2012 4th International Conference on Intelligent Human-Machine Systems and Cybernetics

The application of Dijkstra's algorithm in the intelligent fire evacuation system

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***Abstract*—As to the major building in the city currently ,the traditional fixed signs of the fire evacuation system can't meet people's security needs any longer and the intelligent fire evacuation system has been the current development direction.This article combined the Dijkstra's algorithm with intelligent fire evacuation system self-developed which identified the fires by analyzing the fire linkage signal received and thereby determine the best route to evacuate the people in the fire region safely.**

Key Words-Fire evacuation; CAN bus; Dijkstra's algorithm; The shortest path

I. INTRODUCTION

As the concentration of the urban population in China, the large high-rise buildings and underground structures have emerged, leading to the more lengthy and complex of the building channel. It is a huge challenge for fire evacuation undoubtedly.But the traditional fire evacuation system can't determine the fire situation and can't control the direction of emergency evacuation lights that are likely to mislead people.The Intelligent fire evacuation system has a good solution to this problem. Based on on-site fire situation,this system indicates a safe direction for escaping by emergency evacuation lights so that people can avoid the smoke,convective heat and flame effectively .

Currently, the foreign institutions engaged in computer simulation research for evacuation are mainy located in Germany, Britain, Japan, the United States, Sweden, Australia, etc.[1] The relevant research institutions domestic are behind the developed countries obviously and the companies engaged in the development and production of intelligent fire evacuation system are never less.Therefore, the issue is important for the personnel evacuation and casualties reduction.

II. THE DESIGN FOR EVACUATION SYSTEM

The intelligent fire evacuation system is divided into four levels in structure,that are the monitoring host, the controller slave, controller extension and intelligent terminal devices. Monitoring host is cascaded with the controller slave, controller extension, and intelligent terminal devices through the CAN bus and the parallel bus, and it also receives real-time fire linkage signal. The fire linkage signal is the feedback signal detected by the sensing devices which are installed at the fire scene . The system structure is shown in Figure 1.

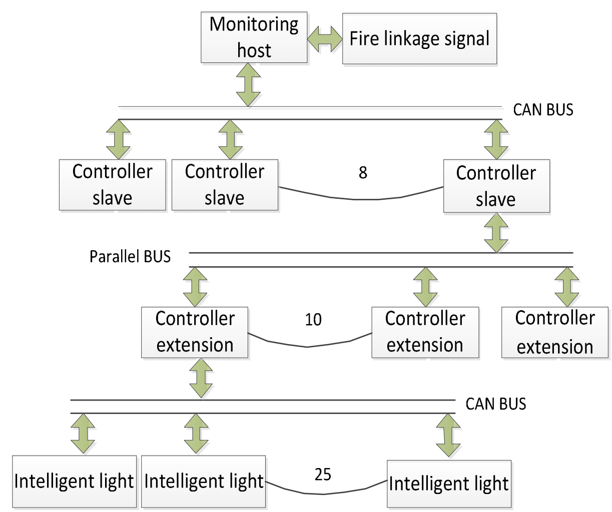

Fig.1.System structure plans

The system uses VB to develop PC software and it has resource management, user interface and other functions, thus achieving personnel monitoring and systems management automation. A motherboard, which is designed for the data transmission between CAN bus and PCI bus ,is placed in the PCI slot of monitoring host (PC) , ensuring the high efficiency of data transmission.

III. DIJKSTRA'S ALGORITHM

A. *Dijkstra's algorithm principle*

The right shortest path is a classic combinatorial optimization problem, and the literatures [2-4] have studied the issue in detail. The Dijkstra's algorithm has been recognized as the best algorithm for the problem since 1959, and the complexity computed by the Fibonacci heap is $O(m+n\log n)$ [5]. The descriptions of the basic idea of Dijkstra's algorithm are as follows:

All points in the weighted graph are stored in two arrays. The first array stores all points starting from the source point 's' to all points of the shortest path and the second array stores the nodes which have not determined the shortest path .Then calculate the shortest path from the source node 's' to the the target node according to the ascending order of the path length and iterative the node in the second array one by one to the first array till all points in the second array are contained in the first array[6].

