

Research Article

Application of Cellular Automata with Improved Dynamic Analysis in Evacuation Management of Sports Events

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In this paper, the cellular automaton simulation technology is applied to the evacuation management of sports events, combined with the dynamic analysis method to analyze the collision of people in the evacuation process. At the same time, the cellular automaton model is used to refine the evacuation space to simplify environmental modeling, and the network model is used to determine the individual evacuation path from a macroperspective, simplify modeling, and improve simulation efficiency. In addition, this article simulates the evacuation process of the cellular automaton according to the actual evacuation situation of sports events and constructs the evacuation management system of sports events. Finally, this article evaluates the effect of the model in conjunction with experiments. The experimental results show that the role of the evacuation management system for sports events based on cellular automata proposed in this paper is obvious.

1. Introduction

The number of stadiums and sports venues with complex structures and diverse functions is rapidly increasing, and sports events of various levels are being held all over the world. In addition, due to the periodicity and intermittent nature of sports events, as well as the increasing use of postmatch use methods such as cultural performances, exhibitions, and food and entertainment [1], stadiums have become venues for large-scale cultural and entertainment activities. Therefore, stadiums have become one of the main gathering places for a large number of people in daily life. The magnificent buildings, complex structures, dense crowds, and numerous equipment have become the characteristics of stadiums. There is a major problem hidden behind these features, that is, security risks. The huge building and complex structure can easily cause the collapse of the stadium and make the safety exit not clear for evacuation [2]. Moreover, crowded people can easily lead to crowds, which can lead to stampede incidents. In addition, when there is many equipment, a little careless management can cause fire and explosion.

At the same time, dense crowds and large-scale venues often become targets of international terrorist attacks. Once these emergencies happen, it will inevitably cause casualties and property losses [3].

Today's stadium is a multipurpose venue mainly for holding sports events and carrying out a variety of activities. At the same time, stadiums have become densely populated places, full of major safety hazards. Therefore, relevant departments and related personnel are urgently required to take effective and feasible measures to minimize the occurrence of incidents and personal and property losses. At the same time, this also requires researchers and scholars to pay great attention to the evacuation of stadiums and gymnasiums. Due to the causes of casualties, there are not only the building structure of the venue itself but also the crowd and external human factors in the venue.

Cellular automata were originally used to simulate the self-replication function of living systems. Its core idea is to discretize the research object into cells with a finite number of states in space and then follow a certain random motion rule in the discretized time. This idea and method were adopted by evacuation researchers and established a

cellular automaton model in the field of evacuation research. The core of the cellular automaton model is the discretization of space and time. It divides the evacuation simulation environment into grids of equal size, and each grid is a cell. Usually, a cell can have three states, namely, occupied by evacuated individuals, occupied by obstacles, and idle; the state of each cell at a time can only be one of the three states, other cells adjacent to a certain cell. It is called the neighbor of this cell; the entire evacuation time is divided into small time slices; these time slices are called time steps; in each time step, the evacuated individual moves from the cell where it is currently located to according to the set movement rule. The neighbors may stay where they are. Therefore, the content of the model mainly includes spatial division method, neighbor type, and time-step update method.

This paper applies dynamic analysis to the evacuation management process of sports events and simulates the evacuation process of sports events through cellular automata to improve the evacuation management effect of sports events.

2. Related Work

Literature [4] studied the time required for evacuation and obtained the corresponding mathematical formula. Researchers on evacuation began to rise. Literature [5] investigates the behaviors of survivors in fires and uses them for statistical analysis. Literature [6] gives the relationship curve between crowd density and average crowd speed and applies computational simulation research methods to the evacuation of fire personnel. During this period, the evacuation of people was studied mainly through observation, investigation, statistics, and mathematical simulation.

There are many simulation models for evacuation, but researchers usually divide them into micromodels, macromodels, and mesoscopic models. The micromodel treats each person in the evacuation crowd as an independent individual for evacuation research. This type of model can show the individual's evacuation behavior more finely, but the amount of calculation is often large; the macromodel studies the evacuated crowd as a whole, and the evacuation crowd is regarded as a flowing fluid. An evacuated person is a particle in the fluid. This model mainly studies the characteristics of the evacuated crowd as a whole and cannot well represent the characteristics of the evacuated individuals; the mesoscopic model combines the microscopic model and the macroscopic model for evacuation of researchers. This model can not only study the individual behavior of evacuees but also study the overall characteristics of evacuees [6].

