The Study of Population Evacuation Problems

Dapeng Li[1(✉)], Xuebo Chen[1(✉)], and Qiubai Sun[2]

[1] School of Electronics and Information Engineering,
University of Science and Technology Liaoning, Anshan 114051, Liaoning, China
304257355@qq.com, xuebochen@126.com

[2] School of Business Administration, University of Science and Technology Liaoning,
Anshan 114051, Liaoning, China

Abstract. With the rapid development of society around the world, the population of cities such as Beijing and Shanghai has increased dramatically, and large social activities have been increasing. Safeguarding the legitimate rights and interests of citizens and strengthening public safety is one of the most important problems. Therefore, it is a very important research topic to study the aggregation phenomenon and the evacuation characteristics of the public places, to explore the reasonable group organization and evacuation mode, and to find ways and means to reduce the risk of accidents. When a sudden event occurs in a public place, the crowd is evacuated using the particle swarm algorithm. In addition, the shortcomings of the traditional particle swarm optimization are improved, and the influence of obstacle on individual evacuation path selection is fully considered. Finally, the thermodynamic diagram is used to simulate the model, and the feasibility of the model is verified.

Keywords: Population evacuation · Particle swarm optimization · Obstacle avoidance mechanism · Thermodynamic diagram

1 Introduction

With the rapid development of urbanization and the rapid development of economic society, recreational activities, exhibition activities, sports events, celebrations and other large-scale crowd gathering activities frequently, civil airports, sports venues, squares and other places of public places in the sharp increase The There is no obvious precursor to the occurrence of sudden public events, and there is a sudden and complex. Under normal circumstances, the occurrence of public emergencies can cause significant casualties, social harm and property damage. Over the years, sudden public events have occurred frequently, especially groups of stampede events, in which the case of a major crowded stampede event is shocking:

- November 29, 2010, in Aksu City, Xinjiang Hangzhou Avenue Aksu fifth primary school serious stampede accident, nearly 100 students were injured [1];
- January 14, 2011, India, Kerala, a more serious stampede incident, the accident at least 100 people were killed and dozens of injuries [1];
- February 21, 2011, Mali capital Bamako stadium took place stampede event. According to the data released by the Government, the incident has caused 36 people were killed and 64 injured [1];

P. Arezes (ed.), *Advances in Safety Management and Human Factors*,
Advances in Intelligent Systems and Computing 604, DOI 10.1007/978-3-319-60525-8_64

- September 26, 2014 at 2 pm, Kunming Mingtong primary school stampede accident, resulting in 6 people were killed and 26 injured [1];
- December 31, 2014, Shanghai Bund occurred crowded stampede accident. Killing 36 people and injuring 47 others [1];
- On September 24, 2015, 717 people were killed and more than 800 others were wounded by the pilgrims in the Mina area, 5 km east of Saudi Arabia [1].

In order to solve the problem of evacuation, the relevant departments should take safe and feasible emergency measures, not only to evacuate the evacuation of individuals in the environment, but also to make the evacuation process as a whole the overall safety and efficiency. In order to accomplish this goal, it is necessary for the research workers of various disciplines to analyze and solve the problems. These disciplines mainly include geography, artificial intelligence, public safety, computer science, geological exploration and other disciplines [2–4]. The most important thing about evacuation is how to ensure that people evacuate quickly and safely in an emergency and complex environment. Therefore, the problem of group evacuation is more and more concerned by scholars, and has gradually become a hot topic. The research direction mainly includes the movement law and characteristics of the group, how to effectively and safely supervise the group, so as to develop the efficient and scientific and reasonable evacuation method for the evacuation work of the group, and effectively direct and guide the crowd. At present, the research on emergency evacuation at home and abroad mainly includes the establishment of evacuation model and two aspects of simulation experiment. On the one hand, the establishment of evacuation model mainly uses game theory, social dynamics [5], cellular automata [6], fluid dynamics and other methods. The evacuation model was established, and the performance analysis of the model was carried out to study the aggregation, friction and crowding of the crowd in different environments, so as to guide the effective evacuation of the crowd. On the other hand, the study of the evacuation process in the shortest evacuation path, the fastest evacuation flow and other issues. However, this research needs to be based on the nature of the different road network analysis, such as the static characteristics of the road network, the dynamic characteristics of the crowd and the vehicle and so on. Therefore, most of the current evacuation measures are to ease the crowd in emergency situations, and the hidden crisis for the characteristics of the crowd is lack of relevant research. Urgent evacuation of the crowd is important, but effective prevention and reduction of the occurrence of an emergency is particularly important. How to effectively manage the complex, large crowd in large public facilities, to prevent the occurrence of an emergency is of great significance.

