Research and Application of Public Safety Model Based on Artificial Intelligence: Simulation of Emergency Evacuation in Zhuhai Innovation Center Building

Zili Zhao[a], Zhi'ao Zhang[b], Xiupeng Zhang[c] and Jiaqi Wan[d]
Zhuhai Institute of Urban Planning & Design, Zhuhai, Guangdong, China

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Abstract: Artificial intelligence has many applicable scenarios in the field of public security. Building safety assessment is an important part of public safety, and emergency evacuation simulation is an important means of building performance evaluation. Based on the evacuation simulation principle of artificial intelligence agent and steering behavior theory, this study uses computer graphics simulation and game role technology to simulate buildings Starting from the evacuation mode selection, parameter setting and evacuation time sequence analysis of the simulation model, available safe egress time (ASET) and required safe egress time (RSET) of the room, floor and the whole building are calculated to determine whether the evacuation process in the building meets the safety standard. In order to make the simulation results more scientific and reliable, three different simulation scenarios were set up in this study, namely: full staircase mode, full elevator mode, and stair based elevator supplemented mode.

1 INTRODUCTION

Public safety is one of the important contents of urban governance at this stage. As a new type of application technology that has gradually matured in recent years, artificial intelligence has been widely used in the field of social public safety and has produced very good results. Artificial Intelligence, referred to as AI, is a technology for researching and developing theories, methods, technologies and application systems for simulating, extending and expanding human intelligence. Artificial intelligence has many applicable scenarios in the field of public safety, and building safety assessment is an important part of public safety. Since 1980, scholars have constructed evacuation models to simulate the evacuation behavior of people in buildings. Among them, the widely used evacuation models are the cellular automata model and the lattice gas model. This research is based on the evacuation simulation principle of artificial intelligence agent and the modeling of Steering behavior theory, so that we can simulate the evacuation of people in emergencies, and simulate the evacuation process of room evacuation, floor evacuation and arrival at the exit on each floor. This model can simulate the escape path and escape time of each individual in the event of a disaster, and compare the simulation results with industry standards to determine the reliability of the evacuation model. Finally, based on the model simulation results, the safety risk assessment of the performance-based design of high-rise buildings is carried out, and the rectification plan and suggestions for the areas with potential safety hazards are proposed. Therefore, the research has great practical significance.

2 OVERVIEW, DATA SOURCES AND RESEARCH METHODS OF THE STUDIED AREAS

2.1 Model Simulation Principle

Artificial intelligence is mainly through deep learning algorithms based on deep neural network and convolutional neural network algorithms, which achieves a certain degree of intelligent calculation through induction, synthesis and other methods. This research is based on the evacuation simulation principle of the artificial intelligence agent and the

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steering behavior theory to model the movement of pedestrians. The modeling is mainly composed of three modules: a graphical user interface, a simulator and a 3D result display. Steering mode. uses a combination of path planning, guidance mechanism and collision handling to control pedestrian movement. If the distance between people and the closest point exceed a certain threshold, the algorithm will generate a new path to change the walking trajectory of pedestrians.

In the Steering mode, the exit will not restrict the flow of people, and a reasonable distance will be maintained between evacuated individuals and evacuated individuals. By combining computer graphics simulation and simulation technology in the field of game roles, graphical virtual exercises are performed on each individual movement in multiple groups. In order to observe the escape route of the personnel, we delete all the external walls and other structures in the model, leaving only the plane layout structure diagram. By picking up the corresponding room, and arranging the corresponding doors, elevators, and stairs according to the specific location of the model, an intelligent evacuation model for people is formed. Finally, we set the relevant parameters of the model, such as pedestrian gender, height, walking speed, floor area, room area, etc. The walking rate in the model is determined by the density of the crowd in each room, and the flow of people passing through the exit is determined by the width of the exit.

