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PROCESSING IMAGES OF TECHNOLOGICAL OBJECTS

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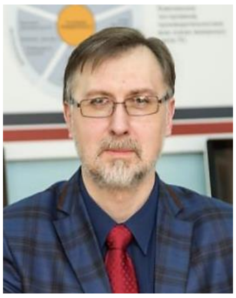

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Annotation. The paper considers the problem of creating a smoke detection and fire detection system for technological objects. Fire detection is carried out using a vision system. Monitoring of technological objects is carried out using an unmanned aerial vehicle. For further actions, processing and classification of images is necessary.

Keywords: image processing, system, unmanned aerial vehicle, fire, smoke, technological object.

Introduction

To assess the state of technological objects and their parameters, technical vision systems built on the basis of artificial intelligence are currently widely used. One of the tasks to be solved by vision systems is the recognition of objects in static images, which include the task of recognizing smoke and fire [1].

An important problem of ensuring industrial and environmental safety is the fire protection of various objects and territories – providing automated operational detection of fires using unmanned aerial vehicle technologies [2-4].

The current trend is the expanding use of video technology in fire safety tasks, characterized as “video analytics”. Used video detectors can detect a fire in a room and in open areas automatically by specific signs in the image, allowing you to assess the situation at the production facility.

Results of research

Formulation of the problem. Most automated video analytics systems are based on computer image processing and analysis of their changes. In this case, video detectors can be used in case conventional fire alarms are not applicable. The literature cites data according to which the probability of false alarms is <1%, and the recognition range is 10 km for a smoke area 10x10 m in size [5]. To monitor and identify fires and fires in the video image, an adaptive background model of the area observed by the video camera and a generalized color model of the fire can be proposed based on statistical analysis of a sample of images containing fire pixels, followed by transmission via radio or optoelectronic channels in digital data processing.

In enterprises of the chemical, petrochemical industry, the main requirement for the detection of fire or smoke is considered the need for early detection of an emergency. A good alternative to traditional chemical sensors is a smoke control video control system, which allows, in addition to the fact of smoke generation, to determine the degree of smoke, the number of smoke areas, the contours and sizes of these areas, as well as the direction of smoke propagation.

Thus, the problem of constructing an intelligent system for assessing the state of technological equipment based on an unmanned aerial vehicle is considered. It is proposed to use expert systems of a new generation [6].

Monitoring technological equipment. For integrated monitoring systems for technological objects, the detection of the effective surface of dispersion, reflection, or emission is of utmost importance. At the same time, in the microprocessor system of the unmanned aerial vehicle, a continuously adjusted reference map of the intensity of the reflected (absorbed) signals or radiation is formed based on the integration of the effective scattering, reflection and absorption surface in the scanning parameters and resolution elements of the reference map generated using the measuring complex. In one resolution element of the measuring complex, the reflectance (emissivity) $S_{\text{отр}}$ of the observed object is found as the total value over the area (1):

$$S_{\text{отр}} = \int_S^{\infty} k_i\, ds, \text{ или } S_{\text{отр}} = \sum_{i=1}^{n} s_i k_i, \tag{1}$$

where: п - is the number of resolution elements of the map with area S_i, reflection coefficient k_i in the resolution element of the meter.

The most important parameter of a fire detector is the maximum detection range of a small-sized fire source by a subsystem with an automatic detection method based on the excess of the video signal generated by the sensor from the object over the threshold signal. In the process of automatic detection of an object (fire), the signal from the output of the photodetector after preliminary amplification is fed to a threshold device that detects the excess of the signal from the object above the threshold. The probability of detection in the presence of a noise signal clearly depends on the signal-to-noise ratio. The object (fire) is always placed on the background. The useful signal at the output of the radiation receiver U is the difference between the signals from the object with the fire source (п) and background (f) in the spectral range of the sensor (2):

