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DEVELOPING DECISION-MAKING MODELS AND ALGORITHMS TO HELP PREVENT EMERGENCIES

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Abstract. *The article is devoted to the solution of the scientific issue of decision-making support for the prevention and elimination of the consequences of emergency situations. The relevance of this issue is related to the need to develop a theoretical basis for optimizing the risk of adverse effects on human health and the environment in connection with emergency situations, and a predictive model for the development of emergency situations and their prevention or elimination of their consequences. The optimization of the importance measure of signs for predicting the values of the factors of fire conditions has been carried out. In addition, a regression model of the least squares method was developed based on the information obtained from the methane sensor, which is considered the most important parameter in the occurrence of fire, in relation to one cycle of sampling, in order to predict fire situations and form a training sampling model.*
Keywords: *model, algorithm, estimation, prediction, optimization, parameters, classification.*

Annotatsiya: *Maqola favqulodda vaziyatlarning oldini olish va oqibatlarini bartaraf etish bo'yicha qarorlar qabul qilishni qo'llab-quvvatlashning ilmiy muammosini hal qilishga bag'ishlangan. Ushbu muammoning dolzarbligi favqulodda vaziyatlar bilan bog'liq holda inson salomatligi va atrof-muhitga salbiy ta'sir qilish xavfini optimallashtirishning nazariy asoslarini ishlab chiqish zarurati bilan bog'liq bo'lib, favqulodda vaziyatlarning rivojlanishi va ularning oldini olish yoki oqibatlarini bartaraf etish uchun bashoratlash modeli taklif qilingan. Yong'in holatlari omillari qiymatlarini bashoratlash bo'yicha belgilarni muhimlilik o'lchovini optimallashtirish amalga oshirilgan. Undan tashqari, yong'in holatlarini bashoratlash, o'quv tanlanma modelini shaklantirish uchun yong'inni yuzaga kelishida eng muhim parametr hisoblangan metan datchigidan bitta sikl tanlanmaga nisbatan olingan ma'lumot asosida eng kichik kvadratlar usulining regressiya modeli ishlab chiqilgan.*
Tayanch so'zlar: *model, algoritm, baholash, bashoratlash, optimallashtirish, parametrlar, tasniflash.*

Аннотация. *Статья посвящена решению научной проблемы поддержки принятия решений по предупреждению и ликвидации последствий чрезвычайных ситуаций. Актуальность данной проблемы связана с необходимостью разработки теоретических основ оптимизации риска воздействия на здоровье человека и окружающую среду в связи с чрезвычайными ситуациями. Предложена модель прогнозирования развития чрезвычайных ситуаций, их предотвращения и ликвидации последствий. Проведена оптимизация меры значимости признака для прогнозирования значений коэффициентов пожарной обстановки. Кроме того, на основе информации, полученной от датчика метана, который считается наиболее важным параметром при возникновении пожара, была разработана регрессионная модель метода наименьших квадратов, применительно к выборке за один цикл, с целью прогнозирования пожарных ситуаций и сформировать модель обучающей выборки.*
Ключевые слова: *модель, алгоритм, оценка, прогноз, оптимизация, параметры, классификация.*

Introduction

Today, as the volume of information transmitted, received and collected through the global network is increasing day by day, issues related to the intellectual analysis of large volumes of information and the development of necessary solutions and approaches remain one of the urgent issues. It is known that during the current period, it is necessary to quickly analyze the information coming from the object and to develop an algorithm and hardware-software complexes that respond to them quickly. In the developed countries of the world, for example, the USA, Germany, France, Great Britain, Japan, Australia, South Korea, China, Scotland, Slovakia, the Russian Federation and other countries, the use of computer models and schematic solutions of the hardware and software complex in processing data from devices great attention is paid to solving theoretical and practical issues of intellectual analysis.

Society is faced with many situations related to various emergencies such as natural disasters, man-made accidents. Effective control and monitoring of such risks requires the development of innovative models and decision support algorithms that allow predicting and preventing emergency situations and minimizing their consequences. Technological advances in the field of artificial intelligence and big data, open the door to new opportunities for the development of such systems. This work is devoted to the research and development of models and algorithms aimed at improving the effectiveness and efficiency of decision-making in emergency situations [1].

