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FIRE MONITORING INTELLECTUAL INFORMATION SYSTEM

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Abstract*—*The software of fire monitoring intellectual information system is developed. A connected graph of the graphical model is proposed. The simulation results are presented.

Index terms—Artificial neural networks; the best evacuation route; intelligent information systems.

I. INTRODUCTION

Today, the construction of large shopping malls in which you can have more than 3000 visitors is 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 fire-related deaths has decreased by 3.2 % and has amounted to 1197 against 1237. The number of injuries in fires has increased by 3.0 % and has 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.

The number of fires in trade and warehouse buildings has increased by 20.9 %. In general, 521 fires appeared on these objects. Direct losses has amounted to 54 m 562 thousand UAH (+ 58.7 %). Incidental damages to these facilities has 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 has been noted in the Khmelnitsky region (2.9 % of their total number in the region). The average in Ukraine is 1.7 % [1].

A serious problem of high-rise buildings is fire safety. Experience of high-rise construction in neighboring countries forces us to approach to designing 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 would have its own autonomous fire extinguishing system and 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.

The researches have shown that the majority of people during evacuation (up to 90 %) are able to adequately assess the situation and act reasonably, but experiencing fear and infecting with it each other can cause 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 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, high-density human flows can be emerged. That is why there is a physical effort on the part of individuals who are evacuated, which significantly reduces the speed.

II. PROBLEM STATEMENT

Let us consider a graphical representation of the object required for solving the problem of evacuation (Fig. 1). As an object a trading room (TR) that is located on one of the floors of multi-storey shopping center (SC) is selected.

There are some shops, partitioned by drywall constructions that may be on both sides of TR (numbered from 1 to 18). Inside of TR may be outlets without walls, restaurants, cafes (marked with circles).

In floor of TR LED lights of different colors are mounted with certain discrete (marked by dots in the figure), which are switched at the time of the fire making evacuation route (light of one color combustion defines one possible route. The principle of switching will be indicated below). Emergency exits from TR are identified (numbered from 1 to 8), and at the door of each store the input/output sensors are installed, which data is processed to determine the number of people in the store at each time point and transfer the data to the fire alarm control panel of SC. The number of people that are in the TR outside of stores can be determined only approximately.

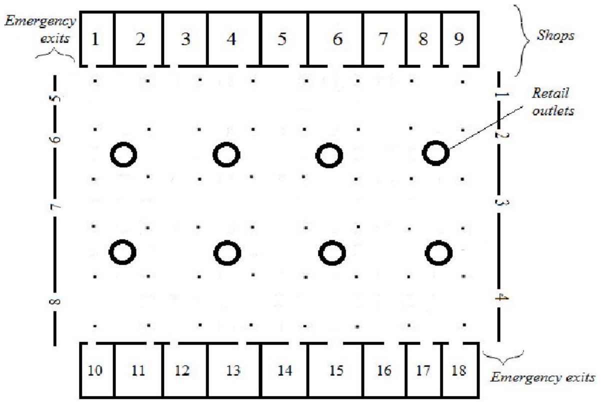

Fig. 1. A graphical representation of the object evacuation

We associate a connected graph with this graphic model that is shown in Fig. 2, for which, the following initial data is determined.

1. $A=\{a_i\},\ i=\overline{1,n}$ is the set of shops and retail outlets in the TR; each element a_i corresponds to a pair of $\{x_i, y_i\},\ i=\overline{1,n}$ is the coordinates of locations of the shops.

2. $B=\{b_i\},\ i=\overline{1,n}$ is the number of visitors who are currently in stores.

3. $C=\{c_k\},\ k=\overline{1,m}$ is the set of exits from TR with coordinates $\{x_k, y_k\},\ k=\overline{1,m}$.

4. $D=\{d_p\},\ p=\overline{1,l}$ is the set of shops where there was a fire with coordinates $\{x_p, y_p\},\ p=\overline{1,l}$.

