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ALGORITHMIC SOFTWARE OF THE FIRE MONITORING SYSTEM

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Abstract—*Program and algorithmic software of information fire monitoring system is developed. The simulation results are presented.*

Index terms—Evacuation; optimal evacuation route.

I. INTRODUCTION

Today, the construction of large shopping malls in which you can have more than 3000 visitors widespread. In winter, due to possible rapid changes in voltage, which cause a short circuit there may be fires.

According to the results of research in the first half of 2014 that was made by the specialists of the Ukrainian scientific-research Institute of civil protection monitoring of fires and the consequences from them on the basis of the accounting data received from local authorities SSES of Ukraine in regions and Kyiv there were registered 30236 fires, representing an increase of 3.5 % over the same period of 2013.

The number of deaths due to fires decreased by 3.2 % and amounted to 1197 against 1237. The number of injuries in fires increased by 3.0 % and amounted to 798 against 775.

Material losses caused by fires, amounted to 2 billion 15 million 3 thousand UAH. of which direct losses are 587 million 32 thousand UAH., and side – 1 billion 427 million 971 thousand UAH.

During the reporting period in Ukraine on an average day there were 167 fires, which killed 7 and injured 4 people, a fire destroyed or damaged 70 buildings and 13 units of vehicles; daily financial losses from fires amounted to 11.1 million UAH.

On trade and warehouse buildings, the number of fires increased by 20.9 %. In general, on these objects appeared 521 fires. Direct losses amounted to 54 million 562 thousand UAH. (+58,7 %). Incidental damages to these facilities amounted to 100 million 856 thousand UAH. (+73,3 %).

Due to fires in industrial buildings, 2 people died (for 6 months of 2013 - 1 person). The largest percentage of fires in industrial facilities noted in the Khmelnytsk region (2.9 % of their total number in the region). The average in Ukraine is 1,7 % [1].

A serious problem in high-rise buildings is fire safety. Experience of high-rise construction in neighboring countries forces us to approach to the design of sprinkler systems in high rise buildings so that each apartment (room) in this house was equipped with a fire alarm system, that the house had its own autonomous fire extinguishing system, emergency elevators [2].

One of the main means of protection against the damaging effects of fire is timely evacuation and dispersal of site personnel from hazardous areas.

Researches have shown that the majority of people during evacuation (up to 90 %) able to adequately assess the situation and reasonable actions, but, experiencing fear and infecting with it each other, can panic.

The movement of people is considered as an important functional process, typical for buildings of any purpose.

In case of fire there is a real threat to the health and lives of people. Therefore, the evacuation process begins almost simultaneously and has a clear focus. As a result of such simultaneous and directional movement and due to the limited bandwidth of emergency routes and exits s a higher density of human flows can be created, there are physical effort on the part of individuals who are evacuated, which significantly reduces the speed..

In the article [3] a system that includes the following tasks is proposed. The system can solve such problems as: to detect fire in time.; rate the fire by the number of sensors which worked; to predict the spread of fire in time and location of the hearth fire; to estimate the number of people in each room; to calculate the optimal evacuation route for each time period of evacuation considering the spread of fire; to implement information for people by audio and visual signals.

The purpose of this article is to develop software and algorithmic support for the proposed information fire monitoring system.

II. PROBLEM STATEMENT

The region D, which covers the totality of the premises with people is set; the field of people location $B_i (i=\overline{1,n})$ and their number in each room

r_i; areas that are not affected by fire and available for the movement of people A_i.

The coordinates of the source of fire S_i are determined. Association of evacuation routes:

$$U_{i=1}^{m} l_j, \, j = \overline{1,m},$$

where $l_j(x_{jn}, y_{jn}, x_{jk}, y_{jk})$ are sections of the path, which correspond to the movement of people during evacuation.

The characteristics of the materials in the premises is given.