$$U = U_{\text{п}} - U_{\phi} = \frac{A_{\text{п}} A_{\text{об}}}{R^2} \int_{\lambda_1}^{\lambda_2} \tau_{\alpha}(\lambda) \Delta L(\lambda) \tau_{\text{об}}(\lambda) S_D(\lambda) d\lambda\,, \tag{2}$$

where: λ - is the radiation wavelength; Aп - the area of the fire; $A_{об}$ - the area of the entrance pupil of the lens; R - distance to the object; ΔL (λ) = $L_п$ (λ) $-L_ф$ (λ) - the absolute contrast of the brightness of the fire source and background; $\tau_а$ (λ) - spectral transmission of the atmosphere, which depends on the following parameters: range to the object, meteorological visibility range at relative humidity and temperature; τ_{ob} (λ) - spectral transmission of the lens.

The relationship between the spectral sensitivity of the receiver S_D (λ) and the specific detectivity D (λ) is described by the expression (3):

$$S_D(\lambda) = D(\lambda)U_п/\sqrt{A_D\Delta F}, \quad (3)$$

where: Δf - is the effective noise band of the electronic path of the sensor;

A_D is the area of the sensitive area of the receiver (pixel, if a matrix receiver is used);

$U_п$ - noise signal generated during monitoring, due to the influence of secondary natural and man-made sources.

The detection range of a small fire with a single-element detector in the infrared range is up to 7–8 km for a clean atmosphere and up to 2-3 km in conditions of poor visibility. The brightness of the background radiation in the visible range of the spectrum (for a video camera) is determined by the formula (4):

$$B_{\phi\lambda} = \frac{\omega_\lambda S_0(\lambda)\mu_0\tau_\alpha(\lambda)}{\pi} + B_\alpha(\lambda) + (1-\omega_\lambda)M_\lambda(\lambda, T_\phi), \quad (4)$$

Where S_0 (λ) is the spectral solar constant (illumination) on the surface of the Earth;

μ_0 - is the cosine of the angle of the Sun with respect to the normal of the observed area;

ω_λ - is the albedo of the reflecting surface of the background;

τ_a (λ) - transmission of the atmosphere between the object and the device;

B_a (λ) - is the brightness of the atmospheric haze between the object and the device;

M_λ $(\lambda, T_ф)$ - is the Planck radiation function for the background temperature.

The brightness of the flame radiation in the visible range is determined by the Planck function with the flame temperature $T_п$. The expression for light illumination in the plane of the object has the form (5):

$$E_{св} = 683\int_0^\infty E(\lambda)V(\lambda)d\lambda, \quad (5)$$

Here: $E_{св}$ - light illumination of the object, lux;

E (λ) - is the spectral density of the energy illumination of the object;

V (λ) - is the relative spectral sensitivity of the eye;

683 - conversion factor of energy values into light, lm / W.

For spectral illumination in the plane of the entrance pupil in the case of solar radiation reflected from background objects, when the intrinsic background radiation at a temperature of 300 K corresponds to (6):

$$E_\phi(\lambda) = \frac{\omega_\lambda S_0(\lambda)\mu_0\tau_\alpha(\lambda)A_п}{\pi R^2} + E_\alpha(\lambda). \quad (6)$$

Here E_a (λ) is the atmospheric illumination corresponding to the brightness of the atmospheric haze on the observation beam. Spectral illumination from radiation from a fire source (7):

$$E_п(\lambda) = \frac{M_\lambda(\lambda, T_п)A_п\tau_\alpha(\lambda)}{R^2} + E_\alpha(\lambda). \quad (7)$$

For light illumination of the background at the entrance pupil in two cases (8) and (9):

$$E_{\phi\ \text{св}} = \frac{683\omega\mu_0 A_{\text{п}}\tau_\alpha}{\pi R^2}\int_0^\infty S_0(\lambda)\, V(\lambda) d\lambda + E_{\alpha\ \text{св}} \equiv E_{\phi\ \text{отр}} + E_{\phi\ \text{св}}, \quad (8)$$

$$E_{\phi\ \text{св}} = \frac{683 A_{\text{п}}\tau_\alpha}{R^2}\int_0^\infty S_0(\lambda)\, V(\lambda) d\lambda + E_{\alpha\ \text{св}} \equiv E_{\phi\ \text{соб}} + E_{\phi\ \text{св}}. \quad (9)$$

