Use of artificial intelligence to prevent spontaneous combustion of coal

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Abstract. The expediency of using artificial intelligence has been repeatedly confirmed by successful practical solutions in various fields of human activity, including in the field of security. The article considers the possibility of creating a distributed artificial intelligence system designed to prevent spontaneous combustion of coal in the places of its extraction, storage, transportation, as well as processing or burning. The system is a software and hardware complex, which includes research laboratories, equipment manufacturers and protected facilities. The algorithm of operation of both the system as a whole and its individual elements is proposed. The algorithm of operation of individual elements is based on the design of a specialized fire detector developed and patented by the authors and in accordance with the laws of the development of the processes of self-heating and spontaneous combustion of coal.

1 Introduction

Coal has long been one of the world's most important energy resources. In addition to being used as a fuel and for the production of electricity, coal is an indispensable raw material for metallurgy, the chemical industry, agriculture and other branches of human activity. At the same time, the use of coal is associated with significant environmental and fire risks at the entire stage of its life cycle from mining to final consumption. Significant Some of these risks are due to the ability of coal to ignite spontaneously under certain conditions and, despite comprehensive long-term studies of the processes of self-heating and spontaneous combustion, the problem of combating spontaneous combustion continues to be relevant to this day [1].

At the Department of Industrial Ecology and Life Safety of the Irkutsk National Research Technical University, one of the priority areas of scientific activity is to ensure safety in mining operations; within this area, one of the tasks is to develop methods for preventing spontaneous combustion of coal [2]. In the process of analyzing the main causes of the most large-scale coal disasters with the death of people and assessing the resulting environmental pollution, it was found that one of these causes is spontaneous combustion of coal. It was also found that spontaneous combustion makes a significant contribution to the unaccounted for environmental load. As a result of laboratory tests, differences in the main properties of

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coals mined in the Irkutsk region and their influence on the likelihood of spontaneous combustion were established, and the effectiveness of the use of mining waste as antipyrogen was proved. The existing methods of prevention of spontaneous combustion of coal were analyzed, as a result of which the following were developed and patented: a method for reducing the tendency of coal to spontaneous combustion during mining in a mine and the design of a specialized fire detector capable of detecting sources of spontaneous combustion of coal even at the stage of self-heating [3-4].

2 Artificial intelligence in security systems

The concept of artificial intelligence was first proposed in 1956 by the American scientist John McCarthy at a seminar at Dartmouth University, although the prerequisites for the emergence of this term existed long before that. Until now, there is no unambiguous understanding of the meaning of the term “artificial intelligence”, this concept may be too broad for its understanding, especially since the very concept of intelligence and, in general, mind, may is not fully known. In this regard, in this article, in accordance with the tasks being solved, the concept of "artificial intelligence" will be used in the sense of "The ability of a system to correctly interpret external data, learn from such data and use the knowledge gained to achieve specific goals and objectives with the help of flexible adaptation” [5]. In general, we can say that artificial intelligence is a certain combination of mechanisms and other devices, as well as algorithms for their activities, designed to solve some problems or problems, while the actions of this set can be characterized as actions and algorithms that reproduce human activity. Initially, devices with signs of artificial intelligence looked more like simple automatic devices. In the mid-1950s, a number of algorithms were developed, such as a program for playing checkers, a speech synthesis program, and the concept of “machine learning” was formulated.

Like most other areas of human activity, this direction developed unevenly - there were periods of rapid development, there were also periods of stagnation. It is natural that these periods basically corresponded to the pace of development of computer technology [6]. With the development of artificial intelligence systems, they begin to play an increasingly important role in more and more diverse areas of human activity, while the development of these systems has reached such a level that, when solving many problems, they are already many times superior to human capabilities.

There is even a fear that the level of self-development of artificial systems may reach such an extent that these systems may begin to pose a danger to humanity, and therefore it is proposed to take appropriate security measures. An illustrative example of how in 2017 one of the corporations set the task for two bots to talk to each other. In the process of communication, they abandoned the use of human language and developed another language, which they communicated in the future [6].

One of the important areas where the use of artificial intelligence is not only justified, but in many cases necessary is various security systems. Currently, artificial devices have a faster response than humans, they are not subject to emotions, self-interest, fatigue, and other features of a living organism. For the effective functioning of such systems, the main task is to build the correct algorithm. It should not be expected that an AI system will have the ability to solve any proposed tasks, all such systems operate within the clear framework of the algorithm embedded in them, and the correctness of this algorithm will determine the effectiveness of the analysis and decision making of the constructed system. One of the main features of artificial intelligence systems, unlike the simplest automatic devices, is the ability to learn and self-learn, it can be said without exaggeration that these properties are decisive.

