Bp-ant colony algorithm: escape the Louvre

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Abstract. With the spread of terrorism in the new era, France has suffered many terrorist attacks in recent years. The new situation calls for a review of emergency evacuation plans for popular destinations. Taking the Louvre Museum as the research object, this paper discusses the emergency evacuation plan in detail. At the same time, in order to make effective planning, this study selects the day with the largest number of visitors to the Louvre Museum as the sample. In the establishment of emergency evacuation model, ant colony algorithm is introduced. The training time of two kinds of traffic evacuation algorithm is given, and BP neural network is used for training. In addition, the dynamic Bottleneck Identification Method Based on fuzzy set theory is used in this study. Through model optimization, the possible bottleneck location is accurately determined. Finally, this paper analyzes the advantages and disadvantages of the model, and gives the specific evacuation routes.

1. Introduction
In recent years, terrorist attacks in Paris, France, have occurred frequently. As a famous scenic spot and landmark in France, the Louvre museum is more likely to be targeted by terrorists due to its large number of visitors, high population density, large number of foreign tourists, diverse personnel, and the preservation of many precious art collections. Therefore, it is very important to establish evacuation plan in case of Louvre emergency.

The Louvre was originally built in 1204 as the palace of France[1] The museum is a u-shaped structure with 480 meters of wings, three floors above ground and two below. On the ground floor there are four main exits for visitors, but there are also other passageways for staff to enter and exit, as well as secret passageways set up by the monarch.

Our model only considers when the Louvre is most visited during the opening period of a day, not when the museum is just opening or almost closing. During these period of time, the number of visitors is relatively small, it is relatively easy to evacuate people in an emergency. Therefore, it is more representative to establish the evacuation model in emergency when the number of tourists is the largest in a day. The research assume that the number of visitors to the Louvre is evenly distributed across the floors, with the same number of visitors on each floor.

2. Model Parameters
The model of parameters are shown in the table 1.
Table 1. Model Parameters

| Parameter      | Meaning                                                                 |
|----------------|-------------------------------------------------------------------------|
| $L_{ij}$       | The physical distance between nodes I and j                             |
| $\zeta_{ij}$   | Coefficient of ease of passage                                          |
| $r_{ij}$       | The pheromone concentration between node I and node j                   |
| $E_{ij}$       | Directed evacuation channels from node I to node j                      |
| $f_y(s)$       | Linguistic diversity index                                              |
| $f_y(p)$       | Diversity index                                                         |
| $f_y(K_p)$     | Personnel density                                                       |
| $M_y(t)$       | Activity index                                                          |
| $V_l$          | Actual evacuation speed of personnel                                    |
| $V_o$          | Normal walking speed                                                    |
| $p_{ij}^t(t)$  | Transition probability                                                  |
| $\eta_{ij}^t$ | Inspired by the function                                               |
| $N_i$          | Standard model library                                                  |
| $N_x$          | Fuzzy subset                                                            |
| $N_{ij}(x)$    | Membership function of $N_{ij}$                                         |

3. Models

3.1. Model 1: New adaptive ant colony algorithm evacuation model

In the model, a finite number of nodes are distributed on all paths in the course of escape, and a directed line segment is formed between each two adjacent nodes. $L_{ij}$ represents the length of a channel from node i to node j.

Pheromone concentration update strategy. The pheromone concentration of node $E_i$ is determined by channel $L_{ij}$ length and pass-through coefficient $\zeta_{ij}$. The pheromones evacuated from node I to node j are updated according to the following rules [2]:

$$r_{ij}(t+1) = \begin{cases} 
(1 - r) r_{ij}(t) + r \Delta t_{ij} \zeta_{ij} < \bar{r} \\
\Delta t_{ij}(t), \ z_{ij} > \bar{r} 
\end{cases}$$

among them,
Calculation of passage coefficient. The new algorithm USES the adaptive learning method of BP neural network to calculate the difficulty coefficient of node passage and can update the stacking concentration and heuristic function of node pheromone dynamically, so as to calculate the node transition probability. The learning mode of the neural network is composed of two parts: traffic speed (forward propagation) and evacuation time (back propagation) [3]. When the deviation between the expected value of traffic speed and evacuation time result is greater than the preset threshold, the reverse propagation gradient adjustment is adopted, and the two processes are repeated until the deviation is less than the preset precision, and the passage difficulty coefficient is obtained. The specific algorithm is as follows:

In the first step, the node set of evacuation channel is defined as \( E = \{ E_{i2}, \ldots, E_{ij}, \ldots, E_{mn} \} \), channel \( E_{ij} \) represents the directed evacuation channel from node \( V_i \) to node \( V_j \). Attributes are divided into static attribute and dynamic attribute, and static attribute is \( E_{ij}(L_{ij}, \xi_{ij}) \), where, \( L_{ij} \) is the physical length of evacuation channel, \( \xi_{ij} \) is the coefficient of accessibility, and its value is:\[\xi_{ij} = \frac{\text{passed - persons}_{ij}}{\text{pass - time}_{ij}}\] (3)

The larger the value of the pass-through coefficient \( \xi_{ij} \), the easier it is for the node to pass through.

Where, \( \text{passed - persons}_{ij} \) is the number of people evacuated from node i to node j.

The second step is to define the activity index, which is composed of three parameters: language diversity \( f_y(s) \), human composition diversity \( f_y(p) \) and human density \( f_y(K) \). The index affecting human activity \( M_y(t) \) is:

\[M_y(t) = f_y(s) \times f_y(p) \times f_y(K)\] (4)

Then the equivalent speed of evacuation personnel is

\[V_t = V_o \times M_y(t)\] (5)

Where, \( V_t \) is the evacuation speed, and \( V_o \) is the normal walking reference speed.

In the third step, the neural network repeatedly calculates the node evacuation speed, so that the output results are constantly approaching the optimal value. It is defined that the input layer has \( n \) neurons, the hidden layer has \( p \) neurons, and the output layer has \( q \) neuron. The initialization of the neural network vector is as follows:

Input vector: \( X_i = (X_1, X_2, \ldots, X_n) \)

Hidden layer input vector: \( hi = (hi_1, hi_2, \ldots, hi_p) \)

Hidden layer output vector: \( ho = (ho_1, ho_2, \ldots, ho_p) \)

Output layer input vector: \( yi = (yi_1, yi_2, \ldots, yi_q) \)
Output layer output vector: 
\[ y_o = (y_{o1}, y_{o2}, ..., y_{oq}) \]

Expected output vector: 
\[ d_o = (d_1, d_2, ..., d_q) \]

Number of sample data: 
\[ k = 1, 2, ..., m \]

Define the precision value \( \varepsilon \) and the maximum learning number \( M \), so as to calculate the error function \( e \) is:

\[ e = \frac{1}{2} \sum_{i=1}^{q} (d_o(k) - y_o(k))^2 \] (6)

The fourth step is to randomly select \( k \) input samples and expected output results:

\[ x(k) = \{x_1(k), x_2(k), ..., x_n(k)\} \]
\[ d_o(k) = \{d_1(k), d_2(k), ..., d_q(k)\} \] (7)

The fifth step is to calculate the input and output results of neurons in the hidden layer:

\[ h_o_h(k) = f(h_i_h(k)), h = 1, 2, ..., p \]
\[ y_o_o(k) = f(y_i_o(k)), o = 1, 2, ..., q \] (8)

The sixth step is to calculate the partial derivative of the error function with respect to the neuron in the output layer according to the expected result and the actual output value

\[ \frac{\partial y_o(k)}{\partial w_{ho}} = \frac{\partial (\sum_{i} w_{ho} h_o_h(k) - b_o)}{\partial w_{ho}} = h_o_o(k) \] (9)

In the seventh step, according to the connection weight of hidden layer and output layer \( \delta_o(k) \), the error function is calculated to correct the connection weight:

\[ w_{ho}^{N+1} = w_{ho}^{N} + \eta \delta_o(k) h_o_o(k) \] (10)

In the eighth step, use the hidden layer neuron delta \( \delta h(k) \) and input parameters to correct the connection weight, and calculate the global error is:

\[ E = \frac{2}{2m} \sum_{i=1}^{m} \sum_{o=1}^{q} (d_o(k) - y_o(k))^2 \] (11)

In the ninth step, determine whether the error is less than the preset accuracy or the maximum number of iterations, and output the pass-through coefficient \( \xi_{ij} \) if the condition is met. [6]

