

## Construction of the Simulation Algorithm for Evacuation of Commercial Complexes under the Panic Factor

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### Abstract

In order to study the behavior and characteristics of crowd evacuation in buildings, and then organize crowd evacuation reasonably and efficiently in emergency, a simulation model of crowd evacuation in buildings is proposed, which not only accords with reality, but also comprehensively considers many factors. Aiming at the shortcomings of the crowd evacuation simulation model in the existing building emergency evacuation, this model provides a multi-agent evacuation simulation method and system based on panic emotion, which aims to more truly simulate the crowd evacuation process in emergency, and has important practical significance for the crowd evacuation plan in emergency and how to effectively organize crowd evacuation and reduce casualties in emergencies. In order to achieve the above goal, a multi-agent evacuation simulation method based on leaders and panic emotions is proposed. The method includes the following three stages: perception stage, decision-making stage and action stage, and each stage is explained step by step.

### Keywords

Commercial Complex; Simulation Model; Optimisation Design; Coupling Mechanism; Evacuation.

### 1. Perception Stage

Establishing a continuous evacuation scene model of indoor scenes, and initializing ordinary individuals into agents, wherein the agents include attributes of location, speed, type, surrounding environment and panic mood, and the types include leaders, conservative ordinary individuals, steady ordinary individuals and sensitive ordinary individuals; Leaders express familiarity with evacuation scenes; Master escape skills; Can be recognized by ordinary individuals; Their emotions will not be influenced by others, such as shopping guides and security guards[1].

Algorithm: In the initialization stage, the attributes of the Agent are defined as follows:

$$Agent = [id, pos(t), \vec{v}(t), type, R_e, den(t), v_{max}(t), F(t), e(t), e_{hold}(t), P_N, panic(t), dim] \quad (1)$$

Wherein, id represents the unique identification number of the Agent; Pos(t) indicates the position of Agent in the continuous evacuation space model; V(t) represents the actual speed vector of the Agent; Type indicates the type of Agent, 0 indicates the leader, 1 indicates the conservative ordinary individual, 2 indicates the steady ordinary individual and 3 indicates the sensitive ordinary individual; Said the visual field radius of Agent; Den(t) represents the crowd density in the circular field of vision with radius of  $R_e$  of the Agent;  $V_{max}$  represents the maximum speed of the Agent, which is obtained according to the crowd density  $den(t)$ .

$F(t)$  indicates whether you are infected with emotions, 0 indicates that you are not infected, 1 indicates that you are infected, and the leader is always 0, indicating that the leader's emotions will not be influenced by others;  $E(t)$  indicates the emotional value of the Agent,  $e_{hold}(t)$  indicates the tolerable emotional value of the Agent, and the leader is always 10000, indicating that the leader's mood will not be influenced by others; Said Agent's emotional perception coefficient, and the leader is always 0, indicating that the leader's emotions will not be influenced by others; Dim represents the Agent's emotional attenuation coefficient,  $panic(t)$  represents the Agent's panic psychological value, and the parameters  $e(t)$ ,  $e_{hold}(t)$ , PN, dim and  $panic(t)$  are jointly determined by the Agent's type and  $F(t)$ , and  $t$  represents the time step.

Each Agent interacts with other agents' behaviors and environmental parameters, and transmits the obtained information to the decision-making stage. The information obtained by the leader in the perception stage is the surrounding obstacles and whether there are ordinary individuals following; The information acquired by ordinary individuals in the perception stage is the surrounding obstacles, whether there is a leader in the field of vision, and the panic situation of other individuals in the field of vision.

## 2. Decision-making Stage

According to the information obtained in the perception stage, each Agent makes evacuation decisions according to the fastest evacuation principle by analyzing its own ability and environmental conditions[2].

The leader's evacuation decision is as follows: Move to the nearest exit; If there are ordinary individuals following, cooperate with the follower's speed; Avoid collision with other Agent and obstacles in the process of traveling[3].

The evacuation decisions of ordinary individuals are as follows: If an exit is found, move directly to the exit; If you can see the leader, follow the leader's movement; You can't see the exit or the leader, so you choose to follow other ordinary individuals in the field of vision; If you can't see people in the field of vision, randomly choose a direction to move; Avoid collision with other Agent and obstacles in the process of traveling.

