ISSN 2616-5767 Vol. 2, Issue 1: 59-63, DOI: 10.25236/AJETS.020015

Study on the Method of Escaping from the Louvre

Ye Wang[1], Hanqi Wang[2], Bowei Yuan[2]

[1]*Department of Chemical Engineering, Dalian University of Technology, Dalian, Liao Ning, China, 116024*
[2]*Department of Electronic Information and Electrical Engineering, Dalian University of Technology, Dalian, Liao Ning, China, 116024*

ABSTRACT. *In this paper, in order to evacuate the personnel in the building under a potential threat, floor topology and the node map are established for preliminary model analysis using the Ant Colony Algorithm. In the analysis, different needs for path planning of evacuators and emergency personnel are considered and the preliminary evacuation model is modified to acquire a three-dimensional dynamic evacuation model for multi-layer buildings which can be commonly applied in a variety of emergencies. To update the path planning in real time, the WSN is introduced to realize the real-time monitoring and data update and develop the latest evacuation plan.*

KEYWORDS: *evacuation, path planning, Ant Colony Algorithm, Queuing Theory*

1. Problem Restatement

1.1 Path Planning and Optimization Problem

In the emergency situation, the target of the evacuators move to the safe area as soon as possible, which is an optimal path planning problem that the destination is the safe areas.

1.2 Solutions to the Special Situations that Occur during the Evacuation Process

In the actual evacuation process, the probability of occurrence of various unexpected situations will be greatly increased. Therefore, the problems to be solved are the evacuation diversion arrangements and the plan to solve the passage congestion like the bottleneck to avoid the secondary accidents.

2. Assumption

• The potential threat occurs inside the building while that from the outside like air raid is not considered in the model.

• The living and security rights of the individuals are equal and no one have an absolute priority to evacuate.

• Every evacuator moves under the direction of the evacuation system and the crowd will not be in panic.

• All elevators will be shut down in case of emergency to prevent possible accidents.

• The speed of evacuators is assumed as, while the speed of different types of evacuators will be modified with a coefficient.

3. The Evacuation Model

3.1 Building of the Evacuation Model

The Shortest Path Algorithm is the core algorithm of the evacuation model in the intelligent evacuation system. Presently, the Dijkstra Algorithm, the Simulated Annealing Algorithm and the Genetic Algorithm are commonly used, which are computationally inefficient and complex. The Italian scholar Macro Dorigo proposed an ant colony algorithm based on population heuristic bionic evolution system in the early 1990s by simulating the ants' collective behavior of path finding, which has the characteristics of distributed computing, information positive feedback and heuristic search and has the advantages of strong robustness and excellent distributed calculating system.

In this model, the floor topology is simulated to establish a map of floor evacuation nodes and the shortest path from node to exit is calculated by the Ant Colony Algorithm. The MCMF node preprocessing method is proposed to optimize the order of the nodes processed by the Ant Colony Algorithm in order to reduce the time that the evacuation model discovers the shortest path.[1] In this case, the change of passage capacity is not considered and the emergency personnel only enter the building via extra entrances, not affecting the evacuation of the evacuators.

3.2 Ant Colony Optimization Algorithm

3.2.1 The Topology Construction of the Building

In the topology, several nodes are set at the intermediate node, the turning point, the security exit, etc., then the nodes are sequentially numbered and the connection relationship between the nodes is determined. The node number set is defined as

ISSN 2616-5767 Vol. 2, Issue 1: 59-63, DOI: 10.25236/AJETS.020015

$V_{node} = \{1,2,\ldots,n\}$, the connection relationship is defined as the edge set $F = \{f_1, f_2, \ldots, f_n\}$ and the relationship between nodes is established as the directed weight graph $G(V_{node}, F)$, in which V_{node} represents the node set and F represents the passage set. Additionally, the emergency exits are preset and the nodes are stored in two-dimensional coordinates.

3.2.2 The Ant Colony Algorithm with Multiple Targets

It is assumed that the tabu list $Tabu_k(k = 1,2,\ldots,m)$ records the node that the ant k is currently passing, m is the number of ants, α, β respectively represent the effects of the information accumulated by the ant and the heuristic factor in the path selection, $\tau_{ij}(N_c)$ represents the pheromones concentration between i and j at the iteration N_c, $\eta_{ij} = \frac{1}{d_{ij}}$ is the heuristic factor and d_{ij} is the weight value of the passage between node i and j. $P_{ij}(N_c)$ represents the possibility of the ant k moving from node i to node j at the iteration N_c, which is determined by the formula as follows:

$$P_{ij}(N_c) = \begin{cases} \frac{[\tau_{ij}(N_c)]^\alpha \times [\eta_{ij}(N_c)]^\beta}{\sum_{k \in allowed_k} [\tau_{ik}(N_c)]^\alpha \times [\eta_{ik}(N_c)]^\beta} & , if j \in allowed_k \\ 0 & , other\ situations \end{cases} \quad (1)$$

In Formula 1, $allowed_k$ is the set of nodes that have not been visited.