Models based on physical forces are also often regarded as continuous microscopic models. The model is continuous in time and space and simulates individual evacuation by calculating the force generated by itself and the environment on the individual. Its representative models are the magnetic field force model and the social force model. The magnetic field force model is a gravita-

tional model of pedestrian motion established by the literature [7] based on the principle of magnetic force. In the model, the target is regarded as the negative pole of the magnetic field, and the obstacle and the person are regarded as the positive pole. In this way, a gravitational force is formed between the person and the target and between the obstacle and the obstacle. Repulsion is formed, and people are evacuated under the action of gravity and repulsion. The social force model is proposed in the literature [8]. This model describes the interaction between people and the environment and goals as repulsive force, gravitational force, and self-driving force and establishes a dynamic differential equation system to describe the movement of people according to Newton's second law. The relationship between speed and position over time. Based on the agent theory in artificial intelligence based on the agent model, the literature [9] defines the evacuated individuals in the model as agent individuals with different characteristics to represent the differences between people in reality. This type of model is divided into single-agent model and multiagent model. The modeling ideas of the two are the same, but the multiagent model emphasizes the interaction between agents. The cellular automaton model is based on the cellular automaton idea proposed by Von Neumann. This model divides the evacuation space into discrete cell spaces with a finite number of states [10], so that the evacuees move in the cell space according to a certain rule to achieve the effect of evacuation simulation. Based on this model are the queuing model, route selection model, and random model. The difference between them is only the rules of individual movement on the cell. The queuing model emphasizes that people move in a certain queue order, the path selection model emphasizes to move according to the path search, and the random model emphasizes to move in the order of random selection. Based on agent and cellular automaton model [11], combine the agent model and cellular automaton model in evacuation modeling, use agent to describe individuals, and use cellular automata to divide the evacuation environment space, so that all the established model can better reflect the scalability of the environment and the intelligence of personnel.

For the study of crowd evacuation time, the literature [12] uses the Legion simulation system to simulate and calculate the three algorithms for evacuation time commonly used in domestic and foreign projects and analyzes and compares the results obtained. It is recommended to use the itinerary method as engineering calculation method for evacuation time of stadiums. For the research on how the structural characteristics of stadiums and stadiums affect the characteristics of evacuated individuals, the literature [13] studied the influence of the width of the safety exits of stadiums on crowding during evacuation and the influence of crowd panic on evacuation.

Literature [14] developed a simulation system for fire evacuation demonstration based on the Superscape system, which can be used for simulation training of evacuation in fire. Literature [15] developed a virtual exercise system named interFIRE VR, which is mainly used to

train personnel how to evacuate in a fire situation. Literature [16] developed a virtual exercise program to train relevant personnel on how to find a safe evacuation exit in a fire building and successfully evacuate. Literature [17] developed a building fire simulation prototype system FVR based on virtual reality and data simulation, which can be used for evacuation drills and fire rescue training in fire situations. Literature [18] proposed a simulation technology DIS and developed a fire remediation simulation drill DIS system. Its application can replace the existing actual field simulation training. Literature [19] uses game engine technology to develop a three-dimensional virtual exercise system to simulate the process of evacuation of personnel to a safe area in an organized and orderly manner according to the unified dispatch and command on the spot after an incident occurs. It can be seen from the above that the virtual exercise technology has been successfully applied by researchers in the simulation research of personnel evacuation, which makes the visual effect of simulation stronger, and the interaction between people and the system makes the individual evacuation in the system more reflected. The characteristics of people in reality can greatly promote the research of personnel evacuation simulation.

3. Application of Cellular Automata Based on Dynamic Model in Evacuation Management of Sports Events

The initial self-driving force of the pedestrian is represented by F_0 , which includes two parts: one is the direction of the force, and the other is the magnitude of the force. First of

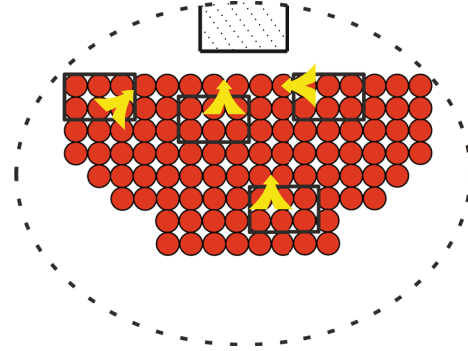


FIGURE 1: The direction of the initial self-driving force.

all, there are differences between different individuals. Therefore, we assume that the range of the initial self-driving force of pedestrians is $0 \sim F_{\max}$, where F_{\max} is the maximum value of self-driving force. Then, the initial self-driving force of pedestrians in the system is

$$|F_0| = F_{\max} \times \text{RAND}. \quad (1)$$

Secondly, taking into account the pedestrian's tendency to leave the dispersal space, it is assumed that the direction of the pedestrian's initial self-driving force F_0 points to the cell around the pedestrian that is closest to the safety exit, as shown in Figure 1. When there are multiple locations around the pedestrian with the same distance to the safety exit, one of them is randomly selected as the direction of the initial self-driving force F_0 , and the distance from a certain cell (x_i, y_i) around the pedestrian to the safety exit is

$$S_{ij} = \begin{cases} \min_j \left(\sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \right) \\ M \end{cases} \quad (2)$$

(x_i, y_i) pedestrian movement position,
 (x_i, y_i) is the wall of evacuation space.

Among them, S_{ij} is the shortest distance between a cell (x_i, y_i) around the pedestrian and a cell (x_j, y_j) belonging to the safety exit. When (x_i, y_i) is a wall, the pedestrian will not choose this position, and M is a large constant, which means that the pedestrian's initial self-driving force F_0 will not point to the wall.

