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Emergency Evacuation Based on Cellular Automata

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Abstract

With the increasing number or scale of large-scale assembly activities, emergency evacuation has become increasingly important. In order to understand the evacuation behavior of people, this paper uses European distance, simulation and other methods to optimize the research and design of evacuation in emergency. The main contents of this paper are as follows: First, based on the principle and update rules of cellular automata, determine the three key factors of gender, age and emotional intensity, and the evacuation model based on cellular automata, and then use MATLAB software to simulate the change of people flow under different anxiety conditions, and output relevant data and visual images. Finally, the differences of the experimental results caused by the key factors are discussed. Secondly, study the evacuation rate change curve, as well as the key factors and their effects. Based on the average speed and average flow model of the system, simulate and output the corresponding visual images. Thirdly, in order to study and determine the best simulated evacuation route and the dynamic process of personnel evacuation in the case of different door widths, based on the evacuation route selection model with the shortest time to reach the two doors, the best pedestrian evacuation route is selected according to the shortest time rule. Fourth, in order to study the impact of reduced visibility in the hall on the whole process. In this paper, the regional discretization method is used to establish the perception range model under visibility and analyze the factor changes in the whole process.

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1. Introduction

1.1. Research background

The establishment of large public places[1] provides convenient conditions for sports, entertainment, religion, culture, learning, business and other activities. When major activities are carried out, people in public places are in a dense and crowded state. In case of life-threatening dangerous events, people are prone to panic. If the layout of public places is unreasonable, the evacuation facilities are not complete, and the evacuation management is not in place, the occurrence of dangerous events is very likely to cause life and property losses. To study the dynamic diffusion characteristics of the emotional fluctuation sources of each person in the event of an emergency, as well as the movement rules of pedestrians in the emergency scene, formulate scientific and reasonable evacuation strategies, and timely and effective evacuation and control of the dense crowd in the place are the key to reduce the casualties in the event of a dangerous event. As an important research field and direction of public safety, the rapid and safe evacuation of people under anxiety has been widely concerned by scholars and researchers at home and abroad. In order to understand the crowd behavior under various conditions, many experiments and numerical simulations have been carried out. The width of the door, the position of the exit and the position of the exit will affect the evacuation effect. The human experiment is effective, but because the

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environment and background as well as the pressure level, personnel density, sample size, etc. cannot be consistent with the real situation, different research results are controversial and contradictory.

The emergency environment will affect the judgment and behavior of pedestrians. At this time, the mental state and physical activity have the following characteristics. (1) Because of the sudden and dangerous nature of the environment, pedestrians will feel nervous and scared. When pedestrians cannot think normally and calmly, they are flustered. Busy will disturb the normal judgment of pedestrians, make them lack of useful emergency skills, and cause pedestrians to adopt unwise strategies or improper actions. When the distance between injury and personnel is close, the fear of personnel will become more intense. Personnel blindly choose steps, which is a typical case of panic. It will even cause the weakness of pedestrians, so that they will collide in a certain direction without control. (2) In an emergency, pedestrians can't respond in time. Personally, I think it is correct and safe to stay with the public. Therefore, the staff will follow most people on their own. At this time, the thinking ability of personnel is lower than before, and there is an obvious downward trend. And the personnel are lack of independent thinking and correct way of thinking. So they will follow blindly, which may aggravate the degree of emergency and cause secondary accidents such as stampede. (3) When people's property and safety are threatened, people will choose to move as soon as possible, stay away from emergencies and try to escape to safer places, based on their survival instinct. In this process, pedestrians tend to rely on each other and think it is safer to gather with most other people, which leads to the possibility that pedestrians will be found wherever they go, and many people will gather together or run away. So in the process of dispersion, if there is no useful identification or accurate guidance.

Based on the traditional pedestrian evacuation modeling and simulation, this paper models and simulates the pedestrian evacuation under different anxiety scenarios, and combines the diffusion of anxiety with the emergency evacuation of pedestrians, and deeply discusses and analyzes the dynamic characteristics of pedestrian evacuation under this scenario.

1.2. Research objective

Because the authenticity of environment and background, stress level, personnel density, sample size, etc. cannot be consistent with the real situation, many different research results are controversial or even contradictory.On the basis of traditional pedestrian evacuation modeling and simulation[2], this paper models and simulates pedestrian evacuation under different anxiety scenarios, combines anxiety diffusion with pedestrian emergency evacuation, and deeply discusses and analyzes the dynamic characteristics of pedestrian evacuation under this scenario.

Model-based research does not need to face the difficulties encountered in the experiment. However, if the assumptions of the model are unreliable, it may produce results inconsistent with reality. Research is carried out for different situations and parameters to understand the different dynamic behaviors[3] that people may exhibit during evacuation[4].To solve the different dynamic behaviors that people may exhibit during evacuation and escape, its main contributions and purposes are:

1.The anxiety level of the crowd will have a significant impact on the evacuation process. Some implementation results show that the increase of emergency degree will speed up the evacuation, but some experimental results show that too high anxiety degree will slow down the evacuation process. This paper first assumes that there are several people in a barrier-free square room (or hall), and only one door can be used for evacuation. To establish key factors to study the impact of crowd anxiety on the evacuation effect, and to study the differences in the experimental results caused by key parameters.

2.In the same room as above, the evacuation process is not uniform. Study the change curve of evacuation rate with time and the impact of key factors and curves.

