Advances in Computer Science Research, volume 75
7th International Conference on Mechatronics, Computer and Education Informationization (MCEI 2017)

Research on the Personnel Evacuation Simulation Model for Large-Scale Stadium

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Keyword: Simulation; AGENT; Personnel evacuation

Abstract. Under the new situation of deepening reform and opening up, people attach more importance to sports activities and the construction of stadiums has been developed rapidly. The stadium is one of the most important places where a sporting event or a national movement is held in a region. It is also a place with high population density. If there is an emergency situation in stadiums, it will inevitably result in overcrowding or stampede. Based on this, this study will evacuate the individual in the stadium using AGENT technology to achieve the evacuation simulation. Using AGENT technology to achieve individual modeling and spatial grid, the main factors influencing personnel evacuation are analyzed. From the simulation experiment, it can be learned that the evacuation of personnel is closely related to the stadium exit layout.

Research Situation

Overview of Personnel Evacuation Simulation Model. In the research of personnel evacuation, evacuation modeling includes: one is to stop the pedestrian as a continuous flow and realize the idea of traffic flow; the other is to use pedestrian flow as some kind of force particle and combine with AGENT to implement modeling [9]. In other words, personnel evacuation simulation can be divided into three kinds: macro model, micro model and medium model.

Macro model is also called fluid model, mainly in the dynamic population modeling and population early evacuation modeling and design. It is mainly to consider the crowd as a whole, in which the process of distribution of personnel is basically the same, and the structure for the basic model is relatively simple. People like to use this method to complete the modeling as in the initial evacuation model analysis.

Micro model is mainly related to crowd behavior and its role is to study the individual behavior parameters and evacuation situation; it is mainly to obtain greater flexibility as an individual.

Media model is between macroscopic and microscopic models, and it can mainly conduct detailed planning and research on whole and individual. That is, the advantages of the macro model and the micro model are sorted and unified, and the heterogeneity of personnel can be shown in the middle.

Research Situation of Personnel Evacuation Simulation Model for Stadium. Current situation of overseas research

Foreign scholars have been studying the evacuation of personnel for a long time. With the continuous transformation of research topics, they have also obtained more results. C.M. Henein mentioned the improvement of cellular automaton and model and the use of computer simulation technology to analyze the behavioral characteristics of multi-agent evacuation. Japanese scholars and British scholars verified the evacuation time formula through simulation experiments.

Current situation of domestic research

Due to the limitation of funds, technology and other factors in China, there are relatively few studies on personnel evacuation. Among them, professor Wen Limin of Northeastern University and her team proposed cluster evacuation to use computer to aid statisticians for evacuation time in the process; the research team of University of Science and Technology of China used Helbing to complete cellular automata model research.

Modeling Feature Analysis

Analysis of Basic Structure of Stadium. Exit feature of stadium

In the process of personnel evacuation of stadium, the setting of stadium exit structure is the most important. When an emergency occurs, personnel can quickly get out of the stadium through various exits, thereby reducing casualties. Therefore, in the construction of venues, the design and layout of exits is needed to pay attention to.

Setting of personnel evacuation exit

Safety exits in stadium need to be properly arranged. In the fire protection zone, the nearest horizontal edge of safety exit should not exceed 50cm;

There should be more than two evacuation exits in the stadium, and the flow of evacuees at each exit should be around 600;

The width of stadium exit is shown in the following table:

Table 1 Minimum evacuation width or each 100 people in the stadium (m)

Grandstand seating		3000-5000	5001-10000	10001-20000
stair		0.5	0.43	0.37
walkway	Flat slope ground	0.43	0.37	0.32
walkway	Step on the ground	0.50	0.43	0.37

Stadium evacuation methods

There are many people in stadium. In order to better manage personnel, the stadium is generally divided into the infield and outfield. The infield mainly includes athletes, staff and VIP members. Outfield is mainly the auditorium and lounge. In that way, in the exit design of the stadium, the exits of infield and outfield cannot be designed together, and its main purpose is to better separate the flow of people. When evacuating people in the stadium, they usually adopt the upward, downward, intermediate and compound.

