Algorithm for search and recognition of fire by means of unmanned aerial vehicles

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Abstract. The paper considers the possibility of providing early detection of fires in oil and gas wells through the use of the RGB palette, as well as intelligent decision-making to eliminate the consequences of fire using the possibility of remote dynamic monitoring based on robotic platforms. The result was a simulated prototype of a hardware-software complex (APC), which allows monitoring of the territory based on the distributed processing of large stream of graphical information in real time (including the exact coordinates of the fire, its size, direction of fire, proximity to settlements). For the most effective detection and prevention of growth of natural and man-made fires. The proposed agro-industrial complex will be implemented on the basis of modern technologies: robotics, GPS-technologies, GIS-technologies, client-server Internet technologies, video surveillance, intelligent information technologies. Accurate automated determination of coordinates with the help of GPS-fire signal makes it possible to timely proceed to the localization and elimination of the fire, thereby preventing and reducing the negative impact on people, nature, wildlife, reducing the damage caused by the fire. The created software and hardware complex will allow to quickly develop and make the most optimal decisions on the direction of fire brigades and fire equipment to the places of fire, especially in particularly remote areas.

Keywords: monitoring of territories · robotic platforms · detection of natural and man-made fires · unmanned aerial vehicles · fire coordinates.

1 Introduction

Fires at gas and oil facilities are a disaster that causes incalculable material, moral and environmental losses.

Analysis of fire statistics shows that every fourth fire is accompanied by the explosion and the subsequent development of the combustion in the area of 5000 m^2. If a fire occurs without an explosion, the fire area in most cases is 500 m^2, and the maximum area reaches 3000 m^2, so its temporary detection of natural and man-made fires is an important factor in ensuring their rapid extinguishing. Currently, this function is performed by drones and unmanned aerial vehicles. In recent years they have become increasingly popular in the detection of fires in forests and fields. They are especially necessary in hard-to-reach places where the definition of fire without the use of aviation is impossible. This task will effectively manage the unmanned aerial vehicle of the type "copter". The main tasks of using quadrocopters in emergency situations are to determine the localization of areas affected by natural disasters, conduct cartographic surveys, Search for missing people.

Centralized control of the unmanned aerial vehicle is carried out by a human operator (one to one). The structure of the control system:

- human operator;

- remote terminal;

- aircraft with on-Board intelligent system of information processing.

The entire process of controlling the aircraft is carried out by the operator through the terminal, the on-Board information processing system displays the image on the operator's screen, and he, based on his experience, makes the appropriate decision.

The paper proposes to develop a prototype of an automated hardware and software complex, which in addition to performing the function of dynamic monitoring of the territory in real time provides a continuous analysis of the data coming from the sensors, and gives the operator an operational emergency alert when the parameters deviate from the specified norm, predicts possible emergencies, is able to calculate and form the optimal route to the source of the fire, i.e. is an expert intelligent system.

The advantages of using a quadcopter for the monitoring of gas and oil wells:

- ability to continuously monitor even the most remote and wild areas, including in any windy weather;

- objectivity of the obtained data (absence of human factor-fatigue, falling asleep during visual observation of fires from specialized towers);

- reducing the cost of one hour flight;

- speed of data collection;

- accuracy of data collection;

- optimization of frames.

2 Related Work

The analysis of modern applications and publications in the field of fire monitoring in Russia and abroad has shown that the use of unmanned aerial vehicles (UAVs) for these purposes is in demand. However, this trend has not yet become widespread due to imperfect implementation approaches and the complexity of processing large amounts of data, as well as the following disadvantages:

- not all systems have flexible integration to adapt the system to different subject areas;
- high technical requirements for equipment;
- have a closed program code.

The relevance of this scientific problem is confirmed by theoretical and practical works of foreign and Russian researchers. The General direction studying the problems of data mining is defined as "Monitoring Wildfire UAVs".

The authors, led by Sharon Rabinovich [1], proposed a coordination strategy with a new methodology for estimating the periphery of a spreading fire using limited observations. The developed information-logical model of the information system displays the data of the subject area in the form of a set of information objects and links between them. A group of researchers from the Ivanovo fire and rescue Academy of the Ministry of emergency situations of Russia under the leadership of V. A. Smirnov considered a set of positive effects from the introduction of unmanned aerial vehicles into the monitoring system of forest fire situation, and also showed all the advantages that are possible when using unmanned aerial vehicles [2].

Scientists from America [3] have developed methods of planning the trajectory of unmanned air transport to monitor the boundaries of fires. The disadvantage of the work is that the algorithm was not tested by the authors, but only an imitation of fire was proposed.