If the ant k uses $P_{ij}(N_c)$ to determine the next node to move to only based on the moving possibility, the convergence speed will be fast, which may result in a local optimal solution. To prevent this, r is defined as a random number which is between 0 and 1. If $r < P_{ij}(N_c)$, the node will be selected to expand the search range. $Tabu_k$ is dynamically adjusted as the evolutionary process and the nodes that have passed are placed in it, which are no longer used to make the decision of which node to move to. Each ant ends the loop when finding the target or reaching the maximum number of cycles and saves the path. When finding the shortest path to the target at a certain generation of cycles, the concentration of pheromones on the path will be updated as below:

$$\tau_{ij}(N_c + 1) = (1 - \delta)\tau_{ij}(N_c) + \Delta\tau_{ij} \quad (2)$$

In Formula 2, δ is the coefficient of pheromones evaporation and $\Delta\tau_{ij}$ represents the pheromones increment between node i and j released by the ant reaching the target at each generation of cycles. When the ant k discovers the shortest path in a certain cycle, the pheromones concentration on which is updated through the Ant-cycle Model as below:

$$\Delta\tau_{ij}^k = \begin{cases} \frac{Q}{L_k} & , if\ the\ ant k passes i, j in\ this\ cycle \\ 0 & , other\ siuations \end{cases} \quad (3)$$

In Formula 3, Q is the total amount of pheromones released at each cycle, which is a constant, L_k is the path length the ant k finishes at this cycle and τ_{ij}^k is the concentration of pheromones the ant k releases on the path to the target at a cycle.

3.3 Modification of the Model for Different Types of Individuals

The differences between particular situations is not considered in the genetic model above. However, the actual evacuation situations are usually complicated due to the variety of the evacuator composition. Thus, different types of individuals should be respectively analyzed, but it is not practical to excessively classify the evacuators. Therefore, in the case of evacuation, people involved in the evacuation are divided into the ordinary people, the people with limited mobility and the emergency personnel.

4. Solution to the Evacuation Bottleneck Problem

In the actual emergency evacuation, the passages and exits are often in jam due to the massive flow of people, which is called the bottleneck. It may lead to the reduction in evacuation efficiency, the significant increase in evacuation time and even some secondary events like stampede, which are against the evacuators' safety. This type of situation is similar to the general queuing problem that the queue line should be prevent to be too long and the queuing time should be reduced.

Previously, some scholars had researched on the queuing problem, such as the Chinese Ding Xiaoqing researched on emergency evacuation capacity based on queuing network model in the background of the station and made a simulation model[2], and the American Stephen Louis Dorton did an investigation into the relationship between security checkpoint and destination airport baggage volume and alarm rate using the queuing network and discrete event simulation[3].

In short, the Queuing Theory is widely applied in planning and optimization of the emergency evacuation. In this model, the Queuing Theory is used to find the bottleneck area in which there is a jam that affects evacuation efficiency by building a model and draw from the Simulated Annealing Algorithm to solve the problem, the target of which is to reduce the evacuation time and ensure that the safety standards for evacuators will not be lowered.

4.1 Evacuation Bottleneck Analysis

Based on the evacuation process system applying the Queuing Theory, the estimated time of different processes are obtained by setting different time of passing for areas and analyzing the data of each area combining the actual situation. According to the above analysis, the time of the evacuators passing different areas through simulating the evacuation process on the Matlab. By comparing the time, the areas and extent of the evacuation bottleneck can be identified.

ISSN 2616-5767 Vol. 2, Issue 1: 59-63, DOI: 10.25236/AJETS.020015

4.2 Optimization of the Evacuation Process

The reduction of the evacuation time of each evacuator improves the evacuation efficiency and the decrease of the variance of the evacuation time leads to stable time of the whole process which contributes to planning better evacuation paths by comparison with the prime time of escape.[4] Otherwise, it may cause severe panic and serious losses. The replanned evacuation time and the minimum variance of the evacuation time are calculated as below:

$$\begin{cases} f(x) = kx \\ S_{min}^2 = \frac{1}{n}\sum_{i=1}^{n}[(y_i - f(i))^2] \end{cases} \quad (4)$$

5. Conclusion

In this paper, in order to solve the problem of evacuation when the Louvre is under potential threat, the floor topology and the evacuation node map are established and the Ant Colony Algorithm is applied to construct the preliminary model. In the analysis, the actual situations are considered to modify the primary evacuation model and a comprehensive three-dimensional multi-layer building dynamic evacuation model that can handle a variety of emergency situations. Furthermore, the evacuation model in the background of the Louvre is simulated on the Matlab to find the best path and the shortest time of the evacuation, which verifies the feasibility of the evacuation model. In order to update the real-time path planning, the WSN is applied to monitor and update the data in real time and develop the latest evacuation plan.

References

[1] Yang Jing, Shi Mingquan, Han Zhenfeng & Zeng Xianhua. An Optimization Method for Evacuation Model of Ant Colony Algorithm[J]. Fire Science and Technology, 2015, 34(03):343-346.

[2] Ding Xiaoqing. Research on Station Emergency Evacuation Capability Based on Queuing Network Model and Pedestrian Simulation[D]. Beijing Jiaotong University, 2016.

[3] Stephen Louis Dorton & Liu Dahai. Analysis of Airport Security Screening Checkpoints Using Queuing Networks and Discrete Event Simulation: A Theoretical and Empirical Approach[A]. IIE Annual Conference[C]. 2012.

[4] Lu Dan. Research and Application of Multi-service Desk Queuing System with Priority[D]. Dalian Maritime University, 2011.