Main part

The analysis of the sources shows that certain results have been achieved in the field of providing the scientific and technical means of fire and explosion protection. But taking into account the increase in the number and type of complex objects, there is a need to improve existing scientific and technical tools with modern information and communication tools and to develop new scientific and practical solutions.

Some types of predictive methods were used in modeling processes based on data obtained from the device to predict fire situations. Below are some of these prediction methods. Prediction methods: least squares method; extrapolation method of prediction; method of sliding average indicators; exponential smoothing method; flexible alignment method; mathematical modeling method; band method; matrix method; imitation method and others.

An algorithm for predicting the occurrence of fire risk was developed using the fire assessment model (Fig. 1).

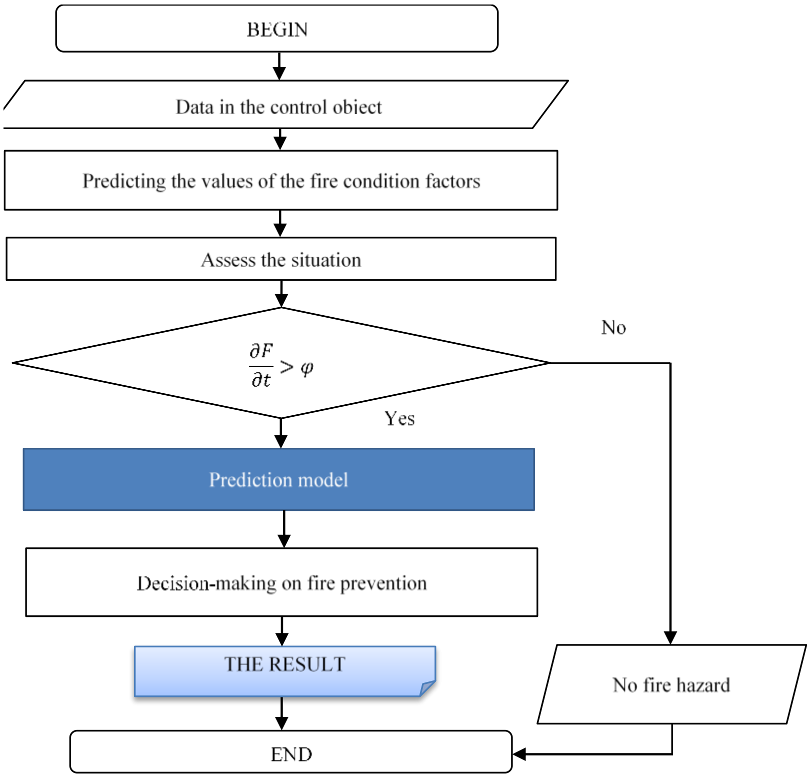

Fig. 1. ***Fire risk prediction algorithm.***

In the block of predicting the values of the factors of fire conditions of this algorithm, the optimization of the sign importance measure was carried out [2, 3].

Step 1. There are n factors that cause the fire hazard. Load sample T_{nml}.

	Factors								
Objects	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	***Class***
1	9	30	40	58	40	2	8	80	High level fire
2	10	29	41	55	35	4	10	78	
3	8	27	45	51	28	9	12	75	
4	7	25	50	23	26	11	14	70	Medium level fire
5	5	26	52	25	24	13	15	68	
6	6	21	55	30	22	15	17	66	
7	4	20	57	15	20	16	18	64	No fire hazard
8	1	18	71	18	18	18	19	62	
9	3	16	85	21	15	20	22	60	

Step 2. Based on the characteristics of the factors, the most important ones are distinguished using the following formula:

$$G_u(S_j) = \sum_{q=m_{u-1}+1}^{m_u} S_{n-\tilde{\rho}(S_j,S_q)}^{k} = \sum_{q=m_{u-1}+1}^{m_u} \frac{[n-\tilde{\rho}(S_j,S_q)]\ldots[n-\tilde{\rho}(S_j,S_q)-k+1]}{1\cdot 2\cdot\ldots\cdot k}. \quad (1)$$