Moreover, at a distance of 1 km, the probability of detecting a fire focus of 1 m in size with a video camera will be significantly less than 0.5. Fire places with a temperature of 1500 K^0 with a linear size of 1 m^2 can be detected using a video camera at a distance of up to 220 m or less. To increase the detection range of a fire or a fire at a distance of more than 1 km, it is advisable to use either traditional video cameras operating in the light range, but with a much higher sensitivity, or infrared sensors.

Information technology video analytics using an unmanned aerial vehicle can be useful for monitoring fire safety and remote monitoring the integrity of the structures of oil, gas and product pipelines and other hazardous production facilities with significant linear dimensions.

At the stage of image processing, the color scheme is balanced, the average value of each R, G, B color component of the image is calculated in order to obtain a real level of gray color.

At the next stage, smoke regions are distinguished, for which purpose the color characteristics of the smoke regions are used. Since smoke has a color from light to dark gray, this property is used to highlight potential areas of smoke in images in which the intensities of the color components are in the following ratio:

$$\begin{cases} |R - G| < T, \\ |G - B| < T, \\ |R - B| < T, \end{cases}$$

where T is a threshold that can be adjusted according to the training set of video files [7].

Naturally, the use of color characteristics to localize areas of smoke is not enough. It is known that the smoke areas are not stationary, but constantly move and change their shape. Therefore, the next step in detecting smoke areas will be the detection of frames on the video stream of objects.

The processing result is presented in binary form. Figure 1 shows the stages of image processing. An example of smoke generation is given.

Figure *1.* – Image Processing Steps

When observing an object against a relatively uniform background, the problem arises of estimating the parameters of geometric transformations with the required accuracy. Thus, the development of effective algorithms for the isolation, detection, and estimation of parameters of airborne objects remains a very urgent task to date [8].

Hazards identification and detection algorithm. As a model of image formation obtained using a video sensor, we consider the space-time model [8], where we consider. only spatial information, then, omitting the frame number, this model can be written in the following form:

$$l(i,j) = h(i,j)\,r(i,j) + g((i,j)\big(1 - r(i,j)\big) + \xi(i,j)\,,\;\; i = \overline{0, N_x - 1}\,,\;\; j = \overline{0, N_y} - 1, \qquad (10)$$

where - N_x, N_y height and width of the frame; l (i, j) is the observed image; g (i, j) and h (i, j) are unknown functions whose values are the brightnesses of the background and object points, respectively; $\xi(i,j) \approx N\big(0, \sigma_\xi^2\big)$is the noise of the video sensor. The function r(i, j), which determines the location of an object in the image, is defined by the rule:

$$r(i,j) = \begin{cases} 1, if\ at\ the\ point\ (i,j)\ of\ the\ frame\ there\ is\ an\ object, \\ \quad 0, \qquad\qquad\qquad\qquad\qquad\qquad otherwise\,. \end{cases} \qquad (11)$$

The task of distinguishing objects is to estimate rˆ (i, j) from the observed image l (i, j). The stage of object isolation, as a rule, precedes the stage of object detection - the decision on the presence or absence of an object in the image l (i, j). In this case, the appearance of smoke. In [9], when observing air objects, a cloudy sky with smooth transitions of brightness is considered as a background component. In this case, it is proposed to use an autoregressive model of the form to describe such a background:

$$g(i,j) = \sum_{\substack{n=0 \\ (n,m) =}}^{L-1} \sum_{\substack{m=0 \\ (0,0)}}^{L-1} a(n,m)\, g(i-n, j-m) + \mu(i,j)$$

where a (n, m) - are the autoregression coefficients; μ (i, j) is an unobservable white generating noise with zero mathematical expectation, the quantity L determines the order of the model. To make a decision about the presence of objects in the frame, it is necessary to compensate for the background, which in turn involves an assessment of the parameters a (n, m). In situations characterized by a priori uncertainty and spatial variability of the observed images, it is advisable to use adaptive methods of information processing in which automatic optimization of the parameters and structure of the algorithm relative to the current background characteristics is carried out.

