Optimal leave path based on ant colony algorithm

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Abstract

With the continuous growth of the population and the continuous improvement of the level of urbanization, how to evacuate safely and effectively in an emergency has become the focus of the people. Taking the Venue Museum in Paris as an example, considering the characteristics of a large number of tourists, the large number of Venue entrances and the complexity of direct calculations in the shortest time, we turn the problem into a solution for the best path. Evacuate visitors and then get the shortest evacuation time. Based on key factors such as human flow density, flow velocity, venue environment, and pheromone, we established a dynamic evacuation model-ant colony model. The results obtained by MATLAB simulation are close to the actual situation, indicating the feasibility of the model. In the model analysis, the accuracy of the results is affected by the characteristics of the ant colony model, such as the convergence speed, which is easy to fall into local optimum. We divided the ants into two subgroups and established an isomorphic two-population ant colony model based on the optimization of particle swarm parameters. Through MATLAB simulation, it is found that the escape time of the calculation is reduced compared with the previous one, which indicates the rationality of the optimization.

Keywords

Ant colony model, Evacuation model, The optimal path

1. Introduction

The Venue is one of the four great museums in the world. It received more than 8.1 million visitors in 2017 and even 10.2 million in 2018. Meanwhile, from students being killed in Toulouse to a soldier attacked outside the Venue museum in Paris, there have been at least 12 major terror-related incidents in France since 2012. For example, on the evening of November 13, 2015, multiple explosions and shootings occurred in the center of Paris, 130 people were killed and injured, and hundreds of people were taken hostage in the Bataclan concert hall, one of which was very close to the Venue museum. In July 2016, 86 people were killed in an attack in Nice, France. In June, the Venue and the Orsay were closed for five more days because of possible flooding.

In recent years, disasters have occurred frequently in major cities and regions around the world. In the face of such concentrated population density, large-scale public buildings in cities are in operation management, and if people in the buildings cannot be quickly organized, the orderly evacuation will result in serious casualties and a serious threat to the safety of the public. Since most public buildings are multi-channel and multi-export, how to make pedestrians most effective in export selection and safe evacuation in the shortest time is an important part of reducing casualties and reducing property losses. The problem of emergency evacuation of groups within buildings has important practical significance Emergency evacuation model has always been a research hotspot. The research on the mathematical model of crowd evacuation can be roughly divided into two categories. One is to treat pedestrians as microscopic particles. Among them, the most famous is Helbing's molecular dynamic model[1], in which he regards pedestrians as interacting particles and focuses on the influence of panic coefficient on evacuation in emergency evacuation. The other is the grid-gas model proposed by Japan, in which people are regarded as particles moving on the grid and the characteristics of crowds are studied through probability and statistics. The other is to treat the crowd as a continuous medium and apply the method of hydrodynamics to study the relationship between velocity and density in emergency evacuation.

Research on evacuation problems began in the 1990 s in China, the first analysis of dynamics of systems is proposed by using the discrete method, first to evacuate the cluster flow evacuation in the analysis of the dynamic characteristics of the cluster set up mobile movement equation of state, at the same time for different spatial characteristics of cluster on the evacuation passageway of flow was studied, and the computer simulation model is established to predict when the emergency evacuation cluster flow properties. [2-4]

In the latest study, Yan-bin Han and Liu Hong proposed a path selection model, which was based on the social force model of obstacle avoidance strategy to construct the evacuation path set, and then adopted the path learning algorithm to discrete and optimize the path in the set. Li-bi Fu et al. studied the influence of pedestrian exit selection behavior, exit distance weighting value or crowd density around exit on evacuation time by combining the minimum effort algorithm with cellular automata model, and finally found that two exits located in different walls, especially symmetrical walls, are conducive to evacuation process.

2. Model establishment and analysis

In order to analyze the problem more clearly and conveniently, we give the following assumptions:

In the unobstructed situation, the running speed of the personnel is consistent and uniform.

The distance between the upper staircase and the lower staircase is the height of the floor.

The population density is consistent at each channel.

