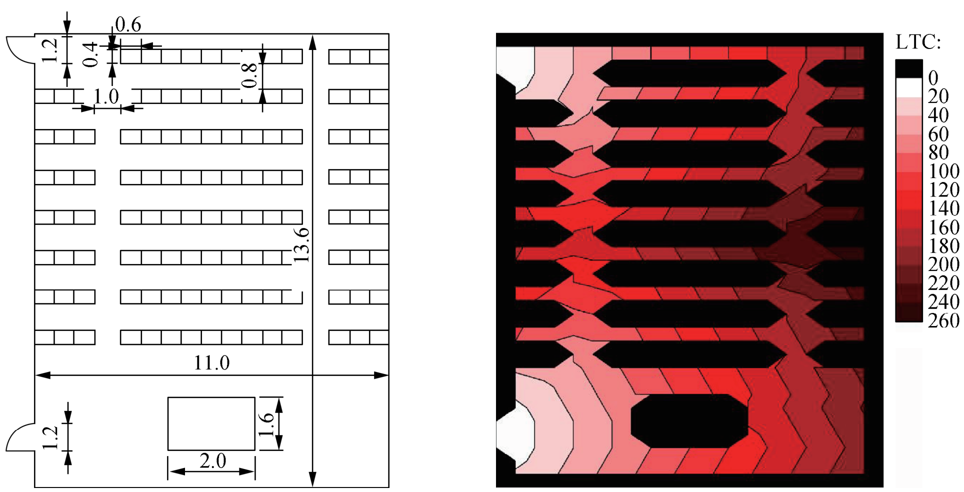

(a) (b) (c) (d) (e)

Fig. 8 Evacuation simulation in a two-exit room. (a) $T=0$; (b) $T=2$; (c) $T=9$; (d) $T=13$; (e) $T=19$

3.3 Classroom simulation

The classroom depicted in Fig. 9 (a) is an actual facility at our university. The classroom has two exits, one in the front and one in the back, and measures roughly 13.6 m wide by 11 m long. The classroom has 117 seats. The front and back rows of tables are separated by 0.8 m, while the aisles are 1.0 m wide. Fig. 9(b) depicts the classroom's static floor.

Assume that at the end of class, the classroom contains



(a) (b)

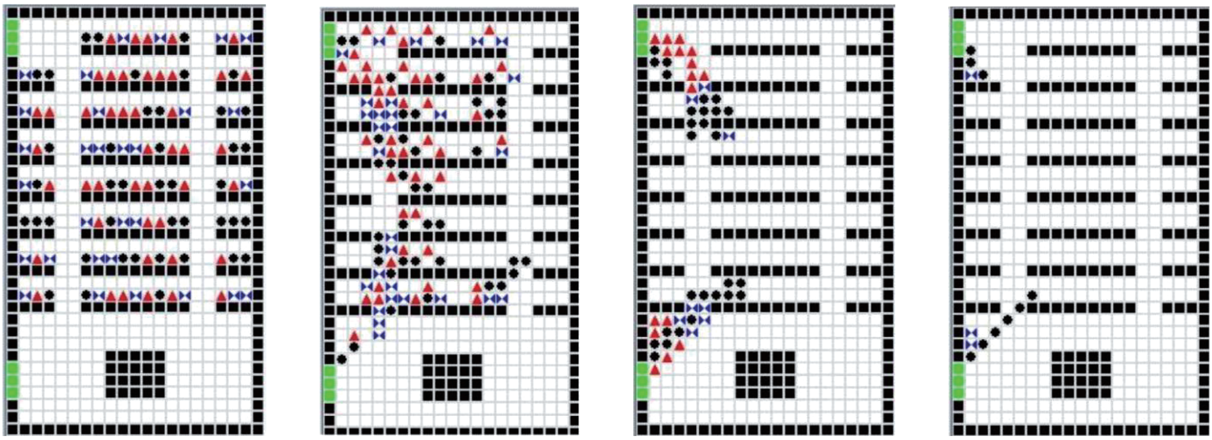
Fig. 9 Classroom scene. (a) Schematic (unit: m); (b) Static field (LTC of every position)

117 students already assigned personalities at random, as shown in Fig. 10. In terms of evacuation results, 45 people used the front door, while the remaining people used the back door. The maximum travel cost for the person in the third row in the middle is 468. The student sitting in the third row on the far right is the last to leave the classroom.