2.2 Model Calculation Method

By analyzing the requirements, we set up the physical scene, and the main functions can be realized after the overall modeling structure and personnel's behavior are determined. Therefore, the agent-based system simulation modeling method can be used. The process of personnel evacuation is closely related to detection, alarm measures, and characteristics of personnel escape behavior. The necessary evacuation time is calculated based on the sum of the alarm time, the evacuation pre-action time of the personnel and the action time of the personnel from the beginning of the evacuation to the safe place.

$$RSET = T_1 + T_2 + T_3 \quad (1)$$

In the formula: RSET is the required evacuation time for personnel; T_1 is the detection and alarm time, which refers to the time from the alarm in the building to the detection of personnel; T_2 is the personnel response time, which refers to the time when personnel begin to evacuate after hearing the alarm or discovering a danger signal and realizing the threat of an accident; T_3 is the evacuation action time, which refers to the time taken from the beginning of the evacuation to the evacuation of all internal personnel to a safe area.

$$T_1 = \frac{DRI}{\sqrt{\mu_{max}}} \ln\left(\frac{T_{max} - T_0}{T_{max} - T}\right) \quad (2)$$

In the formula: DRI is the detector response index; $\mu_{max} = 0.197Q^{1/3} H^{1/2} h^{5/6}$ (r>0.15H); $\mu_{max} = 0.946(Q/H)^{1/3}$ ($h \leqq 0.15H$); Q is the heat release rate of the flame; H is the height of the floor; h is the height of the detector from the roof; T is the induced temperature of the detector.

$$T_2 = 120 + \sqrt{S_0} + 0.4H \quad (3)$$

In the formula: S_0 is the floor area and H is the floor height.

$$T_3 = k \times (T_m + T_n) \quad (4)$$

$$T_m = S / v \quad (5)$$

$$T_n = P/(D * v * W) \quad (6)$$

In the formula: k is the safety factor, and the model is set to k=1.5; T_m is the time to walk to the safety exit; T_n is the time for people to pass through the exit or passage; S is the distance from the initial position to the evacuation safety exit; v is the walking speed of people; P is the total number of people who line up outside the exit or passage; D is the density of people per unit area of queuing people outside the exit or passage; W is the effective width of the narrowest part of the exit or passage.

According to the asylum theory proposed by Marchant, when a disaster occurs, the time sequence of emergency evacuation time calculation is shown in Figure 1. The reaction time of the model design detection alarm device is calculated by the software tool DETACT-QS module developed by NIST, and T1 is about 60s. Personnel response time includes identification time and reaction time, that is, the response time after disaster identification to the start of personnel evacuation. According to the corresponding research calculation, T2 is 120s. Personnel evacuation action time refers to the time required for the people in the building from the beginning of the evacuation action to the end of the evacuation, including the walking time and the time for passing through the exit. T_m is the time required for the evacuees to take emergency actions after responding; T_n is the time required for the evacuees to evacuate from the building to reach the safe area. ASET (Available Safety Egress Time) is the time that can be used to escape safely, also known as "evacuation time allowed."

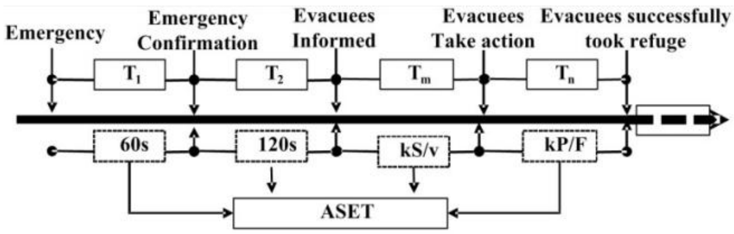

Figure 1: Calculation of emergency evacuation time.

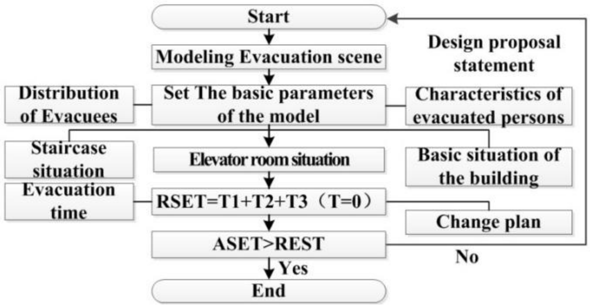

Figure 2: Basic structure diagram of the evacuation model.