When the direction of the pedestrian crowding force is closer to the direction from the pedestrian to a nearby pedestrian, the component force of the crowding force in that direction is greater. Therefore, the pedestrian's congestion force is decomposed into the two cells that deviate from its direction closest. With reference to the axioms of statics, the force decomposition must conform to the parallelogram law of force, and the crowding force F_0 is decomposed into two decomposition forces F_1 and F_2 , as shown in Figure 2. Among them, the resolution is

as follows:

$$|F_m| = |F_0|(\cos \theta_m - \sin \theta_m), \quad m = 1, 2. \quad (3)$$

Among them, $|F_m|$ is the force component of F_0 in the θ_m direction, and θ_m is the angle between F_0 and the pedestrian to the adjacent cell.

In addition, when there is a space in the two cell directions of the crowding force F_0 decomposition, that is, when there is no pedestrian at that position, the component force in this direction remains on the pedestrian itself. Among them, pedestrians have a crowding force F_{0i} for pedestrians. However, the cell without pedestrians does not produce the crowding force but keeps this F_{0j} in the pedestrian itself, acts on the pedestrian itself, and exists as the pedestrian's self-driving force, as shown in

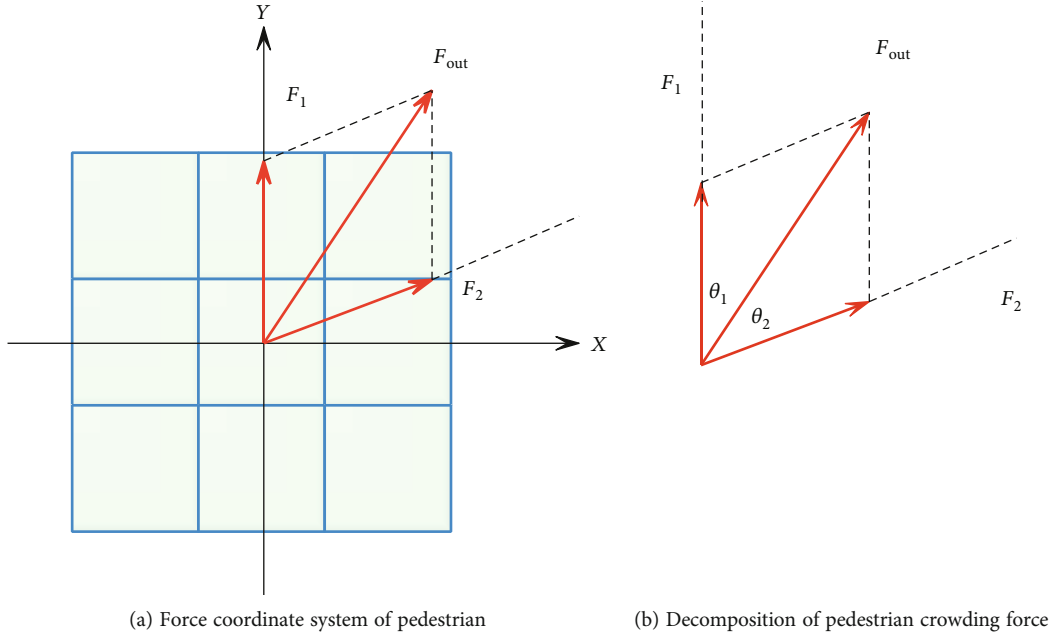


FIGURE 2: Pedestrian crowding force decomposition.

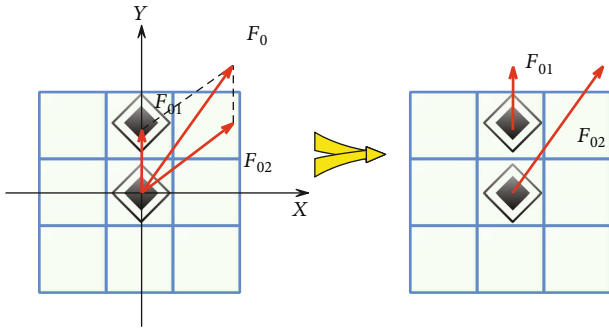


FIGURE 3: Decomposition of crowding force when there are space cells. (a) Pedestrian of crowding force. (b) Effect of crowding force.

Figure 3. That is, at this time, pedestrians are driven by their own driving force F_{0j} , which points to the space cell. Similarly, when the two directions are spaces, pedestrians are, respectively, driven by the driving forces F_{0i} and F_{0j} pointing to the two space cells, which may drive the pedestrian to move to these two positions.

