Development and Design of Crowd Evacuation Simulation System in Complex Environment

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Abstract. In order to better evacuate people in emergencies and ensure the safety of people’s lives and properties, we designed and developed a simulation system for crowd evacuation in complex environments based on the RVO algorithm. The system has completed the functions of scene construction, crowd simulation, optimal path planning, evacuation process simulation and playback, and heat map analysis. After the evacuation process is over, the evacuation drawings, evacuation process and related content can be saved in the form of the entire project if the creator chooses to save it, which is convenient for future review.

1. Introduction
In large buildings with densely populated people, in emergencies, it is necessary to arrange effective evacuation routes and carry out an orderly evacuation in order to maximize the safety of people's lives and property. This is also the original intention of this system. An effective evacuation route is to choose the best and shortest evacuation route that can be selected when facing emergencies to ensure that people are evacuated as soon as possible. Orderly evacuation is to change the evacuation route in time when facing congestion to prevent the evacuation route from being blocked and stampede. The optimal evacuation route for the crowd to achieve the purpose of alleviating congestion. The above two points can maximize people's safety. This system simulates the entire process of crowd evacuation and realizes visualization to facilitate route adjustment and prevention. The users of this system are mainly line planning and operation and major accident plan management personnel.

2. Functional design
2.1. Scene construction (obstacle simulation)
In order to simulate the real scene, we first import the floor plan of the scene to be simulated, and then build the scene according to the floor plan. To simulate the building or obstacle (wall) in the scene, we use a rectangle with a certain width to simulate the thickness Wall. In the process of setting up the scene, in order to facilitate the display and enhance the visualization, we use the mouse to click on two points to create a wall between the two points and display them in a straight line; for the convenience of operation, the line generated after clicking the first point will follow Move the mouse until the position of the next point is determined. At the same time, a reminder function that the line segment will be marked red when the line is horizontal or vertical is designed; if you want to draw a horizontal or vertical
line segment, press and hold the key corresponding to the direction of the four ASDW keys. It is possible to assist in drawing straight line segments in this direction.

![Scene construction (obstacle simulation)](image)

**Fig.1 Scene construction (obstacle simulation)**

2.2. *Crowd simulation*

In the calculation process, in order to simulate a single person in the crowd, we use the method of simulating the individual into a circle corresponding to a coordinate point and a radius of five units with the point as the center of the circle. Crowd simulation is a collection of multiple such single person simulations. Crowd simulation is created along with the room in the building. The initial number of people is set to five. You can change the number of people in the room by clicking on the room, and you can also create a crowd. Create a crowd at the specified location by specifying the area (the number of people can be set), and the crowd generated in the room will automatically set the exit of the room as the first target point.

2.3. *Optimal path planning*

In the calculation process, we first cut the entire area into triangles of similar size and dense enough by the method of triangulation, and the vertices of each triangle serve as a network of navigation points during the crowd evacuation process. According to the location generated by the crowd, the optimal path for each person to evacuate to the exit is calculated, and the navigation point conversion during the recording process is performed.
2.4. Simulation of the whole evacuation process
After the optimal path is planned, the crowd is evacuated according to the path. The entire evacuation process is displayed through OpenGL, the wall is represented by line segments, and each individual in the crowd is displayed through pictures, according to the time every five milliseconds Coordinate point record, record the entire evacuation process, and store it in the form of a file, and then restore the entire evacuation process by reading the file. Recording in file format is convenient for us to replay the entire evacuation process in the future.

2.5. Heat map analysis
During the entire evacuation process, the density of the crowd greatly affects the evacuation progress, and too dense crowds can easily lead to accidents such as trampling, so the heat map showing the density of different locations at different times during the evacuation process is particularly important. In order to show the effect of gradual change, we pass the same time, the point is colored once by someone. For the coloring method, we use multiple circles whose radius gradually increases, but the color changes from red to green. The circle with the smallest radius The radius of the (red circle) is set the same as the radius of the person. In the same area, when a large number of people gather at the same time, it will show continuous red, while the color will be lighter in the places where the people are scarce, so as to achieve the effect of the heat map constantly changing with the flow of people.
3. Technical analysis

3.1. RVO obstacle avoidance principle
In the process of crowd evacuation, from the current position to the next designated target point, the collision between everyone and the avoidance of obstacles in the process of travel are realized through the principle of RVO. When there is an obstacle (wall or person) between the current position and the established target point, offset the current moving direction and move forward a certain distance, return to the previous moving direction, and judge again whether there is an obstacle, if there is, continue The previous operation, if it does not exist, move on.

3.2. Navigation Point Network Settings
Use the triangulation method to lay the navigation points in the entire area. The path selection between the start point and the end point of each person is realized by the navigation point network. The connection between the navigation points is the path. When the path is created, if there is an obstacle between the two navigation points, the path is set to infinity (that is, it does not exist). If there is no obstacle, the path is created successfully. The path is given different weight values according to the length of the path and the different conditions of the road section (whether there is congestion, whether there is an emergency). According to the different weights of each section of the path, the Dijkstra algorithm is used from the starting point to calculate the optimal evacuation path, which changes constantly according to the weight.

3.3. Coordinate transformation
Through the qt coordinate, the coordinate conversion between the natural two-dimensional coordinate system and OpenGL realizes the whole process from drawing to calculation and then to display. Draw obstacles and crowds in the qt canvas, each coordinate point is saved by vector, but the y-axis direction of the qt canvas is downward, and the two axes have no negative values, which will lead to the drawing of the qt canvas and the natural two-dimensional coordinates. The axis is displayed symmetrically about the x-axis, and the whole is in the first quadrant of the natural two-dimensional coordinate system. From the qt canvas to the natural two-dimensional coordinate system, we take the x-axis as the axis for symmetry, that is, the y-axis plus a negative value, which will adjust the direction of the entire building,
and then move the whole to the upper left and adjust it to the origin. The first step of coordinate conversion is realized, and calculation is performed in the converted natural two-dimensional coordinate system. When OpenGL is displayed, the center of the two-dimensional coordinate system is in the center of the screen and corresponds to the natural two-dimensional coordinate system, which can be displayed directly. The coordinate conversion operation is completed by projecting the calculated point onto the OpenGL canvas.

3.4. OpenGL realizes visualization
During the evacuation process, the crowds are in different states at different times, and the crowds in different locations are not nearly the same. Visualization using OpenGL can ensure the detection of changes in various situations throughout the process, and facilitate timely changes and optimization of evacuation routes. At the same time, in various emergencies, changes in path selection caused by changes in path weights can be visually displayed, which also greatly facilitates real-time observation. At the same time, during the evacuation process, compared with the macroscopic evacuation observation, zooming in to observe the details of the evacuation process of a certain place is also one of the important functions of this software. When a place is congested during the evacuation process, carefully observe the situation in that place separately, and then make subtle path adjustments, and change the path calculated by the system to eliminate the congestion at that place. This is also the advantage of single-point amplification.

4. Conclusion
Crowd evacuation simulation system in complex environment builds complex environment scenes by inputting drawings, calculates and outputs crowd evacuation path planning in emergencies, and simulates the entire process of crowd evacuation by route. The system simulates the factual changes of road conditions and random changes of the crowd in emergencies, and monitors the whole process through a real-time visual interface, and finally uses heat map and other data analysis assistance, so that the relevant department personnel can make the best route planning and preventive measures.

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