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T3 ________________	Problem Chosen	F3 ________________
T4 ________________	**A**	F4 ________________

2019
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Summary Sheet

Research for Emergency evacuation of the Louvre

Summary

According to the Louvre's website, nearly 10 million people visited the Louvre in 2018, with an average daily visitor volume of about 30000 during the rush hour. When an emergency occurs, the designer is required to provide the appropriate evacuation plan. In the scheme of this paper, we design a scheme with strong adaptability, which can ensure rescue and evacuation simultaneously, and can be used for emergency evacuation of other large building structures. After analyzing the inner structure of the Louvre, we abstract the distribution map of each floor of the Louvre to make it easy to model and reduce the measurement error, at the same time, Based on the actual evacuation experience, we adopt some of the assumptions in the literature to simplify our model.

We divide the escape into unstable stage and stable stage. According to greedy algorithm, we hope that tourists can transfer to free escape channels as much as possible in the unstable stage, so as to reduce the evacuation pressure. In the stable stage, due to the effect of tourist aggregation, tourists can be regarded as fluid according to the theory of Fegress human flow processing, and the movement of tourists can be analyzed by the fluid equation of motion. According to the environmental perception ability of people in the Agent system and the characteristics of easy access to the near exit during escape, we take the staircase or exit as the circular circle and cover all exhibition areas as equitably as possible. Then according to the cellular automata algorithm, to balance Measure the amount of time a tourist spends on the road and the total cost of competing with others on the stairs. Finally, according to the idea of PSO algorithm, tourists adjust their own escape path selection through the optimal escape path of the group to achieve the overall optimal efficiency.

In the model test, we get the conclusion that all tourists can be safely evacuated within 553.77 s. In sensitivity analysis, we found that exit and stairway width and horizontal channel width are the bottleneck information that affects the speed of tourist movement. In addition, we found that a double increase in the density of people used in the calculation greatly improved the escape speed, so we allocated the space originally occupied by one person in the staircase to two or three people. Not only that, we found that reasonable arrangement of staircase location can save a lot of evacuation time, which provides a better design for other high-rise buildings. Count experience.

Keywords: Agent principle; PSO algorithm; Cellular automata algorithm; Fegress flow processing theory;Greedy algorithm

Contents

1 Introduction

1.1 Background

As one of the largest and most visited art museums in the world, the Louvre receives more than 10 million visitors in 2018. The number of visitors per day is about 30,000. Nearly 10,000 people can be in the museum at the same time every day. However, with the increasing terrorist attacks in France, it is now required to review the Louvre emergency evacuation plan. The plan should ensure that people in the room are evacuated to a safe area with as little time as possible. However, the large differences between tourists, such as language and physical condition, make the evacuation plan of the Louvre in an emergency such as a terrorist attack even more difficult. How to evacuate all the personnel in the museum in the shortest possible time. Going out has become a difficult problem that has to be faced.

1.2 Restatement of the Problem

In order to safely evacuate all visitors to the museum in the shortest possible time, we need to design an emergency evacuation model.In the event of an emergency, the model can provide the owner of the museum with more than two routes to evacuate the visitor.In this process, designers need to find bottlenecks that limit the efficiency of export evacuation, and coordinate the relationship between evacuation time and safety.For designers, they need to be able to deal with as many types of emergencies as possible. We believe that a successful solution should be able to evacuate all visitors within 12 minutes and arrange for people with mobility difficulties. Escape mode, at the same time, allows rescuers to enter the venue to rescue at a faster rate while the tourists are escaping. Of course, this solution should not only apply to the Louvre, but also to the emergency evacuation of other large buildings. .When the program proves its efficiency and rationality, it will be applied to the personnel evacuation control program.

1.3 Overview of Our Work

To achieve fast and safe evacuation, we have developed the following strategies:

- According to the characteristics of the human environment in the Agent system and the characteristics of the exits that are easy to travel to when approaching the escape, we use the stairs or exits of each floor as the center to make the same size circle, so as to cover all exhibition areas as fairly as possible. Tourists in the inner area of the circle are evacuated as far as possible to the center of the circle, and the load on each staircase is approximately the same.
- According to the cellular automata algorithm, we further discuss the evacuation direction of tourists by the cost of the travel of tourists and the pressure of tourists competing with other people at the same time.
- According to the idea of the PSO algorithm, we not only need to allocate routes from the perspective of tourists, but also consider from a global perspective to

let everyone wait for resources as little as possible to achieve the overall optimal efficiency.

- According to the greedy algorithm, in the period of the emergency, people can move freely in the idle escape channel. During this period, they are faster, evacuate the passengers to the free passage as much as possible, and make room for the people behind.
- Finally, we evaluate our program after testing the robustness and sensitivity of the program, and propose objective and feasible improvement suggestions.

2 Model Assumptions and Symbol Table

2.1 General Assumptions

- There is no obstacle in the corridor and on the stairs, which ensures the stability of evacuation speed. For tourist sites such as museums, there are very few obstacles on the roads that hinder the passage of tourists.
- When evacuating, the personnel are arranged in a row and independently and orderly, without affecting each other. Evacuation efficiency can be greatly improved in an orderly situation
- The evacuation personnel are evenly spaced and the travel speed remains the same. In the case of crowded evacuation channels, the overall speed is uniform
- The response time of all personnel is the same, ignoring the emergency response time of personnel, which will make our model clearer.
- The body thickness of the people in the queue is the same, which ensures that the corridor occupied by each person is certain. We use the average body thickness of the tourists to facilitate the formulation.
- The individual obeys the command of the commander, guarantees that the evacuation is carried out effectively, and there will be no accidents. This is also the requirement for the evacuation personnel control procedures.
- During the evacuation process, people may be stranded at the door, at the stairway, due to bottlenecks, and in this case, the team is waiting to be processed.
- Ignore the impact of accidents such as falls and illnesses.
- Due to the large area of the exhibition area, it is assumed that the density of personnel in each exhibition area is the same.
- Only consider the colored area in the Floor plan of Louvre as a manned area, so the -2 floor is unmanned