3.There are two exits with a certain distance in a large enough hall, but when people choose the evacuation exit, they often choose the door with the shortest expected time, not necessarily the door with a closer distance. Simulate the process of evacuation route, and study the dynamic process of different door widths. If the visibility in the hall is reduced, how will it affect the whole process.

1.3. Research meaning

At present, scholars at home and abroad have made relatively rich theoretical achievements in the research field of pedestrian evacuation modeling, but the diffusion characteristics of hazard sources in public places, the corresponding movement laws of pedestrians and the evacuation dynamics characteristics need to be further studied and explored in detail. When a dangerous event occurs, with the continuous spread of panic and anxiety, there are interactions between people and buildings, people and people, and people and hazard sources. At the same time, there are physiological and psychological differences among individuals in emergency situations, and there are also dynamic, complex and changeable sports behaviors in the evacuation process. At present, many scholars at home and abroad have carried out a lot of research work in the field of pedestrian evacuation in emergency, and have studied the law of pedestrian movement, evacuation time, evacuation characteristics and evaluation of pedestrian physiology and psychology in emergency, but the dynamic change characteristics of different hazard sources and the adjustment of individual movement state made by pedestrians with the change of hazard sources are rarely mentioned. In reality, when the hazard source occurs, it will continue to spread to the surrounding with a certain rule. During the evacuation process, the pedestrian will dynamically adjust the movement state, speed and rule with the change of the hazard source.

This paper mainly carries out further research work on the basis of the modeling and simulation of pedestrian emergency evacuation under the existing dangerous scenes at home and abroad, mainly studies the model combining the dynamic diffusion of hazard sources and pedestrian evacuation when the dangerous events occur, and carries out modeling, simulation and numerical analysis on the dynamic change of panic events and the corresponding movement state adjustment of pedestrians, Understand the rules of pedestrian movement and evacuation characteristics in public places under various dangerous scenarios, analyze the key factors that restrict the efficiency and success rate of emergency evacuation of crowds, improve the ability of managers to deal with sudden dangerous events, provide theoretical basis for the rationality of the layout planning in the building, provide reference for the formulation of emergency plans and rescue strategies for pedestrian evacuation in public places, and provide support for strengthening the prevention, control and management of dangerous events, In order to minimize the threat to personal safety and economic losses caused by dangerous events. In an emergency, good evacuation measures will effectively protect the affected people, so it is very meaningful to study how to conduct effective evacuation. In the event of natural disasters, the main task of mass evacuation is to evacuate the affected people safely to the refuge point.

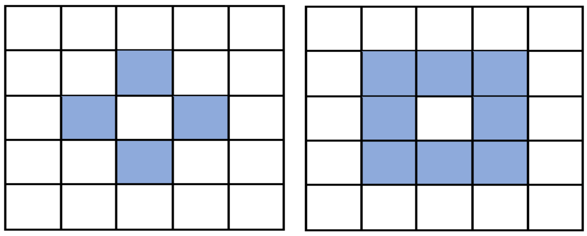
The structure of this paper is as follows. Section 2 describes the principles and evolution rules of cellular automata used, and gives the simulation results and result analysis in static and dynamic fields using the Euclidean distance method. Section 3 analyzes the methods and simulation results and result analysis of pedestrian evacuation under multi-velocity mixing. Section 4 determines the evacuation route selection model and the shortest selection method, and divides the perception range under the optimization based on dynamic changes, The simulation results and results analysis are given. Section 5 summarizes the research methods and contents of the crowd evacuation simulation based on experiments.

2. Study on pedestrian evacuation under cellular automata

2.1. Pedestrian evacuation model based on cellular automata

Cellular automata[5, 6] is a dynamic system defined in a cellular space composed of cells with discrete and finite states and evolving in a discrete time dimension according to certain local rules. It has the following characteristics: (1) The cellular state is selected in the finite state set, and the cellular automata has the characteristics of time discrete, space discrete and state discrete. (2) The cell state follows the same change or update rule when updating synchronization. (3) The change of cell is uniform. (4) The state of the cell at time t is only determined by the cell itself and its neighbors at time $t-1$. This model simulation is safe, stable and repeatable to study pedestrian evacuation.

Cell is also called cell of unit and cell. Its shape, shape and change rule depend on the difference of cell space. The cellular space[6, 7] of cellular automata is composed of a group of uniformly distributed cells. When a cell satisfies certain conditions, domain conditions or boundary conditions, it can be transformed into a boundary cell. The neighbors of two-dimensional cellular automata are Von Neumann type and Moore type[8] (the neighbor style is shown in Figure 1).



(a) VonNeumann Neighbor Style (b) Moore Neighbor Style

Figure 1. Cellular automata neighbor style

There are four update modes in the existing evolution rules of cellular automata: synchronous update, random update, sequential update and random sequential update. We adopt the synchronous update mode, which solves the inequality problem between pedestrians. However, there may be conflicts in the simultaneous movement. The conflict of pedestrian movement represents t+1 moment. At the same time, there are multiple pedestrians moving to the unified cell, and one pedestrian can only occupy one cell, which leads to the algorithm exception. Therefore, the conflict must be resolved when using the synchronous update rule.

Cellular automata is a rule-based discrete model, which can well represent the crowd and path selection of people. Firstly, the concept of field is introduced to build the cellular automata model step by step, and then the static field and dynamic field are proposed to build the pedestrian evacuation model to describe the normal and anxious behaviors of pedestrians during the evacuation process.

