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AUTOMATED SATELLITE AND UAV IMAGE PROCESSING SYSTEM FOR EMERGENCY DETECTION IN KAZAKHSTAN

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ABSTRACT

The investigation is aimed at supporting decision-making in emergency situations using modern information technologies on the example of the Republic of Kazakhstan. The object of the study is a series of satellite or UAV images prepared for analysis. The subject of the study is the identification of emergency situations using an image from satellite or UAV. The purpose of the work is to develop algorithms for processing images obtained as a result of images from a satellite or UAV, providing a solution to the problems of "machine" vision to detect emergency situations. The following tasks had been solved to achieve this goal: researched image recognition technologies for identifying emergency situations; methods and models for detecting an object by external signs are selected; algorithms for preprocessing images have been developed; a software package for image recognition was created to detect emergency situations using the C# programming environment. Research methods are based on the principles of automation and control, system analysis methodology, theory of mathematical modeling, digital image processing, pattern recognition, discrete transformations, modeling using specialized data and image processing packages. A promising direction in solving the research problem for identifying emergencies using satellite or UAV images is the development of a "machine vision" system, the final "product" of which is not the image itself, but the parameters of the controlled process. Thus, for any particular case, it is possible to create a "machine" vision system that far exceeds the capabilities of the human eye, and sometimes even the human as an image analyzer. The creation of a software and hardware complex for processing images from a satellite or a UAV makes it possible to solve the problem of identifying emergencies in vast areas in a relatively short period of time, which can ensure a quick response of the relevant services.

Keywords: *Image Processing, Automation, Ecological Monitoring, Emergency Situation, Fuzzy Logic*

1. INTRODUCTION

The attitude of states to the problems associated with emergency situations, and the impact of these problems on the development of society, have been caused by large-scale accidents and disasters of recent decades. Special structures have been created in the Republic of Kazakhstan, modern equipment has been allocated, active training of qualified personnel is underway, and much attention is paid to the introduction and to development of new progressive methods for monitoring emergencies, their prevention and prompt response [1]. Information armament has paramount importance in this dynamically developing area.

Geoinformation systems continue to develop with spatial information at the core; a part of this information is formed from space. Many countries have established a national spatial data infrastructure, i.e. data that is tied to specific coordinates. The Republic of Kazakhstan has also embarked on a project to create its own national spatial data infrastructure [2].

Kazakhstan's own Earth remote sensing system appeared relatively recently. On April 30, 2014, the KazEOSat-1 satellite was launched into orbit from the Kourou space center of the European Space Agency, located in French Guiana (ESA-CNES-ARIANESPACE Optique video du CSG). In June 2014, the second remote sensing satellite of medium spatial resolution KazEOSat-2 went into orbit. It was built by Airbus Defense and Space's subcontractor, the British company Surrey Satellite Technology Ltd (SSTL) [2]. One of the most important applications of satellite images is the security of our independent state.

The organization and management of the activities of state bodies for the prevention and elimination of the consequences of emergency situations (ES), the protection and rescue of the population and territories from natural and man-made emergencies are based on the processing of large arrays of diverse, rapidly changing (emerging) information. Improving the ways and processes of working with this information is one of the means to improve the efficiency of management and public authorities at all levels.

At present, the structural subdivisions of the Ministry of Emergency Situations of the Republic of Kazakhstan are not equipped with the technical means necessary for reconnaissance of hard-to-reach and large-scale zones of natural, man-made and terrorist emergencies (hereinafter referred to as emergency zones). In this regard, and for these purposes, the territorial bodies of the Ministry of Emergency Situations, as a rule, conclude agreements with aviation enterprises or use the aviation of regional centers. However, the use of pilot aviation capabilities is not always effective due to a rather long response time (up to 6 hours), high financial costs, severe dependence on weather conditions, etc.

The most promising direction for solving this problem is the use of unmanned aerial vehicles (hereinafter referred to as UAVs), which can be equipped with operational groups of territorial authorities of the Ministry of Emergency Situations.

A literature review of research into environmental monitoring issues, the use of GIS to identify emergency situations is carried out in the article [3].

This article focuses on the detection of forest fires, despite the fact that the study was conducted in several areas of emergency detection. The importance and interest in the problem of detecting forest fires is evidenced by a large number of publications on this topic in recent years (2016–2022) [4–6, 8-10, 18, 20-27, 30, 33-50]. Quite a large part of the research is devoted to the development of methods and algorithms for image processing. This is due to the emergence of more efficient modern forest monitoring systems through the use of visible range cameras in conjunction with wireless multi-sensor measuring systems (thermal sensors, sensors of atmospheric pressure, relative humidity, oxygen, carbon dioxide and carbon monoxide, etc.) [4, 5, 6, 7]. The support of the methods is based on the analysis of the color and texture characteristics of the flame from a fire [8, 9, 10, 11, 12], the brightness and texture characteristics of the smoke cloud [13-17], as well as the analysis of the dynamics of the characteristics of moving objects (speed, direction, area) [5, 18, 19].

Existing systems for early monitoring and detection of fires are based on traditional methods of human observation on site or video surveillance [5-7]. However, these methods show inaccuracies and false positives, mainly due to human limitations in surveillance. Researchers are working to automate fire detection systems, taking advantage of technological advances [22-24].

Currently, monitoring of fire hazardous areas around the world is carried out using photo and video equipment [7, 23], unmanned aerial vehicles and various remote sensing tools [25, 28] that use sensitive sensors that respond to fire. Depending on the time of day, the nature of the landscape, the size of the territory, weather and other conditions in which monitoring is carried out, one or another means of observation is used that is most suitable for a particular situation. Accordingly, certain methods of processing information obtained by the means used in the process of surveying the territory are applied.

It is necessary to minimize the direct presence of people in hazardous areas, while eliminating the possibility of their defeat in the event of the occurrence of technological accidents and fires associated with damage to large areas in high-risk areas due to the presence of radiation, chemical and biological contamination of the area, explosion hazard, in order to suppress the fire, carry out fire and rescue and emergency recovery operations. It is especially effective to use special technologies for conducting emergency rescue operations using robotic systems for various purposes to perform these works [35, 36].

One of the most effective and relatively inexpensive methods for obtaining information about fires is the method of video filming and appropriate digital image processing [33, 37, 41].

When processing a video sequence, not only the content of each frame is analyzed, but also tendencies of change (movement) of certain characteristics of successive frames are revealed. However, it is obvious that the quality of data processing in this case largely depends on the methods used to analyze the content of fixed frames.

It is necessary to make a reliable forecast of its spread, depending on many parameters (landscape, weather conditions, etc.) having discovered a fire [45]. Then people need to organize actions for the localization and extinguishing of fires, taking into account the data obtained earlier. It seems possible and necessary to create simulators that use all the achievements of modern science and technology in the field of computer vision and graphics.