In this paper, the particle swarm optimization [7, 8] is used to abstract and model the evacuation of people in the evacuation scene in emergencies. Each individual is abstracted into particles, and the selection of the optimal value of the particle through the particle Explore the optimal information to change the velocity vector of the particle and keep it near the safe location and evacuate.

2 Particle Swarm Optimization

Particle swarm optimization is a stochastic optimization algorithm for population, proposed by Kennedy and Eberhart. The algorithm has been widely concerned. Rada et al. have studied the algorithm's synchronization and neighborhood size problem. Particle swarm optimization produces a new evolutionary algorithm for the study of foraging behavior of birds. The researchers found that in the process of predation of birds or fish, the group in accordance with a cooperative way, through their own continuous access to information, to adapt, and then obtain information, and then adapt, and constantly adjust their own speed and direction, the whole process is Its optimized process. Use the vector group $(x_i^m, v_i^m, pbest_i)$ to represent the particle, use x_i^m to represent the position of the particle itself, use v_i^m to represent the current direction, use $pbest_i$ to represent the best position of the search itself, all the particles by evaluating a function $f(x)$ to determine the fitness value Change the value. Each particle has a memory function that can remember its own optimal position and follow the surrounding optimal particles. In the standard of Particle swarm optimization, the particle's position and velocity are updated as follows:

$$X_{id}^m = X_{id}^{m-1} + V_{id}^{m-1}. \tag{1}$$

$$V_{id}^m = WV_{id}^{m-1} + c_1 r_1 \left(pbest_{id} - X_{id}^m\right) + c_2 r_2 \left(gbest_{id} - X_{id}^{m-1}\right). \tag{2}$$

In the formula: X_{id}^m represents the position of the population; V_{id}^m indicates the speed at which the person moves; $pbest_i$ is the best position for the i particle: $gbest_i$ is the best bit value for the population; c_1 and c_2 are the acceleration factors, respectively, indicating the particle arrives at the best position Good position of the acceleration weight; r_1 and r_2 are the random numbers between 0 to 1; W is expressed as an inertia factor. The formula (2) shows that the particle velocity update can be divided into three parts: the first part shows the velocity inertia of the particle i, which can form a better balance between the global search and the local search. The second part shows the optimal position of the individual The effect of velocity, which determines the ability of the particle to be locally searched; the third part reflects the effect of the optimal position of the population on the speed, which reflects the communication within the group.

3 Avoidance Mechanism

3.1 Evaluation Function

In the classic Particle Swarm Optimization, the particle only focuses on the final target position and finds that the individual moves directly to the point after the target position and does not take into account the limitations of the obstacle, which is negligible in the evacuation process. In reality, pedestrians should consider each step of the escape route choice, in which static obstacles and other pedestrians will have an impact on the choice of the path, the introduction of the evaluation function to simulate obstacles and other pedestrians on the impact of pedestrians:

$$\cos\ t(p, q) = \exp\left(-\left(\frac{(p-q)^2}{\left(\sigma_p + \sigma_q\right)^2}\right)\right). \tag{3}$$

In the formula (3), p represents a particle, q represents an obstacle, including other particles and static buildings, σ_p is expressed as a particle radius, σ_q is expressed as an obstacle coverage. The evaluation function here refers to the impact of obstacles (including other pedestrians and buildings) in the process of pedestrian movement. Considering the evaluation function [9], the objective function can be set to:

$$F_{obj}(p) = c_{obs} \times \max(\cos\ t(p, o)) + \frac{1}{\cos\ t(p, g)}. \tag{4}$$

In the formula (4), o refers to a collection of all obstacles, g is expressed as a particle-oriented and standard position, c_{obs} is expressed as a weight parameter that adjusts the relationship between the obstacle and the target. The setting of the objective function adds the cost function mechanism, which can more effectively and effectively simulate the path selection in the process of pedestrian orientation.