The researchers of the University of Toronto [4] proposed a method for monitoring the occurrence based on the Kalman filter with the use of unmanned aerial vehicles. The authors conducted a fire simulation on the basis of which a method for assessing the behavior of forest fire propagation and the contour of the fire front was developed.

Scientists Zhongjie Lin and Hugh H. T. Liu proposed a model for distributed topology-based optimization for joint monitoring of fires through the use of multiple UAVs. The problem of interaction of several UAVs in a distributed network is formulated. A method is proposed that allows cooperation between UAVs at the group level [5].

The actual research is presented by the authors under the leadership of A. S. Vasilyev [6]. In their article, the scientists considered the key issues arising in the development of software and hardware complex of detection and monitoring of fires on the basis of an unmanned aerial vehicle by combining images, and also presented the architecture of the proposed software.

In work [7] the model of the simulator on the basis of CAVE-technology is presented. The disadvantage of this model is the fact that the movement of the unmanned aerial vehicle must be monitored by the operator and place marks in the system where the fire is detected and describe the procedure for its suppression.

Researchers Connie Phan and Hugh H. T. Liu describe a technique for controlling UAVs through mobile devices. The authors propose a methodology for the interaction of several aircraft through the use of a hierarchical platform [8].

Scientists from China presented the work on fire identification based on deep learning. The authors in their study took into account unmanned aerial vehicles equipped with global positioning systems (GPS), through which it is possible to provide direct georeferencing images, mapping the area with high resolution. The paper presents a 15-level self-learning architecture DCNN called "$Fire_Net$". The disadvantage of such a system is the speed of processing a large amount of data [9].

In his scientific work V. Vipin proposed a method of classification of fire pixels using rule-based models in the RGB and YCbCr color space [10].

Researchers K. Angayarkkani and N. Radhakrishnan developed fuzzy rules for the use Of YCbCr color space for segmentation and fire image detection [11].

Scientist C. Yuan developed a set of algorithms for tracking fires, including median filtering, color space transformation [12]. These works are based on methods of image processing using elements of manual work, the results of which are highly dependent on the accuracy of the manually selected parameters.

Statistical and machine learning methods are not actively used in this direction. The Gaussian mixture model (GMM) is used for flame detection [13]. However, using an empirical value for the number of mixtures may not lead to better results. The SVM classifier is used in [14]. It should be noted that when widely used feature descriptors such as the oriented gradient histogram (HOG) with space invariant feature transformation (SIFT) are used with these classifiers, the false alarm rate is not low enough.

Satellite imagery is a common method of fire detection [15], but the long scanning period and low flexibility make fire detection difficult. Infrared thermographic cameras are used to obtain thermal images of the terrain [16]. Through them it is possible to obtain reliable data on the distribution of heat for fire detection. However, most infrared thermographic imaging systems operate in the wavelength range of 0,75 to 100 microns. They find much less information about the environment on this strip. This information can also be very important, especially when flammable and combustible materials are presented. In addition, according to Nyquist's theorem, the recorded thermal image has a lower spatial resolution than the visible spectrum cameras. In addition, thermographic systems are quite expensive with high maintenance costs.

3 Experimental Part

To get the coordinates of the quadcopter you need to have the coordinates of the UAV, the initial values of which are obtained by GPS. Next, we have a pixel-by-pixel shift of the x and y values. the shift Equation is shown in formulas (1) and (2):

$$X = \frac{x - Camera}{2}, \tag{1}$$

$$Y = \frac{-(y - Camera)}{2}, \tag{2}$$

where x and y are the coordinates of the transmitted images, the X and Y coordinates of the received image, Camera image produced on the camera quadracopter.

To detect the source of fire, we use color analysis based on the RGB model. This model describes each color with a set of the following colors: red, green and blue.

We describe the possibility of flame pixel detection for RGB color model by the following system:

$$\left.\begin{array}{c} R(x,y) > R_{red} \\ R_{red} = \frac{1}{K} \cdot \sum_{i=1}^{K} R(x,y)) \\ R(x,y) > G(x,y) > B(x,y) \end{array}\right\} \tag{3}$$

where values $R_{x,y}$, $B_{x,y}$, $G_{x,y}$ – value of red, blue and green colors in pixel on coordinates x, y, K is the total number of pixels, R_{red} is the average intensity of the red color.

r, g and b are normalized components of RGB space defined by the following formulas:

$$r = R/(R + G + B), \tag{4}$$

$$g = G/(R + G + B), \tag{5}$$

$$b = B/(R + G + B), \tag{6}$$

The algorithm for determining the ignition source is shown in fig. 1.

According to the presented algorithm, the quadcopter transmits the image to a personal computer by scanning the marked GPS point. By using the RGB palette, the color that is closest to the ignition source (red) is determined. If the system detects a fire, it automatically notifies the operator, who decides to take the necessary measures.