2.3 Basic Structure of the Model

The model structure mainly includes basic building conditions setting, evacuation density setting, and overall evacuation characteristics setting of evacuees, stairwell situation setting, and elevator room situation setting. Calculate the evacuation time and the number of evacuees from time t = 0 to the next time interval, then judge whether the number of people arriving at the designated safe place is equal to the total number of people at the initial evacuation, judge whether the available evacuation time (ASET) of evacuees is greater than the necessary evacuation time (RSET), that is, ASET > RSET, and judge whether the design scheme needs to be adjusted after evaluation, If the design scheme meets the requirements of safe evacuation of all personnel, the simulation results will be output.

2.4 Model Parameter Setting

Taking into account the behavioral habits of people in emergencies, and "congestion" is an important factor affecting the evacuation time, this article is based on the Steering mode and the basic theory of SFPE behavior, based on traffic, pedestrians will follow the planned path The exit direction is moving forward. During the emergency evacuation, if the movement of pedestrians is affected by the surrounding environment and other pedestrians, the personnel will automatically move to the nearest exit to re-plan the route, but the queue must comply with the SFPE assumption. Firstly, establish a 3D space simulation model of the building, and then set various constraint parameters for each evacuated person, mainly including the number of people, the height of the person, the shoulder width of the person, the density of the person, the distance from the person to the nearest exit, floor area, house area, walking Speed, effective width at the narrowest point of exit or passage, number of elevators, etc. Among them, the calculation of the number of evacuated persons is based on the GB50016-2014 "Code for Fire Protection Design of Buildings" (2019 revised edition), and finally the escape route and time of emergency evacuees are generated.

3 EMPIRICAL ANALYSIS

3.1 Introduction to the Evacuation Scene

Zhuhai Planning Science and Innovation Center Building serves new industrial projects such as planning and engineering design consulting. Zhuhai Planning Science and Innovation Center Building serves new industrial projects such as planning and engineering design consulting. The population density in the building during working hours is relatively high, and the safety requirements for evacuation are extremely high. The author conducts modeling and analysis of buildings in order to simulate the escape route and time-consuming of personnel in emergencies. This research selects Zhuhai Planning Science and Technology Innovation Center office building as the object of empirical analysis, which has important research significance. The design prototype of Zhuhai Planning Science and Innovation Center Building has 25 floors, 2 underground floors and 23 floors above ground. The floor heights range from 3.5m to 6.6m, and the total height is 99.2m. Among them, B1~B2, F1.5~F5 are parking lots. F6~F22 floors are dominated by office areas, supplemented by a small amount of exhibition, catering and leisure areas.The simulated floors of the model are F14~F22, of which the total number of simulated people is 600, of which 375 are male employees, accounting for 62.5% of the total number. The specific functions and personnel distribution of each floor are shown in Table 1:

3.2 Building a Simulation Model

Combined with the CAD plan of the Zhuhai Planning Science and Innovation Center Building, the Steering mode is used to establish an emergency evacuation simulation 3D model. Combined with the CAD plan of the Zhuhai Planning Science and Innovation Center Building, the Steering mode is used to establish an emergency evacuation simulation 3D model. For the transparency and visibility of the model, so as to observe the escape route of personnel, delete all external walls and other structures in the model, leaving only the plan layout structure diagram. By picking up the corresponding room, and arranging the corresponding doors, elevators, and stairs according to the specific location of the model, a simulation model of intelligent evacuation of people is formed.

Table 1: The specific functions and personnel distribution of the building.

Floor	Department	Floor area (㎡)	Number/ Person	Male/ Person	Female/ Person	Planning number/ Person
14	Water Affairs Branch	2550.94	61	45	16	63
15	Municipal Affairs Branch 1	2414.68	45	37	8	45
	Engineering Technology Center		12	9	3	72
16	Municipal Affairs Branch 2	2397.62	50	42	8	50
	Garden Design Branch		35	21	14	63
17	Building branch 1	2414.68	45	31	14	45
	Project Management Center					47
18	Building branch 2	2397.62	47	32	15	50
	Transportation Branch		46	36	10	63
19	Planning branch 1	2414.68	51	21	30	45
	Political Research Center		24	13	11	47
20	Planning branch 2	2384.62	50	21	29	50
	information Center		15	9	6	51
21	Production Management Department	2456.94	17	4	13	23
	Human Resources Department		9	0	9	15
	Chief Engineer Office		19	10	9	20
22	General Department	2370.19	12	7	5	31
	Finance Department		8	3	5	15
	Academy Party Committee		3	1	2	4