3.4 Subway station evacuation simulation

Here, we use a subway station as an example because it has huge traffic and few exits. A station platform has many steps (exits), structural pillars and partition walls (obstacles), stopped trains, and other accessible spaces. Evacuation will be difficult in event of a fire or other disaster. However, our modeling method is well suited for simulating large-scale population flows and has high calculation efficiency.

A subway station with a width of 70 m and a length of 200 m is shown in Fig. 11. The blue zones in the upper part of the image depict destinations, which are stairs or elevators. The borders, pillars, and trains are represented by the black grids in the upper, middle, and lower regions of the image, respectively. These areas are inaccessible. However, doors between the five railcars are accessible. Fig. 12 depicts the static floor of the subway station. There are 100 pedestrians that are waiting to exit



(a) (b) (c) (d)

Fig. 10 Evacuation simulation in a two-exit classroom containing 117 students. (a) $T=0$; (b) $T=8$; (c) $T=16$; (d) $T=25$

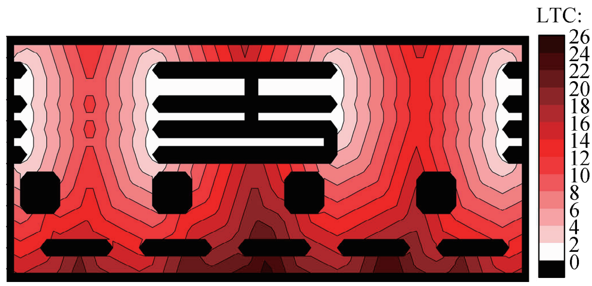
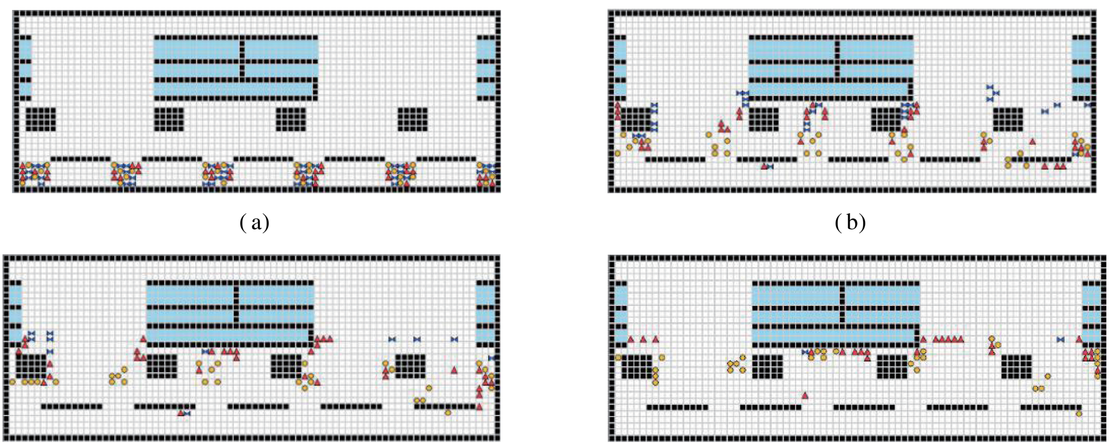


Fig. 11 LTC on a subway station platform



(a) (b) (c) (d)

Fig. 12 Evacuation simulation of 100 pedestrians in a subway station. (a) $T=0$; (b) $T=10$; (c) $T=16$; (d) $T=30$

the subway station behind six doors. On the platform, there are 35 radical pedestrians, 35 stable pedestrians, and 30 conservative pedestrians.