All people have the same reaction time in the event of an emergency.

On the way to evacuation, everyone does not try to surpass the person in front.

2.1 Glossary

The flow density reflects the density of the distribution of people in the flow of people, usually refers to the number of people distributed per unit area.

The speed of people flow is the speed of travel of the whole flow of people, and its value is the spee d of travel of the first segment of the flow of people.

The number of security queues refers to the number of people allowed to pass at the same time whe n the width of the evacuation channel is constant, while ensuring that the security is not crowded.

2.2 Symbols

Symbols	Definition	Units
n_i	Number of people in each venue	J
j	Number of building floor	J
v	speed	J
f	Unit horizontal projected area	K
x	Projection of average level of normal visitors	K
y	Projection of average level of group visitors	km^3
z	Projection of average level of disabled visitors	m
a	The percentage of normal visitors to the total number of visitors	
b	The percentage of group visitors to the total number of visitors	
c	The percentage of group visitors to the total number of visitors	

β	Expectation heuristic factor	

2.3 Overall analysis

In this case, the time for evacuation depends on many factors. If these factors are not simplified, the problem will be very complicated. In order to facilitate the establishment of mathematical models, and find the most reasonable plan to evacuate, we consider the situation first that only the pyramid entrance and the three VIP channels are open, and then making further improvements based on this model to obtain a mathematical model closer to reality. The factors affecting the model are mainly the flow density, the flow velocity(f), the walking speed(v) .

2.4 Retreat distance

Reasonable choice of exit and optimal evacuation route is also an important factor affecting time.

The selection of optimal route for dynamic evacuation is very similar to the foraging process of ants. In the network diagram of n nodes, the starting point of staff evacuation s is regarded as ant nest, and the safety exit node T is regarded as the food source that ants are looking for. Ants walk a certain route from the starting point and reach the target node after the node. Suppose m is the number of ants, and n is the number of nodes. $b_i(t)$ represent the number of all ants in i node at t time, namely, $m=\sum_{i=1}^{n} b_i(t)$.,T_{ij} is the pheromone concentration at t time in path $\langle i, j\rangle$.

$\Gamma=\{\tau_{ij}(t) w_{i_n} w_j \in w\}$ is a collection V of pheromone concentrations remaining on the edges e_{ij} of the nodes connected in t time set. At the initial time, the pheromone concentrations are equal in each path. Assuming that $\tau_{ij}(0)=C$ .In the formula, C is a constant. The optimal path selection based on the ant colony algorithm is realized by finding the nodes in the node set W and obtaining the path minimum. During the movement, the ants $k(k=1,2,3\cdots,m)$ select the next node according to the number of pheromones on each path, and use the taboo table $tabu_k$ to record the nodes that the ants are currently walking. The path set is dynamically adjusted along with the evolution of taboo. Suppose $p_{ij}^k(t)$ represents the state transition probability of ant from i node to j node at t time, and its expression is as follows.

$$p_{ij}^k(t)=\begin{cases}\dfrac{\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}{\sum_{s\in allowed_k}\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)}, ifj\in allowed_k \\ 0, otherwise\end{cases} \tag{1}$$

In the formula, $allowed_k$ represents the node that the ant can choose, and the transition probability $p_{ij}^k(t)$ is proportional to $\tau_{ij}^{\alpha}(t)\eta_{ij}^{\beta}(t)$. The α is an information heuristic factor, representing the pheromone accumulated by ants in the process of movement. The larger the value is, the more inclined the ant is to the path that other ants have gone through, and the more obvious the collaboration ability between ants is. β is the expected heuristic factor, representing the relative importance of information visibility and reflecting the importance of the heuristic pheromone in the path selected by ants in the process of movement. The larger the value is, the greater the probability of the state transition is. $\eta_{ij}(t)$ is the heuristic function, whose expression is as following.