After the calculations are done, a new T_{nml} table is formed, consisting of the most important factors:

$$L' = \sum_{q=1}^{m_1} G_1(S_q) + \sum_{q=m_1+1}^{m_2} G_2(S_q) + \ldots + \sum_{q=m_{l-1}+1}^{m} G_l(S_q), \quad (2)$$

This process is calculated according to the factors of methane, oxygen, temperature and humidity and the important factors are sorted.

Step 3. Classification of selected important factors into 3 classes.

Step 4. Determine which class the newly formed T_{nml} table will vote for.

$$\left.\begin{array}{l} G_1(S_1), G_1(S_2), \ldots, G_1(S_{m_1}) \\ G_2(S_{m_1+1}), G_2(S_{m_1+2}), \ldots, G_2(S_{m_2}) \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ G_l(S_{m_{l-1}+1}), G_l(S_{m_{l-1}+2}), \ldots, G_l(S_m) \end{array}\right\}$$

$(n-k)k + (m_u - m_{u-1}) + 1$ operations are also required to calculate each component.

$$G_u(S) = \sum_{q=m_{u-1}+1}^{m_u} \left(2^{\tilde{r}(S,S_q)} - 1\right). \quad (3)$$

Step 5. Determine the threshold conditions $(MinMax)$ for each incoming critical factor.

- Max and Min values are determined by classes;
- threshold condition for classes: $\varepsilon_i = \frac{Max(M)-Min(M)}{2}, \ i = \overline{1\ldots n}$.

Step 6. A proximity function is determined based on the Manhattan metric for each factor of the control object:

$$d_i = \begin{cases} 1, |M_x - M_i| \le \varepsilon_i^1 \\ 0, |M_x - M_i| > \varepsilon_i^1 \end{cases} \quad (4)$$

Step 7. We calculate the sum of combined factors for each class.

Step 8. In the decision-making phase, a given class will vote for the class with the highest number of votes for an object posing an unknown fire hazard. [4, 5].

In the condition assessment block, a model was developed for evaluating the fire condition based on the important factors obtained on the basis of experimental work.

The equations that express the change of temperature T, oxygen O_2, methane CH_4, and humidity H parameters over time are as follows:

$$\frac{\partial T}{\partial t} = \alpha T + \beta O_2 - \gamma CH_4 - \delta H \tag{5}$$

$$\frac{\partial O_2}{\partial t} = -\theta O_2 + \sigma$$

$$\frac{\partial CH_4}{\partial t} = -\kappa CH_4$$

$$\frac{\partial H}{\partial t} = -\eta H$$

The process equation representing the fire hazard is as follows:

$$\frac{\partial F}{\partial t} = a_1 T + a_2 O_2 + a_3 CH_4 - a_4 H \tag{6}$$

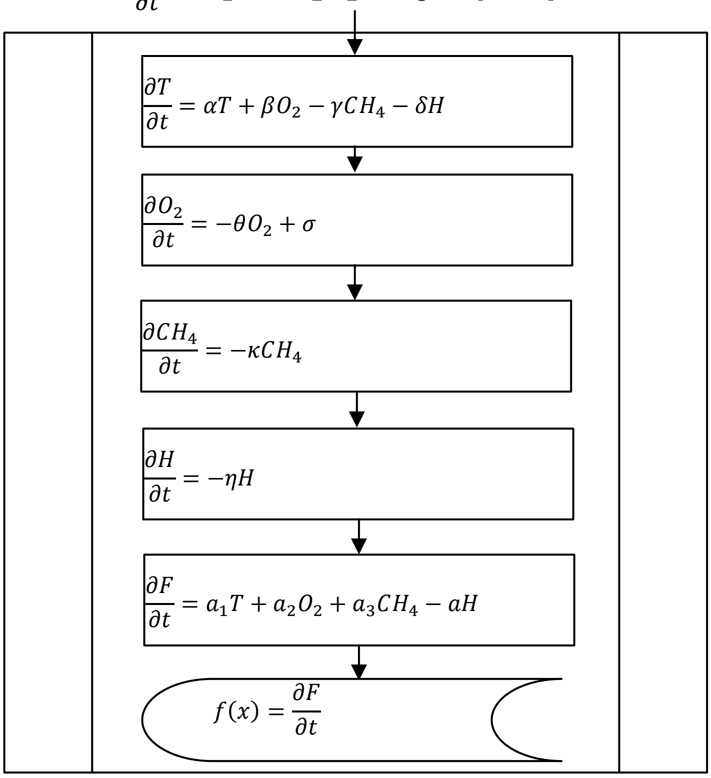

Fig. 2. ***Algorithm for assessing the fire situation.***

Parameters:

- T - Temperature (℃, default value: 25)
- O_2 - Oxygen level (in %, default value: 21)
- CH_4 - Methane level (in %, default value: 0.5)
- H - Humidity level (in %, default value: 50)
- F - Fire risk (unitless value available, default value: 0)

Coefficients and their units:

- α - Temperature variation coefficient (unitless, default value: 0.01)
- β - Oxygen temperature influence coefficient (unitless, default value: 0.01)
- γ - Temperature influence coefficient of methane (unitless, default value: 0.1)
- δ - Temperature influence coefficient of humidity (unitless, default value: 0.1)
- θ - Oxygen variation coefficient (unitless, default value: 0.01)
- σ - Effect coefficient of external sources of oxygen (unitless, default value: 0.1)
- κ - Methane conversion factor (unitless, default value: 0.1)

- η - Humidity change coefficient (unitless, default value: 0.1)
- a_1 - The coefficient of influence of temperature on fire risk (unitless, default value: 0.01)
- a_2 - Fire risk factor of oxygen (unitless, default value: 0.01)
- a_3 - Fire risk factor of methane (unitless, standard value: 0.1)
- a_4 - Coefficient of influence of humidity on fire risk (unitless, default value: 0.1)

Initial conditions.

Initial values and time intervals can be as follows:

- Initial temperature $T_0 = 25$ °C
- Initial oxygen $O2_0 = 21$ %
- Initial methane $CH4_0 = 0.5$ %
- Initial humidity $H_0 = 50$ %
- Initial fire hazard $F_0 = 0$

In the prediction model block, the information obtained from the methane sensor, which is considered the most important parameter in the occurrence of fire, was separately extracted in relation to one sample cycle in order to predict fire situations and form a training sample model [6, 7].

Table 1

Table of data from the methane sensor

№	x_i	y_i (data from the methane sensor)	№	x_i	y_i (data from the methane sensor)
1	1	0,0	25	25	3,4
2	2	0,0	26	26	3,4
3	3	0,1	27	27	3,3
4	4	0,3	28	28	4,8
5	5	0,1	29	29	5,0
6	6	0,3	30	30	6,5
7	7	0,3	31	31	8,5
8	8	0,5	32	32	9,6
9	9	0,9	33	33	9,0
10	10	2,0	34	34	8,8
11	11	4,0	35	35	10,0
12	12	4,6	36	36	10,0
13	13	4,9	37	37	9,4
14	14	4,6	38	38	10,0
15	15	4,4	39	39	10,0
16	16	4,1	40	40	10,0
17	17	5,0	41	41	8,0
18	18	4,1	42	42	10,0
19	19	2,6	43	43	9,5
20	20	2,4	44	44	6,7
21	21	2,8	45	45	0,0
22	22	4,3	46	46	0,1
23	23	4,5	47	47	0,0
24	24	3,4	48		

A graph of the data obtained from the methane sensor versus a single cycle sample is presented in Figure 3.