Since the transmission of force requires a medium, when pedestrians are not in direct contact, the congestion force cannot be transmitted. Therefore, it is assumed that the pedestrian is only subjected to the crowding force of the eight pedestrians around the pedestrian, as shown in Figure 4. Combining the above-mentioned process of decomposing the crowding force, the crowding force of each pedestrian is decomposed to the corresponding pedestrian. This article counts the component forces of other pedestrians around the pedestrian in the direction of the pedestrian, F_1 represents the combined force of the pedestrian crowding force, and F_{close} represents the

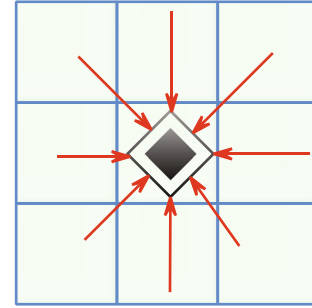


FIGURE 4: The crowding force of surrounding pedestrians on middle pedestrians.

scalar sum of the crowding force received by the pedestrian, as shown below:

$$F_1 = \sum_{i=1}^8 F_{i \rightarrow 1}, \quad (4)$$

$$F_{close} = \sum_{i=1}^8 |F_{i \rightarrow 1}|.$$

Among them, $F_{i \rightarrow 1}$ is the component of the crowding force of the i th pedestrian around the pedestrian to the pedestrian.

The absorption and retransmission of the crowding force are carried out simultaneously. If pedestrians cannot absorb the congestion force, they will continue to transmit the congestion force to other people around. Therefore, it is necessary to consider that pedestrians may be subjected to the crowding force F_{out} that other pedestrians around cannot absorb. However, the congestion force component

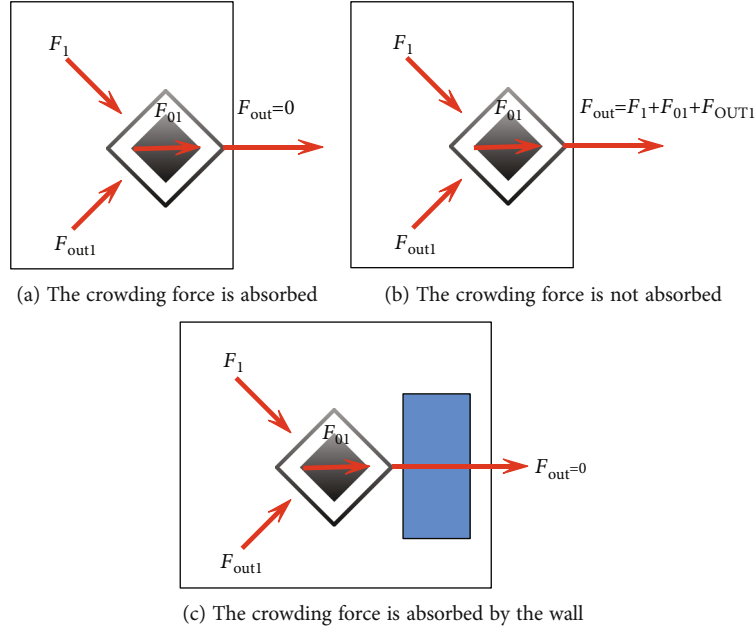


FIGURE 5: The process of absorption and retransmission of crowding force.

transmitted to the pedestrian is F_{out1} , and the pedestrian's congestion force absorption and retransmission process is shown in Figure 5. The transfer rule of crowding force is:

$$F_{out} = \begin{cases} 0 & |F_1 + F_{01} + F_{out}| \leq \alpha, \\ F_1 + F_{01} + F_{out} & |F_1 + F_{01} + F_{out}| > \alpha. \end{cases} \quad (5)$$

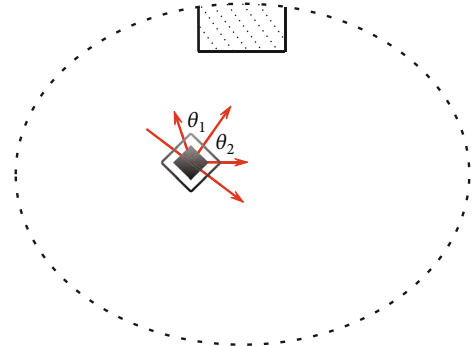
Among them, F_1 is the combined force of the crowding force received by the pedestrian, F_{01} is the driving force transmitted by the pedestrian itself, F_{out} is the component of the crowding force that other pedestrians around cannot absorb the crowding force transmitted to the pedestrian, α is the absorption coefficient, and F_{out} is the crowding force transmitted by pedestrians. The process of its decomposition and transmission refers to the above-mentioned decomposition and transmission process.

When pedestrians are crowded by surrounding pedestrians, the degree of panic among pedestrians is greater. Therefore, it is necessary to determine the pedestrian's panic coefficient p , and the pedestrian's panic coefficient P is determined by the scalar sum of the crowding force received by the pedestrian. Through the analysis of the above decomposition, transmission, absorption, and retransmission process, the crowding force received by pedestrians is divided into three parts.

- (1) The self-driving force of pedestrians interacts with other pedestrians. With reference to Newton's third law, the action of force is mutual, and pedestrians will receive a reaction force of the same magnitude and opposite direction as this driving force. Therefore, the pedestrian will receive the reaction force of the self-driving force, and the magnitude of this force is denoted as f_0

TABLE 1: Relationship between panic coefficient and push force effect.

f	p
≤ 100	0.00
≤ 200	0.10
≤ 300	0.20
≤ 400	0.30
≤ 500	0.40
≤ 600	0.50
≤ 700	0.60
≤ 800	0.70
≤ 900	0.80
≤ 1000	0.90
≥ 1000	1.00

FIGURE 6: The distribution of self-driving force direction, where $\theta_1 = \theta_2 = (1 - p) \times 90^\circ$.