There are many commercial fire detection sensor systems, but all of them are difficult to apply in large open areas such as forests due to their latency, maintenance, high cost, and other problems.

The performance of fire detection is critically dependent on the performance of the flame pixel classifier, which generates the crop areas on which the rest of the system operates. Thus, the flame pixel classifier should have a very high detection rate and preferably a low false alarm rate.

Fire detection methods based on computer vision are the most common and promising. Fire monitoring represents the first level in the system of early monitoring and fire detection. This level is necessary for detecting and localizing a fire in images obtained by vision devices [9-12, 26, 27].

In [12, 16, 19, 30], a combination of various flame characteristics (color, shape and movement of the flame) obtained from video footage obtained by CCTV cameras was presented to reduce the number of false alarms caused by fire.

Color-based detection methods are the simplest and most used methods to solve these problems. They consist in determining the range of pixel values after they have been converted to a specific color space. The YUV color model has also been used for real-time fire detection based on the temporal variation of fire intensity due to the efficient separation of luminance from chrominance compared to the RGB color space [27]. The YCbCr color space was used to create a general chromaticity model for flame pixel classification [38].

However, the performance of color fire detection methods has been limited by the difficulty of characterizing the smoke, which in most cases strays into clouds. This problem was solved by analyzing the spectral, temporal, and spatial characteristics of both flame and smoke [18, 20]. In the same direction, a method based on a combination of both color and the movement of fire or smoke increased the reliability of fire detection both indoors and outdoors [25].

The study [19] proposed to combine thermal IR imaging and frequency modulated continuous wave (FMCW) radar. The combination of IR and FMCW radar sensors has been developed and demonstrated to improve object identification and location accuracy while maintaining real-time processing. The proposed method complements the shortcomings of the sensor and improves the identification and location of the object. The experimental results demonstrated the same accuracy in clear and poor smoke visibility conditions in a fire.

A significant contribution to the development of methods for detecting forest fires was made by scientists T. Celik (Turkey), B. U. Toreyin (Turkey), D. Stipanicev (Croatia), A. A. Lukyanitsa (Russia) and others.

Computer vision based systems [24, 28, 34, 36] typically extract three different fire data and use it for fire detection: color, motion, and geometry. The flame is the visible part of the fire. In the case of organic materials such as trees and shrubs, fire has the well-known red-yellow color. Many natural objects have similar colors to fire and can often be misidentified as flames. For this reason, it is very important to distinguish between such false alarms and real fires.

A forest fire is a complex object, which includes the following main elements: forest fire contour, forest fire front, forest fire rear, and fire flanks (Figure 1.1) [9].

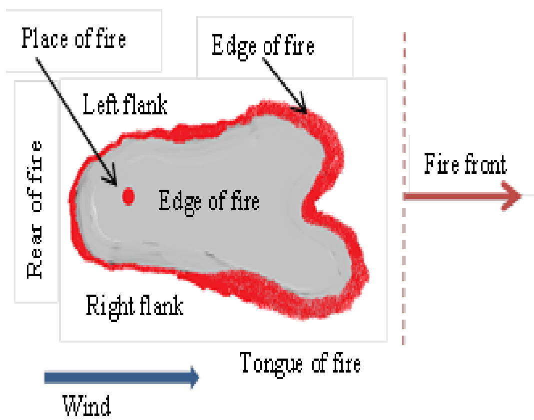

Figure 1: A forest fire: main elements

Visual monitoring is organized, in particular, with the help of an observation tower, for example, Wildland, Delacom Detection Systems LLC (USA), FireHawk, ALASIA MARKETING (South Africa), FireWatch, IQ Wireless (Germany). The hardware of the Wildland and FireHawk systems is based on controlled IP cameras and high-resolution cameras in the visible spectrum [20, 6, 21, 22]. The FireWatch system operates in the infrared and visible range [21].

An automated search for fires in television monitoring systems can be implemented based on the use of algorithms for dynamic interframe cross-validation and multimodal wavelet decomposition for smoke detection in dynamics [8, 23, 24, 25]. Currently, a lot of research is being carried out on the development of fire detection algorithms for the color components of the image. The detected fires are in the 25th spectral range, which make it possible to detect smoke, and in rare cases, the fire flame itself [26, 27]. Modern optoelectronic systems for television monitoring of forest fire detection are built on the basis of digital or network IP cameras.

The technology for obtaining information in lidar (light detection and ranging) optoelectronic systems is based on the use of active optical detection methods [16, 17]. It uses laser sensing of the atmosphere to spectrally analyze the scattering of radiation by particles of organic origin, which are present in the ascending streams of hot air and smoke from a forest fire.

Optoelectronic systems of the near and far infrared radiation range, for example, Tau 640, FLIR, (USA) [10]; Raven-384, Xenics (USA) [27]; Tamarisk 640, DRS Technologies (USA) [7]; C200, Nippon Avionics Co., Ltd. (Japan) [11]; Lynx-1.7-102 4TE1, Xenics (USA) [14].

Multispectral optical-electronic systems are most widely used in monitoring and detection systems for forest fires. The principle of constructing such systems is the joint operation of several previously considered systems. For example, there are OTUS-L170 and OTUS-L205 [28]. A number of such systems based on a gyro-stabilized platform are produced by Pergam-Suisse AG [29] and FLIR [10].

Detection of forest fires with satellite observation consists in using information received from an artificial satellite of the Earth, which performs constant monitoring of the earth's surface.

One of the widely used and effective methods for detecting and fighting forest fires is aviation patrolling of forests, which, subject to flight regulations, is capable of detecting forest fires in an area that makes it possible to eliminate this fire in the minimum areas [30-35]. In the conditions of the current level of development of aviation technologies, a promising direction in the development of monitoring systems has been the use of UAVs as a means of monitoring the OES. The Republic of Kazakhstan uses both imported UAV models and models of its own production, for example, TENGRI PRO 2.0 and TENGRI PRO 2.5. Characteristics of Kazakhstani models are presented on the website https://qazdron.kz/.

Recently, neural networks have been widely used to simulate forest fire detection. These models are used for real-time fire detection and localization [42-45]. Due to the geographical location of Kazakhstan and the weather conditions inherent in this climatic zone, early detection of forest fires in real time is an urgent task. It is necessary to develop models and software for image processing taking into account local conditions and characteristics, as well as take into account the availability and availability of equipment that will be used to solve problems.

The effectiveness of forest fire detection systems as statistically rare events is evaluated based on the probability of correct detection and the probability of false alarm. Many of the existing image processing methods developed to solve the problem of forest fire detection are quite successful in solving the problem. However, insufficient attention is paid to the development of methods and algorithms for image preprocessing in order to reduce the number of false positives of the system under the influence of interfering factors. Therefore, the problem of developing image preprocessing algorithms in forest fire detection systems that provide an acceptable level of false alarm probability is relevant.