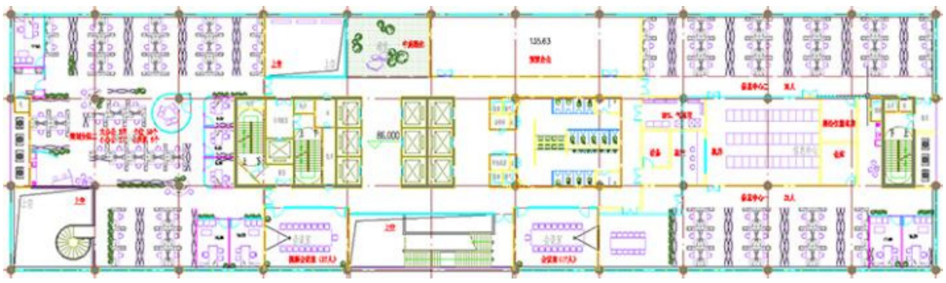

Figure 3: Floor plan design.

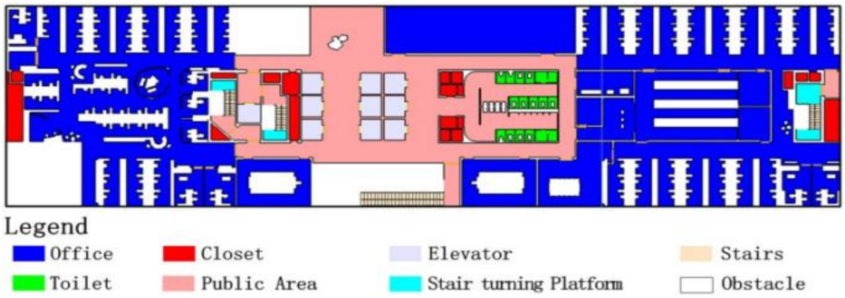

Figure 4: Top view of floor model.

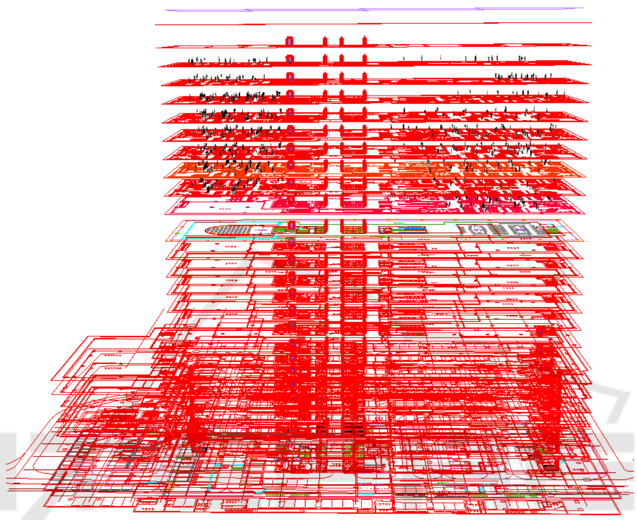

Figure 5: Perspective view of model structure.

