Simulation study on crowd evacuation based on Arnold emotion model

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Abstract. The computer simulation technology can reproduce the crowd movement trend under the emergency situation in a real all-round way, summarize the movement law, and formulate the emergency plan of public places. It can conduct scientific analysis and guidance on crowd evacuation in emergency situations through comprehensive evaluation of crowd evacuation channels in buildings and public places in combination with the emergency situations that can occur in the movement behavior simulation scenarios in emergency situations. In terms of security research hotspot, the emotion of personnel in emergency has a direct impact on crowd evacuation, so it is necessary to summarize Arnold's emotion model. The occurrence of adverse events in emergency should be avoided to achieve more efficient evacuation of personnel.

1. Research status of crowd evacuation based on Arnold emotion model

Emotion is a kind of experience determined by external environmental reasons and attributes of external environmental factors, which can play an important guiding factor for individual decision-making behavior. In general, individuals automatically imitate and synchronize with others' expressions, sounds, postures and movements, and express emotional infection through emotions. In the field of computer simulation, the relationship between emotion theory and crowd movement can be mapped. [1]

1.1. Crowd evacuation

In the study of crowd evacuation, the scene information and other factors of crowd movement were taken as the preliminary stage of sorting and planning by simulating crowd movement in complex situations, and the optimal route was planned for individual movement through familiar cognition of its scene route. The best way to study crowd evacuation movement is to construct scene route and query. Firstly, according to the known scene, the nodes are randomly generated through probability, and then the location of the nodes is checked through the detection collision system. Once the node obstacle is detected inside the obstacle, the node is recorded into the path obstacle point for clearance, and otherwise added to the designated path. In the set of path points planned by the node to the node, the connection between the points is made. By judging the distance between the points, the intersection between the points and the obstacles is estimated. Otherwise, it cannot be connected. In figure 1, the connecting line of nodes is added to the corresponding path as its margin. On its way, the connecting line of nodes that avoid obstacles is taken as the avoiding space, which is transformed into a discrete space to form a topology diagram composed of the same node and edges. In the process of path query, its location and target are selected as investigation nodes according to the path that can be selected in the figure, and the
optimal solution of the algorithm is used to find the motion path of the path, and the target node is found through the sub-target of path analysis[2], and finally reaches the target location, as shown in figure 2.

![Fig. 1 roadmap Generation Diagram](image1)

![Fig. 2 individual motion path query](image2)

1.2. RVO local obstacle avoidance algorithm

By taking the geometric method as the basis of the algorithm in the crowd path planning algorithm, the traditional VO algorithm is corrected, and the motion speed and motion frequency of individuals are planned and adjusted, so as to reduce the number of collisions between individuals A and B in the scene and effectively avoid risks. See figure 3 for detailed algorithm operations [3].

![Fig 3. Principle of RVO algorithm](image3)

Where V is denoted as individual A and VB is denoted as individual B, and is denoted as the velocity of the two. Mirror the B-A table with respect to the reference point. In order to avoid the collision, in
every moment $t$, individual A can adjust the speed, the speed is A location coordinates as the starting point of A gamma ray, and to determine whether A new velocity $V$ and the current velocity $V_{\text{RVO}}'(V_g, V)$ (that is, the figure in the dark grey shaded area) intersection, if two disjoint, A and B is the individual next time won't produce collision behavior. In the process of motion, first of all, according to the maximum velocity $V_{\text{Max}}$ and the maximum acceleration $a_{\text{ax}}$, the velocity of individual A is limited according to formula (1) to obtain the reasonable set of velocities at the next time. Then, the optimal velocity of individual A at the next time $t$ is calculated. Finally, formula (2) and (3) are used to select the candidate velocity that minimizes the penalty penalty of velocity from the reasonable velocity set $AV$ as the individual's motion velocity $V$ at the next moment[4].

\[
AV_A(V_A) = \{V_A | V_A < V_{A_{\text{Max}}} \cap \|V_A - V_A'\| < a_{A_{\text{max}}} \Delta t\}
\]

\[
\text{penalty}_A(V_A) = \sigma_A \left(1/ tc_A(V_A)\right) + \|V_A^{\text{pref}} - V_A\|
\]

\[
V_A = \arg \min \text{penalty}(V^{11}_a)
\]

1.3. Theoretical basis of the model

A typical model based on thermophysical dissipation is adopted, which is based on individual interaction. Each individual has specific expression power and sensitivity, which is used in the process of individual transmission [5]. The model mainly defines five parameters abcde, all of which are between values. Details are shown in table 1:

| Individual reference | meaning |
|----------------------|---------|
| $a_i$                | The ability of an individual to accept the emotions of others. |
| $b_i$                | The ability of an individual $j$ to express his emotions to others. |
| $c_i$                | Emotional intensity of emotional acceptance in individuals $I$. |
| $d_i$                | Emotional intensity of individual $j$. |
| $e_i$                | Channel strength between receiving individual $I$ and transmitting individual $j$. |