First of all, since the initial setting during the simulation of motion will not change with the iteration of the running time, the perceived emotional level in the static field is determined according to the distance G_{ij} from the cell to each exit in the static field a_i:

$$a_1 = exp(u_G G_{ij}) \tag{1}$$

In the above formula, G_{ij} represents the static field distance from the cell (i, j) to each outlet, and u_G represents the non-negative sensitive parameter of the static field.

Secondly, we do not know whether the cell area where the next destination is occupied, so as to avoid conflicts when multiple people reach the same area, so we can determine the condition b to determine whether the cell is occupied:

$$b = 1 - n_{ij} \tag{2}$$

In the above formula, n_{ij} indicates whether the cell is occupied by pedestrians, if $n_{ij} = 1$, indicating that the cell is occupied; If $n_{ij} = 0$, then the cell is not occupied.

Then, according to the continuous change of emotional information in the process of evacuation, what constitutes dynamic information, that is, the amount of change with time, so as to determine the degree of perceived emotional information in the dynamic field a_2:

$$a_2 = exp(u_T T_{ij}) \tag{3}$$

In the above formula, T_{ij} refers to the impact of pedestrian information left in cell (i, j) on others; u_T represents a non-negative sensitive parameter of the dynamic field.

Finally, when the person moves to the next cell, he may encounter obstacles ε_{ij}, and make adjustments, and then multiply the corresponding quantity to obtain the transfer probability of personnel P_{ij}:

$$P_{ij} = a_1 b a_2 \varepsilon_{ij} \tag{4}$$

In the above formula, ε_{ij} is expressed as obstacle parameter. if $\varepsilon_{ij} = 1$, then the cell (i, j) is an obstacle; if $\varepsilon_{ij} = 0$, then the cell (i, j) is an obstacle.

The general formula can be obtained from formula (1) (2) (3) (4), as follows:

$$P_{ij} = N * exp\left(u_T T_{ij}\right) exp\left(u_G G_{ij}\right)\left(1 - n_{ij}\right)\varepsilon_{ij}\right) \tag{5}$$

For standardization factors, it is necessary to meet the following requirements:

$$N = \left[\sum_{(i,j)} exp\left(u_T T_{ij}\right) exp\left(u_G G_{ij}\right)\left(1 - n_{ij}\right)\right]^{-1} \tag{6}$$

2.2. Static field based on euclidean distance

Based on the cellular automata model, the evacuation scene in an independent space is simulated and analyzed. Suppose that a square room (or hall) with an internal barrier-free space field of a and a width of b is divided into $0.5 * 0.5$ cell lattices. It can be considered that a cell is the area occupied by a person in a standing state. Each cell is represented by a set of number pairs, $cell(x, y)$, and the distance between two adjacent cells is $zc = 1$. Because the space has s outlets, the width is $lc, i\epsilon[1, 2, \cdots, s]$. The plane space diagram of single exit (as shown in Figure 2) is as follows:

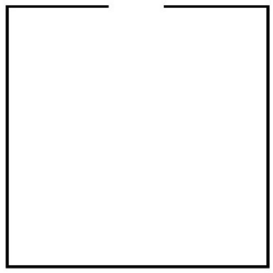


Figure 2. Single Exit Plan

When the initial state $t = 0$, pedestrians will be randomly distributed in one of the positions in space, and each person will occupy a cellular area. At the beginning of evacuation, the area of the cell adopts the Moore neighborhood rule with a radius of 2 (Moore neighborhood rule and direction transfer are shown in Figure 3). Pedestrians can transfer adjacent positions according to the cell in each direction each time, use the transfer probability to determine the next move strategy[9], and proceed in turn until reaching the exit, and safely escape from the danger zone.

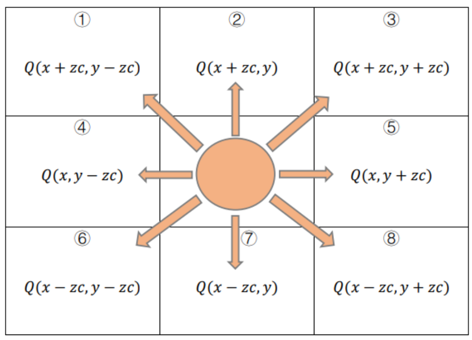


Figure 3. Moore neighborhood rules and direction transfer diagram

First, there is a distance between the cell and the destination. In order to achieve high evacuation efficiency, the shortest distance between the cell and the destination is obtained. The cell area can be considered as a distribution in two-dimensional space, and the Euclidean distance[10] formula is adopted, so the distance to the destination when the cell transfers to the next location is:

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (7)$$

Then, in the static field[9], the shortest distance between the cell and the destination is:

$$d_{min} = mind(x, y, u, c) - mind(i, j, u, c) \quad (8)$$

Finally, on the static floor domain, the static field domain value $G_(i, j)$ will increase with the decrease of the shortest distance between the cell and the destination, making the static field value maximum. The calculation formula is as follows:

$$G_{i,j} = maxd_{min} \quad (9)$$

2.3. Dynamic field based on anxiety

In a state of emergency and panic, people tend to show relatively strong anxiety, self-organization behavior, conformity psychology, etc. The rational behavior of the crowd is mainly manifested in the anxiety state, people still rationally cooperate with each other, rely on each other and support each other, but in the sudden and random nature of major disasters, people's behavior will produce irrational behavior. So the main emotion research in this paper is anxiety, which can not only affect one's own state, but also affect others' emotions.