Heuristic function update strategy. According to the pheromone induction strategy of the ant colony in the neural network, the heuristic function of each node is no longer a fixed value, but a guide for the ant to select the node of the next layer or the safety node with the change of the accessibility coefficient \( \eta_{ij} \). This enlightening method not only reflects the instinctive reaction of individual behaviors in the process of evacuation [7], but also is affected by the overall behavior of the evacuated population to avoid blind search and path congestion. The heuristic function \( \eta_{ij}^k \) reflects the heuristic degree of individual ants migrating from point to node and plays an important role in avoiding premature convergence of the algorithm.
The heuristic function $\eta^k_{ij}$ is:

$$
\eta^k_{ij} = \frac{\xi_{ij}(t)}{t^k \times \text{Num}_{ij}(t) \times d_{ij}^\text{min}}
$$

$$
d_{ij}^\text{min} = \min \{d_{ij}^p \mid p_i \in P\} P = \{p_1, p_2, \ldots, p_n\}
$$

Where, $d_{ij}^\text{min}$ is the minimum value of the distance between the network node of the layer $k$ and the node in the layer $p$, $P = \{p_1, p_2, \ldots, p_n\}$ is the temporary or final security node $P$ of the layer $k$ node as the layer $k$ network node set.

Transition probability. According to pheromone concentration and heuristic information $\tau_{ij}$ of evacuation node channel, individual ants determine their direction of advance. The calculation method of transition probability $p^k_{ij}(t)$ is calculated as follows:

$$
p^k_{ij}(t) = \left\{ \frac{\max \{\tau^\alpha_{is}(t)\eta^\beta_{si}(t)\}}{\sum \tau^\alpha_{is}(t)\eta^\beta_{si}(t)} \right\}
$$

Where, $\max \{\tau^\alpha_{is}(t)\eta^\beta_{si}(t)\}$ is the node $i$ corresponding to the maximum pheromone concentration in the set of evacuation channels connected with nodes, $\alpha$ is the information heuristic factor and $\beta$ is the expected heuristic factor, respectively. [5]

3.2. Model 2: The Bottleneck Problem

Concept of bottleneck. Bottlenecks are the factors that act as a limiting condition during a specific evacuation process, and the slowest link in the evacuation process is usually called "bottleneck". The bottleneck will not only affect the completion of the current process, but also may affect the completion of its adjacent process. [8]

In the process of evacuating tourists from the Louvre museum, the bottleneck is defined as the museum facilities that are overloaded with people or have too high density and too low speed during the emergency evacuation. Bottlenecks are usually caused by the presence of obstacles, narrow channels, or high turnover.

The different categories of bottlenecks under different bases are shown in the Figure 1.
According to the features of the bottleneck phenomenon, the bottleneck can be divided into static bottleneck and dynamic bottleneck. When looking for static bottlenecks, people flow features are generally not considered, but the capacity value of each facility is compared, and the facility with the smallest capacity value is the bottleneck. In other words, The research can calculate the static bottleneck position without considering the flow of people.\textsuperscript{[8]}

When looking for dynamic bottleneck dynamic flow of people should be considered. The sudden change of the flow of people and the change of the opening plan of the museum is the main reason for the dynamic bottleneck. The main factors that affect the dynamic bottleneck location are flow velocity and flow density.

Now The research will analyze the characteristics of static bottleneck and dynamic bottleneck.

### 3.2.1. Characteristics of bottleneck

1. **Characteristics of static bottleneck**
   - **Stability:** static bottleneck is caused by the premature saturation of evacuation capacity of evacuation facilities or the mismatch between evacuation capacity and neighboring facilities. If The research find the worst evacuation in the Louvre museum, The research will find the static bottleneck in the building. And if the structure and shape of the facility are not changed, the evacuation capacity of the facility will not change, so the static bottleneck is stable.
   - **Predictability:** the evacuation capacity of various facilities in the Louvre museum can be solved one by one, and then The research can find the static bottleneck position by comparing with each other. Therefore, static bottleneck locations are predictable.\textsuperscript{[8]}