B. *Dijkstra's algorithm description*

978-0-7695-4721-3/12 $26.00 © 2012 IEEE
DOI 10.1109/IHMSC.2012.7

*1)*For a given weighted graph, $G = \langle E, W, S \rangle$,all nodes in it are stored in set E $(e_0, e_1, e_2 ...... e_n \in E)$ and the weights of each neighboring nodes are stored in set W $(W_0, W_1, W_2 ...... W_n \in W)$ and all points starting from the source point of the shortest path are stored in set S. When initializing ,only the source points 's' are stored in set S and the nodes which haven't determined the shortest path are stored in $E - S$. $D(k)$ represents the distance between the source point 's' and the point 'e_k'. All points in the weighted graph can be represented by the adjacency matrix A . $A(j,k)$ means the distance between point 'e_j' and 'e_k' in matrix A and $A(j,k) = \infty$ when there is not direct path.

*2)*Initialization, $S = \{s\}$, $E - S = \{e_0, e_1, e_2 ... e_n \in E\}$. Select the points '$e_j$' and make $\mathrm{D(j)} = \min\{\mathrm{D(i)} \mid \mathrm{e_i} \in (\mathrm{E} - \mathrm{S})\}$, $\mathrm{S} = \mathrm{S} \cup \mathrm{e_j}$;

*3)*Change the source point 's' to point 'e_k'$\in (E - S)$ and $\mathrm{D(k)} = \mathrm{D(j)} + \mathrm{A(j,k)}$, if $\mathrm{D(k)} > \mathrm{D(j)} + \mathrm{A(j,k)}$.

*4)*Repeat steps (2) and step (3) till obtaining the shortest path from the source point 's' to the rest nodes.

Based on above steps, we can find out the shortest path starting from the source point 's' to any point in the weighted graph.Take figure 2 for example, point 's' is the source point and the steps that calculate the shortest distance between the source point to E1, E2, E3, E4 are as follows:

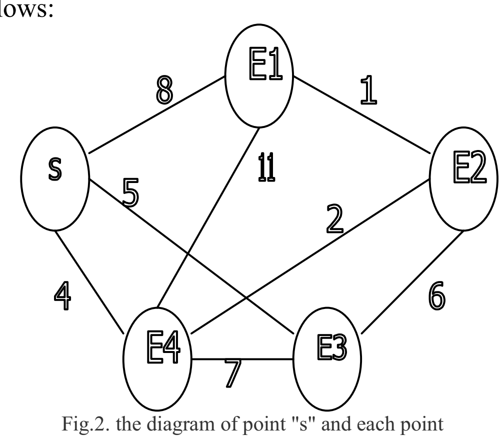

Fig.2. the diagram of point "s" and each point

Step1:give the adjacency matrix and initialize S and $E - S$, $\mathrm{S} = \{\mathrm{s}\}$, $\mathrm{E} - \mathrm{S} = \{\mathrm{E1, E2, E3, E4}\}$, $\mathrm{D}(\,) = \{0, 8, \infty, 5, 4\}$ .The path is $\{\mathrm{S, E4}\}$

$$
\begin{array}{cc}
 & \begin{array}{ccccc} s & E_1 & E_2 & E_3 & E_4 \end{array} \\
A = & \left\{\begin{array}{ccccc} 0 & 8 & \infty & 5 & 4 \\ 8 & 0 & 1 & \infty & 11 \\ \infty & 1 & 0 & 6 & 2 \\ 5 & \infty & 6 & 0 & 7 \\ 4 & 11 & 2 & 7 & 0 \end{array}\right\} \begin{array}{c} s \\ E_1 \\ E_2 \\ E_3 \\ E_4 \end{array}
\end{array}
$$

Step2:find $\mathrm{e_j} = \mathrm{E4}$, $\mathrm{S} = \{\mathrm{s, E4}\}$, $\mathrm{E} - \mathrm{S} = \{\mathrm{E1, E2, E3}\}$ according to $\mathrm{D(j)} = \min\{\mathrm{D(i)} \mid \mathrm{e_i} \in (\mathrm{E} - \mathrm{S})\}$ and modify the shortest path from the source 's' to all points within the collection $E - S$ to 6, $\mathrm{D}(\,) = \{0, 8, 6, 5, 4\}$ .The path is $\{\mathrm{S, E4, E2}\}$.