First of all, in order to describe the impact of pedestrian emotion on the emergency evacuation process, the corresponding emotional intensity of different pedestrian cells is defined. Because each individual's emotion in the crowd will have a certain degree, and there are three factors that affect this degree: the range of emotional perception, personal attributes, and the emotional intensity of others. Thus, a ternary emotional intensity function[9] is constructed as follows:

$$M_i = \sum_{j \in Nr(i)} q_j * l_j \quad (10)$$

In the above formula, i, j represent each cell or individual pedestrian, where each pedestrian has different proportion affected by anxiety, q_j is the coefficient of each pedestrian affected by anxiety; Nr is represented as Neighbor, which is the collection of neighbors around the area where individual i is located; R represents the range of pedestrian's perception of surrounding information and emotions; l_j is expressed as the value of individual pedestrian's emotional divergence of self.

Secondly, anxiety is a special emotional response to a major disaster. The older a person is, the richer his life experience is, so that he can better regulate his negative emotional reactions and pay more attention to positive emotions. So in the process of driving and spreading anxiety, two factors are mainly considered: gender and age. Gender factors can be divided into the impact of different gender attributes of men and women, while age factors can be divided into the impact of age in youth, middle age and old age.

Due to anxiety infection coefficient q_i is easily affected by two characteristic factors: gender and age. The characteristic influence formula is as follows:

$$q_i = \omega_g * \beta_g + \omega_b * \beta_b \quad (11)$$

In the above formula, α_g is the weight of gender characteristics, α_b is the weight of age characteristic factor, β_g is the characteristic factor of gender anxiety, β_b is the characteristic factor of age anxiety, and ω_g is related to ω_b The sum is 1, and the influence degree of features can be adjusted by adjusting the weight of corresponding feature factors.

Then, because emotional divergence affects others' emotions according to the influence of people, it can be considered as the disseminator of emotions, and then conduct emotional divergence. So in the process of producing and spreading anxiety, consider these two factors: gender and age. Through these two characteristics and using formula (7), then affect the individual anxiety divergence value of pedestrians, and then get the emotional divergence value:

$$l_i = M_i * q_i \quad (12)$$

In the above formula, M_i is the infection value of anxiety, q_i is the infection coefficient of anxiety, l_i is the divergence value of anxiety.

2.4. Transfer probability based on dynamic field

In order to describe the impact of people's anxiety on the evacuation effect, it is defined that the anxiety level of individuals is affected by both static and dynamic fields. The size of the long room, the width of the door, and the distance between people and the door affect the level of personal anxiety through the static field, while the gender and age of people affect the level of anxiety through the dynamic field. According to the influence of static field and dynamic field on anxiety, the influence degree E of various factors on anxiety through static field and dynamic field can be obtained:

$$E = exp\left(\frac{1}{M_i} \cdot U_G \cdot G_{i,j} + M_i \cdot U_T \cdot T_{i,j} + U_H \cdot H_{i,j}\right) \quad (13)$$

Then, through the total value of human moving to all positions in the plane space at the next moment at a certain cell position, the mutual influence value N of human in the plane space can be obtained:

$$N = \left[\sum_{i=1}^{i=s} \sum_{j=1}^{j=n} E\right]^{-1} \quad (14)$$

Finally, the transfer probability model under different emotional intensities is obtained through pedestrian anxiety emotional intensity and fuzzy reasoning:

$$P_{i,j} = N \cdot E\nu_{i,j} \cdot \lambda_{i,j} \tag{15}$$

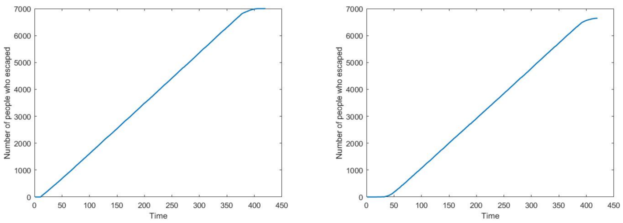
In the above formula (13) (14) (15), in the individual movement area, s, n are the maximum abscissa and ordinate. Where U_G,U_T and U_H is expressed as the weight of static field and dynamic field respectively. $\nu_{(i,j)}$ and $\lambda_{(i,j)}$ is the state of cell (i, j). If cell (i, j) is occupied by pedestrians $\nu_{(i,j)} = 0$; If cell (i, j) is not occupied by pedestrians, then $\lambda_{(i,j)} = 1$. By analogy, if cell (i, j) is occupied by an emergency, then $\lambda_{(i,j)} = 0$; If cell (i, j) is not occupied by pedestrians, then $\lambda_{(i,j)} = 0$.

2.5. Result and Analysis

The model in this paper is to measure the impact of anxiety on the evacuation effect by the probability of cell location transfer under different emotional intensity. Proper anxiety will promote evacuation, and excessive anxiety will slow the evacuation process.

Next, we will consider the promotion and deceleration of anxiety on the evacuation effect.