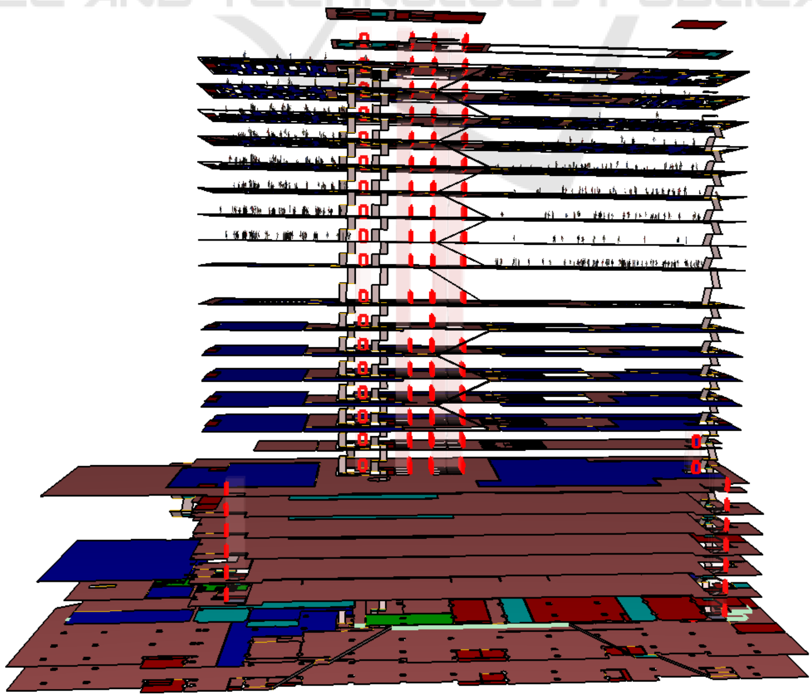

Figure 6: Simulation model diagram.

3.3 Model Parameter Setting

Typically, the evacuation rate increases staff personnel decreases the density, the greater the flow density, the slower the movement of personnel, and vice versa. Foreign research shows: when the general population density is less than 0.54 people/m^2, the speed of the crowd on the level ground can reach 70m/min without being crowded, and the speed of going down the stairs can reach 48-63m/min. On the contrary, when the population density exceeds 3.8 people/m^2, the crowd will be very crowded and basically unable to move. It is generally believed that the relationship between personnel density and moving speed can be described as a linear relationship within the range of 0.5 to 3.5 persons/m^2.

In normal use, the elevator can be used as the main tool for emergency evacuation. The authors set the experimental elevator parameters based on the relevant data of the ThyssenKrupp elevator meta200 model. The maximum operating speed is 3m/s, the maximum lifting height is 150m, and the maximum load is 1600kg. The maximum number of people transported by the elevator is about 21 people. The acceleration is 1.2m/s2. The maximum speed is 7s when the elevator doors open and close. The person's body width will affect their comfortable distance, and the evacuation speed will affect the person's evacuation time. The body width is set according to "Chinese Adult Human Body Size (GB10000-88)", and the specific parameter settings are shown in Table 2.

3.4 Simulation Process

According to the given conditions, the simulated number of people on each floor is set according to the existing statistics of each department. Among them, the number of people evacuated from the office room on each floor, the evacuation speed and time can all be obtained according to the model. In order to make the simulation results more scientific and reliable, this research has established three different scenarios: full stairs mode, full elevator mode, and mode with stairs as the main and elevators as a supplementary. In the evacuation process of the three modes, the fast-or-slow effect is followed, that is, the number of emergency evacuation continues to increase with the passage of time, the evacuation rate is faster at the beginning of the evacuation, but the evacuation rate is relatively slow in the later period of the evacuation. After the model is built, the author combines computer graphics simulation and simulation technology in the field of game characters to perform graphical virtual exercises on individual movements in multiple groups. The simulation results are shown in Figure 7 and Figure 8. In addition to analyzing the personnel's escape time, it can also analyze the bottleneck of the escape channel based on the real-time distribution of the heat map of the personnel, and help designers improve the safety performance of the building.

Table 2: Personnel parameter setting.

Gender	Average speed/(m·s-1)	Velocity distribution threshold (m·s-1)	Body width/cm	Height/cm
Male	1.35	Normal distribution, [1.15,1.55]	45.58	167.1
Female	1.15	Normal distribution, [0.95,1.35]	44.58	155.8

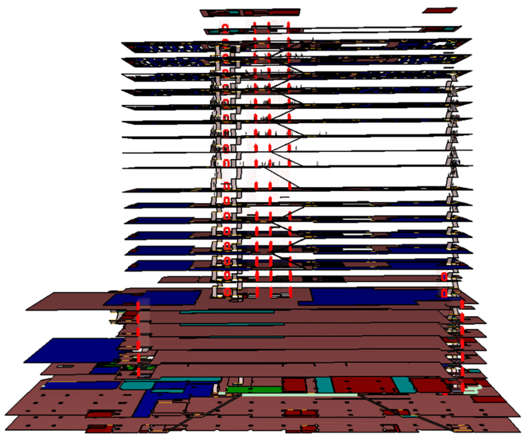

Figure 7: The overall effect of simulation.

