Based On Evacuation Entropy Ant Colony Evacuation Path Optimization Model Considering Classified Crowds

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Abstract. Existing ant colony evacuation path optimization models seldom consider the degree of population chaos and the evacuation status under different classifications of population. Based on the modified ant colony evacuation model of evacuation entropy, this paper establishes models for calm, sensitive and managed crowd respectively. The behavior characteristics of different classified groups in real evacuation scenarios are simulated through modifying its state transition probability and global pheromone updating method. It is of important practical significance for the path optimization in public safety emergency management.

1. Introduction

With the continuous development of urban construction, building models show complex and diverse characteristics. When emergencies occur, how to flee quickly in a large area of space with many obstacles is the key research topic of emergency evacuation model. It is particularly important to design a reasonable crowd evacuation path optimization model to achieve safe and effective evacuation.

The establishment of emergency evacuation model should fully take into account many factors in the real evacuation environment, including psychological and physiological changes, population heterogeneity and so on, so as to make the research results more practical [1]. Li et al. [2] drove mice to escape under panic condition by smoke generated by burning cigarettes, and studied the effect of exit location on panic evacuation efficiency under cluster effect. Wei et al. [3] proposed a multi-agent crowd evacuation model based on entropy, aiming at the fact that the existing crowd evacuation models seldom consider the influence of the degree of "heterogeneous" group movement chaos on the evacuation results. In the optimization of evacuation path, many scholars use ant colony algorithm to construct emergency evacuation model, and get the optimal evacuation path through simulation. Jiang et al. [4] analyzed the influence of the density and visibility of smoke on the evacuation speed and the optimal evacuation path to modify the heuristic function of ant colony algorithm for the evacuation problem in fire smoke environment. Liu et al. [5] proposed a shortest path selection model considering the real-time spread of fire based on the improved ant colony algorithm. By building a hexagonal grid map, the fire spread and evacuation can be synchronized. Zheng et al. [6] aimed at the problem that ant colony algorithm is easy to fall into local optimum, the heuristic function is modified by employee density and the pheromone intensity is adjusted dynamically and adaptively to improve the ant colony algorithm. Du et al. [7] used the ant colony algorithm to find the optimal evacuation path for large passenger flow in complex building structure macroscopically, and adopted cellular automata...
intelligent decision-making model microscopically to construct a subway pedestrian evacuation model based on ant colony algorithm and cellular automata.

However, the above evacuation route optimization models constructed by ant colony algorithm seldom take into account the psychological characteristics of the crowd in emergencies. In the actual evacuation environment, the individual’s evacuation path is easily affected by the psychological and surrounding environment. Therefore, on the basis of Wang Fang’s modified ant colony evacuation model of evacuation entropy, this paper divides the crowd into calm crowd, sensitive crowd and managed crowd. By modifying the state transition probability and pheromone updating method of ant colony algorithm, this paper studies the evacuation path under different crowd classification, so that the simulated evacuation path is more suitable to the psychological status of the real crowd.

2. Evacuation entropy ant colony evacuation path optimization model considering population classification

The evacuation population was divided into calm, sensitive and managed groups. The ant colony evacuation model was established according to the characteristics of the population.

2.1 Calm crowd evacuation model

Calm crowd refers to the transfer according to the rules, not affected by external environmental factors. Therefore, the construction of the calm crowd evacuation model follows the ant colony algorithm model, which moves according to the state transition probability, and updates the pheromone according to the global pheromone updating method. Ant Colony Optimization (ACO) [8] is an intelligent anti-biological optimization algorithm proposed by Dorigo M by observing the walking process of ants from cave to food source. In the evacuation process, the exit is compared to the food source, the starting point is compared to the cave, and the ant is compared to the evacuation individual.