Simulation. Through the programming of MATLAB software[11] and the simulation of the evacuation of 7000 people in the square hall, the relationship between the evacuation crowd and the evacuation time can be obtained as follows:



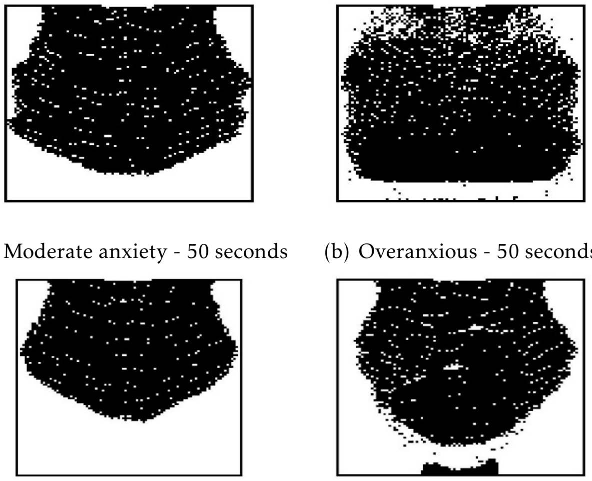
(a) Appropriate anxiety (b) Excessive anxiety

Figure 4. Time-varying diagram of passenger flow

Then, through the comparison between (a) and (b) in Figure 4, it is found that at the beginning of emergency evacuation, the reaction time of appropriate anxiety is shorter than that of excessive anxiety, which is caused by the gender and age in the model; In the end, there are a few people who are flustered because of excessive anxiety and fail to escape because of running in the opposite direction.

Visualization of people flow state process. In the process of simulation, the evacuation process of 50 seconds and 120 seconds in flight was intercepted, as shown in Figure 5, and the same time was compared and analyzed.

Through the comparison between (a) and (b) in Figure 7, it is found that at 50 seconds, the state diagram of appropriate anxiety is dense and orderly, the state diagram of excessive anxiety spreads around, and a small number of people with excessive anxiety run in the opposite direction, which shows that appropriate anxiety is helpful to evacuate people, while excessive anxiety will inhibit the evacuation effect of evacuated people.



(a) Moderate anxiety - 50 seconds (b) Overanxious - 50 seconds

(c) Moderate anxiety - 120 seconds (d) Overanxious - 120 seconds

Figure 5. Emotional transfer state chart

Through the comparison between (c) and (d) in Figure 7, it is found that the overall trend of moderately nervous people is closer to the door at 120 seconds, and the simulation of excessive tension also further explains that excessive tension will lead to running in the wrong direction, thus affecting the overall evacuation effect.

According the comparison between (a) and (c) in Figure 7, it is found that pedestrians are randomly distributed in the square space. In the case of evacuation alarm, all pedestrians rush to the door position. With the passage of time, the number of people looking at (c) as a whole is much less, indicating that the simulation is effective and reliable.

According to the comparison between (b) and (d) in Figure 7, when the evacuation signal rings, some pedestrians see a large number of pedestrians rushing towards the end door, and they are very confused, resulting in the overall panic spread, and finally show the phenomenon of running backwards, but the overall evacuation continues, reflecting the phenomenon of slow evacuation rate.

Analysis of rate curve. In order to highlight the overall effect, use MATLAB to program and simulate the comprehensive curve of the change of appropriate anxiety and excessive anxiety with time[12] (as shown in Figure 6):

It can be more obvious from observing the above figure that the evacuation effect of moderate anxiety is better than that of excessive anxiety. Therefore, this

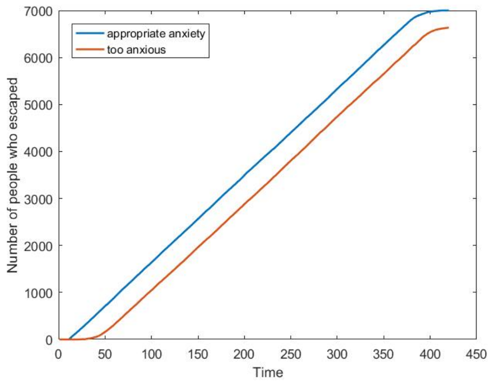


Figure 6. Changes of appropriate anxiety and excessive anxiety over time

paper believes that gender and age are the key factors that affect the evacuation effect of anxiety

The difference of the experimental results is affected by the degree of anxiety, gender and age.

3. Study on Time-varying Evacuation Rate

3.1. Evacuation under multi-speed mixing

In order to study the relationship between the number of people in the system, the average speed and the average flow with the evacuation time under different crowd density, the proportion of pedestrians at different speeds, the exit width and the exit spacing. Thus, the average speed formula[12] of the system is defined as:

$$\bar{v} = \frac{1}{n}\sum_{i=1}^{n} v_i(t) \tag{16}$$

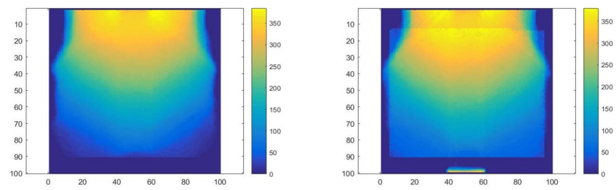
The flow of population can reflect the number of people in the crowd who pass by in the unit time of entering the exit, thus defining the average flow of the system as:

$$\bar{J} = \frac{1}{N}\sum_{i=1}^{n} v_i(t) \tag{17}$$

3.2. Result and Analysis

The distribution and distribution of personnel at different speeds can be obtained by programming and simulating[11, 13, 14] with MATLAB again, and the thermal diagram can be obtained (as shown in Figure 7).