2. **Characteristics of dynamic bottleneck**
   - **Dynamic:** the dynamic bottleneck in the Louvre is caused by the mismatch between the flow of people and the ability of evacuation. Therefore, the flow of people is an important factor affecting the location of dynamic bottlenecks. Because the flow of people is different in different places at different times, the location of dynamic bottleneck is dynamic.
   - **Suddenness:** the location of dynamic bottleneck is closely related to the flow of people. When the flow of people exceeds the upper limit of the evacuation ability of the museum evacuation channel, the bottleneck will appear, so the dynamic bottleneck has suddenness.
   - **Instability:** when the evacuation facility in the museum is connected in tandem or in parallel, the appearance of bottleneck may transform other evacuation facility into bottleneck. So, it's instable.
Predictability: the location of dynamic bottlenecks can be determined by statistical means based on the daily flow of people, or by simulation software. So it's predictable. Based on the analysis of the characteristics of static bottleneck and dynamic bottleneck above, The research can conclude that both static bottleneck and dynamic bottleneck will affect the escape time of tourists in case of an emergency in the Louvre. The static bottleneck is fixed and can be obtained through a series of calculations. The dynamic bottleneck can be predicted, but when measured by statistical methods, though the result is accurate, it will consume a lot of manpower and material resources. And when calculated by simulation software, the accuracy will be slightly lower. Therefore, The research will focus on the determination of dynamic bottlenecks.

3.2.2. Dynamic bottleneck identification method based on fuzzy set theory. First, The research artificially define the corresponding relationship between the open degree of the evacuation channel and the bottleneck level as follows in Table 2:

| State description                  | Open degree | Bottleneck level |
|-----------------------------------|-------------|-----------------|
| Basically free                    | Open        | Non-Bottleneck  |
| Part of behavior is restricted    | Slightly crowded | Bottleneck III |
| Very restricted                   | Crowded     | Bottleneck II   |
| Extremely restricted, needs to be guided | Blocked    | Bottleneck I    |

3.3. Establishment of standard model library

Although The research has classified the open degree of facilities, different people have different feelings and needs for the open degree, and sometimes The research can not only use objective criteria to measure it. Therefore, The research introduces the concept of fuzzy set to identify bottlenecks and establish membership functions for various evacuation channels. [8] In the description method of fuzzy mathematics, universe $\mathcal{M} = \{\text{Evacuation channel bottleneck level}\}$. There are four fuzzy sets on $\mathcal{M}$ to constitute the standard model library $\mathcal{N}_i = \{N_i\} (i=1,2,3,4)$ (Non-Bottleneck, Bottleneck III, Bottleneck II, Bottleneck I). Among them, fuzzy set $N_i (i=1,2,3,4)$ is a family of fuzzy vector sets. It is characterized by the velocity and density of human flow. The research use the trapezoidal distribution in the assignment method to obtain the membership function of fuzzy subset $N_{ij}$. According to the analysis, $\min N_{i1} = N_{i1}$, $\min N_{i2} = N_{i2}$, $\max N_{i1} = N_{i1}$, $\max N_{i2} = N_{i2}$. [8] And according to the classification of small, middle and large phenomena in trapezoidal distribution, the membership function of $N$ can be expressed as:

I. For $N_{i1}$ and $N_{i2}$, select smaller type, and have:

$$N_i(x) = \begin{cases} 
1, & x < a_i \\
\frac{b_i - x}{b_i - a_i}, & a_i \leq x \leq b_i \\
0, & x > b_i
\end{cases}$$

(14)
II. For $N_{21}$, $N_{22}$, $N_{31}$, $N_{32}$, select the middle type, The research have:

$$N_i(x) = \begin{cases} 
0, & x < a_i \\
\frac{x - a_i}{b_i - a_i}, & a_i \leq x \leq b_i \\
1, & b_i \leq x < c_i \\
\frac{d_i - x}{d_i - c_i}, & c_i \leq x < d_i \\
0, & x \geq d_i 
\end{cases}$$  (15)

III. For $N_{11}$ and $N_{42}$, select larger type, The research have:

$$N_i(x) = \begin{cases} 
0, & x < a_i \\
\frac{x - a_i}{b_i - a_i}, & a_i \leq x \leq b_i \\
1, & x > b_i 
\end{cases}$$  (16)