2. IMAGE RECOGNITION TECHNOLOGIES, MODELS AND ALGORITHMS FOR EMERGENCY DETECTION

A whole cycle of procedures must go through to bring image into a form convenient for obtaining and subsequent analysis of visual information from the moment the image is received from a satellite or UAV to the possibility of analyzing it.

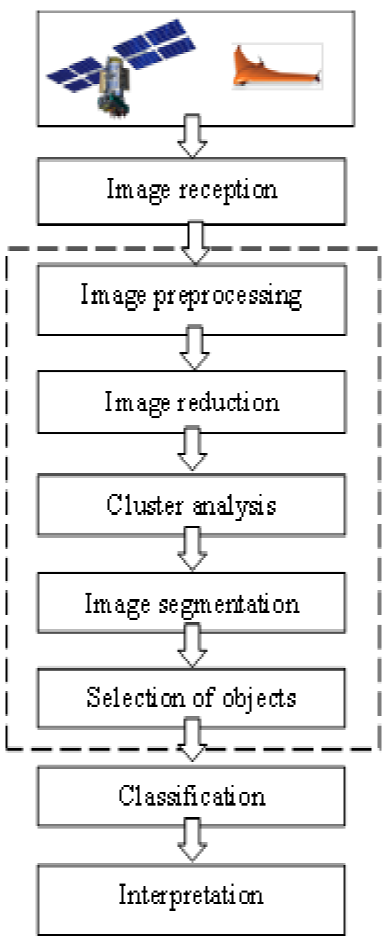

Figure 2: Digital Image Conversion and Analysis Procedure

It is known, that the image is a two-dimensional function f(x, y), where x and y are spatial coordinates, and the amplitude at any point with a pair of coordinates (x, y) is the intensity or brightness of the image at that point [6, 21, 22, 36, 37]. If the variables x, y and f take the values of their finite (discrete) set, then one speaks of a digital image.

Image conversion involves a number of operations. It may also include changing the pixel size to facilitate analysis.

The purpose of the conversion may be to increase contrast, reduce noise, correct defects caused by the optics of the image or the image digitizing device.

The selection of objects consists in identifying various features and determining the boundaries between them. The success of object extraction depends on previous sample preparation, image acquisition and transformation.

In the process of characterization after segmentation stage identified objects are taken and measurements are made on each of them [30, 34]. These measurements depend on the purpose of the work. For example, length, area, etc. can be measured.

If several objects of different types are highlighted in the image, they are divided into corresponding classes. The characteristics of all objects selected in the previous step should provide the required information about them. The classification operation can be used even if the image contains only one object type of interest. For example, to remove artifacts that appeared during sample preparation or image processing.

Finally, stereological methods are used to obtain statistically objective data [9, 30]. Note that the changed characteristics are affected by both the method of information conversion and the method of obtaining an image.

The purpose of the image pre-processing step is to improve the visual quality for subsequent segmentation and classification [38-48]. The stage of preliminary preparation of the image can be singled out as especially responsible. The quality of object selection and the result of further recognition (classification) will depend on the results of this stage.

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Because of the image, along with useful information, can contain noise and high-frequency interference, the system under development requires the implementation of filters to smooth the image in order to successfully cope with this problem [38, 39, 40]. Linear image filtering is one of the most commonly used image processing procedures [41, 42].

Let a function of two variables $f(n_1, n_2)$ is given on a uniform grid $\Omega_2 = \Omega * \Omega$, where $\Omega = \{0, \pm 1, \pm 2, \cdots\}$, which is a distorted image of some object. The task of digital processing is to act on the function $f(n_1, n_2)$ with a digital filter $\Phi f(n_1, n_2) = g(n_1, n_2)$, performing the given transformation by function $e^{i(\xi_1 n_1 + \xi_2 n_2)}, \xi_1, \xi_2 \in [0, 2\pi]$

$$\Phi e^{i(\xi_1 n_1 + \xi_2 n_2)} = K(\xi_1, \xi_2) e^{i(\xi_1 n_1 + \xi_2 n_2)}, \quad (1)$$

where $K(\xi_1, \xi_2)$ is filter frequency response.

Digital filter (1) is a convolution type transformation

$$\Phi f(n_1, n_2) = = \sum_{l_1=-\infty}^{\infty} \sum_{l_2=-\infty}^{\infty} k(l_1, l_2) f(n_1 + l_1, n_2 + l_2), \quad (2)$$

whose kernel $k(l_1, l_2)$ (filter impulse response) has the following relation to the frequency response $K(\xi_1, \xi_2)$:

$$K(\xi_1, \xi_2) = \sum_{l_1=-\infty}^{\infty} \sum_{l_2=-\infty}^{\infty} k(l_1, l_2) e^{i(\xi_1 n_1 + \xi_2 n_2)}, \quad (3)$$

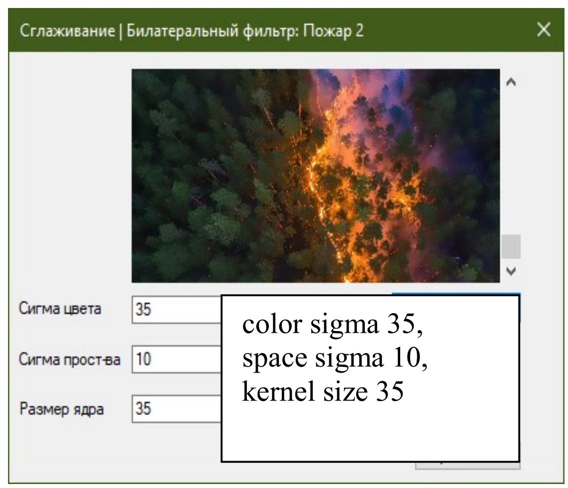
$$k(l_1, l_2) = \frac{1}{4\pi^2} \times \times \int_0^{2\pi} \int_0^{2\pi} K(\xi_1, \xi_2) e^{-i(\xi_1 l_1 + \xi_2 l_2)} \partial \xi_1 \partial \xi_2. \quad (4)$$

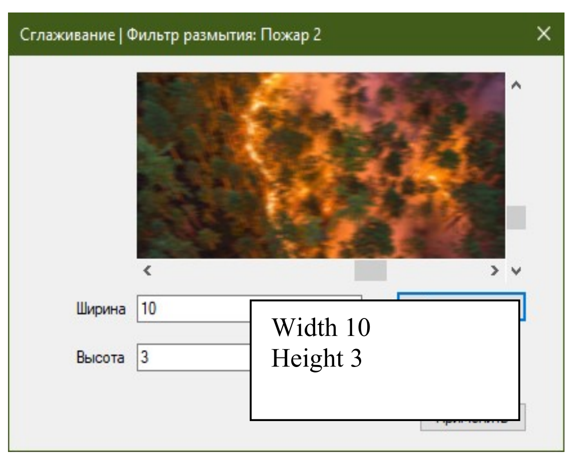
Thus, image processing consists of two parts: in finding the kernel of a digital filter that meets a given frequency response and its subsequent image processing with a calculated kernel.