Upward evacuation

Upward evacuation is that the exit of the stand is mainly at the bottom, and people mainly leave the stadium from the bottom through the channel. Generally, the upward evacuation will occupy a larger area of the stands; at the same time, people evacuating to the bottom will cross the influx of people infield, as shown below:

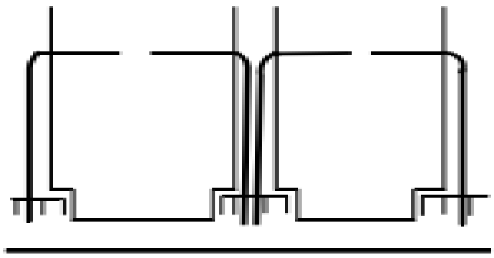


Figure 1. nography of upward evacuation.

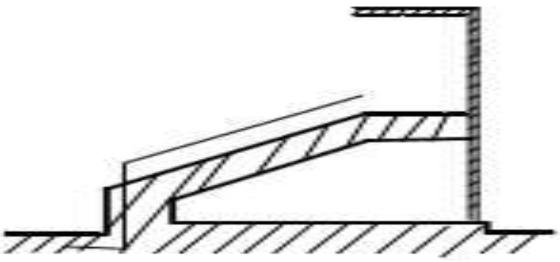


Figure 2. taway view of upward evacuation.

Downward evacuation

The main location of downward evacuation is above the exit of the stand. The audiences in the stadium need to back to field area when escaping from the stadium in case of emergency, from the above passage to reach the outside. The exit cannot be set up in the stand through this form of evacuation, which will not affect the layout of the stadium. It is shown as below:

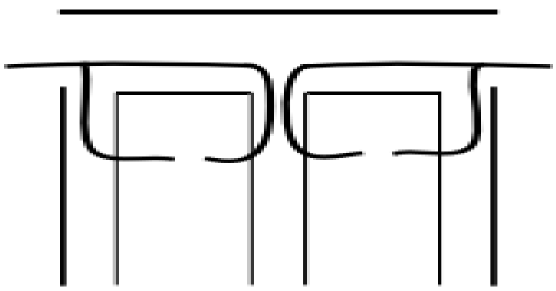


Figure 3. nography of downward evacuation.

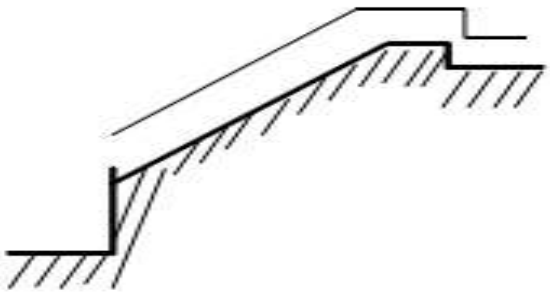


Figure 4. taway view of downward evacuation.

Intermediate evacuation

The exit of intermediate evacuation form is in the lower part of the stand. The audiences need to enter the stadium according to the relevant directive slogan. The intermediate evacuation has the common advantages of upward and downward evacuations. It is shown as below:

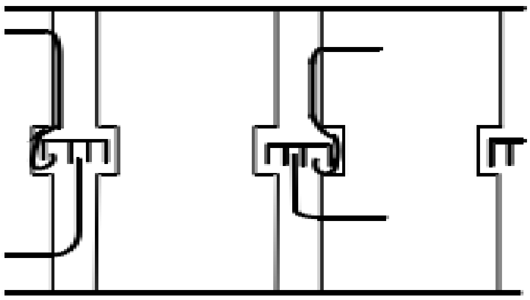


Figure 5. chnography of intermediate evacuation.

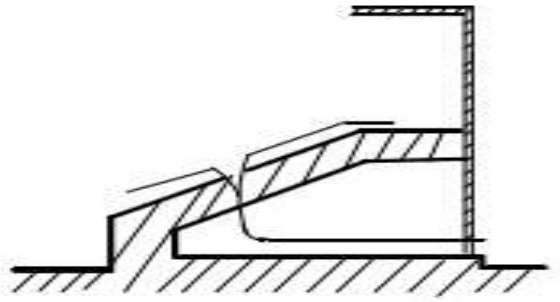


Figure 6. utaway view of intermediate evacuation.