5. $E=\{e_j\},\ j=\overline{1,q}$ is the set of points of fire in the TR with coordinates $\{x_j, y_j\},\ j=\overline{1,q}$.

6. $F=\{f_h\},\ h=\overline{1,v}$ is the set of LED lamps which are mounted in the floor of TR with coordinates $\{x_h, y_h\},\ h=\overline{1,v}$.

The vertices of graph are numbered from 1 to 66, each of them corresponds to a single element. Since the vertices 1–18 correspond to the set of shops, the vertices 19–58 correspond to the set of LED lamps, and the vertices 59–56 correspond to the set of exits.

The task of determining optimal routes for the evacuation of visitors from shops and TK in case of fire in one or more stores from the set D and/or at one or more points of TR from the set E is stated. Each of the routes should be highlighted with different colors, be of minimum length and provide the evacuation of maximum number of people in minimal time.

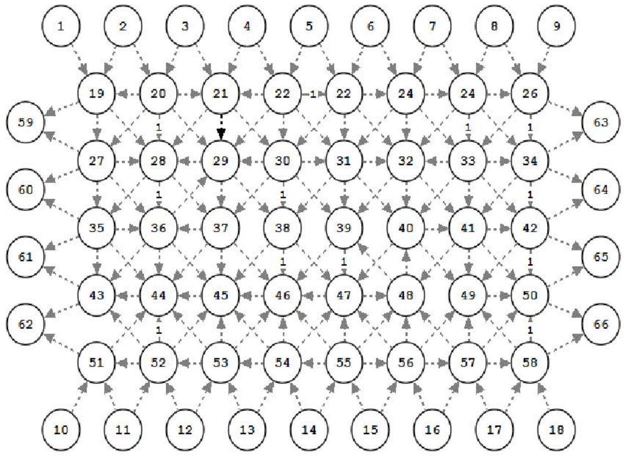

Fig. 2. A connected graph of the graphical model

III. Algorithms of optimal routes for evacuation determination

Let there be given: connected graph G of finitely presented automaton model A, the sets $A=\{a_i\},\ i=\overline{1,n}$ and $C=\{c_j\},\ j=\overline{1,m}$, number of pairs $f_i f_j,\ i=\overline{1,n},\ j=\overline{1,m}$ is the initial-final states (options for evacuation routes) and the set of arcs (number of variants of routes) of the model $N_p(f_i f_j)$, connecting each of pairs $f_i f_j,\ i=\overline{1,n},$ $j=\overline{1,m}.$

It is required to select the only route P_{ijk}, where $k=N_p(f_i f_j)$ (the set of arcs) between each of pairs $f_i f_j$ so as to minimize the time of passage of each path' areas $t_{ijk}=\sum_{i=0}^{r}\Delta t_i$, where r is the number of involved LED lights, corresponding to kth path between the states f_i and f_j, and Δt_i indicates weight corresponding to the arc between two consecutive states of kth route. Then the task will be a minimization of the function

$$\Phi(P)=\sum_{i=1}^{n}\sum_{j=1}^{m}\sum_{k=1}^{N_p(j)} P_{ijk}t_{ijk}\to\min, \qquad (1)$$

under the constraints:

– between each pair of $f_i f_j$ strictly one route is selected:

$$\sum_{k=1}^{N_p(j)} P_{ijk} = 1 \quad \forall k \in N_p(j), \qquad (2)$$

– the total number of shortest routes must be $m \times n$:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{k=1}^{N_p(j)} P_{ijk} = m \times n. \qquad (3)$$

The problem of determining the shortest routes is to choose a pair P_{111}, P_{112} or P_{113} for states a_1 with f_1 and pairs P_{221} or P_{222} for connecting a_2 with f_2. Acceptable or desired to be a solution that satisfies the condition (1) under the constraints (2), (3).

A block diagram of model in Matlab is shown in Fig. 3.