2.1.1 State transition probability. In evacuation environment, assuming that the pheromone content of each path at the initial time is equal, \( \tau_{ij} = \tau_0 \) (\( \tau_0 \) is a constant), the probability of individual transferring from node \( i \) to node \( j \) is shown by formula (1) [8]:

\[
P_{ij}^k(t) = \begin{cases} 
\frac{\tau_{ij}^\alpha(t)\eta_{ij}^\beta(t)}{\sum_{s \notin \text{tabu}} \tau_{is}^\alpha(t)\eta_{is}^\beta(t)}, & j \notin \text{tabu} \\
0, & \text{otherwise} 
\end{cases}
\]

Where, \( \tau_{ij}(t) \) is the amount of pheromone remaining on the path \( ij \) at time \( t \), \( \alpha \) is used to indicate the relative importance of pheromones on path \( ij \), \( \beta \) represents the relative importance of heuristic information, \( \text{tabu} \) is a taboo table that records the path the evacuee has taken in this loop.

\( \eta_{ij}(t) \) denotes visibility and is denoted by heuristic function \( \eta_{ij}(t) = \frac{1}{d_{ij}(t)E_n(t)} \) \( d_{ij} \) is the geometric distance from node \( i \) to node \( j \), \( E_n(t) \) is the evacuation entropy value reflecting the degree of crowd chaos. It is shown by formula (2) - (6) [3]:

\[
E_n = \sum_{i=1}^{2} \alpha_i E_{n_i}
\]

\[
E_{n1} = -\sum_{i=1}^{n} \frac{n_i}{N} \log \frac{n_i}{N}
\]

\[
E_{n2} = -\sum_{j=1}^{m} \frac{m_j}{N} \log \frac{m_j}{N}
\]
Among them, $E_{n1}$ is the velocity direction entropy, $E_{n2}$ is the velocity magnitude entropy, $n_i$ is the evacuee in a certain velocity direction within the grid, $m_j$ is the evacuee in a certain velocity range within the grid, and $N$ is the total number of evacuees in the grid. $\alpha_i$ is the weight coefficient, usually $\alpha_1 = \alpha_2 = 0.5$.

2.1.2 Global pheromone updating. When the evacuation crowd completes an iteration from the starting point to the exit, the pheromones left on the path will evaporate over time. The Volatilization Coefficient of pheromones is expressed by $\rho$. After an iteration, the pheromones on the path need to be updated globally. The update method is given according to formula (7) - (9):

$$\tau_{ij}(t + 1) = (1 - \rho)\tau_{ij}(t) + \Delta\tau_{ij}(t) \quad 0 < \rho < 1$$  \hspace{1cm} (7)

$$\Delta\tau_{ij}(t) = \sum_{k=1}^{n} \tau^k_{ij}(t)$$  \hspace{1cm} (8)

$$\tau^k_{ij} = \begin{cases} Q, & \text{if the individual } k \text{ passes through the path } ij \text{ in the loop} \\ 0, & \text{else} \end{cases} \hspace{1cm} (9)$$

Where, $\Delta\tau_{ij}(t)$ denotes the increment of pheromones on path $ij$ after the end of this iteration, $\tau^k_{ij}$ is the amount of pheromones left on path $ij$ after an iteration by individual $k$, $Q$ represents the intensity of pheromones, and $L_k$ means the total path length that individual $k$ takes in this iteration.

2.2 Sensitive crowd evacuation model
Sensitive people refer to emotional instability, and there is a great randomness in direction selection during escape. During the evacuation process, sensitive people are vulnerable to mood fluctuations, and their node transfer direction will be offset in the direction of the node calculated by the traditional ant colony algorithm according to the state transition probability. Because of this, the evacuation route left behind will bring some misleading information.

2.2.1 Selection of Transfer Direction. In grid modeling, the moving direction of evacuated individuals can be divided into eight directions: up-down, left-right and diagonal. Considering that in the actual evacuation process, most evacuated individuals only consider the forward direction, but neglect the choice of the direction behind them, so the sensitive crowd will appear in the direction selection as shown in figure 1.

![Figure 1. Direction selection of sensitive crowd](image)

In figure 1, the black solid line is the direction of transition calculated by formula 1, and the sensitive crowd will turn 90 degrees left and right according to that direction, as shown in the direction of the dotted arrow in figure 1.

2.2.2 Improvement of global pheromone updating. The reference value of the path out of the sensitive population is not very high, and it will be misleading. Therefore, the volatilization of pheromone can be accelerated by increasing $\rho$. Let $0.9 < \rho < 1$. 

$$i = 1, 2, 3, \cdots, 8$$  \hspace{1cm} (5)

$$j = 1, 2, 3, \cdots, 8$$  \hspace{1cm} (6)
2.3 Managed crowd evacuation model
Managed crowd refers to those who know where the exit is and can quickly and accurately find the optimal path according to the current environment.