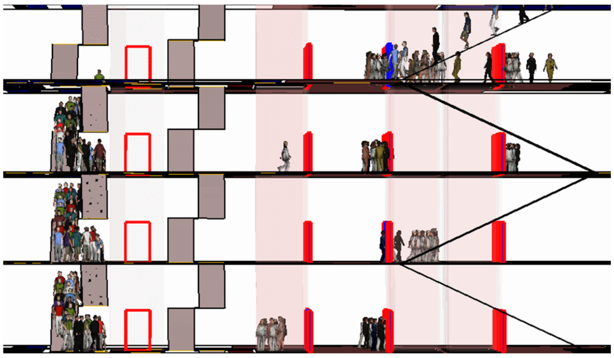

Figure 8: Local effect diagram of simulation.

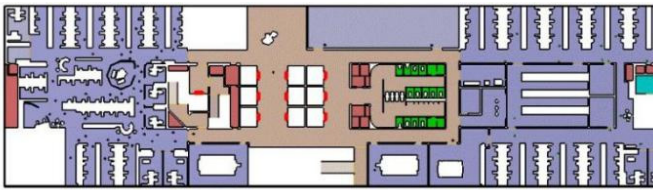

Figure 9: The effect of the flow of people on the floor.

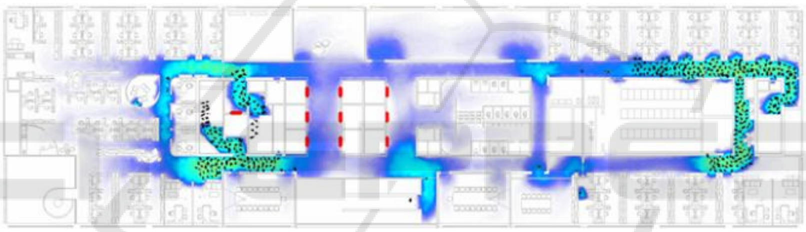

Figure 10: Heat map of real-time dynamic distribution of personnel.

Table 3: Evacuation time for three different scenarios.

Pattern type	T1/s	T2/s	T3/s	RSET/min	ASET/min
Full stairs simulation mode	60	120	666.5	14.11	(24, 48)
Full elevator simulation mode	60	120	569.5	12.49	(24, 48)
A model with stairs as the main and elevators as a supplement	60	120	462.5	10.71	(24, 48)

3.5 Comparative Analysis of Different Scenarios

In the process of emergency evacuation, the traditional evacuation method is that when the safety of the elevator cannot be guaranteed, people can only choose to use the stairs to evacuate, and cannot use the elevator. Therefore, adopting the full-stairs evacuation mode is the lowest guarantee for a smooth evacuation of people. However, as the main tool for vertical transportation in buildings, elevators are also one of the main means of escape for people in the middle and high-rise buildings. Therefore, in order to make the simulation results more scientific and reliable, this study established three different simulation scenarios, namely: full stairs mode, full elevator mode, and stairs as the main elevator auxiliary mode. After simulation, the required evacuation time (RSET) of emergency evacuation personnel under three different scenarios was calculated. Finally, the simulation results are compared with industry standards to determine the reliability of the evacuation model. If the available evacuation time (ASET) of personnel is greater than the required evacuation time (RSET), the building design plan is feasible, otherwise the design plan needs to be adjusted until it meets the safe evacuation of all personnel. See Table 3 for details.