Among them, $\gamma$ says the sensitivity of the individual characteristics, measure to receive individual intensity affected by others' emotions, $\varepsilon$ said individual performance characteristics, will send the individual inner emotions into external performance ability, between individual said to receive and send infection intensity, its value is related to the social relations, the distance between the two. At the same time, in this model[6], it is defined that the infection intensity between individuals $I$ and $j$ is affected by the sensitivity of the sender's emotional expression ability and the sensitivity of the receiver and the channel intensity of the information transmitted between them. Furthermore, we calculated the total number of infection intensity of individual $I$ by accumulating the infection intensity of receiving individual $I$ and other members of the population. The calculation formula is shown in (4). $Q$ represents the emotional change factor of receiving individual $I$, and the calculation formula is shown in (5).

\[
\gamma_i = \sum_{i \neq j} \gamma_{ij}
\]
\[ \Delta q_i = \sum_{i \neq j} \gamma_{ij} e_j / \gamma_i \] (5)

2. Based on Arnold's emotional calculation model

In Arnold's theory of emotion, individual emotions will affect their motor process. If an individual has negative emotions, he will try to stay away from the stimulus. If positive emotions are generated, they will try to approach the stimulus. If it is a neutral emotion, the individual will be ignored, according to the original plan to walk normally. Therefore, based on Arnold's theory that emotion affects individual movement, this paper establishes a crowd movement model based on emotional factors. In this model, firstly, an individual behavior decision-making model is established based on the current individual emotion and other factors. Then the results of individual behavior selection and emotion are applied to the process of crowd motion calculation [7].

![Arnold's emotional calculation model](image)

**Fig. 4** Arnold's emotional calculation model

2.1. SI model

According to Arnold's emotion theory, the SI model divides the population into two types: susceptible individuals (S) and infected individuals (I). In the process of disease transmission, the infected individual will infect the susceptible population with a fixed probability, and the susceptible individual will immediately become infected once infected with the virus and will never be cured.[8]

![Propagation principle of SI model](image)

**Fig. 5** Propagation principle of SI model

In the SI model, \(a\) represents the probability of virus infection when susceptible individuals come into contact with infected individuals, \(a \in (0,1)\) represents the proportion of susceptible individuals in the population to the total population \(N\), and \(I(t)\) represents the proportion of infected individuals in the population to the total population \(N\), \(S(t)+I(t)=1\). The differential equation is shown in the formula [9].
2.2. SIR model
Different from the above infectious disease model, the SIR model divides the population into three types: susceptible individuals (S) and infected individuals (I).

And immune individuals (R). Susceptible individuals have not been infected, but there is a certain probability of emotional contagion, and affect the individual itself has carry emotional contagion, and has a certain probability of infection to other people, but also has a certain probability be cured and obtaining permanent immunity, eventually become immune to the individual, antibodies and immune individuals of the infectious diseases, will no longer be infected[10].

\[
\begin{align*}
\frac{dS(t)}{dt} &= -\alpha S(t)I(t) \\
\frac{dI(t)}{dt} &= \alpha S(t)I(t)
\end{align*}
\]

Fig 6. SIR model propagation principle.

2.3. SIRS model
The SIRS model also divides the population into three categories: susceptible individuals (S), infected individuals (I), and immune individuals (R). But unlike the SIR model, in which immune individuals are permanently effective, the immune individuals in the SIRS model may be re-infected and become infected.[11]

Fig 7. SIRS model

3. Simulation data analysis
In order to more fully validates the effectiveness of the proposed model and the scientific nature, the combination on the basis of the XNA Framework in this chapter, the development environment using XNA Game Studio 2013 and Microsoft Visual Studio 2013, in the laboratory of the crowd movement, on the basis of simulation system, build the 3 d motion simulation platform based on emotional psychology model, calculates the population movement import data information platform, in the 3 d simulation platform to real rendering of different scenarios, based on the emotion psychology model to produce three dimensional motion animation effects, The simulation effect is compared with the real video[12-13]. The platform system is built by intuitively simulating the individual emotional evolution process and crowd evacuation effect, and combined with the simulation system built by the laboratory,
a three-dimensional motion simulation platform based on emotional psychology model is built to produce intuitive crowd motion images. The influence analysis of individual number and individual emotion was carried out respectively, as shown in figure 9. Figure 10.

![Fig. 8 the influence of R on the number of individuals](image)

![Fig. 9. The effect of S on individual emotion](image)

**Conclusion**

Based on the psychological model-arnold emotion theory, this paper makes a psychological model of emotion, constructs an Arnold based emotion computing model, and analyzes the generation and emotional infection process of group emotions. Combined with the improved RVO model, emotion is applied to the process of crowd movement, and individual behavior selection is made by using emotion to change individual motion state (motion direction and speed), so as to make evacuation result more consistent with the real crowd movement.

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