Information security is one of the most demanded areas where artificial intelligence technologies are widely used [7]. This is largely due to the challenges that arise in providing this area of activity and the opportunities that AI can provide. First of all, it is the ability to operate with a significant amount of data, usually in accordance with the same algorithm. The most popular areas of application of AI in information security are related, among other things, to information risk management, anti-virus protection, illegal access attempts to steal information or falsify it, and other tasks. In particular, AI is ubiquitous in protecting financial security. AI methods and algorithms are constantly being improved, both through the efforts of developers and using the ability of AI to self-learn.

One of the important factors of the modern information space is the increasing use of cloud data storage services (including financial information) with the ability to be accessed from almost anywhere in the world. At the same time, modern technologies make it possible to ensure the necessary level of confidentiality even with such an organization of information exchange. The problem of cybersecurity is one of the most important areas of technological development [8].

However, information security is not the only possible area of application of AI for security, one of the most important areas is the use of AI to create and maintain the required level of technological security. There are intelligent systems for ensuring transport security [9, 10, 11], systems for assessing the risks of injury to personnel of various enterprises [12, 13, 14], security systems at mining enterprises [15, 16, 17]. Also, one of the most serious issues in the field of security, including those solved with the help of AI methods, is fire safety [18, 19, 20]. Like many others, fire safety issues require the processing of a large amount of data and require prompt decision-making. The entire array of data available for each fire hazardous situation requires a complete analysis and replenishment of the database of ready-made solutions, that is, the system must be trainable. Thus, the safety system for fire prevention meets all the requirements for AI. Based on these requirements, AI fire protection systems can be implemented.

3 Conditions for the selection and placement of fire detectors

Any fire is a complex of manifestations of various changes in the surrounding space and can be recorded using devices that record these changes. The sooner the physical manifestations of a fire are recorded, the sooner information about them can be transmitted. Therefore, the sooner it will be possible to begin to eliminate the source of the fire, the less negative consequences will occur. Thus, the main parameters that affect the minimization of the consequences of a fire are precisely the temporal characteristics. The total time tfire, elapsed from the onset of a fire to its complete elimination, is the sum of the following intervals:

$$\mathrm{t_{fire.}} = \mathrm{t_{upd.}} + \mathrm{t_{tri.}} + \mathrm{t_{dev.}} + \mathrm{t_{exti.}} \tag{1}$$

where, t_{fire}. - time for the controllable fire factor to reach the sensitive element of the fire detector, upd. – detector reaction time, t_{trig}. – time of arrival and deployment of the fire department, t_{dev}. – extinguishing time (in the case of automatic fire extinguishing means, arrival and deployment times are excluded). Of these time intervals, the minimum is the reaction time of the detector (several times less than other time intervals) anddepends only on its sensitivity and inertia. The time of arrival, deployment and extinguishing depends on the organization of the activities of fire departments - this is the maximum period of time of all. The most important is the time interval during which a controlled sign of a fire that has begun will be recorded - it depends on many factors and, above all, on the parameters of the detectors placement. Detector placement parameters should meet several requirements, including compliance with the standard fire detection time, threshold parameters for fixing the fire factor and a controlled area. Each fire is unique and its development, especially the initial phase, depends on many factors, primarily on the characteristics of the fire load. There are quite a few signs by which one can judge the development of a fire and, depending on the predicted characteristicfeatures of its development, certain detectors and the parameters of their placement are selected. The features of this choice are regulated by regulatory documents, which, in turn, are developed on the basis of scientific knowledge and practical experience and are constantly updated.

Endogenous coal fires, despite the many properties inherent in all other fires, have a number of features due to which they can be characterized as a separate variety and specific methods for their prevention and prevention can be developed. One of these features is that an endogenous fire is always preceded by the process of self-heating of coal, which develops according to its own laws. Another feature is thatthat the process of spontaneous combustion can occur under two conditions - the presence of a sufficient amount of oxygen and insufficient heat removal [21].

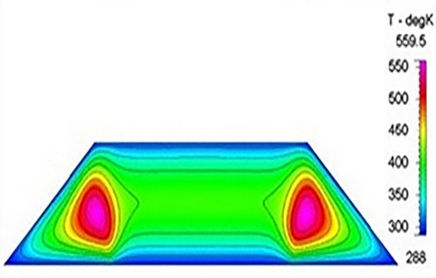

Fig. 1. Temperature fields inside the coal with a width of 26 m and a height of 6 m after 100 days.