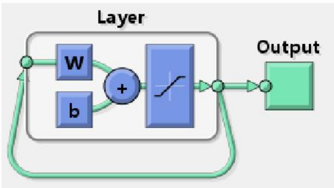

Fig. 3. A block diagram of Hopfield model

IV. SOFTWARE INTERFACES OF THE FIRE MONITORING SYSTEM

Input/output panel is shown in Fig. 4.

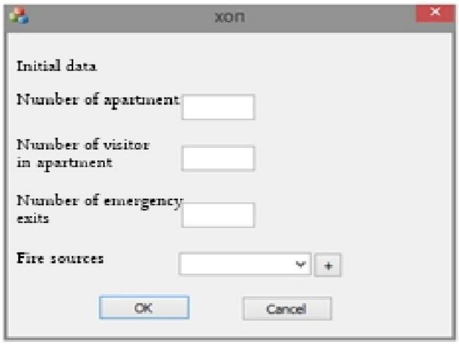

Fig. 4. Input/output panel

The plan of the building is shown in Fig. 5.

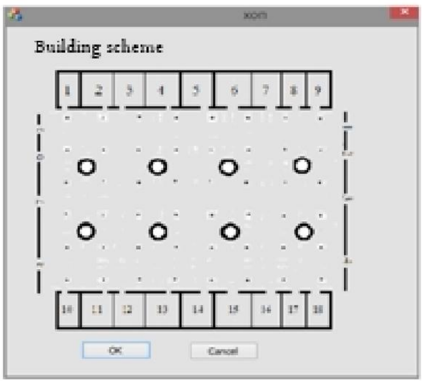

Fig. 5. The plan of the building

V. SIMULATION RESULTS

Let us consider that there is a fire in the shop No.7 on the diagram (see Fig. 1). The number of people in the stores was 700, the number of people in the TR was 500.

First of all, people which are close to the place of fire are evacuated.

According to the proposed algorithm and based on the work of the neural network evacuation routes (shown in Fig. 6) are defined.

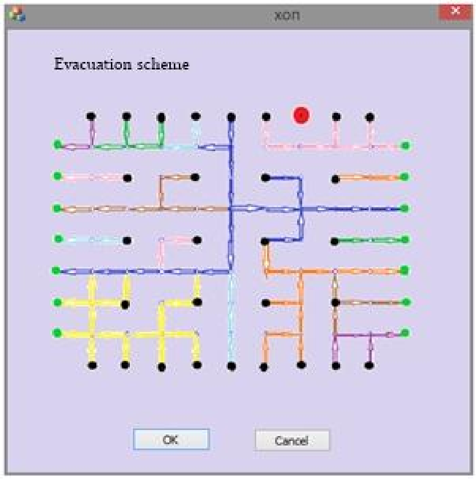

Fig. 6. The scheme of evacuation in case of fire in one of the shops

On the scheme, the red dot is the center of fire, black dots are the shops and retail outlets, green dots indicate locations of emergency exits. The evacuation routes for different stores and retail outlets are marked with the arrows of different colors.

CONCLUSION

An algorithm for optimal evacuation that is based on use of graph theory and the optimization algorithms based on artificial neural network of Hopfield is developed.

The simulation of the information fire monitoring system in determining the optimal evacuation routes from the SC in case of fire is produced.

Program interfaces of the system are developed.

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О. І. Чумаченко, В. Л. Купріянчик. Інтелектуальна інформаційна система пожежного спостереження

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

Ключові слова: штучні нейронні мережі; оптимальний маршрут евакуації; інтелектуальні інформаційні системи.

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Е. И. Чумаченко, В. Л. Куприянчик. Интеллектуальная информационная система пожарного наблюдения

Разработано алгоритмическое и программное обеспечение интеллектуальной информационной системы пожарного наблюдения. Предложен связанный граф графической модели эвакуации. Представлены результаты моделирования.

Ключевые слова: искусственные нейронные сети; оптимальный маршрут эвакуации; интеллектуальные информационные системы.

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