The research refer to some relevant articles and materials and obtain the values of parameters $a_i$, $b_i$, $c_i$, $d_i$ and $N_i(x)$ in the membership function $N_i(x)$ of various facilities as follows in Table 3:

| Evacuation facilities | 1 | 2 |
|-----------------------|---|---|
| **Passage**           |   |   |
| 1                     | 1.26 | 1.57 | – | – | 0.43 | 0.72 | – | – |
| 2                     | 0.85 | 1.02 | 1.26 | 1.57 | 0.43 | 0.72 | 1.08 | 1.43 |
| 3                     | 0.35 | 0.60 | 0.85 | 1.02 | 1.08 | 1.43 | 2.2 | 3.33 |
| 4                     | 0.35 | 0.60 | – | – | 2.2 | 3.33 | – | – |
| **Ascending stairs**  |   |   |
| 1                     | 0.70 | 0.84 | – | – | 0.72 | 1.08 | – | – |
| 2                     | 0.42 | 0.57 | 0.70 | 0.84 | 0.72 | 1.08 | 1.54 | 2.31 |
| 3                     | 0.24 | 0.36 | 0.42 | 0.57 | 1.54 | 2.31 | 2.76 | 3.89 |
| 4                     | 0.24 | 0.36 | – | – | 2.76 | 3.89 | – | – |
| **Down stairs**       |   |   |
| 1                     | 0.75 | 0.90 | – | – | 0.80 | 1.16 | – | – |
| 2                     | 0.47 | 0.62 | 0.75 | 0.90 | 0.80 | 1.16 | 1.62 | 2.39 |
| 3                     | 0.26 | 0.40 | 0.47 | 0.62 | 1.62 | 2.39 | 2.84 | 3.97 |
| 4                     | 0.26 | 0.40 | – | – | 2.84 | 3.97 | – | – |
| **Escalator**         |   |   |
| 1                     | 0.50 | 0.50 | – | – | 0.72 | 1.08 | – | – |
| 2                     | 0.50 | 0.50 | 0.50 | 0.50 | 0.72 | 1.08 | 1.54 | 2.31 |
| 3                     | 0.50 | 0.50 | 0.50 | 0.50 | 1.54 | 2.31 | 2.76 | 3.89 |
| 4                     | 0.50 | 0.50 | – | – | 2.76 | 3.89 | – | – |

3.4. Fuzzy pattern recognition

After the establishment of the standard model library, The research needs to rank the potential bottlenecks, that is, dynamic bottleneck identification. The two main methods of fuzzy pattern recognition are maximum membership principle and the principle of near selection. According to the above analysis, the maximum subordination principle should be adopted in the analysis of Louvre exits.
Principle of maximum subordination: Suppose \( N_i \in F(M), (i=1,2,\ldots,n) \), for \( m_0 \in M \), if \( i \) exists, makes \( N_{i_0}(m_0) = \max \{N_i(m_0), N_j(m_0), \ldots, N_k(m_0)\} \), then it is considered to be relatively subordinate to \( N_{i_0} \).

Definition of membership degree of fuzzy vector set family by ordinary vector \( x \): suppose there are \( n \) fuzzy subsets in the domain of theory, and the membership degree function is \( N_i(x)(i=1,2,\ldots,n) \), and \( N=(N_1,N_2,\ldots,N_n) \) is fuzzy vector set family, and \( N=(N_1,N_2,\ldots,N_n) \) is ordinary vector, then it is called the membership degree of \( x \) to fuzzy vector set \( N \). In our problem, \( x=(x_1,x_2) \) is the membership degree of fuzzy vector set \( N_i(\{1,2,3,4\}) \).

Since the importance of \( x \) to the bottleneck level is different, The research slightly modify the above formula to get:

\[
N_i(x) = \sum_{j=1}^{n} a_{ij}N_j(x)
\]  

(17)

In order to determine the value of \( a_{ij} \), the expert scoring method was adopted, and after statistical analysis, \( a_1=0.35 \), \( a_2=0.65 \).

In this paper, in order to obtain \( x=(x_1,x_2) \) at a certain moment, the value of \( N_i(x) \) must be calculated first, then \( N_i(x) \) can be calculated by applying the above formula, and then which fuzzy vector set family \( x=(x_1,x_2) \) belongs to the standard model library can be determined according to the maximum membership principle, so as to obtain the current bottleneck level of the set.