Let's consider the original UAV image of a forest fire (Figure 3).

Figure 3: Original UAV image of a forest fire

We can see the work of bilateral filter with following parameters: color sigma 35, space sigma 10, and kernel size 35 (Figure 4).





The results of smoothing with blur filter (parameters: width 10, height 3) are presented on Figure 5 and with Gaussian blur filter on Figure 6.

Figure 6: Smoothing. Gaussian blur filter

The result of smoothing with Median filter is shown on Figure 7.

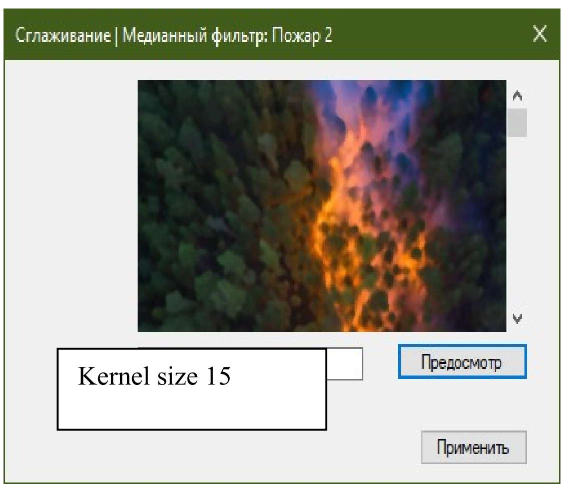


Figure 7: Smoothing. Median filter

All considered filters are implemented in a software application for de-detailing and noise reduction. The work of algorithms for using box filters is also considered and implemented.

The simplest example of a box filter is the convolution of the original image with a window:

$$k(l_1, l_2) = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad (5)$$

The result of smoothing with a box filter using averaging differs from the defocused image. A point of light viewed from a defocused lens looks like a circle of light, and averaging gives a square.

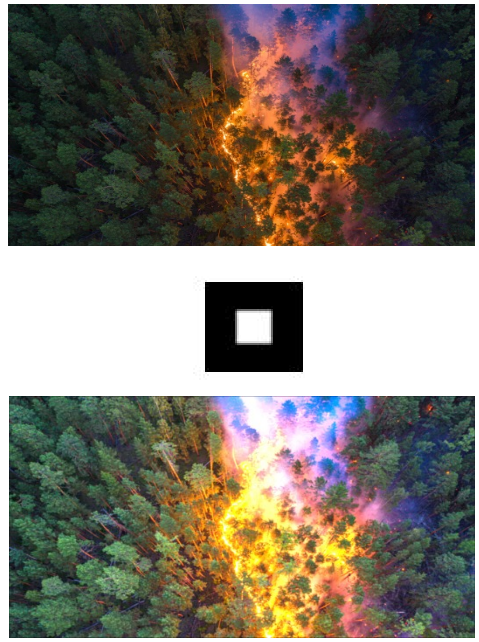


Figure 8: The example of image smoothing with a box filter 5x5

It is possible to use different kernel, for example (6).

$$k(l_1, l_2) = \frac{1}{9}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad (6)$$

The result is on the Figure 9.

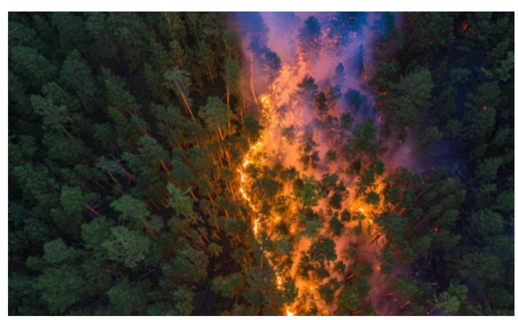


Figure 9: The example of image smoothing with a box filter with kernel (6)

Let's move on to the consideration of methods and models for detecting a forest fire by external signs.

Detection of any objects refers to the field of computer vision and digital image processing with the aim of finding certain types of objects in a digital image or video, in this case fire and smoke.

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There is a set of specific features to detect a fire, which can be used to classify an object: the smell of burning, foggy smoke, restlessness of birds and animals, their migration in one direction even at night, glow reflections on low clouds. In the study, we are talking about an image that needs to detect a forest fire, where these features do not fit.

There are several ways to process and analyze images for detecting and locating a fire in the area [30, 34]. These methods can be divided into three groups: histogram, methods based on dynamic features, and combined. Most of them are based on such a characteristic sign of fire and smoke as color. And the main detection procedure is segmentation. The image is divided into areas with a certain uniformity criterion, for example, the selection of areas in the image of approximately the same color and brightness.

It is necessary to know the color range of the object under study (fire and smoke) to detect a fire correctly. The color changes relatively little within a particular area and changes strongly when moving from one area to another. An open fire flame usually has a characteristic color and differs significantly in flickering intensity from the background light. Fire pixels have a characteristic color: bright orange and yellow and smoke pixels – white, gray and black (Figure 10).

Figure 10: Characteristic colors of fire and smoke

The vast majority of authors in their work, as the first stage of image processing, use the search for image areas with a characteristic color corresponding to the color gamut of fire. The color gamut of fire is set experimentally as a set of possible color states of fire pixels. First, pixels in the image with a characteristic color are searched and potential fire areas are formed. A binary mask of the image is compiled, in which the areas of units correspond to areas of the image with a characteristic color of fire. After that, the dynamics of the selected areas is analyzed.

We used the color histogram method, the most popular of the methods that use color characteristics for image segmentation and indexing [30]. The idea of the method is considered in detail in [30].

It is possible to simplify the segmentation and fire detection algorithms by switching from processing and analyzing a color image to a black-and-white one (Figure 11).

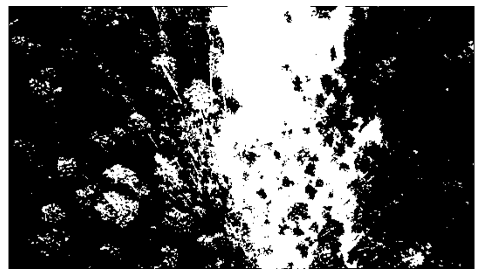

Figure 11: A black-and-white image

In the work, segmentation is carried out using thresholding. The brightness value of each image pixel is compared with the specified threshold value [30, 32]. The image histogram is conditionally divided into two parts using a threshold. Each pixel is marked as related to an object (fire, smoke) or background, depending on whether the brightness of this pixel exceeds the threshold value or not.