Individual Characteristics. Individual age

In the process of evacuation, the age of evacuees determines the ability of personnel to move, and the perception and decision-making abilities of people in every age group are different. Generally people between 18 and 30 years old has relatively strong ability to move, but they also lose their mind first in unexpected situations. The individuals between 31 and 50 years old have plain action capability, but are calmer in unexpected situations; the old people more than 50 years old have weaker action capability. There are differences in action capability and psychological endurance among different age groups.

Individual gender

Individual gender differences also lead to differences in body function. Generally physical fitness of males is relatively good, while women's dependence is strong. In this case, in unexpected circumstances, men generally remain calm, while women present nervous performance. Gender will also determine the action capability of men and women.

Individual physical condition

Individual own physical condition also has a certain relationship with evacuation. In the evacuation of the crowd, there are often some elderly frail individuals who have weak action capability, resulting in greater casualties in the evacuation.

Agent Mdel of Prsonnel Eacuation

Introduction of AGENT Mdel. AGENT has a smart and adaptable computer system under certain circumstances, which can accomplish a certain function mainly through active service. Through the collection of environmental data, AGENT controls the corresponding decision-making caused by environment changes. In the process, it can also cause a variety of behaviors that are affected. AGENT is more complex in the process of interaction; the main feature is to describe the good behavior of the group. Perception - decision - response abilities are used in AGENT.

AGENT Interaction and collaboration between individuals: Interactivity (AGENT can work with individuals), adaptation (AGENT individuals have local behavior control, that is, they do not need any actions, and can perceive their surroundings), initiative (To complete the corresponding operation according to perception of the surrounding environment) and reasoning and planning capabilities (AGENT has the learning knowledge and experience to complete the relevant work).

Agent Mdel Fundation. In evacuation of the AGENT, the simulation of individual evacuation in emergencies also needs to simulate the stadium structure, simulation evacuation form, individual modeling, *etc*. The individual evacuation model has four main influencing factors when it is established, mainly including individuals, human behaviors, environmental spaces, evacuation stadium.

Stadium Eacuation Smulation

Establishment of Eacuation Mdel. In the process of stadium evacuation, due to various constraints of individual behavior and other aspects, the location of the individual, the target exit, the ease of reaching the destination and the like will determine the evacuation speed. When the crowd is evacuated, the personnel will move towards the target exit without regular movements. Among them, there are also differences among individuals, and with the actual evacuation of the crowd, the following points can be summed up:

To evacuate people in unexpected situations, the crowd will gather at the stadium's exit for the first time.

The audience near the exit should take the lead in moving.

The qualities of personnel will determine the casualty rate.

Modeling and Agorithm. Personnel evacuation in the stadium is the movement of personnel to the exit, and the individual decision-making mainly has the following aspects:

1) First of all, it needs to analyze the specific situation of the personnel in the stadium, including the population's gender, age and health problems. In this regard, individual differences can be calculated for different groups of people, mainly based on gender, age and other statistics:

$$\text{Ccrd} = \begin{cases} 1.\ \text{Elderly women} \\ 2.\ \text{Elderly men} \\ 3.\ \text{Young women} \\ 4.\ \text{Young men} \end{cases} \quad (1)$$

Individuals will be judged on the basis of congestion in the movement of people around them:

When individuals in the evacuation process are not crowded or crowded within the scope of its tolerance, the individual can normally walk out of the exit, and then it belongs to the normal evacuation;

When individuals are overcrowded during their evacuation beyond their own tolerance, the individual will be harmed to some extent after being congested to varying degrees. In the process, individuals may lose action capability and stop evacuating.

When individuals are not crowded, they will take the normal evacuation method. According to Figure 3.1, the main reasons that affect the evacuation behavior of individuals in this paper include the distance from the individual to the exit, the number of individuals to the exit, the number of obstacles to the exit, and population density of the exit and so on.

