Simulation Research of Guide Person Evolutionary Game of Evacuation Based on Improved PSO Algorithm

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Abstract

A guide person evolutionary game of evacuation model based on improved PSO algorithm is established, which optimizes the moving intention position of the guide person and the evacuees. The simulation results rational reflect the evacuation process in emergency situations. The results indicate that with the increase of the number of guide persons, the evacuation time under different imitation coefficients have a trend of decreases first and then increases. After reaching of the minimum evacuation time, with the continue increase in the number of guide persons, the contrary the overall evacuation time increase. From view of the cooperation probability, when the guide persons less than 8, the evacuees maintain a cooperative attitude, with the increase in the number of guide persons, the cooperation probability all have varying degrees of decrease under four kinds of imitation coefficients. When the number of guide persons is 6, the bigger the shortest path coefficient is, the longer the whole evacuation time is. When the value of $C_1$ is fixed, the larger the imitation coefficient is, the smaller the evacuation time; When the number of guide persons increase to 50, the larger the value of $C_2$, the smaller the overall evacuation time instead; when the $C_1$ value is fixed, the larger the imitation coefficient, the larger the evacuation time. In the case of a small number of guide persons, the overall evacuation efficiency can be increased by increasing the range of influence of the guide person.

Keywords: group evacuation, improved PSO algorithm, evolutionary game, guiding effect, simulation.

1. INTRODUCTION

With the acceleration of urbanization throughout China, population density is increasing in bustling area of the city (Barik and Pradhan, 2015), the available space is increasingly reduced (Blue and Adler, 2001), in the event of an earthquake, fire and other emergencies the improperly dispose will lead to serious consequences. To study the best solution of evacuation of people in public buildings is the primary method to ensure personal safety and to reduce the loss of property (Liu et al., 2009). With the continuous development of computer technology, adopting computer simulation technology to simulate emergency evacuation or typical phenomenon of pedestrian flow (Bousefsaf et al., 2014), to describe characteristics of group behavior has become the commonly used method of researchers (Seyfried et al., 2006).

At present, the research on emergency evacuation has focused on the setting and optimization of emergency identification or guidance in public places (Varas et al., 2006). Emergency signs, by the establishment of physical barriers or other warnings in prominent locations, such as additional obstacles in the ground, barriers (Lo et al., 2006), set up emergency signs and other to assist evacuation of the group (Zheng and Cheng, 2011). However, the actual results show that people in the emergency scene usually do not see these signs or make their own judgments alone, delayed the precious escape time. The setting of a number of evacuation guide persons can effectively reduce the group panic, and improve evacuation efficiency (Hou and Peng, 2014). For the role of the guide person, the researchers summarized as static guidance and dynamic guidance two aspects (Korhonen et al., 2005; Mourcoul et al., 2014). Through the study of the number of guide person, control range and guidance mode etc (Tanimoto et al., 2010), can fully play the evacuation role of guide person in emergency situations, improve public environmental safety (Yanagisawa and Nishinari, 2007).

Regarding to the above research defects, a guide person evolutionary game of evacuation model based on improved PSO algorithm is established (Nishinari et al., 2003). The model optimizes the moving intention position of the guide persons as well as the evacuees, according to the simulation model, the relationship
between the number of guide person, the influence range of the guide person and the cooperation probability is studied (Frank and Dorso, 2011; Raja et al., 2015). The results show that the simulation model can reflect the evacuation process in emergencies, and can be used as a theoretical reference for similar research.

2. GUIDE PERSON EVOLUTIONARY GAME OF EVACUATION MODEL BASED ON PSO ALGORITHM

PSO (Particle Swarm Optimization) starting from random solution, through iterative computations finding the optimal solution, ultimately global optimization of group behavior, the principle can be expressed as PSO = Momentum + Self-knowledge + Social-knowledge (Liu et al., 2011). During the process of simulation, the number of target population particle is randomly generated in the system region. The monomer particles according to their own individual and social behavior rules, in accordance with each iteration process to update and evolve their own location and gradually move toward the destination (Sugiman and Misumi, 1988; Zhou et al., 2014).

