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Emergency Escape Route Planning for the Louvre Summary

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ABSTRACT. *With more and more terror attacks in France, we established a model to plan routes for tourist evacuation and emergency personnel to enter the Louvre. This model allows tourists to evacuate the Louvre more quickly and safely while emergency personnel can reach all parts of the Louvre as soon as possible. We find out the "exits" that each visitor can reach in the shortest time through Ant Colony Optimization, and divide the area of the same "exits" tourists chose. According to the number of elevators chosen by tourists, the elevator with the least number is selected for emergency personnel. At the same time, by choosing the number of exits, we can determine whether the route is an exit to ground floor or to B2. Then, Poisson distribution calculation based on the probability of a visitor arriving at an elevator, and the waiting time of each elevator is calculated by Queuing Theory. Secondly, we use Logistic Model to simulate the population density growth of these two layers. Then, using population density distribution at each moment to help visitors choose the fastest exit.*

KEYWORDS: *Ant Colony Optimization, Route Planning, Queuing Theory, Flow Density*

1. Introduction

After a steep drop in tourism in 2016 in the wake of the terrorist attacks and the flooding of the Seine in Juneforeign visitor numbers rose to almost 5.7 million in 2017 [4].

According to the construction and the guided tours on each floor, it is found that there are two VIP entrances in ground floor, one VIP entrance on the - 2 floor, one main entrance and one exit to the subway and parking lot. Every floor has elevators, escalators and stairs for tourists to pass through. However, there are many entrances and passages only known by insiders. These passages are small and secret, and generally not open.

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2. Notations

The primary notations used in our models are listed in **Table 1**.

Table 1 Notations

Symbol	Definition
d	Distance
λ	Arrival Flow Intensity
μ	Processing Intensity
p_0	Processing Capacity
P	Loss Probability
Q	Relative Ability of The System
A	Absolute Passing Ability of The System
L	Average Number of People Queued
W	Average Queue Time

3. Our Models

3.1 Ant Colony Optimization Model

We separate the five exhibition floors and analyze each layer one by one. Let's take the underground floor as an example.

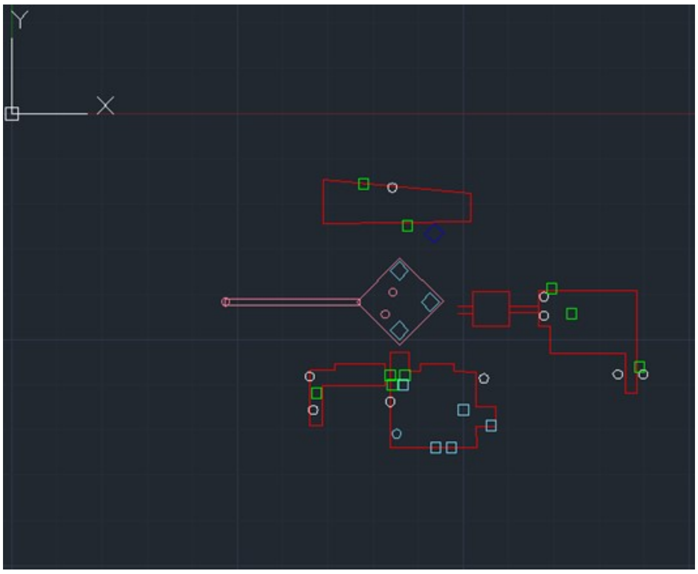

Figure. 1 The View of -1F

ISSN 2616-5775 Vol. 2, Issue 2: 78-84, DOI: 10.25236/AJCIS.010041

In the figure, the circle represents the staircase, the square represents the elevator and the diagonal represents the elevator. The light blue staircase represents that the staircase can reach the next floor, but cannot reach the upper floor, and the other color staircase means it can only reach the upper floor or from the upper floor to this floor, so is the escalator. In addition, the light blue elevator represents the elevator can reach any floor, while the other color elevator can only run up. Visitors on B1 need to escape from B2, where there is a downward staircase, five downward elevators and three downward elevators.

