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THE INFORMATION FIRE MONITORING SYSTEM

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Abstract*—*The information fire monitoring system for support of evacuation of people from shops and trading room in case of fire is considered.

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 Khmelnitsky 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.

II. PROBLEM STATEMENT

Let us consider a graphical representation of the object for which to solve the problem of evacuation is required (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.

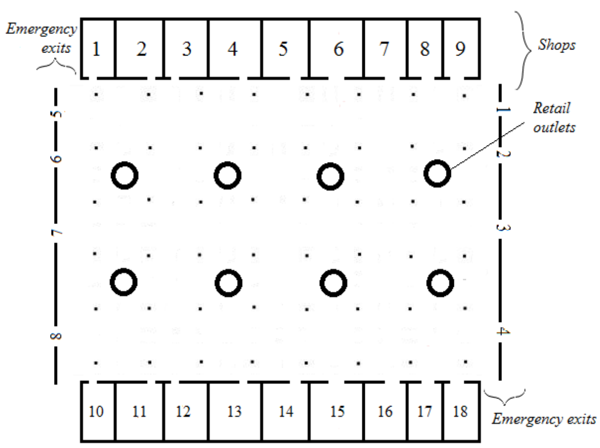

Fig. 1. A graphical representation of the object evacuation

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 to 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.

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 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 maximal number of people in minimal time.

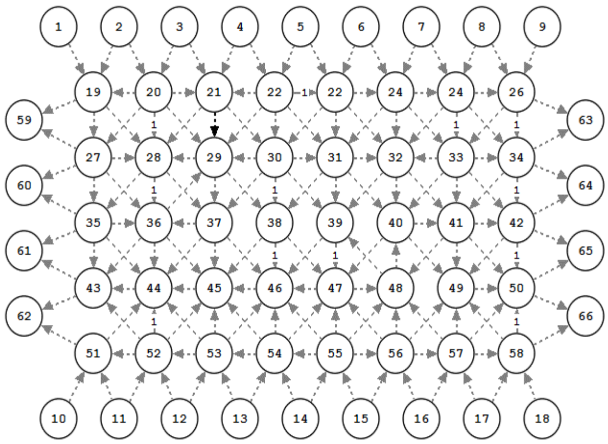

Fig. 2. A connected graph of the graphical model

III. Methods for solving the problem

Since over time the fire spreads in space, it is required for determination of the optimal evacuation routes at each time point to predict which of the areas of the TR will not be available for the passage of visitors during the evacuation, and will end up out of the route. Therefore it is necessary to constantly change the source data. Considering the foregoing, the problem of determining optimal routes for evacuation of visitors from the shops and TR in case of fire in one or more shops of the set D and / or one or more points of TR of the set E will have a slightly different view.

Figure 3 shows the object of evacuation in case of fire.

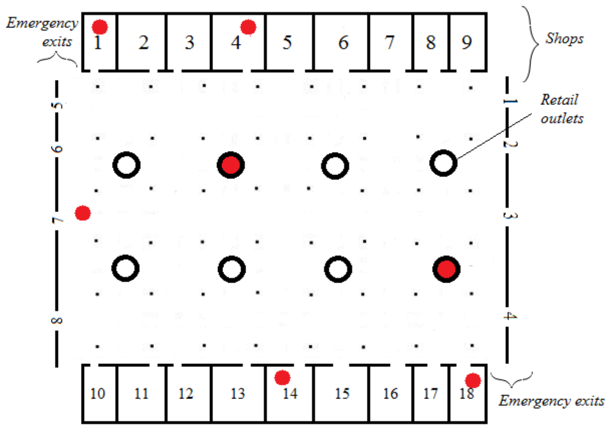

Fig. 3. The object of evacuation in case of fire

In the figure, the red dots indicate the locations of fire.