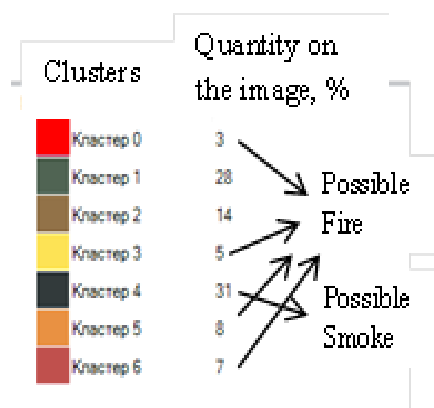

Figure 12: Segmentation

Object detection methods are typically based on either machine learning or deep learning. In this study, the Viola-Jones algorithm was used. The general algorithm for training a network is explained in our work [2].

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Let us consider in detail knowledge base rules formation and the visualization of fuzzy inference. Visualization of fuzzy inference was carried out using the Rule Viewer GUI module of the MatLab software. This made it possible to illustrate the course of logical inference for each rule, obtaining the resulting fuzzy set, and developing the defuzzification procedure.

Each knowledge base rule is represented as a sequence of horizontally arranged rectangles. In this case, the first two rectangles (Figure 13) display the membership functions of the terms of the rule sending (IF-part of the rule), and the last third rectangle corresponds to the membership function of the term-consequence of the output variable (THAN-part of the rule).

An empty rectangle in the visualization of the second rule means that there is no sending to the smoke variable in this rule (smoke is none). The yellow shading of the graphs of the membership functions of the input variables indicates how much the values of the inputs correspond to the terms of this rule.

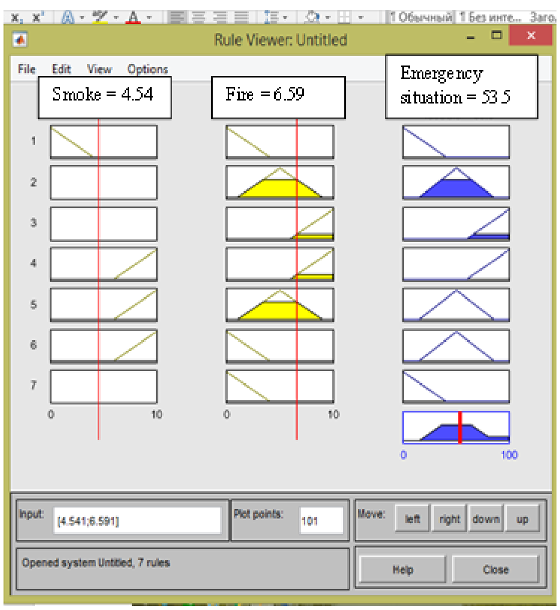

Figure 13: Visualization inference for a system using the Rule Viewer

The blue fill in the graph of the membership function of the output variable represents the result of a logical inference in the form of a fuzzy set according to this rule.