According to the analysis of the thermal diagram of the number of evacuees, the door is located in the middle of the upper end, and pedestrians rush to the square upper door at all positions. Due to the limited width of the door and the crowd rushing towards the door, the density of people near the door is higher, and the color of the door is higher, and the people are



(a) Moderate anxiety evacuation (b) Overanxious evacuation

Figure 7. Thermal diagram of evacuation number

more dense. Compared with (a) and (b) in Figure 7, it is found that the lower end of (b) in Figure 7 also has dark color, which is caused by age, gender and anxiety during the evacuation process. In the process of evacuation, the blue square area of the over-anxiety map ((b) in Figure 7) is larger. In the case of over-anxiety, the people behind will choose to detour from the side because of their fast speed, resulting in more chaos than moderate anxiety.

The conclusion shows that the speed is different for different ages[15, 16], and some people will directly choose the people around them if they are fast. Therefore, the phenomenon that the surrounding area is blue can make them closer to the door, leading to changes in the evacuation rate.

The number of emotional infections in different gender and age groups is different, and will change with time. Because the evacuation rate is not uniform, the evacuation rate is different in different time periods. According to Matlab software programming, the graph of emotional infection of different groups over time (see Figure 8) is obtained, and the graph of moderate anxiety and excessive anxiety over time is simulated (see Figure 9).

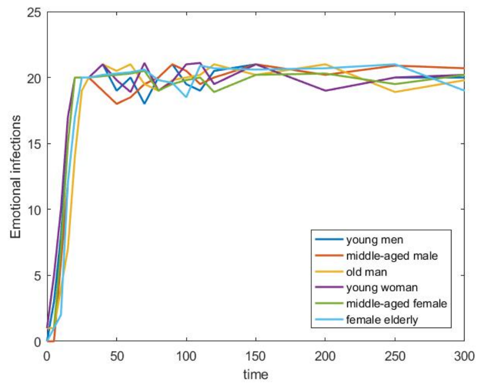
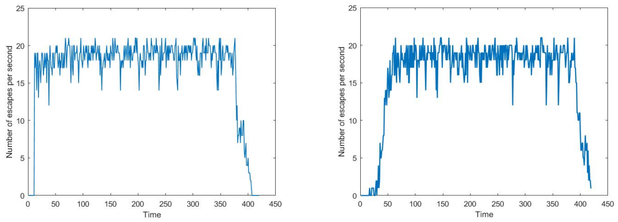


Figure 8. Changes of emotional infection of different groups over time

Through the analysis of Figure 8, it is found that the whole population has been in a state of high infection quantity and high slope from t=0 to t=25, and the population of different sexes and ages has been increasing with high slope over time; Groups of different genders and ages increase with the number of people around them. Due to the limited emotional divergence value of the number of emotional infections, the phenomenon of almost stagnation reached at t=25. At t=25 to t=300, the whole group fluctuates up and down within a certain range, maintaining a certain number of emotional infections, which shows that some individuals have a high psychological bearing capacity.



(a) Appropriate anxiety (b) Excessive anxiety

Figure 9. Anxiety evacuation rate chart

Through the analysis (a) and (b) in Figure 9, it is found that the number of people fleeing in the form of eruption increases from t=0 to t=30 in the process of appropriate anxiety evacuation; When t=30 to t=350, the number of people fleeing per second remains within a certain range and fluctuates up and down, indicating that the evacuation rate is almost constant; After t=350, the evacuation rate gradually decreased, indicating that the number of people at risk continued to decrease until all pedestrians were evacuated successfully. In the process of over-anxious evacuation, the number of people with t=0 to t=50 blowout increased, indicating that people are in over-anxious mood in the face of this sudden disaster, and the evacuation rate is reduced compared with appropriate anxiety; When t=50 to t=350, the evacuation rate tends to be stable, indicating that people are beginning to adapt to this situation and should escape safely regardless of whether they are too anxious; After t=350, the evacuation rate gradually decreased, reaching the exit, and more and more people successfully escaped.

Comparing Figure 8 and Figure 9, it is shown that the number of emotional infections in both male and female groups is increasing regardless of the degree of anxiety of the population from t=0 to t=25, which affects the increase of the overall evacuation rate of the population. It shows that groups of different sexes still attach importance to safety and be alert to the dangers around them, do not play a joke on their own lives, and stay rational and cooperate with evacuation arrangements in case of emergency, So as to escape from success efficiently; When t=25 to t=300, the number of emotional infections in the male and female groups tends to be stable, which affects the overall evacuation rate curve of the population tends to be horizontal, indicating that the male and female groups have different attributes, but there are still people with strong psychological quality to maintain rationality and cooperate with the evacuation arrangement. In different age groups, young people, middle-aged people and elderly people, because of their different ages, have different speed of action, and have more experience, and often have greater psychological endurance, which can reduce emotional infection. During the period from t=0 to t=25, the number of people of three age groups affected by emotion is increasing, which also affects the slope of the overall evacuation rate curve of the population, resulting in the continuous increase of evacuation rate, indicating that people of different age groups will also be affected by emotion and psychological oppression in a short time to increase the speed of escape, so the overall evacuation rate will be higher; When t=25 to t=300, the number of emotional infections in young, middle-aged and elderly groups fluctuated up and down, and tended to be stable, which affected the gradual level of the overall evacuation rate curve, and also fluctuated up and down, and tended to be stable, indicating that different age groups, older people can adapt to the environment faster, and younger people are relatively immature in mind, and are easily affected by others, After being affected by older people, they also began to calm their anxiety, thus reducing the number of emotional infections in the whole environment and gradually stabilizing.