Moving profit $P_{ij}$ is used to simplify the dynamic parameter evacuation model, $P_{ij}$ can be expressed as:

$$ P_{ij} = D_{ij} + E_{ij} $$

In the formula $E_{ij}$ is a space parameter, which reflects the attraction of the idle position and the occupied position to the monomer particle. $D_{ij}$ represents the direction parameter, the expression is:

$$ D_{ij} = \begin{cases} \frac{S_m - S_s}{1} & \text{Level, } i + j = 1, -1 \\ \frac{S_m - S_s}{\sqrt{2}} & \text{Inclined, } i + j = 0.2, -2 \end{cases} $$

$S_{00}$ is value of the static field which is the center position of the moving field; $S_{ij}$ is the static field, which indicates the shortest distance from the exit; the method for calculating the static field is usually Euclidean distance, the formula is:

$$ S_{ij} = \min_m \left( \min_n \sqrt{\left(x - x_n^m\right)^2 + \left(y - y_n^m\right)^2} \right) $$

$(x, y)$ is the coordinates of the particles in the system region and $(x, y)$ is the space, $(x_n^m, y_n^m)$ is the coordinates of the nth particle in the nth gate; when $(x, y)$ is Obstacles, $S_{ij}$=M, M is a positive number, and the value is large, indicating that obstacles has almost no attraction on the individual.

Based on the above analysis, an improved guide person game model is established, through the optimization of formula 1, the influence of the information transmission on the evacuation process under the guidance mechanism is analyzed (Wang et al., 2012). The main idea is that the system area is divided into N intervals, each interval contains a guide person, people in this range all willing to follow the command of the guide person, each movement of the monomer can be expressed by iterative method:

$$ X(t+1) = X(t) + G_L + P_{best} $$

In the formula, $G_L$ is the guide persons in the region; $P_{best}$ is the shortest path. On this basis, we can calculate the particle swarm iterative algorithm of the evacuees and guide persons. Evacuee is calculated as:

$$ X(t+1) = X(t) + C_1 \cdot G_L + C_2 \cdot P_{best} $$

Guide person is calculated as:
\[ X(t+1) = X(t) + C_1 \cdot G_L \]  \hspace{1cm} (6)

\( C_1 \) and \( C_2 \) is the shortest path and the guide person's weight coefficient respectively, the range of both is \([0,1]\).

After multiple iterations, the particles in the system are concentrated to the individual strategy with the highest profit in the region (Yuan and Kang, 2009). In each round of game, an individual gains a profit and updates the rules based on their neighbor's strategy.

\[ w(P_x > P_y) = \frac{1}{1 + \exp[-(P_x - P_y)/k]} \]  \hspace{1cm} (7)

\( K \) is the parameter; \( P_x \) and \( P_y \) are the profits of any two particles. The more participants in the model compete for the same position, the less the individual profits. After a single game simulation, the individual has a chance to learn from neighbors, to imitate the character of neighbors with more profits, the group all synchronized to imitate the neighbor character. The individual chooses his neighbors to find the individual with the greatest profits, that is:

\[ p_{max} = \frac{1}{1 + \exp\left(\frac{P_{pro_i} - P_{pro_j}}{K_p}\right)} \]  \hspace{1cm} (8)

\( P_{pro_i} \) is the individual profits of participant \( i \). \( P_{pro_j} \) is the neighbor profits of the maximum individual profits; \( K_p \) is the imitation coefficient.

3. EVOLUTIONARY GAME OF EVACUATION SIMULATION BASED ON GUIDE CHARACTERISTICS

3.1 Simulation result and analysis with single exit

According to the established guide person evolutionary game of evacuation model based on PSO algorithm, the simulation analysis is carried out, and the model is shown in Figure 1. The system model is a single exit rectangular space with an exit width \( L \) of 2 grids and an initial population density \( K = 0.3 \). In the model of Figure 1, set the imitation coefficient \( K_p = 1 \), the number of guide persons is six, and \( C_1 = C_2 = 0.5 \). In the figure, the green squares represent the collaborators; the blue squares represent the betrayers; the red squares represent the guide person. The ratio of collaborator to betrayer is 1:1, the collaborator and betrayer can transform to each other during the evacuation process.

![The dynamic evolution of the guide person evacuate the group with single exit](image)

**Figure 1** The dynamic evolution of the guide person evacuate the group with single exit
It can be seen from the figure that, after initialization of the model, the evacuees and the guide persons are distributed in the rectangular indoor space. When the number of iterations is 10, the groups including the guide persons are all heading towards the only exit direction. After 50 time iterations, the guide person gathered around a number of people, follow the guide to evacuate from the exit. As the number of iterations increases, the number of betrayers decreases. When the number of iterations exceeds 100, the betrayers disappear and the evacuees are left with the guide persons and collaborators. The model established in this paper also consider guide persons as part of evacuees, the guide persons will help to evacuate others while they are also evacuating, it is more in line with the actual situation.