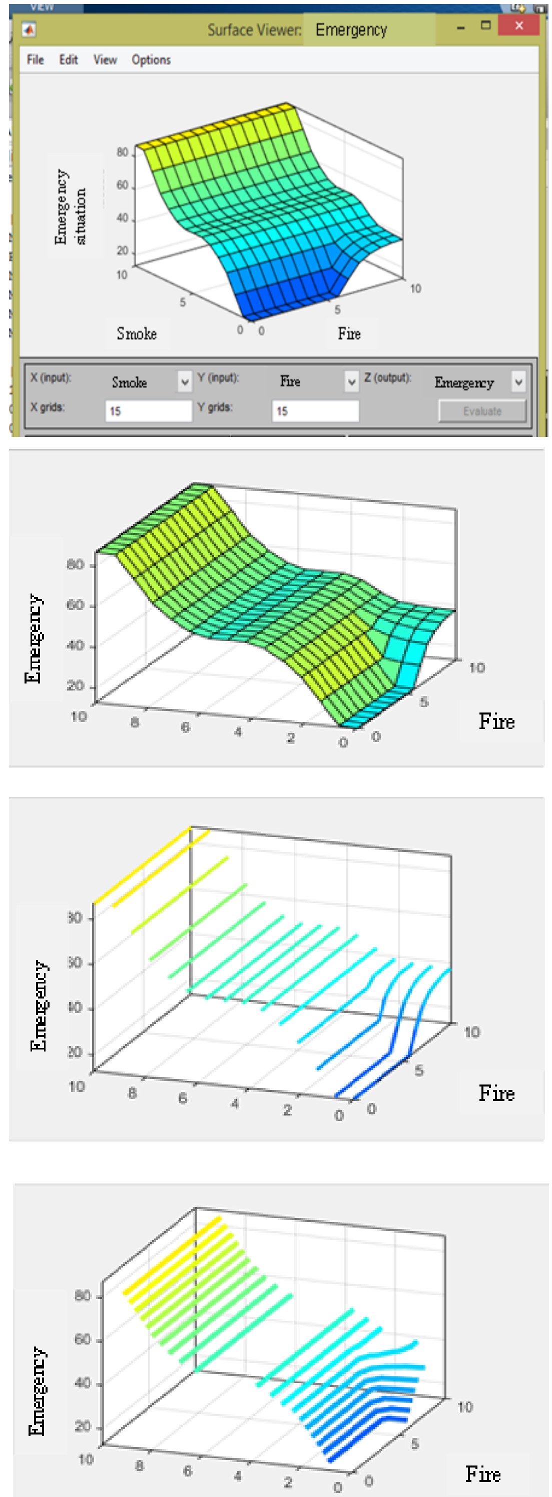

Figure 14: Surface formats “inputs – output”: Surface, Mesh and Lit surface

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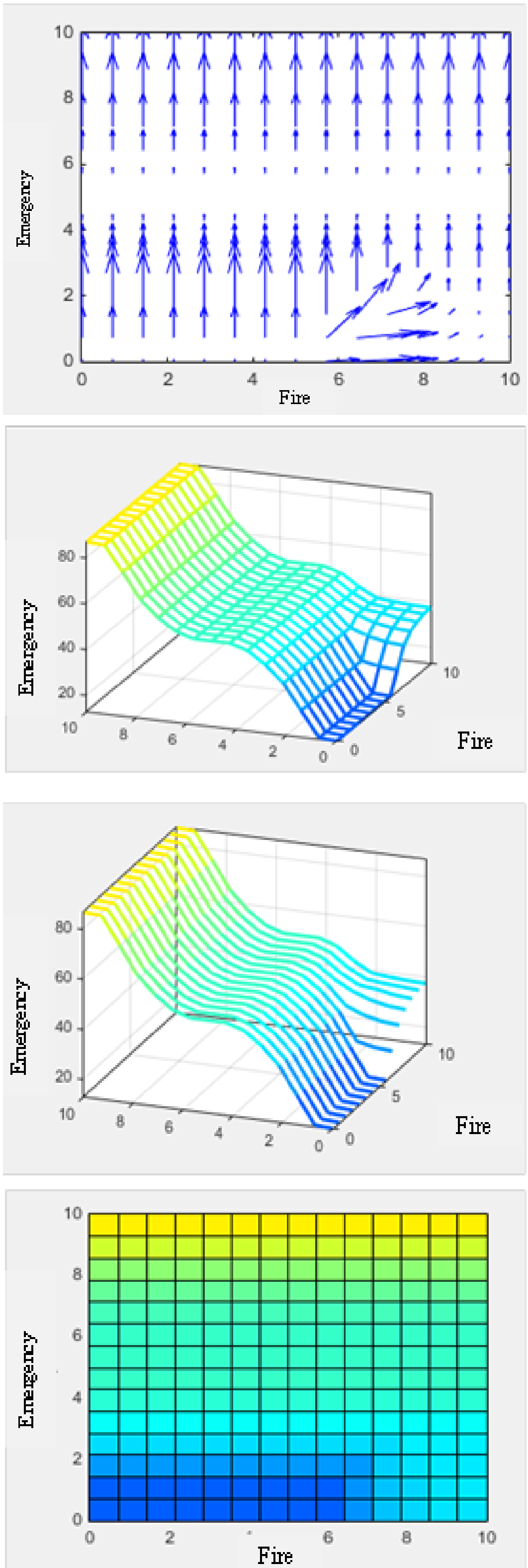

Figure 15: Surface formats "inputs – output": Quiver, Contour, Mesh and Pseudo color

The resulting fuzzy set corresponding to the logical conclusion according to all the rules is shown in the lower rectangle of the last column of the graphics window. In the same rectangle, the red vertical line corresponds to the clear value of the inference resulting from the defuzzification. As a result, for a given block of rules a fuzzy system was modeled.

The training set was loaded in the Neuro-Fuzzy Designer editor (Figure 16).

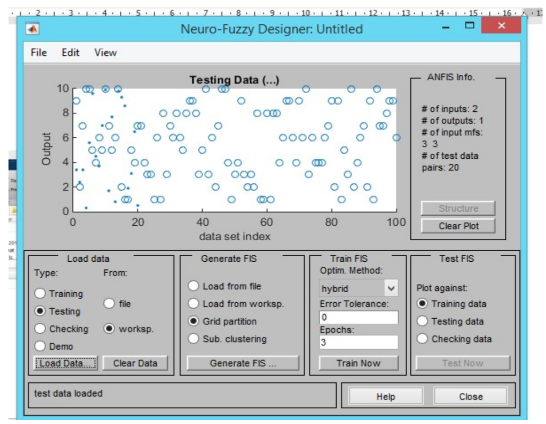

Figure 16: Neuro-Fuzzy Designer editor window where blue dot (.) – testing sample; blue circle (o) – training set

Experimental data and simulation results are displayed as a set of points in two-dimensional space. The abscissa shows the serial number of the data line in the sample (training, testing or control), and the ordinate shows the value of the output variable for this sample line.

Figure 17: Testing window where blue plus (+) – control sample; red asterisk (*) – simulation results

After testing a synthesized neuro-fuzzy network it is possible to see the structure of the synthesized network (Figure 18).

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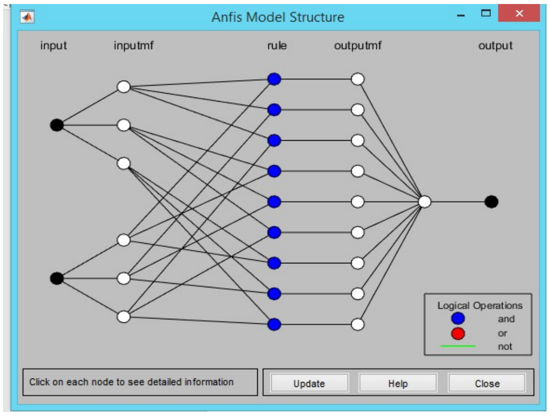

Figure 18: A fragment of the synthesized network structure

The clusters' centers of multidimensional data were found using the fuzzy c-means algorithm and the subtractive clustering algorithm using the Findcluster GUI module.

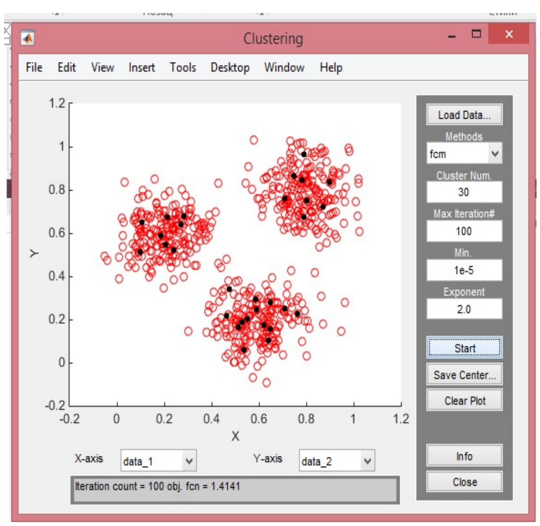

Figure 19: Example of clustering with 10 clusters and 100 iterations where a red circle (o) - image, a black dot () - a center of cluster

3. PROGRAM IMPLEMENTATION

The first level of application architecture is the collection and formation of the corresponding database tables.

Images from satellite or UAV are sent for analysis. Weather conditions play important role in the process. We can receive monitoring data from Kazhydromet meteorological organization (Figure 20).

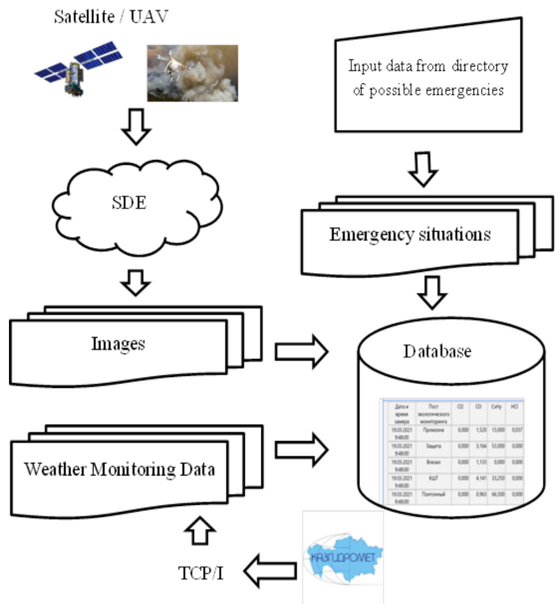

Figure 20: The first level of application architecture

The database of heterogeneous data is included in the information level of the knowledge base.