4. Study on evacuation route selection

4.1. Evacuation route selection model

In a large enough hall, set two large enough doors[13] (the hall model is shown in Figure 10). There are multiple doors, which means there are multiple exits to evacuate. Most people will choose the nearest door to evacuate, but ignore the time to go out. The time is divided into the time to reach the crowd at the door t_1 and the time to get out of the crowd t_2. The time of both is related to the speed. When the sum of the time of people arriving at the crowd[17] and the evacuation time is less, the route will be taken. Therefore, this question uses the length of the evacuation time to explain the route selection. For the evacuees, the time required for visual inspection is longer. This paper uses the crowd density to measure.

First of all, the idea[18] of dynamic programming is used for modeling. It is assumed that there are people around the door, resulting in the crowd at the door presenting a semicircle with radius r, where the radius of the left exit is set as r_1. The right exit radius is r_2 (as shown in Figure 10), at this time, the area of people around the left exit is:

$$S_1 = \frac{1}{2}\pi {r_1}^2 \tag{18}$$

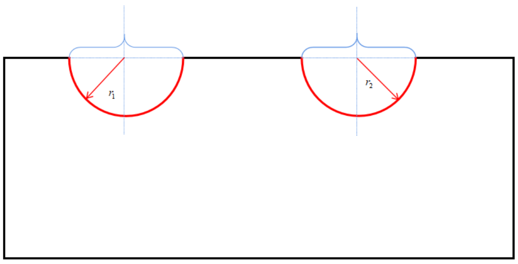


Figure 10. Schematic diagram of double-door hall

The area of people around the right exit is:

$$S_2 = \frac{1}{2}\pi {r_2}^2 \quad (19)$$

The crowd density around the door on the left is:

$$\rho_1 = \frac{m_o}{S_1} \quad (20)$$

Where, m_t represents the number of people around the left door at time t.

The crowd density around the door on the right is:

$$\rho_2 = \frac{m_o}{S_2} \quad (21)$$

Where, m_u represents the number of people around the left door at time t.

The time for people to reach the periphery of the left crowd is:

$$t_1 = \frac{d_{1min} - r_1}{v_1} \quad (22)$$

Where d_{1min} means the shortest distance to the left door, v_1 indicates the speed of reaching the crowd.

The time for people to reach the periphery of the right crowd is:

$$t_2 = \frac{d_{2min} - r_2}{v_1} \quad (23)$$

Where d_{2min} indicates the shortest distance for personnel to reach the right door.

It is assumed that people can go out orderly in the crowd, so the rate of evacuation in the crowd is set as v_2. Therefore, the time for personnel to leave the left door:

$$t_{1c} = \frac{r_1}{v_2}, \quad (24)$$

The time when the right door goes out is:

$$t_{2c} = \frac{r_2}{v_2} \quad (25)$$

Finally, the time required to go out from the left at the current position is:

$$t_{sum1} = t_1 + t_{1c} = \frac{d_{1min} - \sqrt{\frac{2m_t}{\pi\rho_1}}}{v_1} + \frac{\sqrt{\frac{2m_t}{\pi\rho_1}}}{v_2} \quad (26)$$

The time required to go out on the right side is:

$$t_{sum2} = t_2 + t_{2c} = \frac{d_{2min} - \sqrt{\frac{2m_t}{\pi\rho_2}}}{v_1} + \frac{\sqrt{\frac{2m_t}{\pi\rho_2}}}{v_2} \quad (27)$$

The recursive evacuation route model of dynamic planning is obtained as follows:

$$t_{sum} = min\{t_{sum1}, t_{sum2}\} \quad (28)$$

4.2. Simulation of evacuation routes

In theory, it is impossible for people in the hall to judge the specific time. Therefore, when selecting an evacuee that is easier for people to observe, the density of people piled up at the door is used to express it. When evacuating people, it is only necessary to measure the density and radius of people piled up at the door to determine it.

The relationship between the radius and density of personnel during evacuation is obtained through MATLAB software[11, 19] programming, as follows:

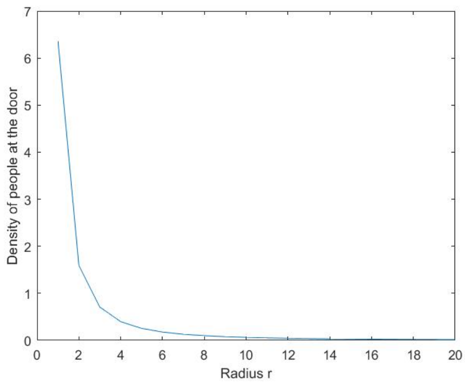


Figure 11. Curve of stacking radius and density at the entrance

According to Figure 11, the larger the radius and the smaller the density, the better the route will be selected. Finally, the principle reflected from the personnel density is to make the personnel choose the shortest route[17].

4.3. Optimization model based on dynamic change

In order to study the dynamic change of the width of the door[20], first of all, pedestrians will move during the evacuation process, and may arrive at one of the positions inside and outside the circle. According to the planned route that pedestrians will move to the destination, we can obtain the route for each step, and multiply the moving probability of the next step to reach the destination, to obtain the number of people in the circle m_o:

$$m_o = \prod P_1 \cdots P_S \quad (29)$$

In the above formula, m_o The formation condition is that in the square space, the probability of the pedestrian moving continuously from the position to the position of the door, and the probability obtained by multiplying the pedestrian probability, m_o needs to be greater than p_i value.For the number of people in the circle, according to the pedestrian transfer rules, it is required to meet $m_o \geq 0.75$.