It is necessary to calculate the optimal path of escape from high-rise buildings during a fire. The optimal is the way that ensures the evacuation of the maximum number of people (N = max) in minimum time (t = min).

To lead the mathematical solution of the problem and the block diagram of the algorithm.

III. The structure of algorithmic software

Algorithmic software consists of the following parts:

1. The algorithm for processing of sensor readings.
2. The algorithm for predicting the spread of fire.
3. The algorithm for determining the number of people in the premises.
4. The algorithm of optimal evacuation.
5. The algorithm for informational support, which is the conclusion of the evacuation route using light and sound alarm.

The general algorithm of the system:

1. The determination of the location of fire on the basis of the triggered sensors; determining the type of premises, information about it.
2. The determination of the number of people in each location at time of fire.
3. Modeling of fire spread in space and time.
4. The calculation of evacuation routes.
5. The implementation of the information for the people.

In the work a new evacuation algorithm is developed.

IV. Problem statement of the shortest path searhing

Let $G = (V, E)$ is a weighted directed graph that corresponds to the location of evacuation, $w(v_i,v_j)$ is the weight of arc (v_i, v_j).

Shortest path problem is to find the shortest path from a given initial vertex a to a given vertex z. The following two problems are the direct synthesis of the problem on the shortest path.

1. For a given initial vertex a to find the shortest path from a to all other vertices.
2. To find the shortest path between all pairs of vertices.

V. Review of methods of searching evacuation routes

For solving the problem of searching of optimal evacuation routes in practice the most used are the three algorithms: Dijkstra’s algorithm (D), the algorithm of Floyd-Warshal (FW), Bellman-Ford algorithm (BF).

Dijkstra’s algorithm is designed to determine the shortest paths from one vertex of weighted directed graph $G = (V, E)$, where V is the set of vertices of the graph; E is the set of arcs of the graph with the source vertex s, in which the weights of all edges are non-negative. The essence of Dijkstra’s algorithm lies in the gradual build-up of a tree of shortest paths from the source node. In the process, the method requires a mandatory condition: after the addition at each stage of the communication line and the node, the updated route should be minimal in all boundary nodes that are not included in the tree. In the course of building a tree of shortest paths the vectors of weights of routes are determined, as well as vectors of the initial component of routes are adjusted.

The algorithm of Floyd-Warshal allows to find the shortest distances between all vertices of a weighted directed graph. This algorithm is based on the fact that in the graph that has no negative edges, each shortest elementary path consists of a set of elementary shortest paths. The algorithm of Floyd-Warshel is more general compared to Dijkstra’s algorithm, because it allows to find the shortest path between any two vertices of the graph. The algorithm contains three nested cycles, i.e. it has a cubic complexity.

Bellman-Ford algorithm is the search algorithm of the shortest path in a weighted graph. The algorithm finds the shortest paths from one vertex to all the others. To calculate the shortest path with its use it is needed to perform the entire (n – 1) cycles. However, in practice, the algorithm can be used to track the negative cycles, having exactly n cycles [4].

Lee algorithm – an algorithm that allows to find the minimal path in the graph with edges of unit length. It is based on the search algorithm in width. It is used to find the shortest path in the graph, in general, it finds only its length.

Advantages of Lee algorithm is that it can be used to find the route in each maze and with any number of prohibited items (walls). The only drawback of this algorithm is that when you build the tracks it requires a lot of memory.

These algorithms have their own advantages and disadvantages, but the most promising is the algorithm of Floyd-Warshel that requires modification.

VI. Development of an algorithm for optimal exit

To apply the algorithm of searching the optimal path it is necessary to present the evacuation plan of the building as a weighted directed graph $G=(V,E)$, $|V|=n$, the vertices of which correspond to the groups of the adjacent premises, and the weights of the arcs determines the possibility of the passage between the vertex and its effectiveness (Fig. 1).