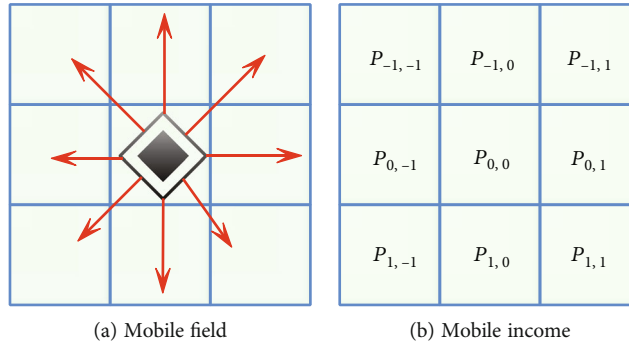


FIGURE 7: Pedestrians' mobility field and mobility revenue.

- (2) When the pedestrian's self-driving force acts on the surrounding pedestrians, each pedestrian may be subjected to the crowding force of eight other pedestrians around him, and the scalar and accumulation of each crowding force need to be recorded as f_1
- (3) When pedestrians judge the absorption and retransmission of the congestion force, there are situations in which the congestion force cannot be absorbed and transferred. Pedestrians will be affected by the crowding force transmitted to the pedestrian that the surrounding pedestrians cannot absorb the crowding force and the reaction force generated by the pedestrians themselves being unable to absorb the crowding force and crowding other pedestrians. The scalar and accumulation of this part of the crowding force are denoted as f_2

The congestion force of the above three parts is superimposed; that is, all the congestion force effects that pedestrians may receive in a time step are

$$f = f_0 + f_1 + f_2. \quad (6)$$

Through the analysis of simulation data and reference to related documents, the panic coefficient of pedestrians is calibrated. The relationship between the panic coefficient P and the crowding force effect is shown in Table 1.

The higher the pedestrian panic, the more the pedestrian expects to leave the evacuation space. Therefore, when the panic coefficient P is greater, the pedestrian's self-driving force is also greater, and its direction is closer to the safety exit. The self-driving force of pedestrians consists of two parts: the self-driving force new F_0 that is expected to leave the safety exit generated by the panic coefficient P and the congestion force F_2 that has not been transmitted at this time step.

The self-driving force new F_0 must determine the magnitude and direction. First of all, the magnitude of this force consists of two parts, one part is the different crowding force caused by the different panic levels of pedestrians, and this part of the force is proportional to the panic coefficient p . The other part is the random self-driving force generated by pedestrians' own psychology toward safe exits, which is relatively random due to individual differences. Therefore,

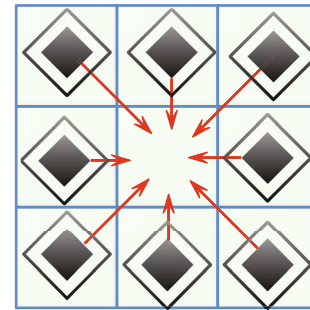


FIGURE 8: The moving field of the space cell.

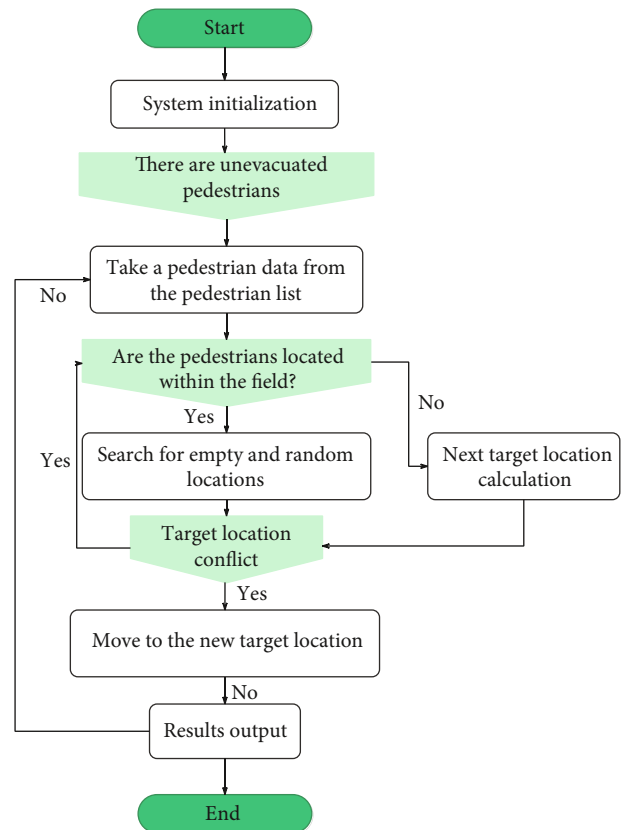


FIGURE 9: Personnel movement process.

the size of the pedestrian's self-driving force new F_0 is

$$|\text{new}F_0| = p \times F_{\max} + A \times \text{RAND}. \quad (7)$$

Among them, $|\text{new}F_0|$ is the magnitude of the pedestrian's self-driving force, p is the pedestrian's panic coefficient, F_{\max} is the maximum self-driving force, and $A \times \text{RAND}$ is the random self-driving force generated by different pedestrians.