Symbol	Definition
D	The stair width
l	The stair length between adjacent floors
v_{00}	The horizontal movement speed of people in an open space
v_{01}	The speed at which people move down the empty stairs
v_{10}	Human flow horizontal movement speed
v_{11}	The speed at which people flow down the stairs
b	The average shoulder width of visitors
b_0	The evacuation channel width
n	The number of people in the stream
f	The average projected area of a single visitor
d_0	The flow length
m	The number of security queues
T_s	The travel time of the visitor to the stairs or exit
T_1	The time to go down the stairs
P_0	The flow density in horizontal channels
u	The difference between the speed of the horizontal channel evacuating tourists and the speed o
p_1	The flow density in the stairs
P	The flow density

2.2 Symbol Table

3 Justification of our model

3.1 Model Description

According to the Aent system, PSO algorithm, cellular automaton algorithm and greedy algorithm, our model has the following principles:

- We abstract the corridors during emergency evacuation into rectangles of the same width and ignore the narrow passage between different blocks to bring trouble to emergency evacuation.
- In each floor, the stairs or the exit are the center of the circle, and the circle is drawn at the same radius, so as to cover all the exhibition areas as fair as possible, and the visitors within the circle are evacuated as far as possible.
- Determining the direction of the evacuation of tourists is the cost of the visitor's journey and the number of other people who compete with the same purpose in the same time.
- The model not only needs to assign routes to individuals from the perspective of the individual, but also considers asking him to wait as little as possible for others.
- At the beginning of the evacuation, evacuate the passenger to the unoccupied free passage as much as possible.

The commander only needs to master the following strategies during evacuation:

1. The area in which the visitor is located is covered by the stairs (if the area is covered by multiple stairs, the appropriate escape route is assigned to the visitors based on the time the passengers rush to the stairs plus the waiting time that may be due to queuing reasons). Or export)

2. Understand the current crowded state of each staircase (if a certain area is covered by only one staircase, then we think that unless the stairs collapse, the extreme phenomenon is that it is unwise for tourists to choose another stairs to escape, because their time will be wasted on the road. And it can cause confusion, and if an area is covered by multiple stairs, the commander needs to be reasonably scheduled according to the crowded state of each staircase covering it)

3. Considering the inconvenience of some special tourists, they should be assigned as close as possible to the stairs. At this time, the congestion of the stairs can be ignored.

4. High-rise visitors will affect the flow density of the lower floors when they flee to the lower floors, and have an impact on the escape speed. They should be arranged as different evacuation destinations as possible.

3.2 Rationality of the model

Geometric abstraction of the distribution maps of the Louvre floors can make our calculations as convenient as possible in the design scheme, although there will be narrow passages between different blocks to limit the movement speed of the flow, but this is unavoidable. of.In fact, if we consider the actual narrow channel situation, the conclusions obtained will have relatively large calculation errors and measurement errors, and will greatly increase the complexity of the model.

According to Agent's research, people will have a tendency to move to the nearest escape route when a dangerous situation occurs. We give each region a center, so that visitors can clearly define their first choice. In the Agent system, people have self-learning and Perceived to judge the characteristics of the surrounding environment, we can cover almost all areas by dividing the center of the stairs, and let tourists and conductors more clearly determine the shortest escape route for tourists.

According to the idea of the PSO algorithm, visitors can not only perceive the escape route nearest to themselves, but also can perceive the optimal escape route of the group, and adjust their escape route selection through the optimal escape route of the group, for example, in the problem we need to solve. In view of the fact that the waiting time of the high-floor pedestrians to the low-floor people is much longer than the time taken by the tourists in the corresponding area to re-select the target channel, we will adjust the target channel according to the pso algorithm. Other visitors are more convenient, while at the same time he saves time himself, which of course brings great benefits to our overall evacuation.

According to the cellular automaton algorithm, the points near the cell will compete for the cell resources, that is, other people near the visitor and other people in the area who are closer to the center of the circle will compete with the tourists for escape routes, so the tourists pass their own distance. The shortest path length of the center to get your own positional risk and it is possible and necessary to update your target channel at all times.

According to the greedy algorithm, we always hope that the most people can be evacuated in the shortest time. At the beginning of the escape phase, there are a large number of free passages that are not occupied, which makes the visitors move faster in these places. That is to say, these free passages are occupied by more tourists, and the faster the tourists are evacuated.

For special people who have difficulty moving, it may be difficult for them to follow the flow of people, so we hope that they can use special channels, so as to ensure the evacuation efficiency of others and ensure that the special population has a reliable escape route.

4 Emergency evacuation model

4.1 Same floor destination selection model

According to the distance distribution idea of the Agent algorithm, we build the model as follows:

- Centered on stairs or exits on each floor
- Circles at the same radius, indicating the area of the visitor that can be covered by the exit under normal conditions

The above established model can cover all exhibition areas as fairly as possible. Accord-

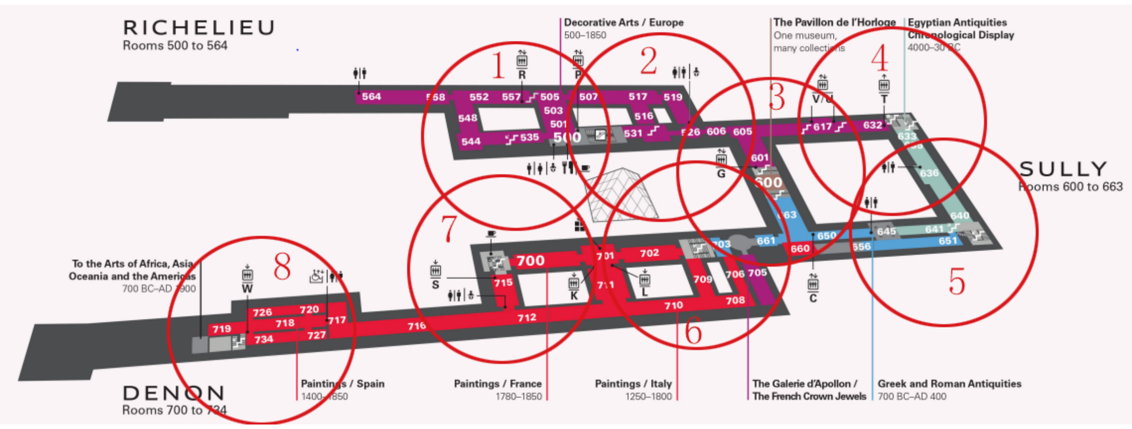

Figure 1: The first floor model

ing to the actual situation of evacuation, we divide the evacuation into two time periods:

- When going to the stairs or exits and evacuating tourists through the 2nd floor, the tourists are moving faster because the passages are empty at first, which is an unsteady state of evacuation.After reaching a steady state, the tourists are evacuated in a state of flow.
- For the steady state, we use the Fegress flow processing theory, the flow of people has a certain density, speed and flow, without considering the specific characteristics of each person in the flow.