2.3.1 Improvement of state transition probability.
For managed crowd, they are familiar with evacuation scenarios and know the general direction of safe exit, each step of evacuation must be closer to the exit. In traditional ant colony algorithm, $d_{ij}$ is usually used to represent the distance between two nodes. Starting from the $i$ node, it tends to select the $j$ node which is close to each other. The distance between two adjacent nodes can be calculated in real time. For the managed crowd, $d_{ij}$ can be directly calculated by calculating the distance between the current node and the exit. That is, $i$ is the current node, and $j$ is always the exit node. The managed crowd always choose a shorter distance to move forward, step by step close to the exit.

2.3.2 Improvement of global pheromone updating.
The evacuation path of managed crowd has great reference value, so in ant colony evacuation model, the influence of pheromone left behind by managed crowd can be enhanced by greatly reducing the volatilization coefficient of pheromone ($0 < \rho < 0.1$). It is convenient for the calm and sensitive people to find the optimal path according to the useful tips left by the managed crowd, which is similar to the guiding role played by the managers in the actual evacuation.

3. Experimental simulation and data analysis
In this paper, an evacuation space containing obstacles is set up. The evacuation population of 50 people is placed at the starting point in turn. Among them, 20 people are calm, 20 people are sensitive and 10 people are managed. All kinds of people look for the exit from the starting point. Setting parameters

3.1 Simulation scenario.
In this paper, the experimental scenario is a 100 m * 100 m double-exit square room, which is equipped with obstacles of different sizes. The whole evacuation space is gridded, each grid edge length is 5 m, a total of 20*20 grids. The specific evacuation scenario is shown in Figure 2 below.

![Rasterized evacuation scene map](image)

Figure 2. Evacuation Scene Diagram
In figure 2, the obstacles are shown with blue marks. The green circle is the initial starting point, and the red square module is gate 1 exit and gate 2 exit respectively.
3.2 Setting parameters

The settings of initialization parameter values in the algorithm are shown in Table 1 below.

| parameters | value |
|------------|-------|
| $\alpha$, $\beta$ | 2, 3 |
| $Q$ | 1 |
| $maxgen$ | 100 |
| $popsize$ | 50 |
| $V_{max}$ | 2.0 m/s |
| $\tau_0$ | 0.1 |

3.3 Analysis of simulation data

Figure 3. Ant Colony Evacuation Path Map under Different Classification Populations

The red and blue paths in figure 3 are the optimal paths for calm and managed people to get to Exit 1 and Exit 2, while the purple-red path is the path for sensitive people to get to Exit 1 and Exit 2. It can be seen that after a hundred iterations, the shortest path can be found for both the managed crowd and the sensitive crowd. The sensitive people will wander and detour due to the uncertainty in the path selection, which is consistent with the real evacuation scenario. The crowd has a blind escape due to poor psychological quality. The iterated path map is complex and not the shortest, which greatly increases the evacuation time and reduces the evacuation efficiency.

Figure 4. Managed crowd and calm crowd path iteration curve
Figure 4 is the iteration chart of the path from the starting point to exit 2 for managed people and calm people. It can be seen that although the shortest path has been found in the end, managed crowd can find the best path to exit more quickly because they are familiar with the scenario route.

4. Conclusion
Based on the improvement of the traditional heuristic function of evacuation entropy, this paper constructs an ant colony evacuation path optimization model for different classified populations, which divides the evacuated population into calm, sensitive and managed crowd, and takes into account the behavior characteristics of different groups to construct their own ant colony evacuation path optimization model based on evacuation entropy. The classification of the crowd is universal, which fits the psychological characteristics of the actual evacuation crowd, and can more realistically simulate the evacuation path of different groups of people.

However, the model does not take into account the relationship between cooperation and competition in the process of group evacuation. In the actual evacuation process, there are often three or two pairs of cooperation and competition in a single site. The follow-up research process will focus on the above situation to make the model more realistic.

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