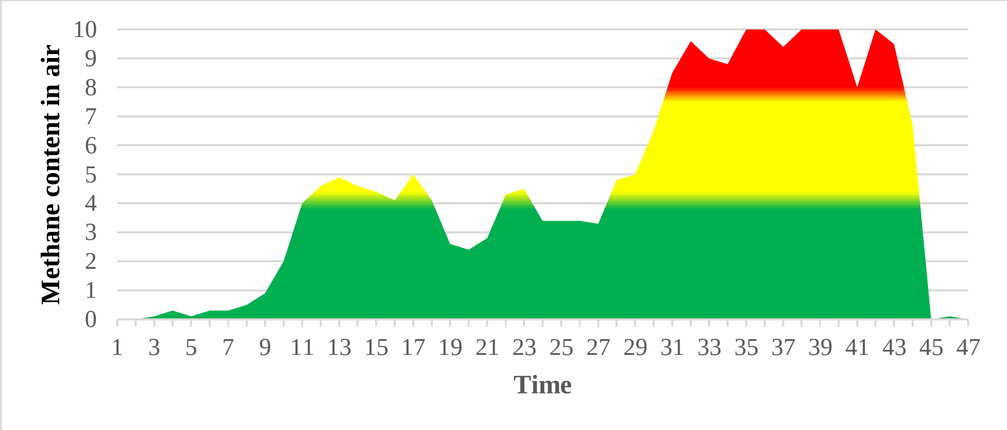

Fig. 3. ***A graph of data obtained from a methane sensor versus a sample of one cycle.***

Let's look at building a model using a least squares regression model to predict fire events.

$$\widehat{y_i} = \hat{b} + \hat{a}x_i \tag{7}$$

here, at first, it is required to find the coefficients $\hat{b}$ and $\hat{a}$.

$\hat{b} = \overline{y} - \hat{a}\,\overline{x},$

$$\hat{a} = \frac{\sum(y_i - \overline{y})(x_i - \overline{x})}{\sum(x_i - \overline{x})^2}.$$

$$\hat{y}_{i(x_i)} = \begin{cases} 0, & \alpha_1 > x_i \\ \hat{a}x_i + \hat{b}, & \alpha_1 \le x_i < \alpha_2 \\ l, & x_i \ge \alpha_2 \end{cases} \tag{8}$$

here, $\alpha_1,\ \alpha_2$ – are the values given by the experts, passing from the middle level to the high level of combustion, l – is the high index information coming from the methane sensor $R \in l$.

$a_k = (y_{k,}\ \ y_{k+1,}\ \ y_{k+2}),$

$b_k = (y_{k,}\ \ y_{k+1,}\ \ y_{k+2}).$

First, the obtained results are analyzed, and then the errors are evaluated.

Based on the above model, the data coming from the methane sensor and the graphs created on the basis of the model are compared [8, 9].