![Figure 2](image.png)

**Figure 2** The relation curves of guide person number with cooperation probability and evacuation time

Figure 2 shows the relationship between the number of guide persons and the cooperation probability of evacuees and the evacuation time. The evacuation characteristics of $K_p$ are 0.1, 0.5, 1 and 10, respectively are investigated. From the evacuation time, On the whole, with the increase in the number of guide persons, the evacuation time of different imitation coefficients decreases first and then increases. When the minimum evacuation time is reached, the overall evacuation time increases with the number of guide persons increases. This is because when the number of guides is too many, the transmitted information will be too much, contrary it would interfere with each other cause confusion, to some extent affect the judgment of evacuees, delay the reaction time, that is too many guide persons will not improve evacuation efficiency, but will delay the evacuation time, reduce the evacuation efficiency. The number of guide persons needed to achieving the minimum evacuation time is different under different imitation coefficient, when $K_p=1$, the number of guide persons with the minimum total evacuation time is 26 and the evacuation time is 180 iterative time steps. With the increase of the imitation coefficient, the number of the guide persons with the minimum overall evacuation time is gradually decreased, but the shortest evacuation time is gradually increased. When $K_p=10$, the minimum evacuation time is 190 iterative time steps, but only 8 guide persons needed. From the view of cooperation probability, when the guide persons is less than 8, under the four kinds of imitation coefficient the cooperation probability curve values are 1, indicating that when guide person is less, the evacuees maintain a cooperative attitude, when the number of guide person is more than 8, the cooperation probability curve of $K_p=10$ decreases firstly. With the further increase of the number of guide persons, the cooperation probability of the four kinds of imitation coefficients decreases to varying degrees. When the number of guide persons increases to 36, the cooperation probability under the four imitation coefficients is reduced to the minimum value of 0.5, indicating that when there are too many guide persons, the individuals in the group begin to imitate the neighboring individuals, which leads to the increase of the conflict and the increase of overall evacuation time.
Figure 3 shows the relationship between the weighting coefficient $C_1$ and the evacuation time in the case of two kinds of guide person numbers. The larger of $C_1$, the stronger of the subjective ability of evacuees, the more believe in themselves. On the contrary, the smaller of the value, indicating that evacuees are more trust guide person’s decision. From the figure can be seen, when the number of guide persons is 6, the larger the $C_1$ is, the longer the whole evacuation time is. When $C_1$ is fixed, the $K_p$ is bigger and the evacuation time is smaller. When the number of guides increases to 50, the larger the $C_1$, the smaller the overall evacuation time; when $C_1$ is fixed, the larger the $K_p$, the greater the evacuation time. When $C_1=1$, the guide person has lost the role of evacuating, the individual by intuition to escape from the nearest exit, under different imitation coefficients, the evacuation time are all 230 iterative time steps. From the above analysis we can see that the number of the guide person is not the more the better, the evacuees can quickly and frequently exchange information, increase the conformity effect, promote the evacuation process, and when the guide persons is more, the individual subject to interference information from different guide persons, on the contrary it will causes the conflict of adjacent individuals, leads to the overall increase of evacuation time.

3.2 Simulation result and analysis with multi-exit

Based on the single-exit model, a multi-exit evacuation model is established, and the model is shown in Figure 4. The model has two exits, one is the exit A just below and the other is the exit B at the upper right. The width of each exit is two grids. The initial evacuation population including the guide persons is set to 200, and the imitation coefficient $K_p=0.5$.

Figure 5 shows the change of exit A, exit B and overall evacuation population with evacuation time in the case that the number of guide persons is six and the range of influence of each guide person is four grids. It can be seen from the figure that evacuation population of the two exits is almost same and the evacuation curve of the
whole population showed a steady upward trend at the beginning of the evacuation simulation. Since the outlet A is located just below and the location is better, more people choose to evacuate from the A exit. Start from the iteration time \( t = 30 \), the evacuees of exit A is much larger than that of exit B. When the iteration time \( t = 60 \), the difference between the evacuees of exit A and that of exit B is the largest, with a difference of 9 persons. With the evacuees of exit gradually increase, the exit clogging effect occur, the group conflict increase, evacuation efficiency reduce. From the whole evacuation curve, it can be seen that the evacuation speed is obviously reduced at the iteration time \( t = 70-80 \); At the same time, there are some pedestrian change evacuation strategy, to choose exit B to evacuate, thus when the iteration time \( t = 90 \), the number of evacuees of exit B gradually over that of exit A, the overall evacuation efficiency increased significantly. In the end, the total number of evacuees in exit A is 96, and that in exit B is 104. The simulation process is in good agreement with the actual situation.