In this regard, a fire can occur only inside the mass of coal, but not far from the surfacepurposes, odor, humidity, capacitive, microparticle detectors, smoke detectors, thermal imaging installations are used. Air and space methods use multispectral and thermal remote sensing [22, 23, 24]. Each method has its own advantages and disadvantages, in connection with which combined methods are also used.

4 A specialized fire detector for detecting spontaneous combustion of coal

The specialized detector developed at IRNITU has several significant differences from most of the used designs. Its main feature is that it measures the controlled mass of coal directly inside the array itself: samples of the gas-smoke-air mixture are fed from the stack to the measuring chamber located outside by means of an aspirator. Measurements are made according to three parameters - temperature, the presence of smoke particles and the concentration of tracer gases. The generation of an alarm notification is set programmatically and can be adjusted. The triggering algorithm is determined by the critical values of temperature, concentration of smoke and indicator gases, the rate of their change, as well as the ratio of these values to each other. The ratios are determined by a complex algorithm, depending on the relative position of the detectors, the characteristics of the controlled coal, and other parameters. The described detector has another feature - it does not have external power supply circuits. This became possible due to the fact that the electricity to power the detector is generated inside the device itself due to the built-in thermo EMF generator. Since the process of self-heating in a sufficiently large mass of coal will take place constantly, the operability of the device will be ensured during the entire time of control. Thus, after installing the detector at the place of observation, it will take some time to reach a working state.

The detector operates in a cyclic mode, the calculations and laboratory tests have shown that the self-heating energy of coal is able to ensure its performance. The values of the control parameters can be determined according to various scenarios. The simplest option is to exceed the critical values of temperature or smoke concentration, or tracer gas concentration, that is, the disjunction (logical OR) of these parameters. A more complex option is the conjunction (logical AND) of critical values. Also, the parameters can be the rate of increase of these values.

To build an artificial intelligence system to prevent spontaneous combustion of coal, it is planned at the first stage to create a testing laboratory in which the parameters of the detector operation will be simulated and its control tests will be carried out in order to pre-configure it and develop recommendations for its placement. Further operation of the system is expected to be in close connection with coal mining enterprises, storage sites and coal consumers. The task of the system will be to organize the relationship of these objects in order to develop optimal settings for threshold values and conditions for placing detectors.

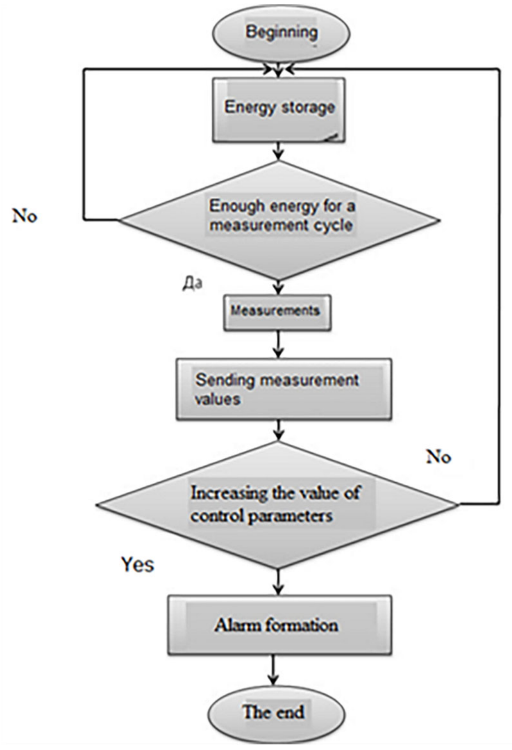

Fig. 2. The algorithm of operation of a specialized fire detector.

5 System for the prevention of spontaneous combustion of coal with elements of artificial intelligence

Employees of the Department of Industrial Ecology and Life Safety of the IrNITU on the basis of the FGBU SEU FPS IPL for the Irkutsk region (testing fire laboratory) conducted a study of the properties of coal mined at the deposits of the Irkutsk region, as a result of which it was found that during forced heating, various coals have different dynamics of the development of smoke emission and spontaneous combustion [25]. There are also reasons to believe that the dynamics of the formation of tracer gases will also differ for different coals.