## 3. Action Phase

Each Agent responds to the evacuation decision in the decision-making stage, moves, and updates the information after moving to the perception stage of the next cycle. In the action phase, the speed update mode of Agent is as follows:

For the leader, the speed update includes the following steps: iteratively calculating the leader speed according to the particle swarm optimization algorithm; According to his ordinary individual situation, adjust the calculated leader speed; Update the adjusted leader speed according to the surrounding obstacles; For ordinary individuals, the speed update includes the following steps: iteratively calculating the speed of ordinary individuals according to particle swarm optimization algorithm; According to the emotion value, calculating the panic emotion value of ordinary individuals, and adjusting the speed of ordinary individuals according to the panic emotion value; According to the surrounding obstacles, the adjusted ordinary individual speed is updated. For leaders, the speed update includes the following steps: according to the improved particle swarm optimization algorithm, iteratively calculate the leader speed, and the calculation formula is as follows:

$$\vec{v}_l(t+1) = w \cdot \vec{v}_l(t) + c_1 r_1 (Pbest_l(t) - x_l(t)) + c_2 r_2 (x_{exit} - x_l(t)) + \frac{1}{m_l} \sum_{j \in \Omega_l} \vec{f}_{lj} \cdot dt \quad (2)$$

According to his ordinary individual situation, adjust the calculated leader speed; Update the adjusted leader speed according to the surrounding obstacles. For ordinary individuals, the speed update includes the following steps:

According to the improved particle algorithm, the iterative calculation of ordinary individual velocity can be divided into five situations:

(1) If the ordinary individual I can see the nearby exit within the field of vision, the velocity formula of the ordinary individual I is:

$$\vec{v}_l(t+1) = w \cdot \vec{v}_l(t) + c_1 r_1 (Pbest_l(t) - x_l(t)) + c_2 r_2 (x_{exit} - x_l(t)) + \frac{1}{m_l} \sum_{j \in \Omega_l} \vec{f}_{lj} \cdot dt \quad (3)$$

(2) When the ordinary individual I can't see the exit but can see the leader in the field of vision, and if the fitness is greater than fitness<sub>i</sub>, the velocity formula of the ordinary individual I is:

$$\vec{v}_l(t+1) = w \cdot \vec{v}_l(t) + c_1 r_1 (Pbest_l(t) - x_l(t)) + c_2 r_2 (x_{exit} - x_l(t)) + \frac{1}{m_l} \sum_{j \in \Omega_l} \vec{f}_{lj} \cdot dt \quad (4)$$

(3) When the ordinary individual I can't see the exit but can see the leader in the field of vision and fitness<sub>i</sub> < fitness<sub>i</sub>, the velocity formula of the ordinary individual I is revised as follows:

$$\vec{v}_l(t+1) = w \cdot \vec{v}_l(t) + c_2 r_2 (x_l(t) - x_i(t)) + \frac{1}{m_i} \sum_{j \in \Omega_l} \vec{f}_{lj} \cdot dt \quad (5)$$

(4) If the ordinary individual can't see the exit or the leader, but can see other ordinary individuals nearby, the speed update of the ordinary individual I is revised as follows:

$$\vec{v}_i(t+1) = w \cdot \vec{v}_i(t) + \frac{1}{m_i} \left( herd c_3 r_3 \sum_{j \in \Omega_l} \vec{f}_{ij}^{attr} + \sum_{j \in \Omega_l} \vec{f}_{ij} \right) dt \quad (6)$$

(5) If you can't see any ordinary individuals in the field of vision of ordinary individuals, the speed update formula of ordinary individuals is:

$$\vec{v}_i(t+1) = w \cdot \vec{v}_i(t) + (x_{rand} - x_i(t)) \quad (7)$$

In which subscript 1 represents the leader; P 1 (t) indicates the best position in the leader's history; X1(t) indicates the position of the leader; X<sub>exit</sub> indicates the exit position; C1 represents the weight of the individual historical optimal solution part; C2 represents the weight of the group optimal solution part; R1 and r2 are random numbers between [0,1]; W is the inertia weight, which enables the particle to have the ability to keep the inertia of motion, and is used to balance the local and global searching ability of the particle; M1 represents leader quality, ω 1 represents leader neighborhood;  $\vec{f}_l$  represents the force between the leader and the individual J in the neighborhood; Subscript represents ordinary individual I; Pbest<sub>i</sub>(t) represents the best position in the history of ordinary individual I; X<sub>i</sub>(t) represents the position of the ordinary individual I; M<sub>i</sub> represents the quality of ordinary individual I, ω I represents the neighborhood of ordinary individual I;  $\vec{f}_i$  represents the force between the ordinary individual I and the individual J in the neighborhood; Herd represents the herd coefficient;  $\vec{f}_i^{attr}$

represents the attraction between ordinary individuals I and J; Xrand represents any position in the environment:

Update the adjusted ordinary individual speed according to the surrounding obstacles; According to the emotion value, calculating the panic emotion value of ordinary individuals, and adjusting the speed of ordinary individuals according to the panic emotion value; According to the surrounding obstacles, the adjusted ordinary individual speed is updated. Preferably, the calculated leader speed is adjusted according to the situation of ordinary individuals following him, and the formula is as follows:

$$\vec{v}_i(t) = \begin{cases} \min(\vec{v}_i(t), i \in \Omega_i) & |\Omega_i| \neq 0 \\ \vec{v}_i^0(t) & |\Omega_i| = 0 \end{cases} \quad (8)$$

$\Omega_i$  represents the neighborhood of the leader,  $i(t)$  represents the speed of the individual I in the neighborhood, and  $i(t)$  represents the expected speed of the leader himself; According to the surrounding obstacles, the adjusted Agent speed is updated. Based on SFM model, the force  $f_{io}$  between people and obstacles is calculated as follows:

$$f_{io} = \left\{ A_i \exp \left[ \frac{r_i - d_{io}}{B_i} \right] + kg(r_{ij} - d_{io}) \right\} + kg(r_i - d_{io})(v_i \cdot t_{io})t_{io} \quad (9)$$

Among them,  $A_i$  is the coefficient of psychological repulsion and  $B_i$  is the distance coefficient.  $R_{ij}$  is the sum of the radii of ordinary individual I and ordinary individual J;  $r_i$  is the model radius of ordinary individual I;  $D_{io}$  is the distance from ordinary individual I to obstacle O;  $N_{io}$  is a vector of 0 pointing to I;  $T_{io}$  is tangent vector;  $K$  is the elastic coefficient of extrusion, and  $V_i$  represents the speed of ordinary individual I;  $G(x)$  is a piecewise function:

$$g(x) = \begin{cases} x, & x > 0 \\ 0, & x \leq 0 \end{cases} \quad (10)$$

After considering obstacles, the general individual velocity update formula is:

$$\vec{v}_i(t) = \vec{v}_{APSO} + \sum_{w \in \Omega_i} \frac{1}{m} \vec{f}_{iw} dt \quad (11)$$

Wherein, it represents the adjusted Agent speed, which is the weight of the ordinary individual I, and represents the acting force between the ordinary individual I and the ordinary individuals in the neighborhood. According to the emotion value, the panic emotion value of ordinary individuals is calculated, and the speed of ordinary individuals is adjusted according to the panic emotion value. The details are as follows:  $\vec{v}_{APSO} \vec{f}_{iw}$ .

For the Agent whose emotion is not infected, calculate the emotion value, and update the panic value formula based on the emotion value.

$$panic_i = c_1 q_i^{PS-Durupina} + c_2 (v_i^0 - v_i) + c_3 Q + c_4 \quad (12)$$

In panic, update the speed formula.

$$v_i(t) = (1 - panic_i)v_i^0 + panic_i \cdot v_{max} \quad (13)$$

Among them,  $c_1$ ,  $c_2$  and  $c_3$  are proportional constants,  $c_4$  is a constant, which is not 0 if ordinary individuals are still in the evacuation site;  $0$ : QPS-Durupinar means the calculated emotional value if ordinary individuals flee the scene;  $Q$  represents neighborhood  $\omega$ ; Cumulative value of panic;  $V$  represents the expected speed of ordinary individual  $I$ ;  $V_{max}$  stands for the maximum speed of ordinary individual  $I$ . Use PS-Durupinar emotional contagion model considering emotional perception and emotional attenuation to calculate the emotional value of ordinary individuals, as follows:

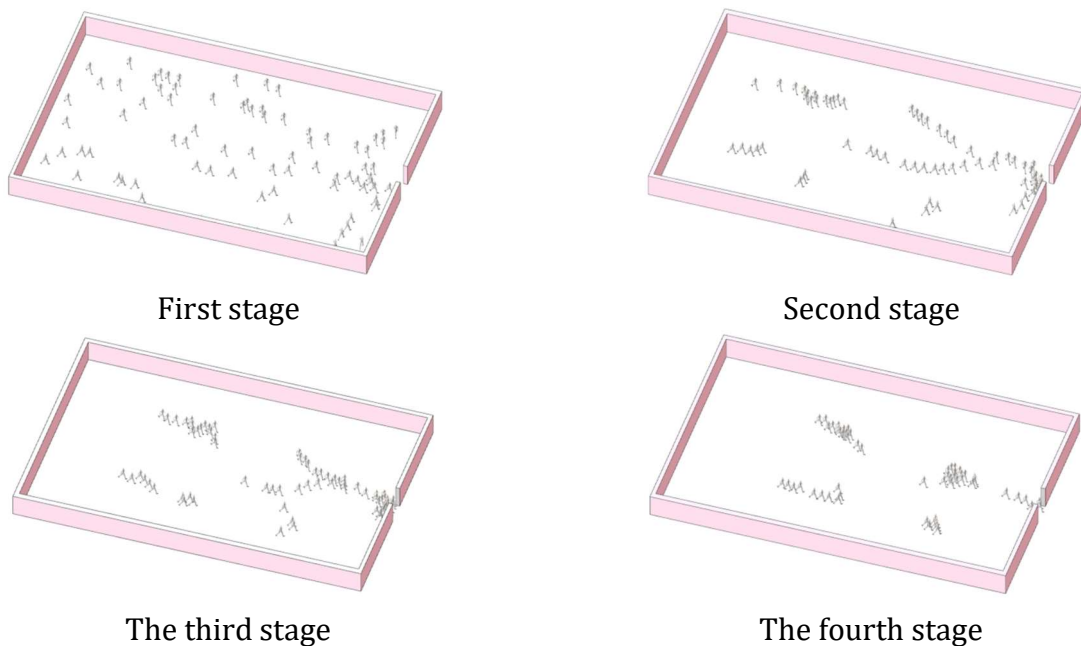
Calculate the neighbor domain of ordinary individuals. According to the neighbor domain and panic, use the following formula:

$$Q(i, R_e) = \sum_{j \in \Omega_i} q_j \tag{14}$$

Judge whether  $q$  is greater than or equal to the panic threshold  $T$ . If so, it means that the individual accepts that the sum of panic in his neighbor domain exceeds his own tolerance threshold, and updates it to emotional contagion state, and the emotional value is updated as follows: if the individual is conservative, then  $e(t) = \text{rand}(0,0.4)$ ; B if the individual is stable, then  $e(t) = \text{rand}(0.4,0.8)$ . C. if the individual is sensitive, then  $e(t) = \text{rand}(0.8,1)$ ; Otherwise, it means that the emotional value accepted by the individual does not reach its threshold, so  $e(t) = 0$ ; Then use the following formula to update the emotional value:  $e_i(t) = p_i \cdot e_i(t)$  If the exit or leader can be seen in the individual's field of vision, then the individual's emotional value will decay, and use the following formula to update the individual's emotional value;

$$e_i(t) = (1 - d_{im_i}) e_i(t) \tag{15}$$

When  $e(t) < e_{hold}(t)$ , the individual will be restored to the emotional uninfected state.



**Fig. 1** optimized evacuation behavior

Image: Self-painted by the author

Generally speaking, through the above technical scheme conceived by this model, the following beneficial effects can be achieved: this model analyzes and summarizes the attributes and behaviors that affect individual evacuation, abstracts the evacuated individual as an Agent, models its attributes, perception, decision-making and behaviors, and establishes an individual Agent model. Considering the interaction between different individuals, individuals and the environment, the behaviors of individuals following the leader, the spread of panic in the crowd, and the avoidance of pedestrians and pedestrians/obstacles are modeled separately, and a crowd evacuation model based on multi-agent is established, which can more truly simulate the process of crowd evacuation in emergency and can more truly simulate the crowd evacuation in emergency.

In this model, an improved particle swarm optimization (PSO) algorithm is proposed as a path selection strategy for individuals during evacuation. Considering visual field factors, the evacuation scenes in buildings are divided into regions, the influence of limited visual field on individual path selection is studied, and the global optimal individual selection strategy of particles is optimized. For individual panic psychology, the quantitative description of panic factors is given, and the speed update formula of the algorithm is optimized to reflect the influence of panic factors on individual evacuation. The social force model is used to solve the interaction between different individuals and obstacles, which makes the improved particle swarm optimization more in line with the actual situation of crowd evacuation in buildings.

## References

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