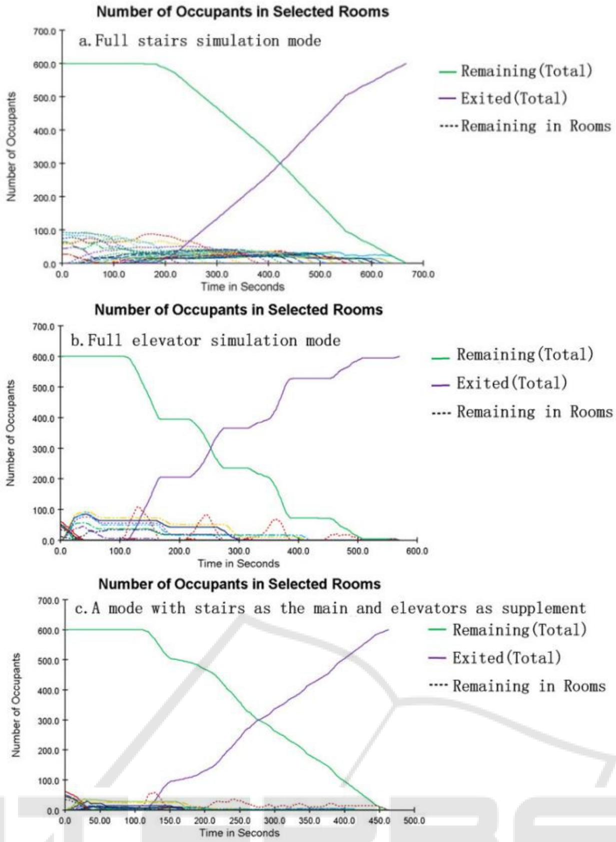

Figure 11: Simulation of three different scenarios.

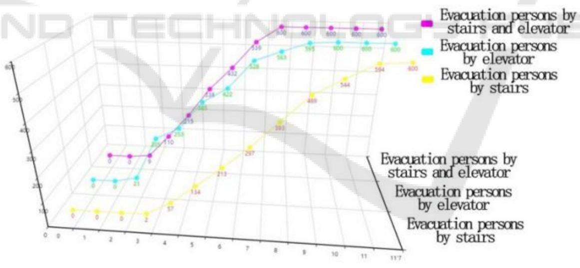

Figure 12: Simulation comparison analysis of three different modes.

After analysis, it can be found that the full staircase mode takes 14.11mins, the full elevator mode takes 12.49mins, and the staircase main elevator takes 10.71mins for the auxiliary evacuation mode. By comparative analysis, it takes 14.11mins for the full staircase mode, 12.49mins for the full elevator mode, and 10.71mins for the staircase main elevator and auxiliary evacuation mode. In an emergency, the first reaction of a person is to choose the stairway closest to him as the first escape exit. Judging from the behavioral characteristics of the evacuees, people showed a clear herd mentality when they chose to take the elevator, and few people would take the elevator without queuing up. Therefore, people waiting to take the elevator during the emergency evacuation process are the main factors affecting the evacuation time. Secondly, the congestion, detention and the turning design in the stairs are also the key factors affecting the evacuation time.

4 CONCLUSIONS AND RECOMMENDATIONS

(1) The evacuation simulation model based on agent technology and Steering mode reflects the evacuation

behavior of the evacuated people more objectively and truly. But there are still many uncertain factors in the evacuation process, such as the physical condition of the personnel, stressful psychological factors, evacuation methods as well as the emergency rescue situation. In the actual process, people show obvious herd mentality when choosing stairways or taking elevators to escape. Therefore, regular emergency evacuation drills can reduce the fear of people in the event of a disaster, so that the crowd can escape in an orderly manner in the event of a disaster, shorten the evacuation time greatly.

(2) In the process of emergency evacuation, the evacuees will choose the closest stairway as the first escape exit, so the stairwell and stair turns are most likely to cause congestion. Reducing the gathering of people between different floors at the stairway can greatly increase the evacuation rate. For example, each stairwell can be equipped with a monitoring system, so that the control room commander can dynamically monitor in real time, and open the completed or about to complete evacuation of the stairwell to other floors. So that the waiting personnel can obtain a new escape route, which can improve the evacuation efficiency to a certain extent.

(3) Under a certain floor height, the evacuation mode supplemented by stairs as the main elevator is more time-saving than the evacuation mode of full stairs or full elevators. Therefore, in the actual disaster escape, if the safe use of elevators can be ensured, choosing the evacuation mode with stairs as the main elevator as the auxiliary will greatly improve the escape efficiency of middle and high-rise buildings.

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