For simulation of the spread of fire in time and space a few models are used, namely [3]:

– the band model (to predict the development of fire in a partially enclosed spaces);

– the field model (based on the Navier–Stokes equations);

– the model of sensors (to predict the response time of different detectors);

– the model of evacuation (to predict the amount of time that is required to evacuate people from the burning building);

– the model of structures' sustainability to the fire (takes into account the features of the building structure to predict the effect of temperature on the mechanical properties);

– evolutionary modeling [4] (is mainly used to optimization of discrete-valued functions).

There are a lot of algorithms to solve the problem of determining optimal routes for evacuation of visitors from the shops and TR in case of fire [5]. Some of them are listed below:

– Floyd algorithm;
– Danzig algorithm;
– Rosenthal algorithm;
– Dijkstra's algorithm;
– wave algorithm (Lee algorithm).

Since the assigned task relates to optimization problems, the mentioned algorithms are not suitable to solve it. For this purpose, it is proposed to use a neural network.

According to [6], neural networks have some benefits and advantages over traditional computing systems, namely the following:

1. Solving problems with unknown regularities using learning ability on the set examples.
2. Ability to work with a large number of non-informative, noise input signals.
3. Adapting to a changing environment.

In particular, neural networks, trained to act in a certain environment can be easily retrained to work in conditions of small oscillations of parameters of the environment. Moreover, for operation in no stationary environment (where the statistics change over time) neural networks retraining in real time can be generated:

1. Potential ultra-high speed due to the use of massively parallel processing of information.
2. Fault tolerance for the hardware implementation of neural network (their performance under unfavorable conditions falls slightly).

To solve the problem it is proposed to use Hopfield network [7].

IV. ALGORITHMS FOR SOLVING THE PROBLEM OF DETERMINING OPTIMAL ROUTES FOR EVACUATION OF VISITORS FROM THE SHOPS AND TR IN CASE OF FIRE

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 is the indicates a 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 mn:

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

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).

Let us consider a model of Hopfield neural network with continuous states and continuous time, used to select the shortest path between the given $f_i f_j$, $i = \overline{1, n}$, $j = \overline{1, m}$ pairs in the network.

The topology of network is represented in Fig. 4.

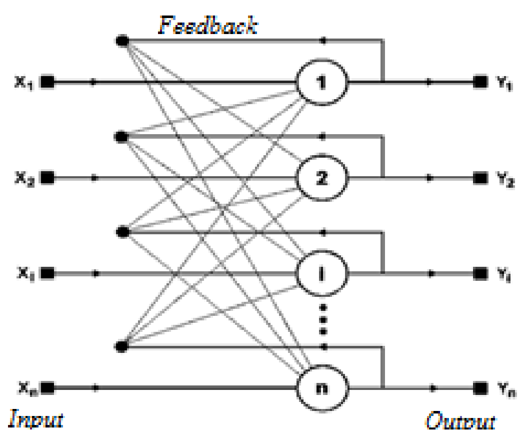

Fig. 4. The scheme Hopfield network

The Hopfield network [8] uses three layers: an input and output layer, and Hopfield layer. Each layer has the same number of neurons. Hopfield layer's outputs are connected to the inputs of all neurons in Hopfield layer, except itself, as well as to the corresponding elements in the output layer. In the operation mode, the network sends data from the input layer through the fixed weight of the compounds to the Hopfield layer.

The dimensions of the input and output signals in the network are limited in the software implementation only with capabilities of a computer system on which the neural network is simulated, in a hardware implementation – with technological capabilities. The dimensions of input and output signals are the same.

Each neuron of the system can take one of two states (which is similar to the output of a neuron with threshold activation function)

$$x_i = \begin{cases} 1, \\ -1. \end{cases}$$

Spin interaction in the network is described by the equation ("energy" function that decreases during the operation of the network)

$$E = \frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} w_{ij} x_i x_j,$$

where w_{ij} is the element of interaction matrix W, which consists of the weights of connections between the neurons. In the learning process M "images" are recorded in this matrix – *N-dimensional binary vectors*: $S_m = (s_{m1}, s_{m2}, ..., s_{mN})$.

In the Hopfield network the matrix connections is symmetric ($w_{ij} = w_{ji}$), and the diagonal elements of the matrix are set equal to zero ($w_{ii} = 0$), that excludes effect of influence on the neuron itself and is essential for the Hopfield network.