Secondly, the direction of the self-driving force new F_0 is also determined by the panic coefficient p . When the pedestrian is in the most panic state, that is, when $p = 1$, the pedestrian expects to leave the evacuation space very much, so the direction of the self-driving force points to the nearest safety exit. When the pedestrian's fear coefficient is small, the pedestrian's psychological state is relatively stable. However, since the ultimate goal of the pedestrian is still to leave the evacuation space, the direction of its self-driving force should deviate at a certain angle along the exit direction. As p decreases, the deviation range increases. Therefore, taking the direction of pedestrians to the nearest safety exit as the normal direction, this paper believes that the direction of self-driving force is randomly distributed within the range of $(1 - p) * 90^\circ$ on both sides of the normal, as shown in Figure 6.

In addition, the crowding force of pedestrians cannot be passed on in a time step. Therefore, in the process of judging that the congestion force absorption will be transmitted again, some pedestrians still have untransmitted congestion force F_2 themselves, rather than being in a balanced state. However, force cannot disappear out of thin air. Therefore, this part of the force F_2 is combined with the self-driving force new F_0 generated by pedestrians and updated as the self-driving force for the next time step.

Therefore, the pedestrian self-driving force at the next time step is updated as

$$F_0 = \text{new}F_0 + F_2. \quad (8)$$

Among them, F_0 is the initial self-driving force of the pedestrian at the next time step, new F is the self-driving force generated by the pedestrian itself, and F_2 is the congestion force that has not yet been transmitted.

In the dynamic parameter model, all the positions that can be moved within a time step of the pedestrian are defined as the pedestrian's moving area. In the cellular automaton simulation, the pedestrian's moving area is a 3×3 cellular area. Pedestrians occupy the center of the mobile field. Pedestrians can choose to wait or move to the other eight cells within a time step. Mobile revenue is the evaluation of pedestrians on all locations in the mobile field, as shown in Figure 7.

Because in the process of pedestrian evacuation, the main consideration is the pedestrian direction parameter and space parameter, therefore, these two parameters are used in the simulation of crowded evacuation to describe the movement benefits of pedestrians.

In the process of pedestrian movement, the pedestrian's movement income must first be calculated. Pedestrian's movement income consists of two parts: the direction parameter D_{ij} and the space parameter E_{ij} ^[19]. P_{ij} represents the mobile income of pedestrians; then, there is

$$P_{ij} = D_{ij} + E_{ij}. \quad (9)$$

During the evacuation of pedestrians, the purpose of pedestrians is to leave the evacuation space. Therefore, pedestrians always move in the direction of the safety exit; that is, pedestrians will choose the position closest to the safety exit in the moving area as their target location. The direction parameter D_{ij} refers to the reduced value of the distance for the pedestrian to reach the safety exit when the pedestrian moves from the initial position to the target position within a unit step.

When calculating this parameter, this thesis uses static domain parameters to express the attractiveness of different locations to pedestrians. When the target location is closer to the safety exit, pedestrians are more likely to choose the location, and the location is more attractive to pedestrians. In different models, due to different simulation rules, the static domain parameter calculation methods used are also different. In this paper, the static field parameter values based on Euclidean distance are used, and the calculation is as follows:

$$S_{xy} = \begin{cases} \min_n \left(\min_m \left(\sqrt{(x - x_n^m)^2 + (y - y_n^m)^2} \right) \right) & \text{cells}(x, y) \text{ are not walls or obstacles,} \\ M & \text{cells}(x, y) \text{ are walls or obstacles.} \end{cases} \quad (10)$$

Among them, (x, Y) is the coordinate of a cell in the system, S_{xy} is the static field parameter value of the cell (x, Y) , x_n^m, y_n^m are the m th cell in the n th gate, and M is a large positive number, which means that pedestrians cannot move to this location.

Pedestrians have 9 optional positions in their moving fields, and each position has a static field parameter value. When the pedestrian stays still, the pedestrian's moving

income is 0. When a pedestrian moves horizontally or vertically, the pedestrian's step length is 1, and the movement gain is the difference between the pedestrian's current position and the static field parameter of the target position. When a pedestrian moves obliquely, that is, the pedestrian's step length is $\sqrt{2}$, and the movement benefit is the difference between the pedestrian's current position and the static field

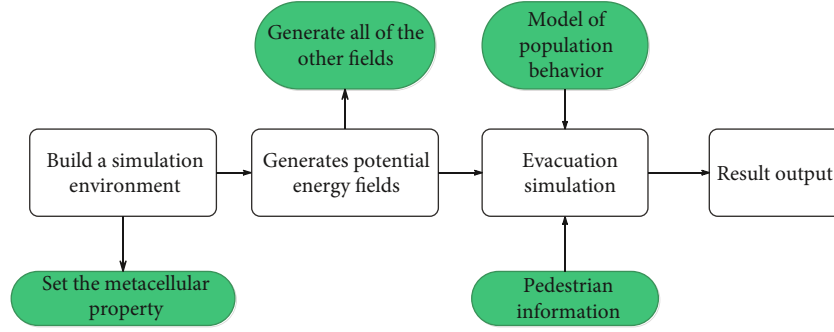


FIGURE 10: Simulation system structure.