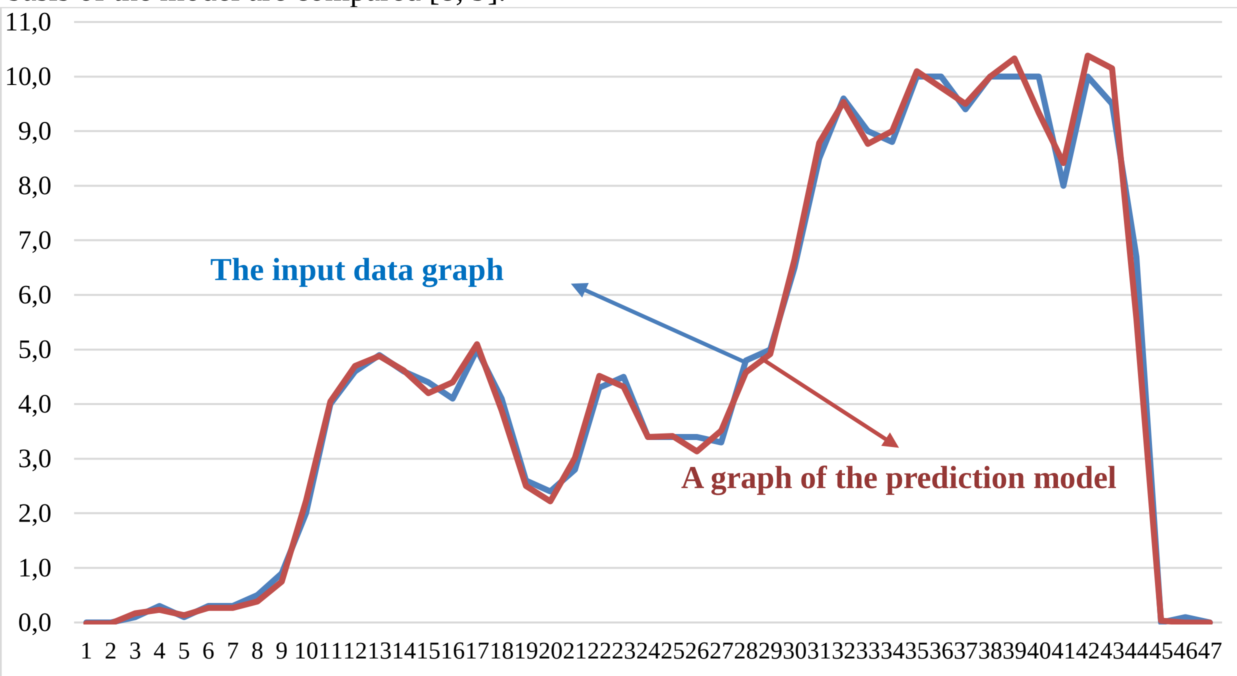

Fig. 4. ***Comparison of graphs generated based on model and data from methane sensor.***

According to this comparison graph in Figure 4, it can be seen that the fire prediction accuracy based on the proposed model is higher and the error is much lower.

In the “Prediction model” block, an algorithm for predicting the state of the fire is developed (Fig. 5, here, the information obtained for k - one cycle sampling).