The calculation of weights (learning of network) is derived by the following formula

$$w_{ij} = \frac{1}{N}\sum_{d=1...m} X_{id} X_{jd},$$

where N is the vectors' dimensions; m is the number of output vectors that are stored; d is the number of stored output vector; X_{ij} is the i th component of the stored output j th vector.

For neural network interpretation of the problem we introduce a network of neurons $\left[V_{ijk}\right]$ with the dimension of $n \times m \times N_p(i)$. The output voltage of the neuron (which determines its state) of this neural network approaches to the binary values $V_{ijk} = \{0,1\}$ in process of transition to a state sustainable balance with minimal energy when selecting the activation function of the neuron as a sigmoid

$$g(U_{ij}) = -\frac{1}{1+e^{\lambda U_{ijk}}},$$

where λ is a number that determines the type of sigmoid.

The excited state of the neuron $V_{ijk} = 1$ in the network corresponds to the fact that between f_i and f_j states the shortest route is chosen:

$$P_{ijk} \Leftrightarrow V_{ijk},\ i = \overline{1, n},\ j = \overline{1, m},\ k = N_p(f_i f_j).$$

The dynamics of the network is described as

$$\frac{dU_{ijk}}{dt} = \frac{U_{ijk}}{\tau_{ijk}} + \sum_{\mu=1}^{n}\sum_{\nu=1}^{m}\sum_{\chi=1}^{N_p(\nu)} T_{ijk\mu\nu\chi} V_{\mu\nu\chi} - I_{ijk},$$

$$V_{ijk} = g\left(U_{ijk}\right),\ V_{ijk}(t_0) = g\left(U_{ijk}(t_0)\right) = V_{ijk}^{(0)},$$

where $T_{ijk\mu\nu\chi}$ is the coefficient of synaptic connections between the neurons ijk and $\mu\nu\chi$; I_{ijk} is the shift, that is applied to the neuron ijk, $N_p(\nu) = N_p(f_i f_j)$ is the number of routes between $f_i f_j$ pair, and τ_{ijk} is the time constant of ijk th neuron.

V. SIMULATION RESULTS

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

First of all, the evacuation of people that are close to the place of fire.

According to the proposed algorithm and based on the work of the neural network evacuation routes (shown in Fig. 5) are defined.

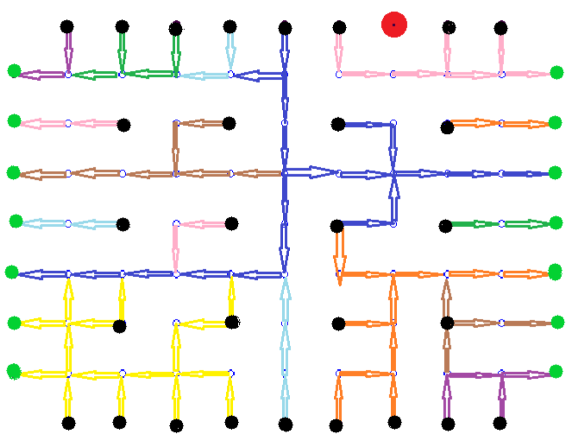

Рис. 5. The scheme of evacuation in case of fire in one of the shops

On the shame, 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.

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В. М. Синєглазов, В. Л. Купріянчик. Автоматизоване проектування інформаційної системи пожежного спостереження

Розглянуто інформаційну систему пожежного спостереження для підтримки евакуації людей з магазинів і торгового залу у разі виникнення пожежі.

Ключові слова: евакуація; оптимальний маршрут евакуації.

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В. М. Синеглазов, В. Л. Куприянчик. Автоматизированное проектирование информационной системы пожарного наблюдения

Рассмотрена информационная система пожарного наблюдения для поддержки эвакуации людей из магазинов и торгового зала в случае возникновения пожара.
Ключевые слова: эвакуация; оптимальный маршрут эвакуации.

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