From the data in the table, The research can calculate the flow rate of people at each exit in the whole evacuation process. According to the data of the size of each exit of the Louvre museum collected through various channels, the size coefficient \( \theta \) and human flow density \( x_2 \) of the four exits A, B, C and D can be obtained as follows in Table 4:

| Exit number | A  | B  | C  | D  |
|-------------|----|----|----|----|
| Area coefficient \( \theta \) | 1  | 0.85 | 0.8 | 0.6 |
| Crowd density \( x_2 \) | 1.6 | 2.2 | 2.3 | 2.5 |

According to the fuzzy identification method, The research can get the bottleneck level of the four channels as follows in Table 5:

| Exit Number | A  | B  | C  | D  |
|-------------|----|----|----|----|
| Bottleneck level | Non-bottleneck | Bottleneck III | Bottleneck III | Bottleneck II |

According to the judging method of the bottleneck level, the main causes of the bottleneck are high crowd density, many obstacles and small exit. Therefore, our recommendations are as follows:
Can regularly clean up the museum may affect the evacuation of obstacles. Change the position of the exhibits in the museum so that people can be evacuated as soon as possible in case of emergency.

The crowding situation at exit D can be alleviated by guiding some tourists at exit D to exit A nearest to exit D.

3.5. The simulation tests

3.5.1. The number of sets

Table 6. Visitors to the Louvre in France in the past seven years

| Year | Visitors (millions) |
|------|---------------------|
| 2018 | 1020                |
| 2017 | 810                 |
| 2016 | 730w (Terrorist attacks in France) |
| 2015 | 870                 |
| 2014 | 930                 |
| 2013 | 940                 |
| 2012 | 970                 |

Combined with the above data in Table 6, it can be predicted that the average annual passenger flow of the Louvre in the next few years will be 10 million. Among the 365 days, 52 weeks will be closed on Tuesdays, so it is 313 days. Therefore, the theoretical daily number is 32,000. Because the number of visitors varies from season to season, The research choose the day with the largest number of visitors, which is also the most representative. Combined with the peak season data, the peak capacity was 36,000 people per day. The Louvre is open 12 hours a day, so it can accommodate up to 3,000 people per hour at its peak. Considering that floor -2 is the ticket hall and floor 0 is the residence of tourists who have just arrived at the Louvre museum, there are a large number of visitors. Meanwhile, considering the distribution of exhibits, the personnel distribution ratio from floor 2 underground to floor 2 above is set as follows in Table 7:

Table 7. People distribution in different floor

| Floor | Distribution proportion | Number of people |
|-------|-------------------------|------------------|
| -2    | 30%                     | 900              |
| -1    | 20%                     | 600              |
| 0     | 25%                     | 750              |
| 1     | 15%                     | 450              |
| 2     | 10%                     | 300              |

However, in fact, the distribution of exhibits on each floor has different attraction for tourists. In order to simplify the model and facilitate calculation and modeling, The research generally consider that the personnel on each floor are evenly distributed.

3.5.2. Set the environment. According to the data, the four entrance positions are all on the ground floor, and A, B, C and D in the figure respectively represent the four exit positions according to the Figure 2.
A: The Pyramid entrance
B: The Passage Richelieu entrance
C: The Carrousel du Louvre entrance
3.5.3. Coefficient of ease of passage. According to characteristics of each node traffic data, combining "Affluences" waiting time of each entry, decided in the BP neural network input layer adopts three layer neurons, at the same time, the C + + on the Matlab software is used to calculate the dynamic relationship between traffic and traffic difficulty coefficient, which is shown in the Figure 3, maximum training times for 3000, expect error goal is 0.001, initial learning rate is 0.01, the initial baseline normal walking speed $V_o$ is $2 \text{m/s}$. The relationship between the accessibility coefficient $\xi_{ij}$ of different exits and the human activity index is calculated, as shown in Figure 4.

![Figure 3. The relationship between the research evacuation difficulty coefficient and staff activity index](image)

3.5.4. Analysis of simulation results. Set the total number of people as 3000, the initial pheromone concentration $\tau_{ij}$ as 2, and the routes as 1500. The pheromone concentration update is dynamically guided by the accessibility coefficient $\xi_{ij}$ and the evaporation coefficient $\rho = 0.15$. Figure 5 is the evacuation efficiency curve of the four methods.
Figure 4. Evacuation efficiency curve of the four methods

As can be seen from the figure:

a. The new algorithm can evacuate nearly 95% of the staff within 330 seconds and all the staff within 360s, which is much better than other algorithms.