Fegress believes that human flow density refers to the horizontal projected area of a person on an evacuated walkway per unit area. It is a fractional value whose size is:

$$p = nf/(d_0 * (b_0/m))$$

n is the number of people in the stream

f is the horizontal projected area of a single visitor

d_0 is the length of the flow

b_0 is the width of the evacuation channel

m is the number of security queues:

$$m = int[(b_0 - 0.238)/b*]$$

$b*$ is the minimum width required for a person to walk freely,

int means rounding Root Predtechenskii Milinskii's study, under normal circumstances, the flow rate of people in the horizontal channel:

$$v_{10} = (112p^4 - 380p^3 + 434p^2 - 217p + 57)/60$$

Speed of people going down the stairs:

$$v_{11} = v_{10}[0.775 + 0.44e - 0.39p * sin(5.16p - 0.224)]$$

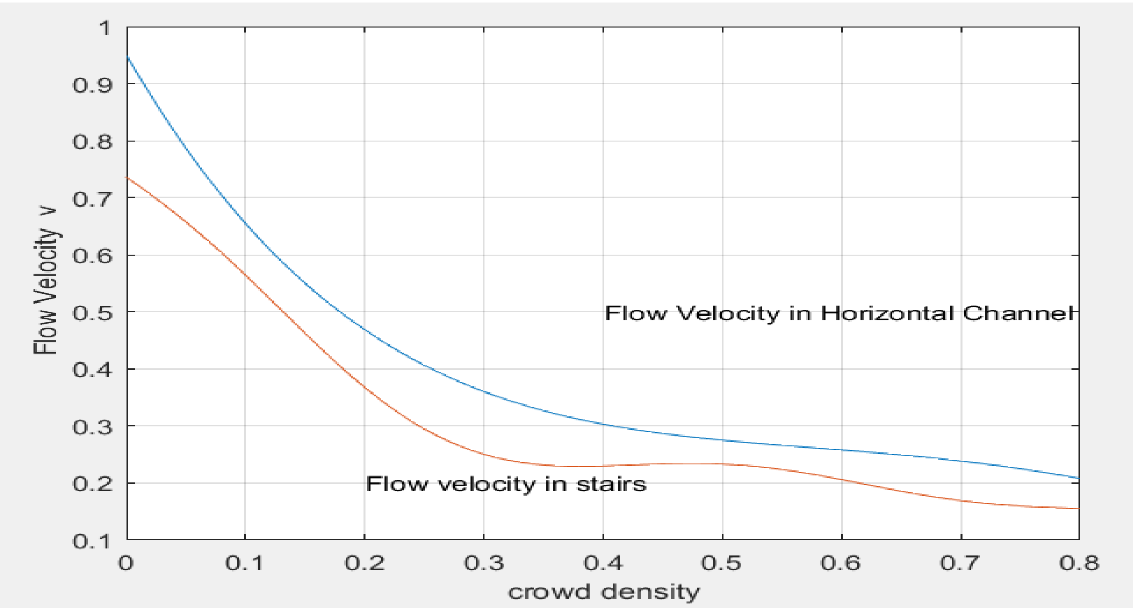

Figure 2: Relationship between human flow density and human flow velocity

Therefore, the travel time of visitors to the stairs or exits of this floor is computable:

$$T_s = s/v_{10}$$

Time to go down the stairs:

$$T_l = l/v_{11}$$

From the above formula, we use the moment when the emergency occurs as the origin of the time axis. At time t, according to the idea of the cellular automaton algorithm, the formula used by the commander to judge the evacuation direction of the tourist is:

$$P = T_s + T_{wait}$$

$$T_{wait} = T_n - T_s, (T_n > T_s)$$

$$T_{wait} = 0, (T_n < T_s)$$

T_n quoting time for visitors to wait for the same time because the rest of the competition for the cell:

$$u = b_0 v_{10} p_0 - D v_{11} p_1$$

$$T_n = p_0 * S/u$$

p_0 is the flow density in the horizontal channel

p_1 is the flow density in the stairs

d is the width of the stairs

u is the difference between the speed of evacuating tourists in the horizontal channel and the speed of evacuating tourists in the stairs.

The length of the shortest path (red area) of the target area (stairs) in the area where the visitor a (the green area below) is located is the lever, centered on the target ground, and the length of the lever is the standard, and the shortest path to the center is less than the lever length. The rest of the area (blue part) is a competitor with a higher priority than the visitor a, and the sum of the areas they are scattered is S

Figure 3: The cell competition pressure analysis chart

4.2 Evacuation model between different floors

In our algorithm, the high-floor visitors to the next floor through the stairs will have a greater impact on the flow density of the corresponding stairway, so we will provide a reasonable scheduling strategy according to the PSO algorithm, combined with the best purpose of the overall evacuation. Adjust the best evacuation destination for the individual. Because u is greater than 0, we can think of it at the moment T_1 Later high-rise visitors will cause the stairs on the lower floors to be congested.

$$T_1 = l/v_{01}$$

If no adjustments are made, the theoretical worst case will increase the waiting time for visitors to the corresponding stair coverage area on the lower floors:

$$\Delta T_{wait} = n_{up}/(Dv_{11}p_1)$$

n_{up} is the number of visitors covered by the stairs on the upper floor

This is obviously unreasonable and unscientific. Space resources are not fully utilized and the efficiency of evacuation is seriously reduced because of crowded people.So we made some changes on the basis of 4.1 combined with the information about the Floor plan of Louvre we obtained.When our two stairs cover more than 60% of the area, the area covered by the two stairs will be divided into one of the stairs for accepting the upper level of visitors and let the upper level visitors give priority, while the other Stairs refuse to accept the upper level of visitors, only to provide evacuation services for the visitors of this level, as shown in Figure 2, Area 1, Area 3, Area 4According to our design, there should be 4 elevators to serve only the tourists of this layer. In fact, through the strategy in 4.1, we calculate the maximum time cost for the four elevators to refuse to receive the upper-level tourists. :

$$\Delta P_{max} = 0.6 * n_{up}/(d_0 v_{10} p_0)$$

will ΔP_{max} versus ΔT_{wait} after comparison, there are the following relationships:

$$\Delta P_{max} \simeq \Delta T_{wait} * 10\%$$

Obviously able to use $\Delta P_{max}, Thiscosttoavoid$ ΔT_{wait} Time wastage is undoubtedly a huge optimization for overall evacuation.