$$\eta_{ij}(t)=\frac{1}{d_{ij}} \tag{2}$$

In the formula, d_{ij} is the distance between two adjacent nodes. The heuristic function represents the expected degree of transition from node i to node j. After n moments, the ant completes a cycle, and the pheromone quantity on each path is adjusted according to the following formula:

$$\begin{cases} \tau_{ij}(t+1) = (1-\rho)\cdot\tau_{ij}(t) + \vartriangle\tau_{ij}^{k}(t,t+1) \\ \vartriangle\tau_{ij}^{k}(t,t+1) = \sum_{k=1}^{m}(t,t+1) \end{cases} \tag{3}$$

In the formula, $\tau_{ij}^{k}(t,t+1)$ represents the amount of pheromone that the ant k left on the path $\langle i, j\rangle$ at time n, and its value depends on the degree of performance of ants. The shorter the pathway, the more pheromone are released. $\rho\in(0,1)$ is the attenuation coefficient of pheromone trajectory, $(1-\rho)$ is the decay coefficient of the pheromone trajectory, and the coefficient $\rho<1$ is usually set to avoid the infinite increase of the trajectory quantity on the path.

According to the global optimal solution, the global pheromone updating adopts the following ant-week system model.

$$\tau_{ij}^{k}(t,t+n) = \begin{cases} \frac{Q}{L_k} \\ 0 \end{cases} \tag{4}$$

In the formula, if the ant k goes through path $\langle i, j\rangle$ in this cycle, then $(t,t+n)$ means that the ant completes the cycle once after n steps. L_k is the path length taken by ant k in this cycle. Q is a constant.

2.5 Find the optimal route

Firstly, all the ants are concentrated at the starting point s. Ant k starts from point s and follows the selection strategy to select a path from the set associated with s.

Then, we start at another node a on this edge, and we pick another edge from the set of edges associated with it, and so on until you reach the end T of the search. Each time the ant selects an edge, it updates the amount of information on the edge. After the ant k searches, the ant starts out and, in the same way, searches out a path from d to T, and gets a solution.[8-13]

Until all the ants have searched, m solutions (including duplicates) are obtained. Based on m solutions, a local search algorithm is adopted to obtain the local optimal solution. The global information increment (global update) is calculated according to the local optimal solution. After the global update, the iteration continues until the stop condition is met, and the stop condition is the maximum number of iterations. Among all the local optimal solutions obtained, the solution with the smallest value is the global optimal solution, that is, the distance value of the shortest path. The main implementation steps of solving the shortest path problem with the basic ant colony algorithm are as follows:

nc is the number of iterations or the number of searches, initialize τ_{ij} and $\vartriangle\tau_{ij}$, and put ants on n vertices at random.

The initial starting point of each ant is placed in the current solution set. For each ant k, move probabilistically to the next vertex j and place vertices in the current solution set.

Calculate the value of each ant's objective function Z_k, and record the current best solution.

Modify the track strength according to the update equation.

Regarding (i, j), command $\tau_{ij}\leftarrow 0$, $nc\leftarrow nc+1$

If $nc<$ the number of scheduled iterations, and there is no degenerate behavior. Then go to step two.

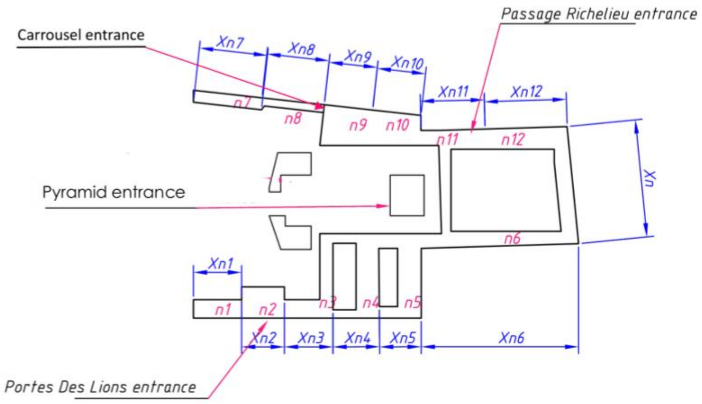
Output the best solution available

The specific flow of ant colony model is shown in the figure 2.