The results of the fire detection simulation are shown in fig. 2.

Thus, the process of modeling the ignition of oil wells is carried out and the algorithm for early fire detection is described. The developed methods and approaches for analyzing oil well ignition are planned to be used in forecasting and intellectual verification of upcoming changes in the heterogeneous infrastructure of the complex model, based on spatial and temporal distribution and proactive forecasting of the use of computing resources.

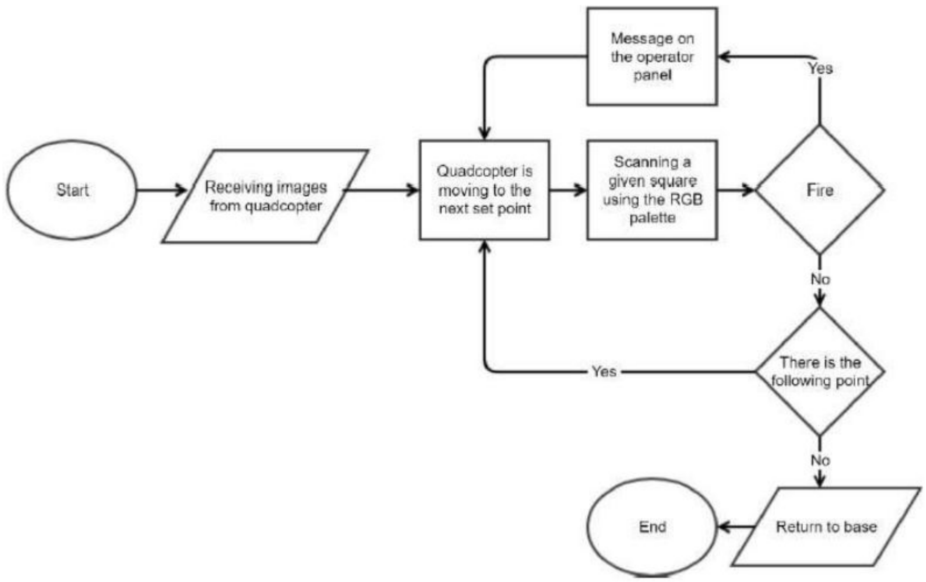

Fig. 1. Algorithm for determining the source of fire

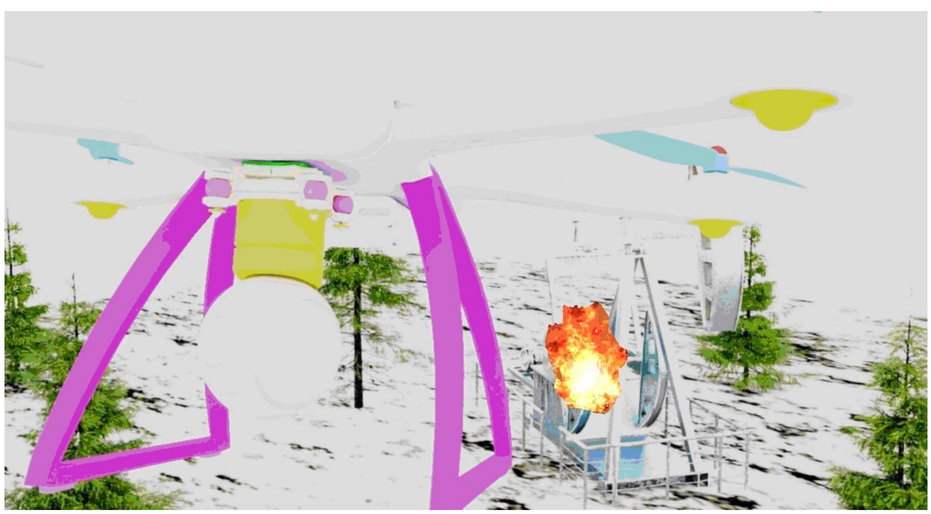

Fig. 2. Simulation results of the detection of a fire

4 Conclusions

The paper proposes an algorithm for color processing of RGB palette, which allows to control the territory on the basis of distributed processing of a large flow of graphic images in automatic real-time mode (including accurate determination of the coordinates of the fire, its area, the direction of the flame, the proximity of settlements, etc.).

The socio-economic effect of the implementation of the proposed intelligent automated software and hardware complex is as follows:

- remote access via the Internet to an interactive map of operational monitoring, which allows you to obtain information about the state of the controlled territory;

- the use of agriculture will significantly reduce the cost of special services to monitor fires, through the use of drones;

- collection and analysis of operational data on the state of the fire situation.

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