The second level of the application architecture is the formation of a knowledge base, including:

✓ the executive system, which in this case has a problem orientation and ensures the implementation of the generated program;

✓ intelligent interface with a flexible structure;

✓ an information base that ensures the use of computing facilities of the first two complexes of an integral and independent of processing programs knowledge system about the problem environment, which is the knowledge base itself.

The third level of the application architecture includes the visualization of results using a software package - an application developed in the C# environment.

Main specifications:

- ✓ Microsoft Windows 10 any version,
- ✓ CPU: not less INTEL CORE I5-3330.
- ✓ Video adapter: GEFORCE GTX660 (2GB) / RADEON HD 7850 2GB, DIRECTX 9.0C .NET FRAMEWORK 4.5.1
- ✓ RAM: not less 4 GB.
- ✓ Free hard disk space: not less 1 GB.

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The characteristic of reference and input information is represented by input and output documents.

The input documents of the system are:

- ✓ Directory on emergency situations;
- ✓ Directory of possible objects;
- ✓ Directory of images.

The directory of possible objects is filled in as needed. Here is an approximate list of possible emergencies that fall into this category in Kazakhstan. Technogenic (artificial) nature: fire, explosion at the facility, etc. Natural character: flood, fire, landslide.

Output documents are the results of image analysis in the form of a percentage of clusters corresponding to a certain emergency situation. It is possible to work with streaming video in real time. But there were difficulties with obtaining the source material, so only work with images was debugged.

When starting the software, the main window appears.

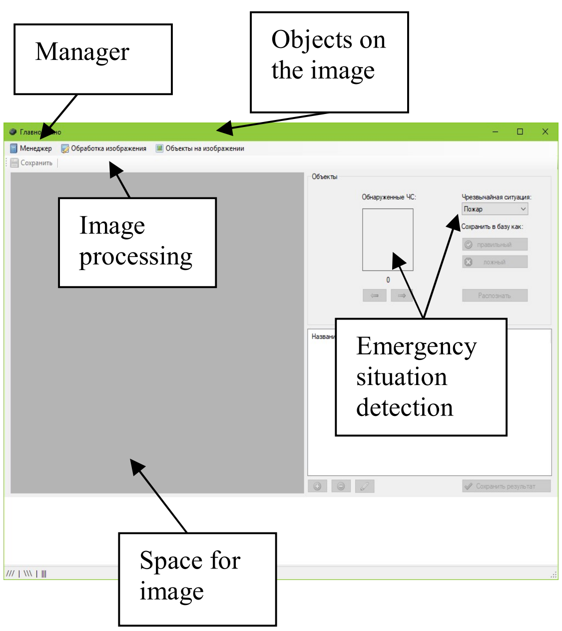

Figure 21: The main window of the application

When select the "Manager" tab, the "Image Manager" window opens, where we can see the available satellite or UAV images of various parts of the Earth. Each image has characteristics: region, result (in use/ not use yet), comments and date.

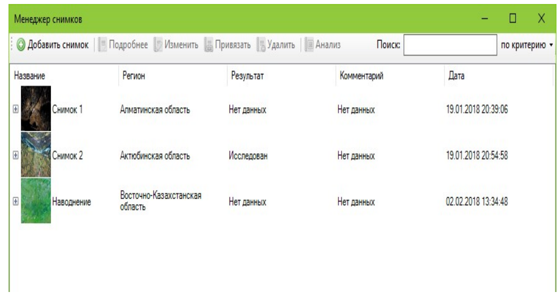

Figure 22: Window "Image Manager"

When one of the images is selected, the tabs for working with the image become available: "Details", "Edit", "Link", "Delete", and «Analysis". It is possible to search the database by criteria.

After clicking on the “Details” tab in Figure 23, we can see all the information about the image in detail: region, date and time of the image, comments, etc.

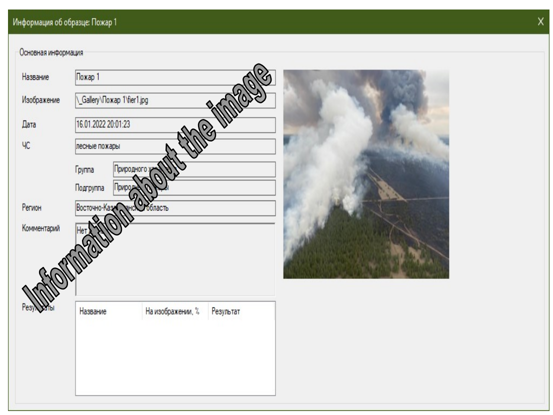

Figure 23: The information about the image in detail

Let’s consider the operation of the program on the example the original UAV image of a forest fire processing (Figure 3).

The algorithm, which is implemented in the software product, is shown in the figure 24.

It is possible to realize six main stages of image processing from pre-processing till saving results.

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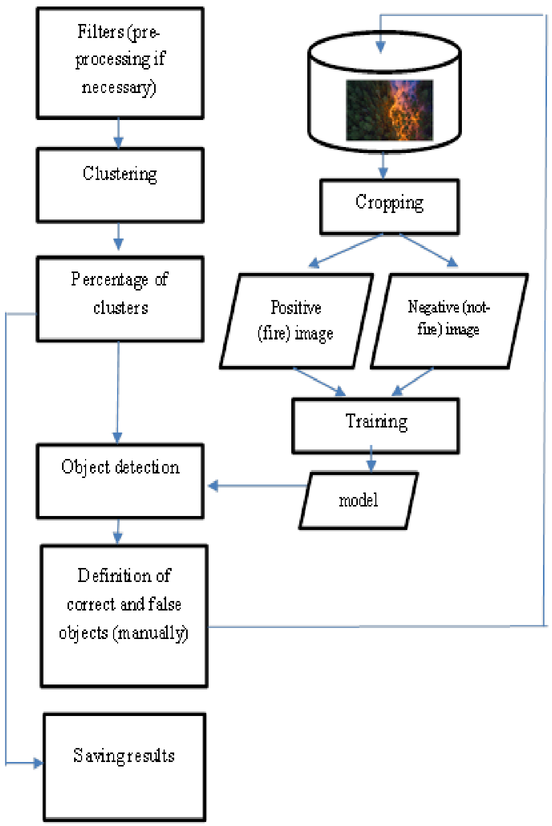

Figure 24: The algorithm

We use the function of lowering the pyramid to select a fragment of the image of the alleged fire (Figure 25).