3.2 Judgment Mechanism

The introduction of the value factor in the evaluation function makes the particles can realize the avoidance of obstacles and other pedestrians to a certain extent. For the more realistic simulation of the actual situation, we introduce the following judgment mechanism [10] on the basis of the above evaluation function, Whether the new position of the trend conforms to the common sense rule and determines whether the new position is accepted as follows:

$$\text{prob}(f) = 1 - \frac{f}{e^{-k}}. \tag{5}$$

In the formula (5), it is the value of the new position, it is constant, used to control the particles near the obstacles and other pedestrian behavior, the function can better prevent the collision between particles. In order to simulate pedestrian obstruction and other pedestrian route selection, if the new location is not accepted, in the original position on the basis of ±15° angle to change the search for the appropriate location. At the same time as the distance and obstacles and other pedestrians close to the distance gradually reduced, the impact of obstacles on the speed as follows:

$$speed = speed \times (1 - \cos\ t(p)). \tag{6}$$

4 Simulation and Analysis

The simulation is evacuated in the form of thermodynamic diagram [11], which shows the geographical area of the population in a special highlight. According to the above algorithm and process, simulation and analysis. In a block size of 10 m × 10 m square, divided into 100 square small area, with red dot. The degree of darkness in each small area represents the number of individuals in the area, that is, the density, the total number of individuals is 500. The degree of light and dark corresponding to the initial density and individual thermal diagram shown in Fig. 1.

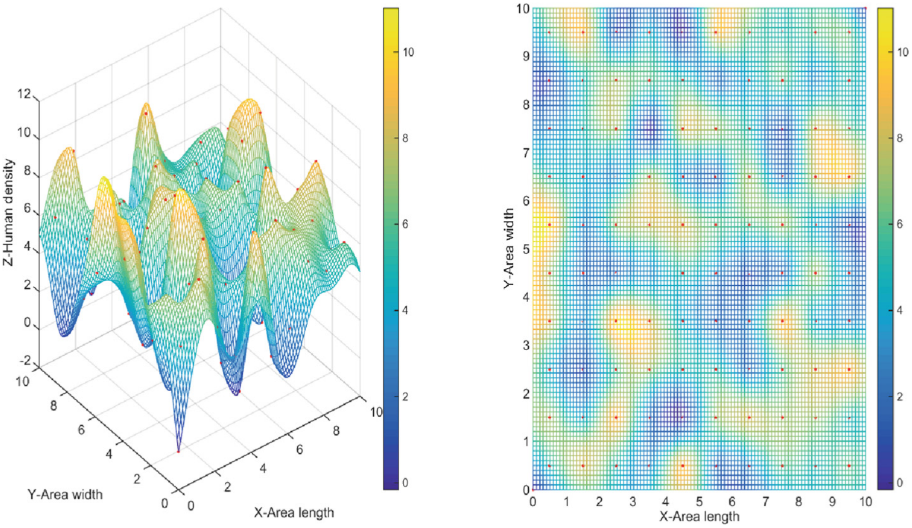

Fig. 1. Population density initial distribution.

In Fig. 1, the x and y axes represent the area range, and the z-axis represents the individual density (i.e., the number of individuals) in each region. Brightness color of the light and dark corresponding to the size of the individual density of each region, the greater the density the more bright colors, and vice versa the darker.