The research results allow us to state that the data obtained are important characteristic values of the studied coals and can be used to build a model of their spontaneous combustion and, accordingly, contribute to the development of recommendations for the parameters of the use of fire detectors. Usage parameters in this context should be understood as the setting of critical (threshold) values and placement conditions. Thus, the statement about the need to create a database for all available coals and the development of an algorithm for using this database to configure detectors can be considered fair. The next step in creating an artificial intelligence system to prevent spontaneous combustion of coal should be the organization of information exchange between producers, consumers, coal custodians and other interested enterprises [26-37].

The data exchange algorithm is as follows: based on the available data, the testing laboratory generates detector settings and recommendations for their placement, the equipment manufacturer configures the detectors and supplies them to the consumer, the consumer installs them in accordance with the recommendations. The work process starts according to Figure 2. for each detector. Each detector at the end of the measurement cycle forms a data set of measuring instruments and transmits it to the monitoring station (central monitoring console) of the object. Thus, a temporal picture of the measured indicators is formed. With a certain frequency, these data are transferred to a common database and analyzed by the research laboratory. The accumulated data will make it possible to draw a conclusion about the correctness of the detector settings and, in case of errors in its operation, make adjustments. The corrected settings are sent to the manufacturer and to the protected objects, where the corresponding changes are made.

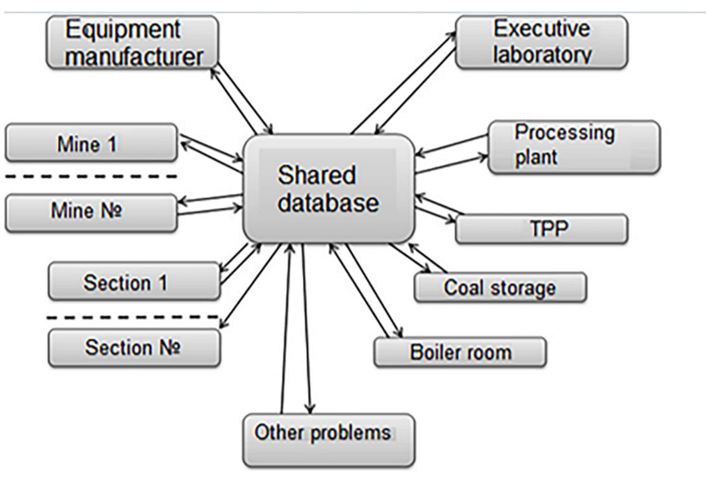

Fig. 3. Organization of data exchange.

Incorrect detector settings (threshold parameters or placement configuration) will be considered both the presence of false alarms and non-operation in the event of a fire. Also, when bringing the system to the optimal configuration, it will be necessary to strive to minimize the amount of equipment without sacrificing reliability.

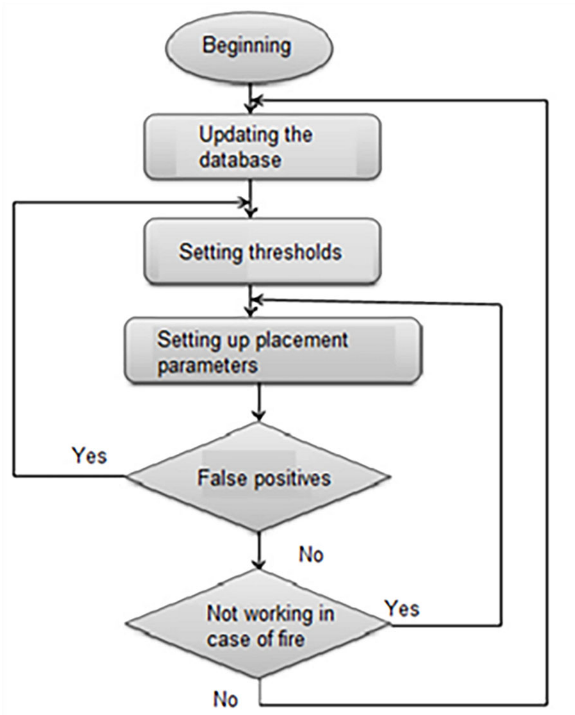

Fig. 4. Detector setup algorithm.

6 Conclusion

False alarms, as a rule, indicate that the sensors are too sensitive and require an increase in the response threshold. Failure in case of fire may indicate insufficient sensitivity of the sensors or an excessive distance between them. In any case, each reaction of the detector is entered into the database and contributes to the optimization of the system. The system can also be configured to work with other detector designs, while analyzing subjected to their fixed settings and placement options. In the process of operation, the system replenishes the database, both for devices and for various coals, after analyzing these data, it develops new operation algorithms and can help reduce the level of fire risks associated with spontaneous combustion of coal.

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