For this model, we divide it into 328020 small square lattices in 710m*462m rectangle. Assuming that each of the four vertices of each lattice has a visitor, the corresponding coordinates are (0,0), (0,-1)... (0,-461) (1,0), (1,-1)... (1,-461) (2,0), (2,-1)... (2,-461), (709,-1)... (709,-461).

The corresponding coordinates of each visitor are the linear distances to light blue stairs, elevators and escalators and the linear distances can be calculated according to the distance formula [6] between the two points:

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (1)$$

Having done those steps, we can obtain the minimum path of stairs, elevators or escalators, and record them. At the same time, we take the average speed of people in emergency situations is 0.6 m/min, and find out the time to reach the stairs, elevators or escalators.

Of course, restricted by the terrain, the distance between two points is not necessarily the distance between visitors and the stairs, elevators or escalators. So we re-divide the area into four areas.

Then we counted the usage times of all stairs, elevators and escalators, and selected five of them as exit points for rescue workers with the least usage times. We excluded the five exits from the tourist escape corridor conduct the recalculation by the above model. In the rest of the population, we draw the flow distribution map based on the data obtained as the work done above.

3.2 Export Level Population Model

After completing the ant colony algorithm, we get the regional route of each coordinate point in each layer. Next, we need to connect each layer to form the general escape route [7]. Considering the impact of terrain, our team divided the whole model into three parts, namely B2, ground floor-south and ground floor-north. The volume, population input and population output of the three regions were discussed separately. From the general data, we can calculate the normal evacuation rate of two-storey elevator is 2.68 persons per second, the normal evacuation rate of single-storey elevator is 5.36 persons per second, the normal evacuation rate of escalator is 8.57 persons per second, and the normal evacuation rate of staircase is 12 persons per second. The evacuation rate of general escape exit is 400 persons per minute. We can calculate the population growth rate of B2 is 51.18 persons per

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second, that of ground floor-source is 43.26 persons per second, and that of ground floor-north is 37.37 persons per second.

The corresponding function image is:

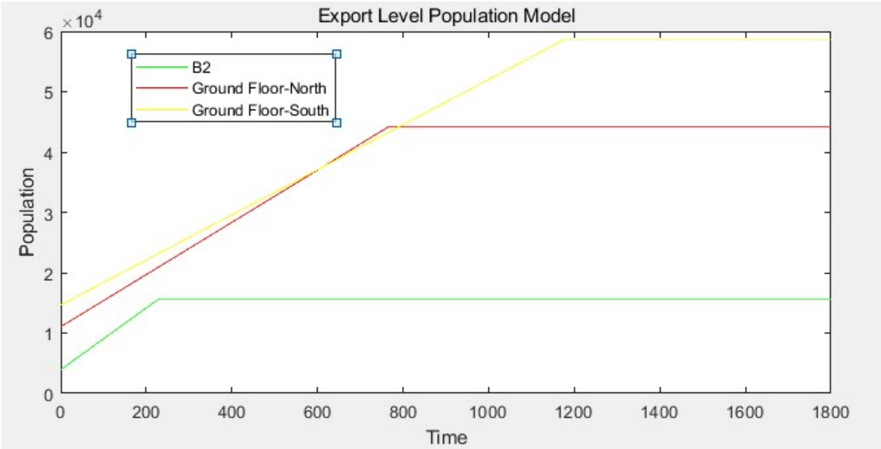

Figure. 2 Export Level Population Model

As can be seen from the graph, the congestion gap between the three areas is too large. B2 has been already congested in 3 minutes, while the other two areas need 10 minutes or even 20 minutes. Two reasons account for the gap. One is that the two areas of ground floor occupy a larger area, so the saturation time is longer. The other is that the growth rate of ground floor is low because of the difference in the number of through elevators in each area.