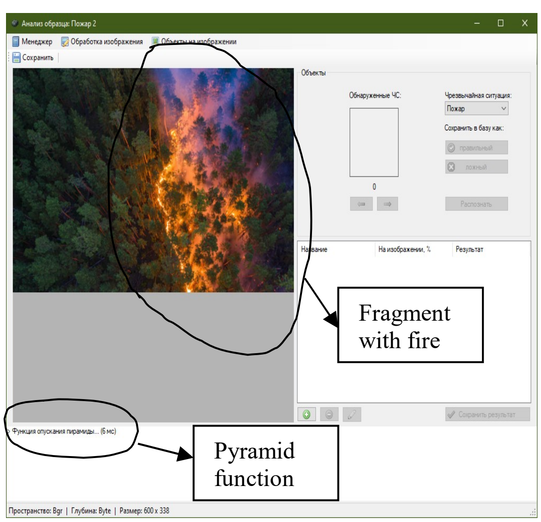

Figure 25: Result of the function of lowering the pyramid

The result of clustering with parameters seven clusters and 10 iterations is demonstrated on Figure 26.

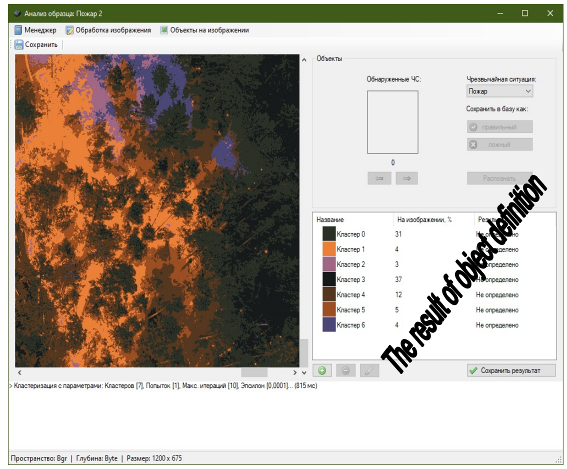

Figure 26: Result of clustering

Object definition (fire/ not fire) is demonstrated in the left part of the window. The result of the analysis is shown in Table 1.

Table 1: The result of object definition

Number of cluster	Quantity on the image, %	Result
1	2	2
Custer 0	21	Not found
Custer 1	4	Fire
…		
Custer 6	4	Not found

The result of clustering the image (original image before processing is presented on Figure 23) with smoke is shown on Figure 27.

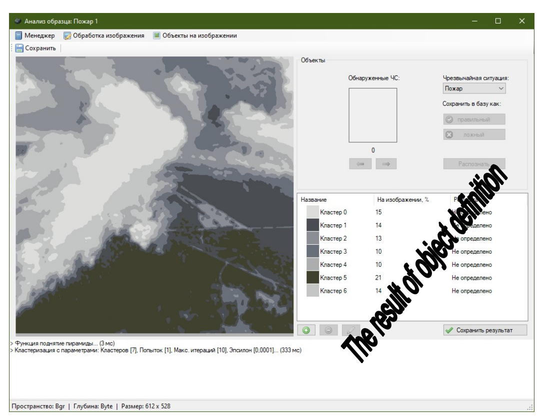

Figure 27: Result of clustering

The software product implements the algorithms of the Laplace and Sobel operators and

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the Canny edge detector for a more detailed analysis of images.

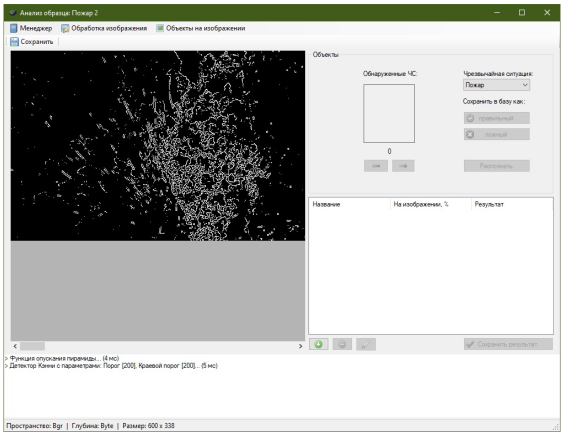

Figure 28: The result of Canny edge detector algorithm

Figure 28 shows the result of the operation of the "Canny Edge Detector" algorithm, which confirms the possibility of an emergency "Fire".

The filtering window (Figure 29) is used to work with the obtained images in the HSV color space.

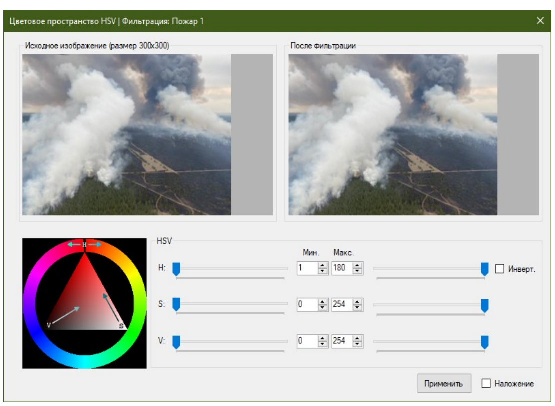

Figure 29: The filtering window

It is possible to see the original image in the left part of the window, on the right - the image after filtering. This window sets the required value for each of the three directions: H in the range from 0 to 180, S and V from 0 to 254. It is also possible to invert colors by selecting the appropriate checkbox in the right part of the window. The "Apply" button is used to save the processed image.

Figure 30: A certificate No. 23433, from February 08, 2022

All the considered methods and algorithms are implemented in the software package in C# programming language. This information confirms by a certificate on data registration in the state register of copyrighted objects of the Republic of Kazakhstan No. 23433, from February 08, 2022 (Figure 30).

5. ACKNOWLEDGEMENT AND CONCLUSION

The algorithms for processing images obtained as a result of images from a satellite or UAV, providing a solution to the problems of "machine" vision to detect emergency situations were developed.

Different image recognition technologies for identifying emergency situations were adopted for local Kazakhstan conditions, taking into account accessibility and availability of equipment.

Methods and models for detecting an object by external signs were selected in the research. In addition to previous studies, differences between fire smoke and natural smoke were taken into account, as well as the natural colors of the forest, characteristic of the forests of Kazakhstan, which, when processed, can give false alarms and not be a fire.

As the analysis criteria, the criteria for the accuracy and scale of determining the fire on the image were chosen, and the factor of early fire detection was taken into account – the appearance of smoke, as well as the difference between fire smokes and not associated with fire smoke or fog.

The algorithms for preprocessing images have been developed and realized in a software package for image recognition using the C# programming environment. The purpose of the work was achieved.

6. FUTURE RESEARCH DIRECTIONS

Currently, research in the field of choosing the actual UAV trajectory after fire detection is of great interest and practical significance. This interest is due to the fact that it is not enough to detect the source of a fire or detect its presence, it is equally important to monitor its further development: the direction of movement, possible attenuation, or a change in the direction, intensity and nature of the process. Further research involves setting up and modeling the behavior of the UAV after a fire is detected: in which cases the UAV can return to the base, in which cases it can stay at a certain point, and in which situations it can move in the right direction.

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