parameter of the target position divided by $\sqrt{2}$. With pedestrians as the center, the direction parameter in the moving field is D_{ij} :

$$D_{ij} = \begin{cases} \frac{S_{oo} - S_{ij}}{1} & \text{when pedestrians wait or move horizontally or vertically,} \\ \frac{S_{oo} - S_{ij}}{\sqrt{2}} & \text{when pedestrians move obliquely.} \end{cases} \quad (11)$$

Among them, S_{oo} is the static field parameter value of the center position of the pedestrian moving field, and S_{xy} is the static field parameter value of the moving position that the pedestrian can choose.

When $D_{ij} = 0$, it means that when pedestrians choose this location, the distance to the safety exit will neither increase nor decrease. When $D_{ij} > 0$, it means that pedestrians choosing this location will reduce the distance to the safety exit; that is, pedestrians are more inclined to choose this location. When $D_{ij} < 0$, it means that pedestrians choosing this location will increase the distance to the safety exit. Therefore, pedestrians will reduce the possibility of choosing the location.

During the evacuation of pedestrians, the cell position in the moving area may be occupied, repelling pedestrians from entering this position. However, if there are space cells in the moving area, it will have the greatest attraction to pedestrians. Therefore, the value of the space parameter E_{ij} is given by

$$E_{ij} = \begin{cases} 1 & \text{cell position is empty,} \\ 0 & \text{central cell location,} \\ -1 & \text{cell position occupied.} \end{cases} \quad (12)$$

In addition, because the pedestrian direction parameters D_{ij} and E_{ij} space parameters are of different magnitudes, they cannot be added directly. Considering that when a position in the moving area is empty and the direction parameter of the position is the largest, the position of the pedestrian's maximum moving income is that position. When there is a moving position, the pedestrian's moving income is positive, but the position is occupied by other

pedestrians; the pedestrian will hardly choose this position. Therefore, $\max(D)$ is taken as a constant parameter and multiplied by the space parameter E_{ij} to make it have the same magnitude as the space parameter E_{ij} and the direction parameter D_{ij} . Therefore, the pedestrian's mobile income P_{ij} is

$$P_{ij} = D_{ij} + E_{ij} \times \max(D). \quad (13)$$

Among them, P_{ij} is the pedestrian's movement income, D_{ij} is the pedestrian's direction parameter, E_{ij} is the pedestrian's space parameter, and $\max(D)$ is the maximum value of the direction parameter's profit in the pedestrian movement field.

Similar to the moving area of pedestrians, the moving area of the space cell refers to the space cell as the center, and pedestrians in the eight positions around it may move to the space position, as shown in Figure 8. When formulating an appropriate probability model, the movement probability of the surrounding pedestrians is determined by the crowding force received and the initial target position, and the movement probability determines the moving pedestrian.

The final crowding force E of the eight pedestrians around the space cell is decomposed in the direction of the space cell, and the force component of the pedestrian in the direction of the cell is

$$|F_{ij \rightarrow \infty}| = \begin{cases} |F_{ij \rightarrow \infty}| & F_{ij \rightarrow \infty} > 0, \\ 0 & F_{ij \rightarrow \infty} \leq 0. \end{cases} \quad (14)$$

Among them, $|F_{ij \rightarrow oo}|$ is the force component of the pedestrian (i, j) in the direction of the space cell in the moving field, and $F_{ij \rightarrow \infty}$ is the force component of the pedestrian (i, j) in the direction of the space cell.

Therefore, the probability that pedestrians in the moving area of the space cell choose the cell due to the crowding force is

$$m_{ij} = \frac{|F_{ij \rightarrow \infty}|}{\sum(|F_{ij \rightarrow \infty}|)}. \quad (15)$$

TABLE 2: Effect evaluation of the dynamic analysis model.

Number	Dynamic simulation
1	87.9
2	88.9
3	94.6
4	92.9
5	87.0
6	92.2
7	94.0
8	86.8
9	89.6
10	89.2
11	86.4
12	91.2
13	87.0
14	93.2
15	92.6
16	86.4
17	94.0
18	89.7
19	93.3
20	90.1
21	89.7
22	86.1
23	92.3
24	90.1
25	95.0
26	90.8
27	94.9
28	91.4
29	93.1
30	89.5
31	94.6
32	92.6
33	93.7
34	90.0
35	91.1
36	92.0
37	90.2
38	93.4
39	90.3
40	91.7
41	90.7
42	88.1
43	87.9
44	88.7
45	92.6
46	93.8
47	87.5
48	86.3

TABLE 2: Continued.

Number	Dynamic simulation
49	91.4
50	94.2
51	93.0
52	94.6
53	88.1
54	89.4
55	89.9
56	91.7
57	94.7
58	93.6
59	91.7
60	93.0

Among them, m_{ij} is the probability of pedestrians (i, j) in the mobile field choosing space cells due to crowding forces.