Step3:find $\mathrm{e_j} = \mathrm{E2}$, $\mathrm{S} = \{\mathrm{s, E2, E4}\}$, $\mathrm{E} - \mathrm{S} = \{\mathrm{E1, E3}\}$ according to $\mathrm{D(j)} = \min\{\mathrm{D(i)} \mid \mathrm{e_i} \in (\mathrm{E} - \mathrm{S})\}$ and modify the shortest path from the source 's' to all points within the collection $E - S$ to 7, $\mathrm{D}(\,) = \{0, 7, 6, 5, 4\}$ .The path is $\{\mathrm{S, E4, E2, E1}\}$.

Step4:find $\mathrm{e_j} = \mathrm{E1}$, $\mathrm{S} = \{\mathrm{s, E1, E2, E4}\}$, $\mathrm{E} - \mathrm{S} = \{\mathrm{E3}\}$ according to $\mathrm{D(j)} = \min\{\mathrm{D(i)} \mid \mathrm{e_i} \in (\mathrm{E} - \mathrm{S})\}$ and modify the shortest path from the source 's' to all points within the collection $E - S$ to 5, $\mathrm{D}(\,) = \{0, 7, 6, 5, 4\}$ .The path is $\{\mathrm{S, E4, E2, E1}\}$.

IV. THE MODEL CONSTRUCTION OF THE FIRE EVACUATION

The model requires the interrelations of on-site environment, space and human .It should take a full account of relevant factors impacting the evacuation. It is more important to grasp the psychological state of the person and improve the efficiency of the evacuation to the maximum extent . In the actual scene of the fire, there are many factors impacting the weights of the path, including the spreading speed of the fire,the smoke and toxic gas content in the air, the convective heat in the road for escaping, the escaping speed and psychological qualities of the people in different gender and age, the population density and road congestion status ,etc. Therefore, the author assumes an area as the plan of a mall, which is shown in Figure 3.

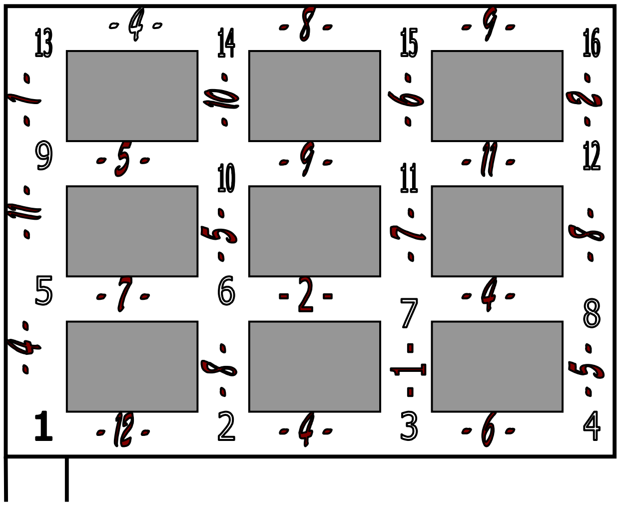

Fig.3.Simulation plan of a mall

Make a weighted graph $G=<E,W>$ represent this plan and each intersection of the sections as the node in the graph weighted $(e_2,e_3,e_4.....e_{16}\in E)$. The position of the node 1 is for the exits,which is the source point 's' , $s=e_1$ .The weights of the adjacent nodes are $(w_1,w_2,w_3...w_{24},w_{25})=(12,4,6...8,9)$,The weights vary as different site conditions .The greater the weight, the worse the road conditions, furthermore,the lower the escaping coefficient.The weight value of the path is infinite,which is $w_n=\infty$,when a section of the escaping routes are cut off completely by the disaster. It is assumed that the sections (e_9,e_{13}) (e_9,e_{10}) (e_9,e_{10}) (e_9,e_{10}) (e_9,e_{10}) are cut off due to severe fire in this mall , that is $(w_2,w_9,w_{13},w_{15},w_{18})=\infty$, and the weights of the remaining sections are unchanging. According to Dijkstra's algorithm ,we can get a adjacency matrix A in 16 × 16 .Then input this matrix to matlab for calculation and get the shortest distance and the corresponding path between the nodes and the source as shown in Table 1.