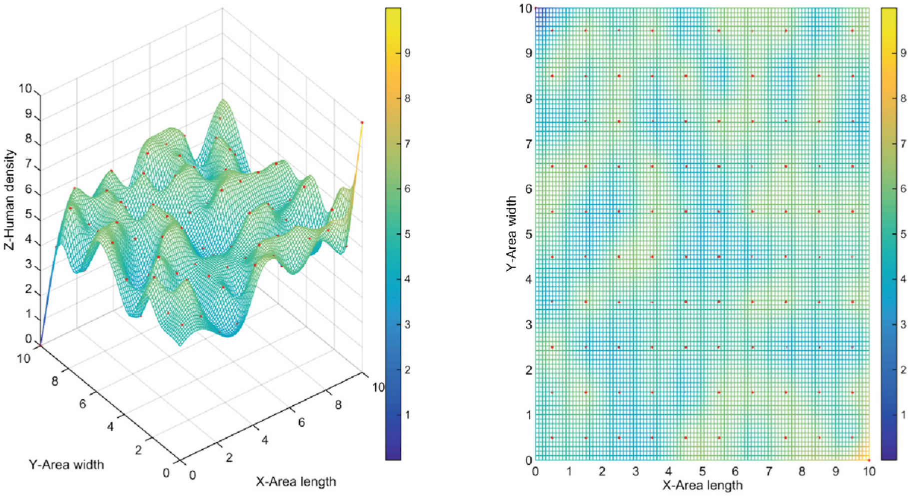

Fig. 2. Population density after evacuation.

In the particle swarm optimization and avoidance mechanism, the density of large areas of the individual flow to the density of small areas, effectively alleviate the pressure of the highlighted area, the density of the dispersion is more average, effectively reducing the incidence of accidents, to protect people The safety of life. as shown in Fig. 2.

5 Conclusion

Effective evacuation of the crowd is an important link in the protection of social security, in recent years due to evacuation and the occurrence of stampede more and more accidents. Through the real-time satellite came the thermodynamic diagram to monitor the gathering of crowded population, once the bright areas immediately into the evacuation process, the use of communications devices highlight the area to evacuate. The evacuation model is combined with particle swarm optimization and thermodynamic diagram, and the improvement and optimization of the evaluation function and the obstacle avoidance mechanism are carried out. The feasibility of the model is verified by simulation. In the future study, we will increase the evacuation guidance factors, group characteristics and dynamic disaster model in the model, and further study the evacuation process of the crowd under complex scenes such as disasters. So as to provide a more in-depth and detailed theoretical basis for the evacuation management of the crowd.

Acknowledgements. This research reported herein was supported by the NSFC of China under Grant No. 71571091.

References

1. In recent years, a list of vicious stampede events. http://china.caixin.com/2015-01-01/100770129.html
2. Cai, C., Niu, Z.: Modeling and simulation of mixed traffic flow at intersection. J. North China Instit. Aerosp. Technol. **19**(2), 18–20 (2009)
3. Chen, T., Ying, Z., Shen, S.: Evacuation simulation and analysis of social force model influenced by relative velocity. J. Prog. Nat. Sci. **16**(12), 1606–1612 (2006)
4. Chui, X., Li, Q., Chen, J., Chen, C.: Research on evacuation model of public places based on multi-agent technology. J. Syst. Simul. **20**(4), 1006–1010 (2008)
5. Zeng, W., Chen, P., Nakamura, H., et al.: Application of social force model to pedestrian behavior analysis at signalized crosswalk. J. Transp. Res. Part C Emerg. Technol. **40**(1), 143–159 (2014)
6. Hu, J., You, L.: Cellular automata model for three-dimensional space pedestrian evacuation. J. Phys. **63**(8), 65–74 (2014)
7. Izquierdo, J., Montalvo, I., Perez, T., et al.: Forcasting pedestrian evacuation times by using swarm intelligence. J. Phys. A **388**(7), 1213–1220 (2009)
8. Zheng, Y., Chen, J., Wei, J., et al.: Modeling of pedestrian evacuation based on the particle swarm optimization algorithm. J. Phys. A **391**(17), 4225–4233 (2012)
9. Rada-Vilela, J., Zhang, M., Seall, W.: A performance study on synchronicity and neighborhood size in particle swarm optimization. J. Soft Comput. **17**(6), 1019–1030 (2013)
10. Chen, Y., Lin, Y.: Controlling the movement of crowds in computer graphics by using the mechanism of particle swarm optimization. J. Appl. Soft Comput. **9**(3), 1170–1176 (2009)
11. Thermodynamic diagram. http://baike.baidu.com/link?url=N_GvhSAIL4a41RKMA9fNT0a-yD4AK_NQa2-Y7smzbDUDAnnKE4eF9j_uOiiU5Q5jo52iwKkB0nrIqY2efxI–9P1qOSlVDz9geFzMkkU7EJDfmiwGovncN8Y3jeMAm_w