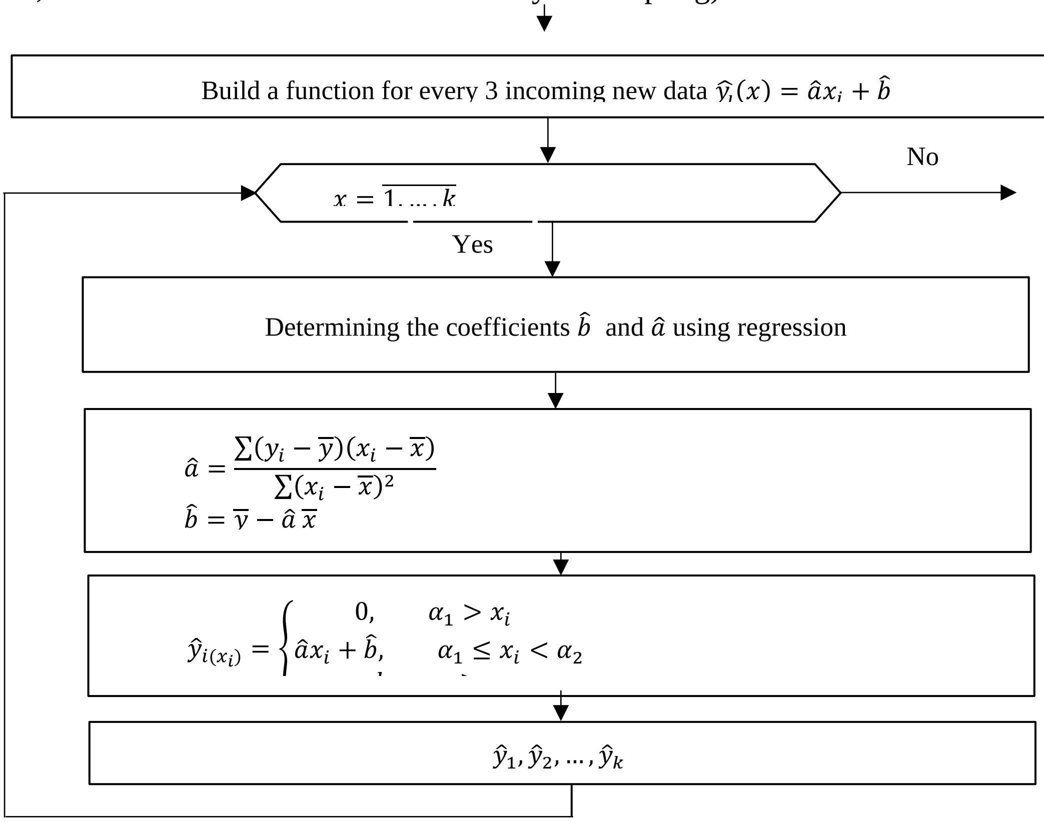

Fig. 5. ***Algorithm for predicting fire conditions.***

Using this model, fire prediction software was developed, and the software allows for real-time fire prediction and assessment (Figure 6).

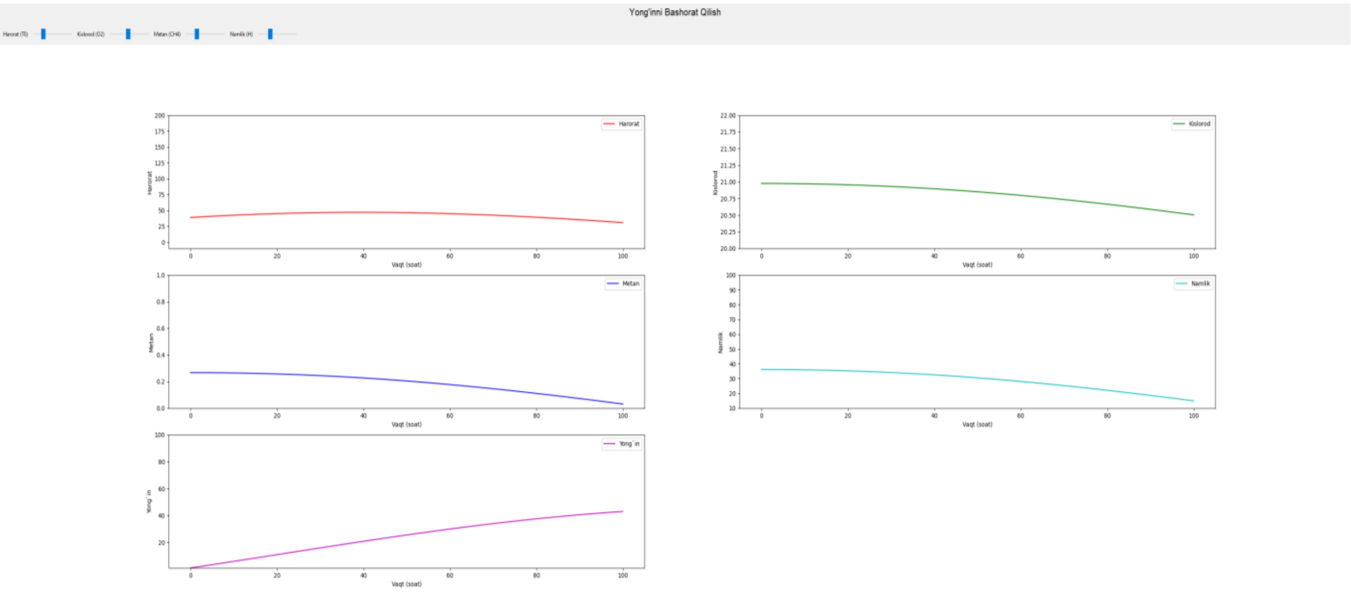

Fig. 6. ***Real-time prediction of the fire situation.***

In addition, the block of the above algorithm (Fig. 1) "Making a decision to eliminate the fire situation" was also separated as a separate block diagram (Fig. 7). In this block, the four parameters (gas, oxygen, humidity and temperature) necessary for predicting the fire situation in objects with a high fire-explosion risk are presented as threshold values of small or high fire risk levels [10].