The distance to the exit:

Generally, the individuals to the exit will be calculated according to Euclidean distance. The corresponding exit destination is selected based on the shortest distance. If there are N exits in the stadium, D represents the actual distance between these N exits. The shortest distance evacuation exit formula is as follows:

$$D_{(i,j)} = \min(D_1, D_2, \ldots\ldots, D_N) \quad (2)$$

Among them, the distance D (i, j) between the i^{th} action direction (i = 1, 2,, 9) and the j^{th} exit (j = 1,2,, N) is as follows:

$$D(i,j)=\sqrt{\left(x^i-x_{ex}^j\right)^2+\left(y^i-y_{ex}^j\right)^2} \quad (3)$$

(x^i, y^i) is the position coordinate of the i[th] action direction of the individual, (x^i_{ex}, y^i_{ex}) is the position coordinate of the j[th] exit.

The number of individuals to the exit:

Suppose the i[th] individual to the j[th] exit grid coordinate set is U, then the j[th] exit number is:

$$P(i,j)=\sum_{(x`,y`)\in U} g_1(x`,y`) \quad (4)$$

$$g_1(x`,y`)=\begin{cases}0 \text{grid}(x`,y`) \text{Not occupied}\\ 1 \text{grid}(x`,y`) \text{ Occupied}\end{cases} \quad (5)$$

The number of obstacles to the exit:

The number of obstacles O from the i[th] location to the j[th] exit route is as follows:

$$O(i,j)=\sum_{(x`,y`)eu} g_2(x`,y`) \quad (6)$$

$$g_2(x`,y`)=\begin{cases}0 \text{grid}(x`,y`) \text{Not occupied}\\ 2 \text{grid}(x`,y`) \text{ Occupied}\end{cases} \quad (7)$$

Comprehensive determination of exits:

In the actual evacuation process, it has relationship with all the above-mentioned factors. The comprehensively determination of the target exit E_{exit} is as follows:

$$(x_{exit}, y_{exit}) = \arg_{(i,j)}\left\{\min[a_1 D_{(i、j)} + a_2 P_{(i,j)} + a_3 o_{(i,j)} + a_4 p_{-x(i,j)} + a_5 o_{(i,j)}]\right\} \quad (8)$$

The position of target exit E_{exit} and parameter systems of $a_1 \sim a_5$ exits are as follows:

The greater the value of a_1 indicates that the exit distance occupies a larger influencing factor, which means that it is not necessary to change the exit. The greater the value of a_2 indicates the number of individuals occupies a larger influencing factor, and at this time individuals need to move to the place with fewer people. If a_3 exit obstacles occupy a larger impact, individuals need to change the exit; a_4 value is larger, indicating that the density of individual number is large, and individuals need to move to the place with fewer people; if the obstacle density of a_5 exit is large, individuals need to move to the place with fewer obstacles.

Determining the direction of action

When determining its target exit, the individual will choose a reasonable exit direction j (j = 1,2, ..., 9)

When individuals choose the exit, first of all, they need to choose the distance and degree of difficulty of exit E_{exit}. After determining the direction of an exit, the distance to the exit, the number of people and the distance from the obstacles to the Eexit D^E (i, j) is:

$$D_{(i,j)}=\sqrt{\left(x^i-x_{Eex}^j\right)^2+\left(y^i-y_{Eex}^j\right)^2} \quad (9)$$

If the individual to the target exit coordinate set is V in the j direction, exit number p is as follows:

$$P^E_{(I,j)}=\sum_{(x^i,y^j)ev} g_1(x`,y`) \quad (10)$$

The number of the obstacles in the exit:

$$O^E_{(I,j)}=\sum_{(x^i,y^j)ev} g_2(x`,y`) \quad (11)$$

From the actual situation, it is needed for comprehensive comparison to determine the exit direction. The formula is as follows:

$$(x_{EDed},\ y_{EDed})=\arg_{(i,j)}\left\{\min\left[a_6 D^E_{(i,j)} + a_7 D^E_{(i,j)} + a_8 D^E_{(i,j)} + a_9 D^E_{(i,j)} + a_{10} D^E_{(i,j)}\right]\right\} \quad (12)$$

The coefficients $a_6 \sim a_{10}$ of the above formula are the decision-making parameters to determine the direction. If the value of a_6 is greater, it shows that the direction of the distance occupies a larger factor, and individuals do not need to change the exit; the larger the value of the a_7 is, the greater the number of views is in the individual direction, and individuals need to move to the exit with less field of vision; if a_8 value is greater, then there will be more obstacles, and individuals need to move to the place with less field of vision; the greater value of a9 is, the larger the population density of the field of view is, and individuals need to move to the place with small population density. The greater the value of a_{10} is, the greater the obstacle density is in the field of view of the individual, and individuals need to move to the place with small obstacle density.