TABLE 1

Node	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Shortest distance	12	49	49	4	11	48	44	15	16	25	36	30	26	31	38
The corresponding path to source point	1 2	1 5 6 10 11 12 8 7 3	1 5 6 10 11 12 8 4	1 5	1 5 6	1 5 6 10 11 12 8 7	1 5 6 10 11 12 8	1 5 9	1 5 6 10	1 5 6 10 11	1 5 6 10 11 12	1 5 6 10 14 13	1 5 6 10 14	1 5 6 10 11 15	1 5 6 10 11 12 16

V. THE ANALYSIS OF ALGORITHM APPLIED

The smoke, gases, temperature and other sensors installed at the fire scene send the signal detected to monitor host through the CAN bus and the host gets the weights of the corresponding sections of the fire scene by analyzing and processing.Due to the fact that the size of the weights reflect the evacuation status of the road directly and based on Dijkstra algorithm ,the host reflects the contents of the table 1 to the simulated shopping malls. It can control the emergency evacuation lights in the corresponding location and the escaping route map of the scene is shown in Figure 4.The direction of the arrow means the safe escaping direction .

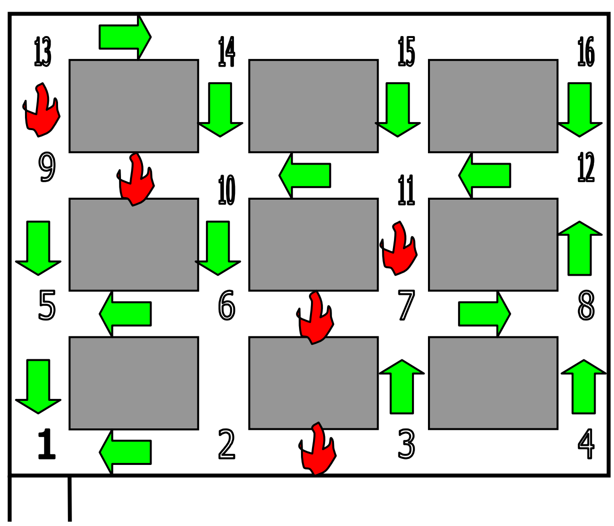

Fig.4.Escaping route of the fire scene

It should be noted that different people for evacuation have different weights in the same sections in the evacuation site due to the different physiological and psychological characteristics of the people evacuated.Therefore, it doesn't require all personnel to choose the shortest path and it leads to road congestion and the evacuation time extended otherwise[7]. The correct operation is that monitoring personnel can observe the overcrowding condition of various sections by the monitoring video and evacuate the people to the shortest route firstly, which can ease the road congestion, thus ensuring the safe evacuation of all personnel.

VI. CONCLUSION

There are many shortest path algorithms and some classic algorithms,such as A* algorithm, Dijkstra's algorithm and Floyd's algorithm.These algorithms have advantages anddisadvantages and it mianly depends on the target problem. A* algorithm aims to solving the shortest distance between one point to another. Dijkstra's algorithm aims to solving the shortest distance between one point to the remaining points .While Floyd's algorithm aims to solving the shortest distance between two of all points in the network.Thus Dijkstra's algorithm is one of the best methods for solving the evacuation safely.However, Dijkstra's algorithm applies only to the situation that all the weights are above or equal to zero.Whereas, the weight of the sections just meet this condition.

This article makes a good use of Dijkstra's algorithm to solve the fire evacuation.The monitoring host can analyze the situation of the fire site in real time,which makes the system self-calculated and control the evacuation light firstly to guide the safe evacuation of personnel and makes the system intelligent and automated.The practice shows that Dijkstra's algorithm is feasible.In practice, the fire control and monitoring personnel need to make an advance analysis of several cases that are most likely to get fire and get the shortest evacuation routes advance,in order to achieve faster evacuation, reducing the computation time[7].In this way, it is is more effective and flexible in evacuation when this plan is combined with Dijkstra's algorithm.

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