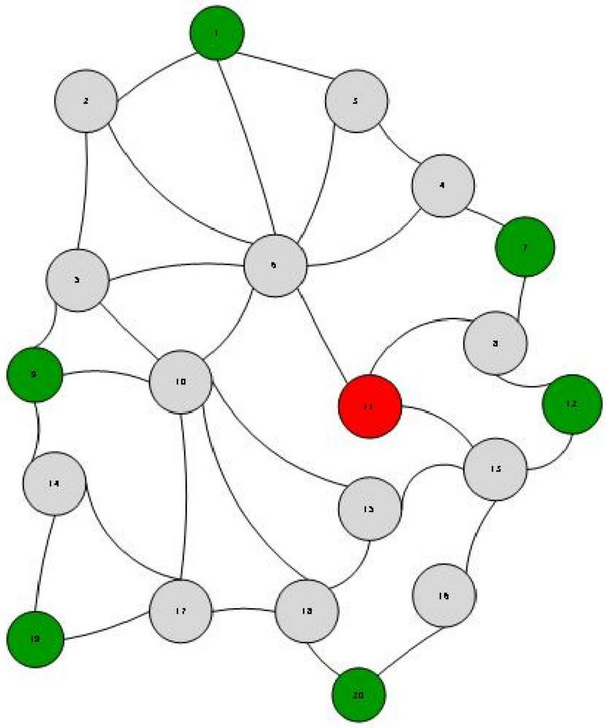

Fig. 1. The graph corresponding to the evacuation building

Let the vertices of the graph $G=(V,E)$, $|V|=n$, be numbered from 1 to n. The designation to the length of the shortest path from 1 to j is introduced, which in addition to the vertices i, j passes only through vertices i ... k. It is obvious that d_{ij}^{0} is the length (weight) of the edge (i, j), if it exists (otherwise its length can be designated as).

There are two different values of d_{ij}^{k}, $k\in(1,...,n)$:

1. The shortest path between i, j does not pass through the vertex k, then $d_{ij}^{k}=d_{ij}^{k-1}$.

2. There is a shorter path between i, j that passes through the vertex k, then it passes first from i to k, and then from k to j. In this case, it is obvious that $d_{ij}^{k}=d_{ik}^{k-1}+d_{kj}^{k-1}$.

Thus, to find the function it is enough to choose the minimum of two designated values.

Then the recurrent formula for d_{ij}^{k} has the form:

$$d_{ij}^{0} - \text{length of edge } (i,j);$$

$$d_{ij}^{k}=\min\left(d_{ij}^{k-1}, d_{ik}^{k-1}+d_{kj}^{k-1}\right).$$

The algorithm of Floyd-Warshel sequentially calculates all values of $d_{ij}^{k}, \forall i,j$ for k from 1 to n.

The obtained values of d_{ij}^{n} are the lengths of shortest paths between vertices i,j.

VII. The simulation results

The simulation results are presented in (Fig. 2).

Fig. 2. The simulation results

The fire in the figure marked with red diamonds. Emergency exits are marked by the numbers from 1 to 9. The premises are numbered from 1 to 104.

Based on the developed algorithm, the calculations of the best ways to exit the building during a fire were made. Evacuation routes are marked with different colors in the figure.

So as a result of algorithm the optimal evacuation routes for all premises corresponding to certain emergency exit.

Conclusion

The necessity of building the information system fire monitoring, which would release people from public buildings high-rise buildings in case of fire is substantiated. Program and algorithmic software of information fire monitoring system is developed. The simulation results are presented.

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В. М. Синєглазов, В. Л. Купріянчик, І. О. Степаненко. Алгоритмічне забезпечення системи пожежного спостереження

Розроблено програмне та алгоритмічне забезпечення системи пожежного спостереження. Представлено результати моделювання процесу евакуації.

Ключові слова: евакуація; оптимальний маршрут евакуації.

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Разработано программное и алгоритмическое обеспечение системы пожарного наблюдения. Представлены результаты моделирования процесса эвакуации .

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