Then, according to the emotional divergence value and the previous model, the probability model of pedestrians and all directions with reduced visibility is obtained:

$$m_q = \sum m_o \quad (30)$$

In the above formula, m_q means at radius r_i Total number of stacked people in the middle circle, m_o is the number of people in the circle in radius r_i.

The width w of the door is:

$$w = \sum_{i=1,2j=0}^{j=\infty} d_{ij} \quad (31)$$

Where d_{ij} refers to the distance of pedestrians outside the circle to the ith door and the jth cell on the door.

According to the distance from pedestrians outside the circle to the gate and the relationship between crowd radius and pedestrian transfer speed, the time t_i for pedestrians outside the circle to hit the circle is obtained:

$$t_i = \frac{d_{ij} - r_i}{v_1} \quad (32)$$

In the above formula, t_i is the time when pedestrians outside the circle arrive at the circle; r_i is the radius of the crowd around the door; v_1 indicates the transfer speed of the accumulated pedestrians outside the circle.

4.4. Perception range under visibility

Other people's influence and behavior choice during indoor evacuation show that pedestrian's emotion and evacuation behavior are more affected by proximity than distance. If an individual is in different environments, its visual area will be different. When the visibility is reduced properly, the visible area will be reduced accordingly. According to the analysis of the emotional perception radius and range, the pedestrian's emotional perception radius and range are related to the perception intensity. The perception area[5, 18, 21] can be divided into high perception HS, medium perception KS, and low perception GS. Taking the position of the individual as the center of the circle and the shortest distance to the edge of different areas as the radius, construct the perception areas with different intensities as shown, and discretize them (see Figure 12 for the map of people's discrete perception range). It can be considered that the emotional state of each person in the perception area can be known by n people.

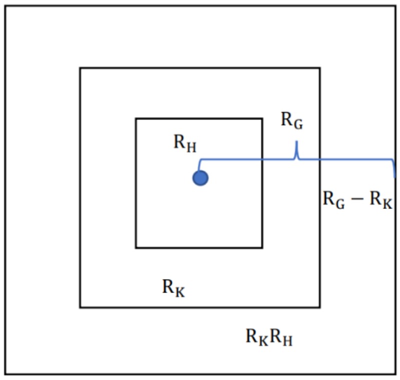


Figure 12. Perceived range map of personnel dispersion

According to the different degree of infection of pedestrian j by others in different perception areas, the function of pedestrian j's emotional intensity can be improved, and the analysis of each differentiated perception area can be obtained for the emotional intensity M_{j1} of pedestrian j in the range of high perception HS area with radius R_H:

$$M_{j1} = \sum_{j \in R_H} \delta_1 \mu_j l_j \quad (33)$$

For radius R_K. The emotional intensity of personnel j in the range of medium perception KS area M_{j2}:

$$M_{j2} = \sum_{j \in R_K} \delta_2 \mu_j l_j \quad (34)$$

For radius R_G. The emotional intensity of personnel j in the range of medium perception GS area M_{j3}:

$$M_{j3} = \sum_{j \in R_G} \delta_3 \mu_j l_j \quad (35)$$

For person j, the emotional intensity M_j in the whole space is:

$$M_i = M_{i1} + M_{i2} + M_{i3} \quad (36)$$

From formula (33) (34) (35) (36), the general formula can be obtained as follows:

$$M_j = \sum_{j \in R_H} \delta_1 \mu_j l_j + \sum_{j \in R_K} \delta_2 \mu_j l_j + \sum_{j \in R_G} \delta_3 \mu_j l_j \quad (37)$$

In the above formula (33) (34) (35) (37), R_H represents the radius of high sensitivity HS, R_K is the radius of perceived KS, R_G refers to the radius of low perception

KS, and the coefficient of the degree of influence of pedestrians in different cell areas on pedestrian j is $\delta_1, \delta_2, \delta_3$; μ_j is the emotional infection coefficient of personnel j; l_j represents all the emotional divergence values of personnel j.

The conclusion shows that with the increase of the width of the door, the radius of the crowd circle increases and the evacuation speed increases, while the crowd density decreases rapidly. The decrease of the door width is the opposite. The change of the door width affects the shortest time for pedestrians to escape and the choice of routes outside the circle through the rapid change of the crowd density and the change of the radius around the door.

With the reduction of visibility, the anxiety level of pedestrians will increase, which will affect the probability of the direction of movement of pedestrians outside the circle, the number of people inside the circle, the density of people and the degree of crowd evacuation, and then affect the shortest time for pedestrians to escape and the choice of evacuation routes outside the circle.

5. Conclusion

On the one hand, based on the real evacuation experiment, this paper obtains the information of crowd evacuation behavior and emotion transfer probability, and based on the crowd evacuation simulation model and analysis, makes the parameter sources of the simulation model real and effective; On the other hand, the internal psychology and evolution of evacuees are combined with typical evacuation behaviors, and the research methods and contents of crowd evacuation problems are developed, which makes the crowd evacuation simulation model more authentic, and the conclusions obtained have certain value.

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