The greater the crowding force component of the pedestrian in the direction of the space cell, the greater the probability that the pedestrian will choose the location, which is consistent with the fact that pedestrians are crowded to other locations due to the crowding force in the actual movement.

Secondly, it is also necessary to consider the pedestrian's own initial target location selection. After calculating the pedestrian income, the target positions of all pedestrians are obtained. Through the judgment of the congestion state, the situation where multiple pedestrians may choose a location is processed. q_{ij} indicates whether the pedestrian (i, j) in the mobile field chooses the location; then, there are

$$q_{ij} = \begin{cases} 1 & \text{pedestrians select this location,} \\ 0 & \text{pedestrians do not choose.} \end{cases} \quad (16)$$

Therefore, the probability that the pedestrian (i, j) in the moving field of the space cell selects the space cell due to its initial target position is

$$n_{ij} = \frac{q_{ij}}{\sum q_{ij}}. \quad (17)$$

Among them, n_{ij} is the probability that pedestrians (i, j) choose the space cell due to their own initial position selection. Finally, the probability of the pedestrian (i, j) in the space cell moving field moving to the space cell is

$$P_{ij} = \begin{cases} \beta * m_{ij} + (1 - \beta) * n_{ij} & \sum m_{ij} = 1 \text{ CO } \sum n_{ij} = 1, \\ m_{ij} & \sum m_{ij} = 1 \text{ CO } \sum n_{ij} = 0, \\ n_{ij} & \sum m_{ij} = 0 \text{ CO } \sum n_{ij} = 1, \\ 0 & \sum m_{ij} = 0 \text{ CO } \sum n_{ij} = 0. \end{cases} \quad (18)$$

TABLE 3: Effect evaluation of the evacuation management system for sports events based on the cellular automata.

Number	Evacuation effect
1	72.3
2	72.1
3	80.3
4	70.4
5	81.7
6	71.3
7	83.3
8	82.4
9	79.3
10	80.8
11	72.2
12	71.0
13	72.5
14	86.2
15	84.6
16	74.1
17	79.5
18	77.2
19	81.4
20	81.7
21	77.4
22	85.2
23	75.5
24	69.1
25	69.3
26	82.2
27	81.0
28	78.6
29	86.7
30	86.5
31	72.4
32	69.9
33	70.5
34	77.9
35	69.2
36	82.5
37	70.0
38	75.9
39	78.5
40	83.2
41	80.1
42	69.5
43	83.7
44	80.6
45	83.8
46	81.4
47	80.8
48	75.7

TABLE 3: Continued.

Number	Evacuation effect
49	84.2
50	74.3
51	70.3
52	76.2
53	77.1
54	84.0
55	85.3
56	76.8
57	85.1
58	86.1
59	74.1
60	72.7

Among them, m_{ij} is the probability of pedestrians (i, j) choosing the space cell due to crowding force, n_{ij} is the probability of pedestrians (i, j) choosing the space cell due to their own initial target position selection, and β is the adjustment parameter. When β is close to 1, the influence of pedestrian crowding force is relatively large. When β is close to 0, the influence of pedestrian's initial target position selection is relatively large. In this paper, 0.5 is considered to be equivalent. When $\sum m_{ij} = 0$ and $\sum n_{ij} = 0$, it means that no pedestrian in the moving area has selected the space cell.

4. Model Effect Analysis

The third part builds an intelligent evacuation model and evaluates the evacuation management effect of sports events on this basis. Generally speaking, whether a person can reach a goal grid is affected by knowledge, reason, physical strength, and other comprehensive forces. The method of movement is as follows in Figure 9.

According to cellular automata, this system includes scene editing, potential energy field calculation, crowd behavior model, and evacuation simulation. The structure is as follows in Figure 10.

The dynamic analysis model of this paper is studied through experimental research, and the performance effect of the cellular automata in the dynamic analysis model is statistically evaluated by the expert evaluation method, and the results shown in Table 2 below are obtained.

It can be seen from Table 2 that the cellular automata perform very well in the dynamic analysis model. On the basis of the above research, the evacuation management system of sports events based on the cellular automata constructed in this paper is evaluated, and the evaluation results are shown in Table 3 below.

From the experimental analysis, it can be seen that the evacuation management system for sports events based on the cellular automata proposed in this paper can play an important role in the evacuation of sports events.

5. Conclusion

In the study of evacuation of stadium personnel, it is necessary to study the evacuation characteristics of stadiums as well as the characteristics of individual personnel in evacuation situations. The research on the virtual exercise of stadium personnel evacuation includes the above two research aspects, which can provide an effective research approach for the evacuation of stadium personnel and even other venues. Therefore, the research on the virtual exercise system for evacuation of stadiums can not only provide a basis for determining the rationality of stadium construction but also provide a basis for the formulation of evacuation plans. This paper applies dynamic analysis to the evacuation management process of sports events and simulates the evacuation process of sports events through cellular automata to improve the evacuation management effect of sports events. The experimental research results show that the evacuation management system for sports events based on cellular automata proposed in this paper can play an important role in the evacuation of sports events.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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