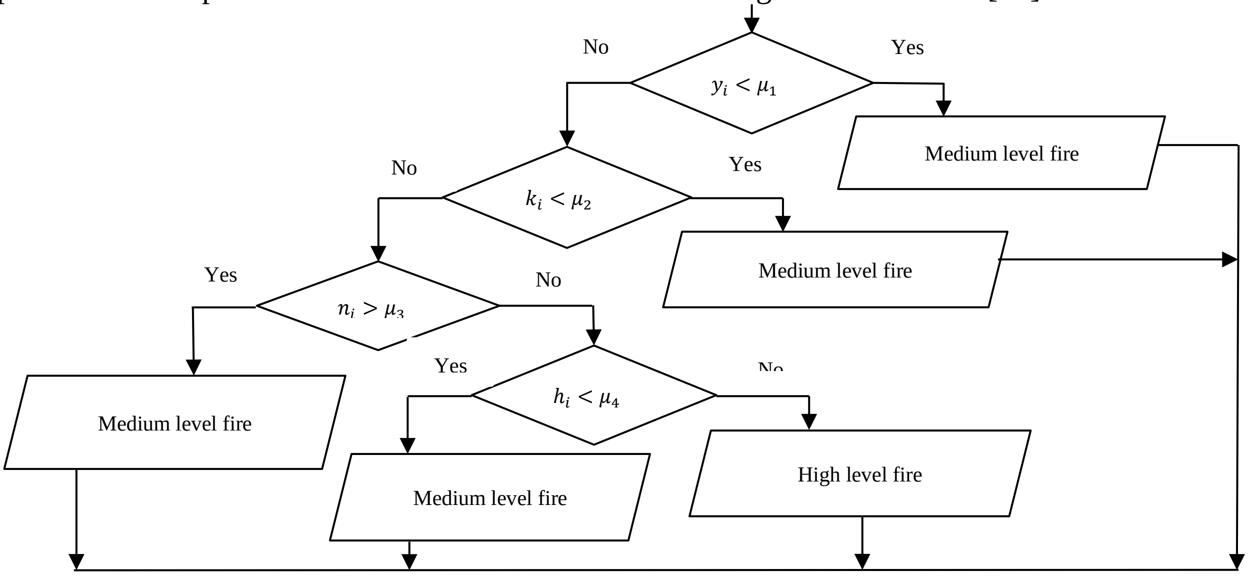

Fig. 7. ***Block "Decision-making on elimination of the fire situation".***

here, $\mu_1, \mu_2, \mu_3, \mu_4$ – are the threshold values given by the expert.

The results obtained in the "Result" block of the block diagram (Fig. 8) are presented both graphically and tabularly.

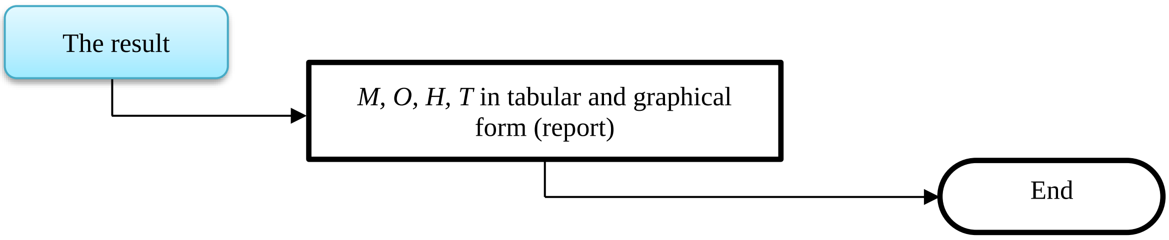

Fig. 8. ***"Result" block.***

Conclusion

Thus, by predicting information about the times and results of responding to fire situations, it is possible to reduce the occurrence of fire in objects with a high risk of fire-explosion and to improve the fire safety system can be improved. In the future, further refinement of these models and algorithms, as well as their integration with new technological advances such as the Internet of Things (IoT) and blockchain, will contribute to more effective risk management and disaster prevention. Including, continuing research in this direction is not only urgent, but also a necessary step to ensure the safety and sustainable development of society.

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