b. The proportion of the number of evacuees in the standard group algorithm is almost linearly related to the time. This is because the dynamic change of the accessibility coefficient is not taken into account, so most people flock to the optimal exit, i.e., the pyramid exit, resulting in congestion, but in comparison, the evacuation efficiency of the standard ant colony model is still higher than that of the cellular automata model.

c. The cellular automata model is a causal relationship and interaction between space for time for local grid dynamics model, it is mainly based on an individual, not evacuated to consider the influence of the overall behavior, so in the optimization process experience be directed to other export overseas, even wandering between different export, will ultimately affect the wasted time, increase the evacuation time.

d. The evacuation of the least efficient is the shortest path algorithm, this algorithm to an emergency personnel relative to the position of the entrance, on the basis of calculated directly by the path length, the escape velocity to escape, but the reality is not so, because this algorithm doesn't have the ability to dynamically select the optimal route, is only the result of not reasonable use of all exports, most of the crowd gathered in several entrance and lead to longer waiting time and greatly extended the escape time.

Table 8 is the statistical table of the number of evacuees after the simulation test of the four algorithms.

| Algorithm name        | A   | B   | C   | D   |
|-----------------------|-----|-----|-----|-----|
| New algorithm         | 1097| 609 | 592 | 702 |
| Standard ant colony   | 1133| 677 | 517 | 673 |
| Cellular automata     | 998 | 688 | 735 | 579 |
| Shortest path         | 1623| 499 | 323 | 521 |
Due to the large difference in the coefficient of traffic difficulty between different exits, most of the personnel in the new algorithm were reasonably shunted under the influence of both the heuristic function and pheromone, which effectively reduced the phenomenon of switching between different exits. The number of evacuations at each exit of the cellular automata model is relatively uniform, indicating that the friction microforce finds a balance among four different exit nodes. However, in the actual situation, people tend to choose the entrance into the Louvre as the escape exit, so the cellular automata model cannot be well applied in the actual situation. The node of the shortest path algorithm has the most uniform evacuation number and strong randomness. The optimal algorithm will lead to a large area of exit A, which is close to most of the personnel, to be blocked, seriously affecting the final escape time.

In order to better show our model results, the research uses the new algorithm simulation test, it is concluded that the different at different times have through the export amount of crowd evacuation of choose the proportion of the total number of the export, the results below, among them, the ordinate said the number of people were evacuated by the export of choice, the proportion of the total number of exports.

![Figure 5. Evacuation time for four exits](image)

From the Figure 5, The research can get:
1. Exit A can be completely evacuated at 360s
   Exit B can be completely evacuated at 350s
   Exit C can be completely evacuated at 347s
   Exit D can be completely evacuated at 335s
2. Four export within about 335 s to 360 s can be relatively synchronously all crowd evacuation, no idle or large Numbers of people gather in the same export situation, the model due to the introduction of the pass difficulty coefficient of this variable, make to evacuate the crowd got reasonable arrangement, the end result is consistent with our expectations.
3. Evacuation efficiency was very low at the beginning, because only a few people could reach the exit in a short time. After about a minute, after each exit reaches saturation, the output efficiency is almost proportional to the time, because the crowd is fleeing from the exit at a relatively stable speed. After 250s, the main personnel at each exit have already been evacuated. At this time, it is mainly some difficult personnel such as the disabled who affect the evacuation time.
4. As the main entrance of the pyramid door, since more people choose to exit from this exit, the evacuation time of this exit is still the longest.

4. Conclusion
This article on how to evacuate from the Louvre seriously analyzed, combining with the standard ant colony algorithm, our model is put forward, to join the difficulty coefficient, set up the adaptive ant
colony model based on BP neural network, it not only considers the instinctive reaction of individuals in the evacuation process, also considered the evacuation crowd that a group of individuals, the effect of more realistic, and better solve the problem.

In the evaluation of dynamic bottleneck, the research use the dynamic bottleneck identification method based on the fuzzy set theory, through the establishment of the standard model library and fuzzy pattern recognition two processes, more accurate evaluation of the four exports bottleneck level, and get the best results.

The research discussed the strategies and Suggestions in detail and put forward specific and feasible operation methods and Suggestions, which can not only be used for the evacuation of the Louvre, but also have great reference significance for the evacuation of other similar large buildings.

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