The time complexity of the whole algorithm is $O(nc?n^2 \cdot m)$,if select $m \approx n$, then the time complexity of ant colony algorithm is $O(nc?n^3)$. Theoretically, this complexity is acceptable in computing time.

3. Solution of model

Take a venue as an example. The floor plan is as follows.



it is divided into 12 nodes and 4 exits. The algorithm is implemented by MATLAB, and it can be obtained according to the proportion:

$n_1 = n_2 = n_3 = n_4 = n_5 = 48m,\ n_6 = 240m\ ,n_{11} = n_{12} = 120m$

The number of tourists in the Venue on a certain time of a certain day in the evacuation route is 1000. The population group number is set as 4 groups, and the pheromone attenuation concentration coefficient is set as 0.01. The optimal evacuation plan can be obtained through programming in MATLAB, namely, people in n_1, n_2, n_3 walked the portes pes lions entrance for evacuation, people in n_4, n_5, n_6 walked the carrousel du louver entrance for evacuation, people in n_7, n_8 and n_9 should be evacuated by public entrance, while people in n_{10}, n_{11} and n_{12} should be evacuated by passage Pichelieu entrance.

4. Evaluation and Promotion of Model

4.1 Strength

Wide range of applications, with good versatility.

Easy to combine with other algorithms to improve the performance of the algorithm.

Support indirect communication with typical self-organizing features.

Its a population-based evolutionary algorithm with parallelism that is easy to implement in parallel.

4.2 Characteristics of the model

Based on the above analysis and description, it can be known that the ant colony algorithm is a probabilistic algorithm for finding an optimized path on the way, which can be summarized as two aspects.

Diversity

The diversity ensures that the ants do not enter the dead end and infinite loops while feeding, ensuring the system's ability to innovate.

Positive feedback

The positive feedback mechanism ensures that relatively good information can be saved. We can think of diversity as a creative ability, and positive feedback is a learning enhancement.

It is the clever combination of these two points that makes intelligent behavior emerge. The two must be just the right combination. If the diversity is too much, that is, the system is too active, this is equivalent to the arbitrarily random movement of the ants, it will fall into a chaotic state; on the contrary, the diversity is not enough, the positive feedback mechanism is too strong, then the system is like a pool of stagnant water. This is manifested in the ant colony, the behavior of the ants is too rigid, and when the environment changes, the ant colony still cannot be properly adjusted.

4.3 Generalization and application

In summary, the ant colony model can be applied to the evacuation of personnel in emergency situations in large-scale locations. In addition, it is necessary to pay attention to the problems of traveling salesman, secondary distribution, work scheduling, vehicle routing, and sequencing. The constraints of each problem will change, just adjust the relevant parameters of the ant colony algorithm according to the actual situation.

5. Conclusion

The purpose of this model is to minimize the time required to evacuate the Venue . Through analysis, to minimize the time, we must first plan the optimal path, and then establish an ant colony algorithm model to plan the optimal path. Assume that all four entrances are open and the visitors are classified to calculate the minimum time. Programming in MATLAB found that the theoretically predicted curve trend is consistent with daily experience, and the magnitude is in good agreement with the existing data. then, for the ant colony algorithm, the convergence speed is slow and it is easy to fall into the local optimum. We have optimized the relevant parameters of the ant colony algorithm.

6. Suggestions

Taking into account some possible potential threat factors, the following Suggestions are made, such as a sudden danger in a certain area, in order to ensure that the emergency personnel reach the dangerous place and the minimum time of the escape time of the tourists, add an entrance (service gate, employee entrance, VIP entrance, Emergency exits and old secret entrances built by the monarchy, etc.) as a dedicated passage for emergency personnel, In addition, if an entrance cannot pass for some reason, such as too congestion, failure, etc., the ant colony algorithm is also used to plan the path, just the restriction conditions have changed. Finally, for large buildings such as the Venue , the number of tourists is increasing. For the safety of tourists, more safety signs can be set in the venue, and some entrances and exits can be added to ensure the safety of tourists.

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