3.3 Queuing Theory Model

Due to the large number of tourists in Louvre, people must wait in line at the exit or elevator exit, and this time is generally long, which seriously affects the speed of tourists' escape. Therefore, this problem should be considered when planning the escape route. For this problem, we solve it through the Queuing Theory Model.

Set the system visitor arrival flow as Poisson flow, and its intensity is lambda. There are n'exitsin the system. The'exits' have the same service time and obey the Exponential distribution. Its strength is. When the visitor arrives, if the elevator is busy, the visitor waits in line until there is an elevator to serve him.

For multi-channel waiting system, there are:

$$p_0 = 1 - \lambda \tag{2}$$

Service Intensity:

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$$\rho = \frac{\lambda}{\mu} \tag{3}$$

Loss Probability:

$$P = 0 \tag{4}$$

Relative Passing Ability of the System:

$$Q = 1 - P = 1 \tag{5}$$

Absolute Passing Ability of the System:

$$A = \lambda Q = \lambda \tag{6}$$

Average Number of Queued Visitors:

$$L = \frac{\rho^{n+1}}{n \cdot n!} P_0 \frac{1}{(1 - \frac{\rho}{n})^2} \tag{7}$$

Average Queue Time:

$$W = \frac{L}{\lambda} \tag{8}$$

From this formula, the average queuing [10] time for each ’exit’ can be calculated.

The intensity of arrival flow [11] of each elevator (λ) can be obtained by calculation.Through the code, the average waiting time of each elevator can be calculated as follows:

ISSN 2616-5775 Vol. 2, Issue 2: 78-84, DOI: 10.25236/AJCIS.010041

Code	Arrival Flow Intensity	Processing Intensity	Average Waiting Time
f1	20.51	0.33	3.08
f5	38.57	0.33	3.06
f7	89.43	0.33	3.04
f9	57.45	0.33	3.05
f11	70.95	0.33	3.04
f12	33.08	0.33	3.06
f13	29.82	0.33	3.06
f14	53.53	0.33	3.05
f15	69.73	0.33	3.04
f16	71.65	0.33	3.04
f17	63.57	0.33	3.05
f18	79.43	0.33	3.04
f19	82.98	0.33	3.04
f20	131.15	0.33	3.03
e2	233.56	0.18	5.56
e4	29.48	0.36	2.81
e5	28.76	0.36	2.81
e7	292.65	0.18	5.56
e8	26.43	0.36	2.81
e9	42.01	0.36	2.8
e10	10.75	0.36	2.87
e11	51.01	0.36	2.79
e12	54.98	0.18	5.57
e15	15.13	0.18	5.62
e16	23.08	0.18	5.6
e17	39.81	0.36	2.81
e18	142.42	0.36	2.78
e19	149.22	0.18	5.56
s1	79.19	0.33	3.04
s2	78.03	0.33	3.04
s3	32.14	0.33	3.06
s4	40.81	0.33	3.06

These waiting times can then be uploaded to Affluences App for visitors and emergency personnel to have a view and plan new routes [9].

4. Conclusion

For the Louvre escape problem, we were asked to establish a grooming model, as well as the main route for rescuers, and evacuation issues are very common in our lives. Almost all large buildings and important places of interest have their own evacuation system to deal with different disasters and avoid crowding and disorder.

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According to thiswe establish Ant Colony Optimization ModelExport Level Population Model and Queuing Theory Model to study how to Plan an escape route correctly and find out a route for rescue workers to arrive at the rescue site successfully and rapidly.

Considering different conditionswe still need to make progress in our model. Escape route will change when facing different conditions of a disaster.For example, elevator will turn off when fire happens .Export B2 will close and everyone need to evacuate by the export in ground floor when earthquake occurs .In the condition that our model is not suitable for all the condition ,we will optimization model by creating a more adaptable model.

Acknowledgments

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