4.3 Evacuation model in the unsteady stage

For the unsteady state, because the tourists can move freely in the open space, through the statistics, we get the normal moving speed when the person escapes.v_{00}And the speed at which people move down the empty stairs v_{01}:

$$v_{00} \in (1.2, 2.0)$$

$$v_{01} \in (0.7, 1.0)$$

This value is much higher than the flow rate of people, so we use the greedy algorithm to hope that tourists can reach the open space as soon as possible in an unstable period

of time.
For horizontal open road sections, the unstabilized time period is:

$$T_0 = s/v_{00}$$

S is the long distance from the stairs or exits to which the tourists are going On the stairs, the unstabilized time period is:

$$T_1 = l/v_{01}$$

l is the length of the stairs

Then T_{star}=T_0+T_1after each channel forms a stable evacuation flow

So on the basis of 4.1 and 4.2, when time t < T_{star} At the time, we try our best to let the passengers occupy the unmanned passage to reduce the flow density and further alleviate our evacuation pressure. Before we assumed that the -2 layer is the no-man's land, according to the information provided by the Floor plan of Louvre, - The 2nd floor has direct access to the entrance to the transparent pyramid, and the width of the transparent pyramid entrance is much larger than the internal passage, which means that we can think that visitors can successfully escape by reaching the bottom of the -2 pyramid.T_{star}The number of people moving from the -1 floor to the -2 floor during the time period is:

$$n_{trans} = d_0 p_0 v_{00} T_0 + D p_1 v_{01} T_1$$

The remaining number is the total number of visitors to the -1 floor $n_{-1)}$-n_{tran}sIn fact, taking the parameter data we collected into the formula, we calculated that in the unstabilized phase, 78.2% of the -1 layer was transferred to the -2 layer.

4.4 Model Validation

Because each floor in our model works in parallel, if we can find the longest evacuation time on a certain floor, then the evacuation time of this floor can be used as our total evacuation time. In our model, we put After the evacuation is defined as the number n of the region becomes 0, and because we set the initial passengers to be evenly distributed, the initial number of people can be obtained by counting the area of the corresponding area, as shown in the figure:

0-T_{star} The number of people who moved to the target area during the period was n_{nd}

$$n_{nd} = b_0 p_0 v T_{star}$$

We should note that due to the geographical differences of different floors and the choice of targets, different floorsT_{star}The size of v and v may be different.

0-T_{star}During the second floor, visitors from all areas of the 2nd floor will transfer the visitors to the Passage Richelieu entrance and the Carrousel du Louvre entrance on the 0th floor, as there are two elevators and there is no free horizontal passage on the 2nd floor, so:

$$T_0 = 0$$

$$n_{20} = b_0 p_0 v_{10} (2T_1)$$

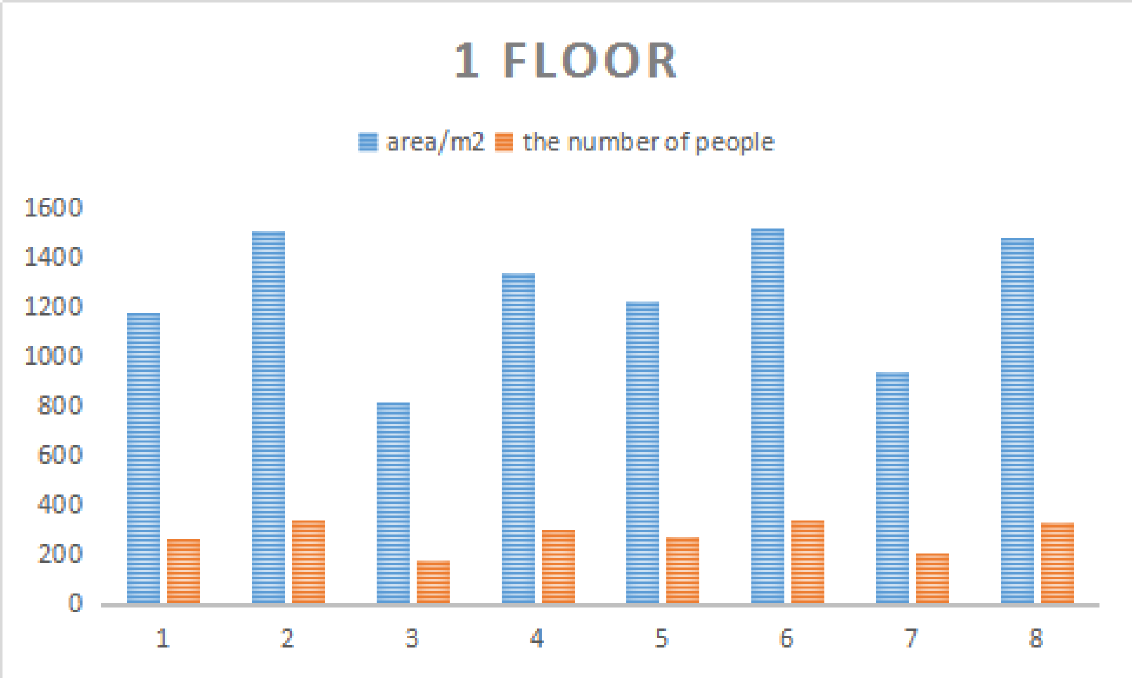

Figure 4: Example of area and population data of each area on the first floor

- The number of 1, 2, and 3 areas of the first floor of Richelieu and Sully to the Passage Richelieu entrance and the Carrousel du Louvre entrance on the 0th floor are:

$$n_{10} = b_0 p_0 v_{10} T_1$$

- The number of persons transferred to the -1 floor in the 4th, 5th, and 6th zones of the first floor is:

$$n_{1-1} = b_0 p_0 v_{10} (2T_1)$$

Number of moving from the 7, 8, 9 area of the first floor to the Portes Des Lions entrance on the 0th floor

$$n_{100} = b_0 p_0 v_{10} T_1$$

- The number of visitors in the 1, 2, and 3 areas of the 0th floor to the Passage Richelieu entrance and the Carrousel du Louvre entrance on the 0th floor is:

$$n_{00} = b_0 p_0 v_{10} (T_0)$$

- Number of 4, 5, and 6 areas on the 0th floor to the 2nd floor

$$n_{0-2} = b_0 p_0 v_{10} (2T_1)$$

- The number of moving to the 0th floor of the 7,8,9 area to the 0th floor of the Portes Des Lions entrance is:

$$n_{000} = b_0 p_0 v_{00} T_0$$

- In the 2nd, 3rd, 4th, and 5th floors of the 1st floor, 78.2% of the visitors moved to the 2nd floor:

- Number of 1st floor of the 1st floor to 0th floor:

$$n_{-10} = b_0 p_0 v_{10} T_1 + b_0 p_0 v_{10} T_0$$

- After that, enter a steady state and calculate the time when all the people in each area have been evacuated.T_{end}If you don't consider a special group, you need a maximum of time:

$$T_{end} = n_{ij}/b_0 p_0 v_{10} + n_{ij}/D p_1 v_{11}$$

- Total time:

$$T_{all} = max(T_{star} + T_{end})$$

4.5 Conclusion

After the solution of the above model is established, our emergency evacuation proposals for the Louvre are as follows:

- Visitors from all areas of the 2nd floor pass through the 1st floor staircase to the 0 floor Richelieu entrance and the Carrousel du Louvre entrance
- Visitors in the 1, 2, and 3 areas of the first floor move to the Passage Richelieu entrance and the Carrousel du Louvre entrance on the 0th floor.
- The 4th, 5th, and 6th layers of the first layer are transferred to the -1 layer
- The 7, 8, 9 area of the first floor moves to the 0th floor of the Portes Des Lions entrance
- Visitors in the 1, 2, and 3 areas of the 0th floor move to the Passage Richelieu entrance and the Carrousel du Louvre entrance on the 0th floor.
- The 4th, 5th, and 6th layers of the 0th layer are transferred to the -2 layer
- The 7, 8, 9 area of the 0th floor moves to the 0th floor of the Portes Des Lions entrance
- 2, 3, 4, 5 regional tourists on the 1st floor transfer to the 2nd floor
- The 1st layer of the 1st layer is transferred to the 0th layer
- **The total transfer time is 553.77s.**

5 model testing and simulation

In the official website and inquiries to visitors to the Louvre, we obtained some data through statistical means: there are roughly three types of stairs in the Louvre, type A (60 steps, height 9m, length 20.12m, width 5.82m), B Type (45 steps, height 6.75m, length 15m, width 7.54m), C type (45 steps, height 6.75m, length 15m, width 2.94m). The horizontal channel is uniformly set to 16m wide, taking into account the tourists of different

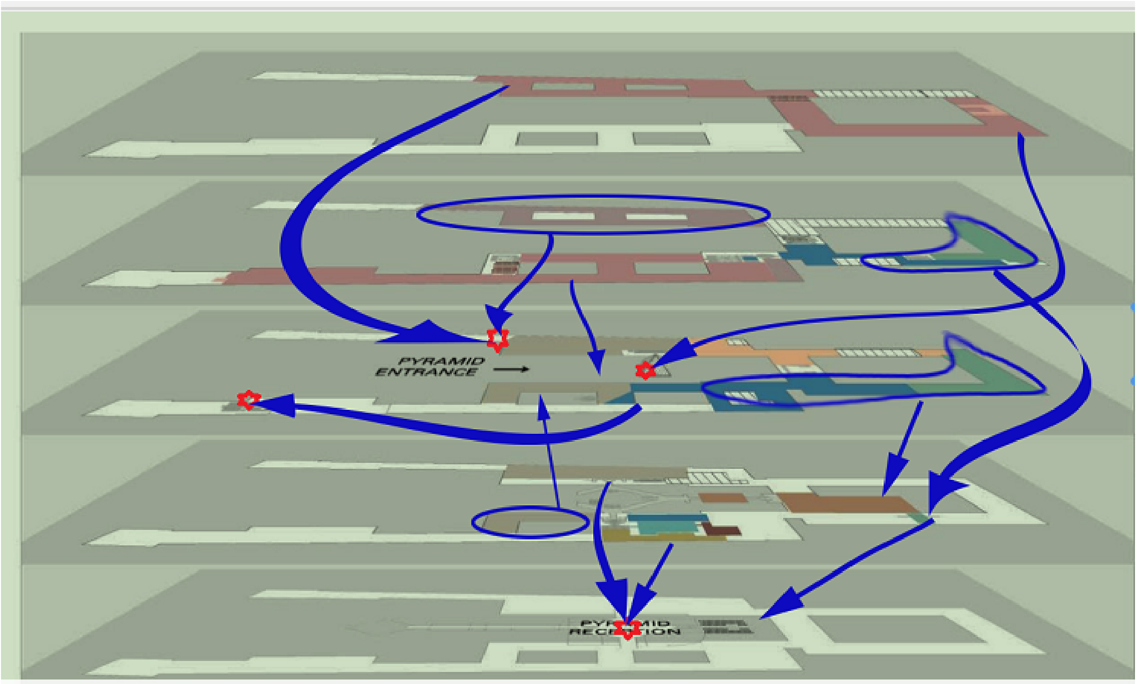

Figure 5: Schematic diagram of the evacuation plan

countries. Proportion and wearing clothes, we calculated the per capita horizontal projection area is 0.15m*m. The per capita shoulder width we set to 0.9m, the number of visitors given by the official and the exhibition area, we calculated through the scale to the second floor, the evacuation pressure of the area 1 is the largest, in the initial unsteady stage 0-57.486s During the period, we set the free movement speed of the tourists in the building to 0.7m/s, and calculated that the number of people transferred from the second floor to the stairs was 150. Because the coverage overlap, 52 tourists were assigned to the area 2, and the remaining 197 people passed the flow. The state was evacuated and passed 137.08s. All the visitors in Area 1 were evacuated to the stairway. During this period, 138 people were transferred to the stairs. The remaining 59 people were transferred to the stairs through 58.51s, and then evacuated to the stairs exit by 148.75s. After 151-194s everyone arrives at the exit, a total of 553.77s is required. We can get 1 layer of evacuation time of 521.73s and 0 layer of evacuation time of 502.31s.