At time $T=0$, 100 pedestrians, comprising all three types of personalities, are ready to leave the railcars. When $T=10$ and $T=16$, the number of steady pedestrians reduces rapidly because they employ intelligent path prediction, congestion anticipation, and collision avoidance during the evacuation. The radical pedestrians prefer to choose the exits on the two sides rather than the middle. They choose the path with the shortest waiting time, although the distances to the exits are farther. All conservative pedestrians try to find their paths with the minimum consumption. Therefore, most of them remain on the platform when $T=30$.

In the same scenario, we increase the evacuation time considerably after increasing the population to 400, as shown in Fig. 13. This population includes 136 radical, 162 steady, and 102 conservative persons. The average waiting time for conservative persons is approximately twice that for radical persons. As displayed in Table 3, the difference between the actual travel cost and static floor per person is far smaller for conservatives than for the other two types of pedestrians. This comparison indicates that conservative pedestrians tend to accomplish evacuation in a way that conserves physical effort, although they may waste a little time. In contrast, 77% of radicals are more likely to abandon the original path and choose a new exit that requires slightly more effort. Meanwhile, steady persons, most of whom are probably middle-aged, try to find a balance between physical effort and time.

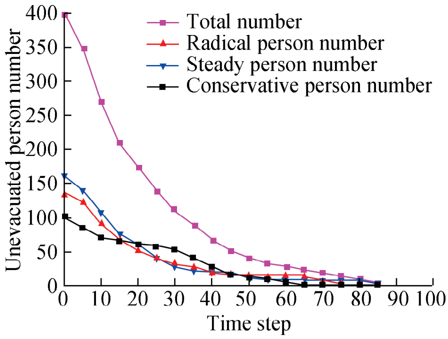


Fig. 13 Crowd evacuation simulation of 400 pedestrians in a subway station

Table 3 Evacuation data of 400 pedestrians in a subway station

Type of person	Number of different types	Average wait time per person	Difference between the actual travel cost and static floor per person	Proportion of people switching to other exits/%
Radical	136	9.25	228.8	77
Steady	162	9.49	206.1	67
Conservative	102	18.08	161.9	0

4 Conclusions

1) This essay investigates the comprehensive effect of human behavior and evacuation environment on crowd evacuation using FFCA. Different personalities have different decision-making mechanisms for deciding escape routes and exits. Radical people (more young people) are more inclined to save time, while conservative people (more old people) are more inclined to save physical energy. Middle-aged people fall somewhere in between.

2) When different personalities are using the same escape space, exits should be increased if the number of conservative pedestrians is greater. Evacuation time is closely related to the personality classification of the people in the crowd.

3) Several simulations and analytical instances reveal the usefulness of our crowd evacuation concept. The outcomes indicate that our model can convincingly and correctly simulate the crowd evacuation process involving different personalities. This new model opens opportunities for optimizing building interior design under emergency escape psychology.

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基于势能场元胞自动机的不同个性人群疏散仿真

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摘要: 为了综合考虑人群个性和室内环境对疏散的综合影响,采用势能场元胞自动机(FFCA)模型模拟混合有不同性格行人的疏散. 该模型构建了人群疏散环境的时空网络图,并通过计算最小运动消耗(LTC)路径建立静态势能场. 疏散人群根据性格特征被分为 3 类,每类人群都可能使用不同的策略来平衡疏散中的运动和时间消耗. 在每个时间步,每位行人都能根据随时变化的 FFAC 模型选择下一个移动目标. 行人会根据自己的决策机制不断规划新路线或选择等待,直到到达出口. 疏散模拟选择在不同的复杂疏散场景中进行,如多出口房间、教室和地铁,且疏散人群由不同性格的稠密人群混合而成. 该研究为揭示行人心理、逃生环境与疏散行为之间的内在联系提供了一种新的方法.

关键词: 行人行为;人群疏散;时空网络;势能场元胞自动机

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