Simulation Eperiment

In this simulation experiment, the structure of designed exit is as follows: red represents staff, black is an obstacle, and the following gap is the exit.

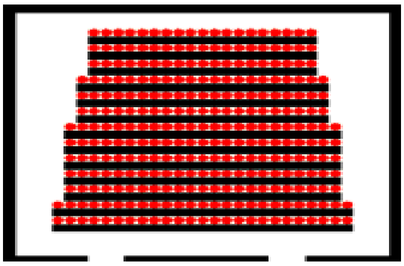
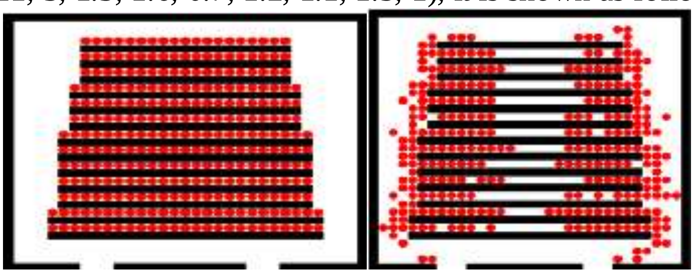
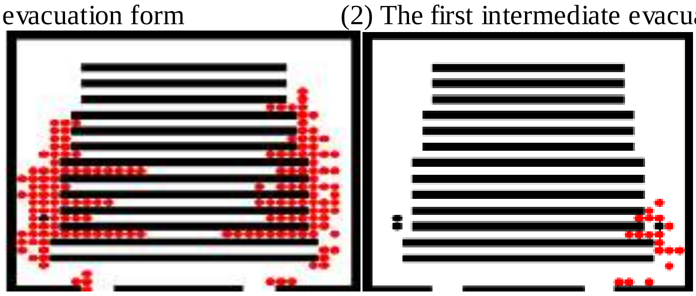


Figure 7. he scene graph of exit structure.

The simulation data of the stadium is as follows:
The stadium area is 132 m × 132 m grid;
Each grid is 0.4 m × 0.4 m;
There are two exits below the stadium, and each exit has 3 grids;
Suppose there are 1850 stadium individuals
When ($a_1 \sim a_{10}$) is (2, 21, 3, 1.3, 1.6, 0.7, 1.2, 1.1, 1.5, 1), it is shown as follows:



(1) Initial evacuation form (2) The first intermediate evacuation form



(3) The second intermediate evacuation form (4) At the end of the evacuation form

Figure 8. mooth evacuation form of two exits.

It can be seen from the figure that in the process of evacuation, all individuals spontaneously gather at the exit; individuals who are near the exit evacuate first, and then individuals who are behind the stadium move further. The evacuation speeds of the two exits are basically the same.

For the different widths of the exits in the simulation study, including 0.4 m ×1, 0.4 m ×3, 0.4 m ×5, the simulation results are as follows:

Table 2 two data statistics of unimpeded personnel evacuation

Exit width	Evacuation time (s)	Steps to evacuate
1	221.4	23596
2	182.3	21014
3	129.4	16253

It can be found from the above table that with the continuous increase of the exit width, the evacuation time and number of steps will be reduced.

Conclusion and Epectation

Based on the AGENT technology, this paper simulates the evacuation of stadium personnel, which mainly studies the effect of exit width of the stadium and individual characteristics on evacuation of personnel. The smoothness of the exit directly affects the efficiency of personnel evacuation. In the process of personnel evacuation, it also has an important relationship with the layout of the exit location and the individual's own conditions.

Acknowledgements: This work was financially supported by Basic Research Projects of Weinan Technology Bureau（2017JCYJ-2-5） and Shaanxi Social science 2018 projects of major theoretical and practical problems research（Large and Medium-sized Stadiums Personnel Safety Evacuation Strategy Optimization Research based on Computer Simulation）.

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