The evacuation time of the -1 floor is 459.44s, because the floors are evacuated in parallel under our schedule, so the time spent on the floor with the longest evacuation time can be the longest time for our evacuation, ie 553.77s.

In the information we obtained, we obtained a matlab open source code for the same floor escape simulation, and the resulting renderings were roughly consistent with our multiple floor evacuation effects:

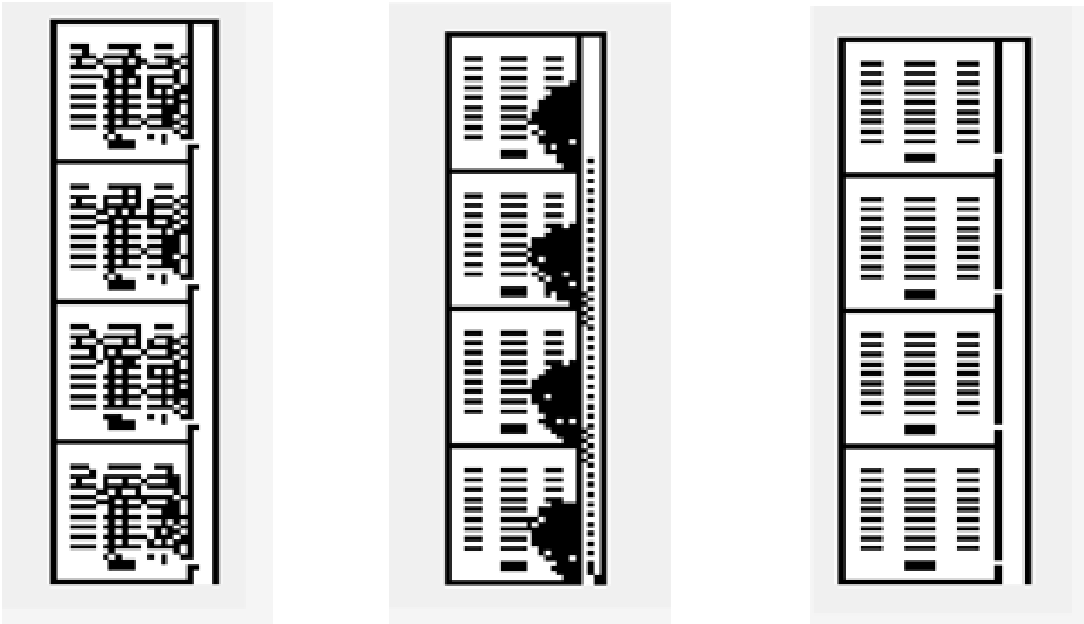

Figure 6: The diagram of personnel evacuation changes

6 Model Evaluation

6.1 advantages

- The model is very robust.The emergency evacuation model will be affected by many complicated factors. We analyze this problem from the perspective of distance dimension, time dimension, individual and global, first modularize complex problems, and then gradually refine and give the optimal solution.
- The model is considered to be delicate and the analysis is ingenious.We skillfully compare human walking to the flow of water, build a flow model, and visualize the problem.
- The model is considered more comprehensively. In the sensitivity analysis module, the factors that can affect the results are analyzed as much as possible to dig out more rules.
- The model has a strong applicability.We consider various uncertain factors in emergency evacuation, and adopt reasonable methods to deal with bottlenecks that exist widely in real life, so that the model can be widely used in other large-scale, pedestrian-flow building sites.
- The model has obvious practical effects.The museum's entire evacuation control time is 553.77s, and the results are ideal and realistic.
- The model is highly risk-resistant. A visitor has multiple alternative escape routes. If a channel is blocked, visitors can change routes immediately.

6.2 Disadvantages

- The considerations are not comprehensive enough.In the event of an emergency, there are many accidental factors in the process of evacuation, so the model incorporates some subjective knowledge, puts forward some assumptions, ignores the secondary factors, and may cause some deviation from the facts.
- The result is too idealistic. We just keep the areas of each floor as parallel as possible, and get our solution through the balanced distribution of pressure, but this is not as good as the ergodic calculation of the evacuation time between all areas. Excellent results are convincing.
- Some special data is not found, so we can only make some correctness assumptions before building the model. If there are more data sources, we can get a more comprehensive and accurate conclusion.

7 Sensitivity analysis

- Sensitivity analysis of human flow density

We find that the flow density of people has a relatively large impact on the movement speed of people in the stairs and horizontal channels. For this reason, we write the image of the v=f(p) function through matlab to reflect the relationship between them:

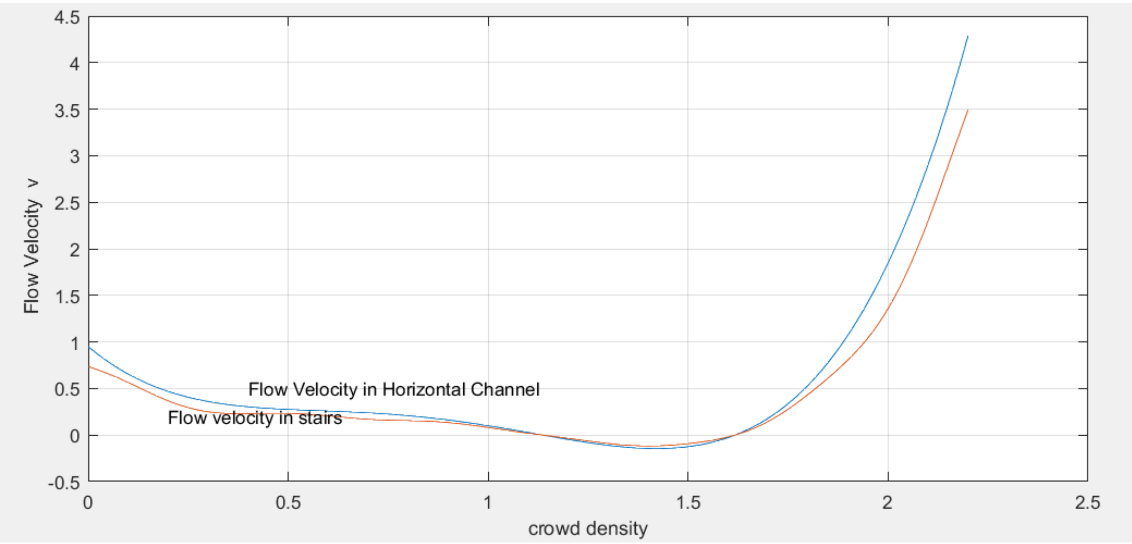

Figure 7: Further study of human flow density and human flow velocity

From the function image we observe that v is negatively related to p when p<1.5, and v is positively related to p when p>1.5, and we use the calculation formula of the human flow density we obtained to bring in the relevant data. Can not be greater than 0.92, we boldly guess, if you do not use Fegress's flow density calculation formula, but calculate the p according to the volume of space can accommodate people:

Each person accounts for about 0.5*0.9m*m. The horizontal area, then p = 1 / 0.45 = 2.22, at this time v is greater than 2m / s, which is undoubtedly excellent, but in fact this value is larger than the actual situation, but after the query data we found that the flow density is 2 people /m*m. At the time, the flow rate of people can reach a maximum of 1.6m / s, so we still have reason to believe that the appropriate increase in the flow density helps us to evacuate people, so that the space can be properly applied.

- Sensitivity analysis on the type of stairs

We mentioned before that there are three types of stairs: type A (60 steps, height 9m, length 20.12m, width 5.82m), type B (45 steps, height 6.75m, length 15m, width 7.54m), C type (45 steps) , 6.75m high, 15m long, 2.94m wide), we found the law by testing the time required for 100 passengers to pass through three stairs:T_A =33.95,T_B=25.71,T_C=45.12;We noticed that the widths of b-type and c-type stairs are almost half different, and their evacuation time is nearly half. It can be seen that different types of stairs have a greater impact on evacuation time, especially for high-rise buildings. Visitors from high places need to go through multiple stairs to escape, so we recommend that the stairs of the building be as wide as possible and as short as possible.The relevant test principle of the horizontal escape channel is the same as that of the stairs. If the horizontal escape channel is designed to be wider, the evacuation time will be shorter, and they are approximately proportional.

- Analysis of the position of the stairs

When we modeled, we found that covering the certain area with the stairs as the center of the Louvre can make all the areas get a reasonable distribution, but we want to explore if a certain area is not covered by the stairs, it will result in evacuation. Big impact: We assume that if there is no downstairs in the No. 8 area on the 1st floor, then they must go to the Lions Gate after the 7th area, and the evacuation time will increase from 228.4s to 557.8s, nearly double the growth.It can be seen that the location of the stairs has an important impact on evacuation.

8 Description and promotion of the model

- Through sensitivity analysis, it can be obtained that increasing the flow density can improve the efficiency of evacuation. In our model calculation, the calculated human flow density usually fluctuates around 0.6, and if it is expanded by 2 times, the flow speed will be significantly improved. We have a bold idea: in the case that we can't change the stairs, we abandon the traditional Fegress flow density calculation formula, but artificially control the flow density according to the actual space can accommodate the volume of people, that is, the original one The occupied space is allocated to 3 people, which will cause a certain free space in the stairs, so that emergency personnel can be arranged to go upstairs from the free space of the stairs, and the uplink and the downlink are parallel, further improving the efficiency of evacuation.

- Use of alternate channels

1).Because special personnel such as disabled people move slowly, if they are evacuated together with others, not only will the overall speed be slowed down, but their speed will also be affected. After the inquiry, we know that the safe evacuation of the people with mobility is allowed. About half of the normal person, so after three minutes of the accident, if the special personnel are still in the museum, we will open an alternate channel for them. Although the safety level of the alternate channel is lower than the main channel, the evacuation effect will be greater than The effect of crowding in the main channel.

2).Since the normal person's safe evacuation time is 7 minutes, we get the evacuation time of 553.77s.Therefore, in order to be able to evacuate everyone, only the alternate channel can be opened, and those who are far away and spend more than 7 minutes together with special personnel can be evacuated from the alternate channel to improve the efficiency of evacuation.

- The model has high applicability. Other large and crowded buildings can also adopt this model. According to the principle of the Agent system, the stairs and exits of the building are rounded to cover all areas, and then according to the cellular automatic The principle of the machine is to judge the best evacuation direction of the personnel. Finally, according to the PSO algorithm, the whole evacuation process is reasonably scheduled from a global perspective.

- Potential bottlenecks that may limit export movement: In the sensitivity analysis, we found that the width of the exit and stairs and the horizontal channel are almost proportional to the evacuation efficiency, which means that the width of the exit determines whether the exit will restrict the movement of visitors. If the stairs are connected before the exit, the width of the stairs will also limit the movement of the tourists. At the same time, we find that during the evacuation of the Louvre-2 floor to the glass pyramid exit, visitors need to climb up the stairs to get out, which also makes evacuation. The efficiency is greatly reduced. If the exit and the stairs are wider than the horizontal channel, then this is an ideal design. Of course, we have no obstacles at the exit.

- Our model provides a two-way escape idea that can handle most emergency evacuations: using the pso algorithm to think that our scheduling has a global view, and visitors in areas with repeated coverage of more than 60% have multiple evacuation destinations. At the same time, we have flexible scheduling through the time and load caused by the competitive pressure of the cell, ensuring that when a channel is not accessible, the museum owner can immediately assign another route to the visitor.

9 Conclusion

In order to realize fast and safe evacuation personnel, we used the principle of Agent system, PSO algorithm, cellular automata algorithm, and related knowledge of greedy algorithm to construct a comprehensive emergency evacuation model, and finally got the evacuation of the entire museum. The figure (see Figure 3) and the overall evacuation time are 553.77s.