![Figure 5](image5.png)

**Figure 5** Change of numbers of evacuation people at exit A and exit B with evacuation time

Figure 6 shows the effect of the number of guide persons on the evacuation time under the dual exit conditions. It can be seen from the figure that, as with the single exit case, the evacuation time tends to decrease significantly with the number of guide persons increasing within a certain range. When the number of guide persons is 2, the evacuation time is 180 iterative time steps, and when the number of guide persons increases to 8, the evacuation time is reduced to 110 iterations.

![Figure 6](image6.png)

**Figure 6** Relationship between evacuation time and number of guide person

Figure 7 shows the effect of the influence range of the guide person on the evacuation process. Set the number of guide person to 6, the influence range increase from three to seven grids. It can be seen from the figure that the overall evacuation time of the system decreases significantly as the influence range of the guide person increases. When the influence range of the guide person is 7 grids, the evacuation is completed in 90 iterative time steps, while the influence range is 3 grids, it is increased to 140 iterative time steps. That is, when the range of influence of the guide person is small, most of the evacuees unable to get effective evacuation information, only with their own intuition and the imitation of the surrounding individuals, the overall evacuation efficiency is low; while with the range of influence of the guide person expand, its guiding role is enhanced, can
effectively help evacuees choose a reasonable evacuation path. Therefore, when the number of guide persons is small, the overall evacuation efficiency can be improved by increasing the influence range of the guide person.

![Figure 7 Relationship between evacuation time and influence range of guide person](image)

### 4. CONCLUSION

A guide person evolutionary game of evacuation model based on improved PSO algorithm is established, which optimizes the moving intention position of the guide person and the evacuees. The simulation results rational reflect the evacuation process in emergency situations. The analysis results are as follows:

1. The guide person is also regarded as part of the evacuation group, that is, the guide person help to evacuate others while themselves is also evacuate, in this way the simulation results more in line with the actual situation. With the increase of the number of guide persons, the evacuation time of different imitation coefficients decreases first and then increases, and when the minimum evacuation time is reached, on the contrary the overall evacuation time increases with the increase of the number of guide persons. If there are too many guide persons, the transmitted information will also be too much, which will interfere with each other and cause confusion, to some extent affect judgment of the evacuees, under different imitation coefficients, different number of guide persons is required to reach the minimum evacuation time, with increase of imitation coefficients , the number of guide persons with the minimum overall evacuation time is gradually reduced, but the shortest evacuation time is gradually increased.

2. In the view of probability cooperation, when the guide persons is less than 8, the evacuation group maintain cooperative attitude. With the increase in number of the guide persons, the cooperation probability of the four imitation coefficients decrease in different degrees, when there are too many guide persons, the individuals in the group begin to imitate the neighboring individuals, resulting in increased conflict, which will make the whole evacuation time increase.

3. When the number of guide persons is 6, the bigger the shortest path coefficient is, the longer the whole evacuation time is. When the value of C1 is fixed, the bigger the imitation coefficient is, the smaller the evacuation time is. When the number of guide persons increase to 50, the larger the C1 is, the smaller the overall evacuation time is; when the C1 value is fixed, the bigger the simulation coefficient, the greater the evacuation time. That is, the number of guide persons is not the more the better, evacuees can quickly and frequently exchange information, increase the conformity effect, promote the evacuation process, and when the guide persons is more, the individual subject to interference information from different guide persons, on the contrary it will causes the conflict of adjacent individuals, leads to the overall increase of evacuation time.

4. In the duel exit evacuation model, the evacuation time is decreasing with the number of guide person increase within a certain range. With the increase of the influence range of the monomer guide person, the guiding effect is enhanced, and the overall evacuation time of the system is obviously reduced. In the case of a small number of guide persons, the overall evacuation efficiency can be increased by increasing the range of influence of guide person.
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