However, the evacuation of personnel itself is relatively complicated, involving factors such as people's psychological quality, education, living habits, etc., which are difficult to quantify, and these influencing factors are difficult to accurately describe with mathematical models, so it will inevitably lead to the solution results. deviation.This also confirms that the orderly evacuation is shorter than the disorderly evacuation, so the rationality and scientificity of the evacuation plan is very important. Based on the solution and analysis of the model, we put forward a number of constructive comments on the museum:

a)On the floors with more people, ensure that the corridor doors of each building are unobstructed and there are no obstacles on the corridor.

b)Museum managers should strengthen the rules for learning escapes, familiarize themselves with the location of the stairs in the museum, and learn the length of the stairs from each pavilion to give accurate indications to visitors during evacuation.

c)The museum should conduct evacuation and evacuation drills regularly, improve the safety awareness and coping ability of all personnel, and ensure that non-main channels can be used normally when needed.

d)In the construction of the building, the use of the building should be fully considered and the situation that may be dealt with in order to reasonably determine the width of the corridor, the width of the exit and other relevant parameters, effectively increase the number of evacuation queues, thereby reducing the overall escape time.

In the process of implementing the model, we also found some weaknesses in our model: too idealized. In the unstabilized stage, although the speed that the tourists can achieve is relatively fast, we cannot guarantee that there will be no pedaling, because at this stage It is difficult to coordinate the relationship between speed and safety. The calculated data is not authoritative. In the process of calculation, our data sampling part comes from the official, and some of them are consulted or calculated according to the scale. The result will naturally have some measurement error. And the calculation error, at the same time, our model does not give a targeted strategy for fire, earthquake and other destructive, complex and variable emergencies.If our time can be more adequate and give us more powerful computing resources, we can achieve traversal of evacuation time between regions, and find more rules in a large amount of data, which may make our model More convincing and more efficient.

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Appendices

.1 Floor analysis chart

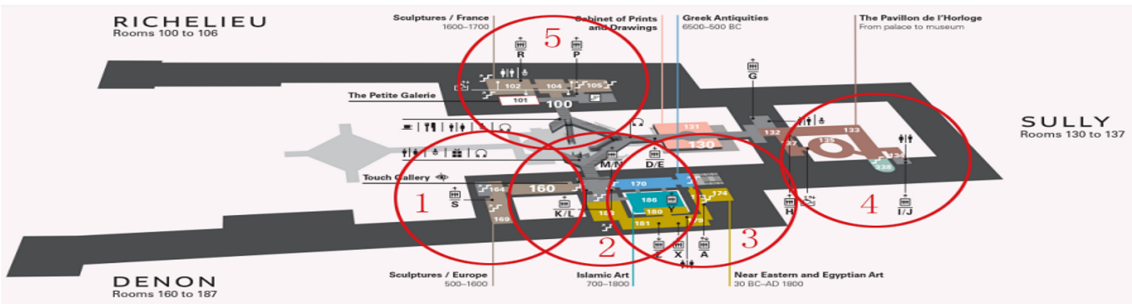

Figure 8: -1 floor

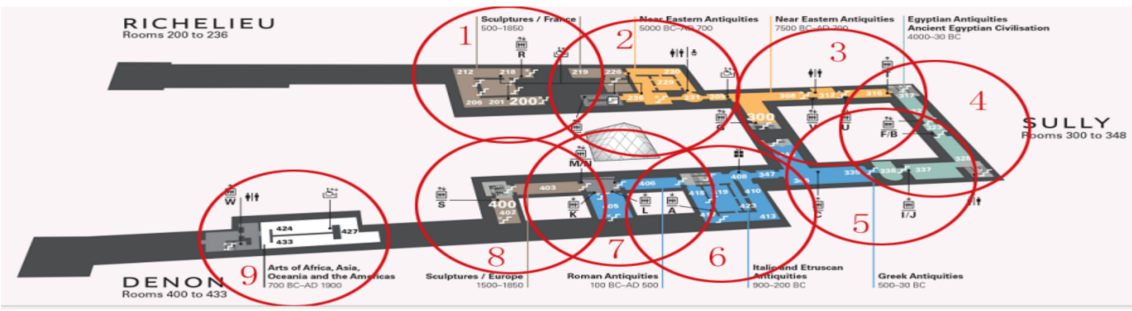

Figure 9: 0 floor

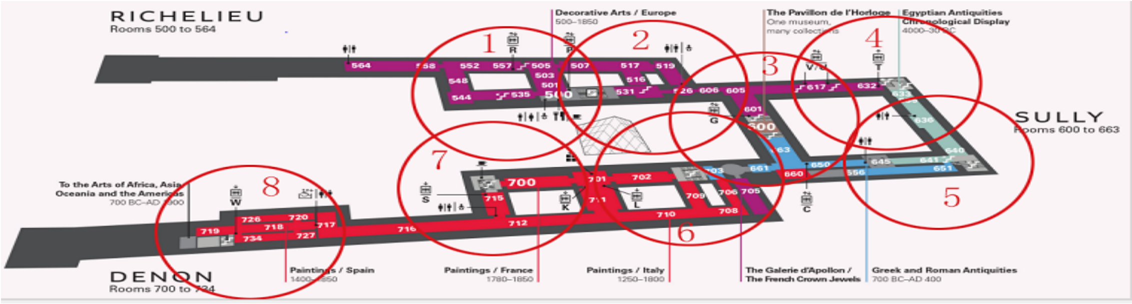

Figure 10: 1 floor

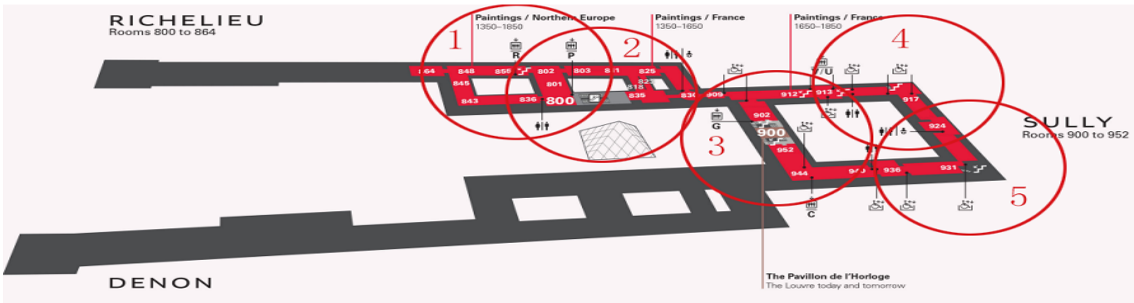

Figure 11: 2 floor

.2 Corridor information statistics table

.3 The average walking width and average projected area of the person are calculated