Next, image processing is performed using the Laplace, Sobel, Prewitt, Gaussian [10-12] transformation methods, histogram processing.

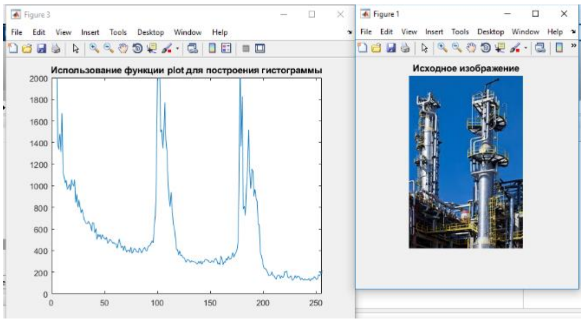

Figure *2.* – Histogram of the source image

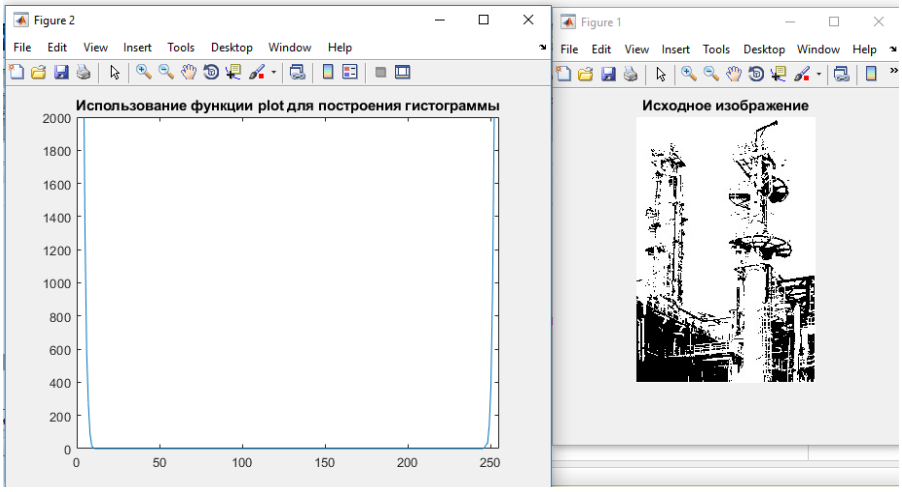

Figure *3*. – Image histogram after Gaussian transformation

In [10], a function is considered that corresponds to Gaussian blur:

$$h(r) = -e^{\frac{r^2}{2\sigma^2}}, \tag{12}$$

where $r^2 = x^2 + y^2$, σ^2 - standard deviation. After convolution of the image with a similar function, we get the same image, but slightly blurred. The degree of blur is determined by the value of σ. If we calculate the Laplacian for this function, we get the following expression:

$$\nabla^2 h(r) = -\left(\frac{r^2-\sigma^2}{\sigma^4}\right) e^{\frac{r^2}{2\sigma^2}}. \tag{13}$$

Since the characteristic feature of smoke is smoothing of the faces of objects, smoke areas are then estimated based on the combination of moving image areas and areas whose color components correspond to gray, various methods have been proposed for [11-14] forming contours at different resolution levels (Fig. 2.3) With the help of binarization and conversion, the coefficient of difference between the energy of the spectra and the gray opaque object present is determined - smoke is detected.

Conclusion

When observing the technological apparatuses of the chemical and petrochemical industry, problems arise associated with the large size, distribution and extent of objects [15]. There may be situations in which there are violations of the technological regulations and, as a result, the occurrence of fire, fire and smoke. Using the technology of unmanned piloting, monitoring and monitoring of large-sized objects becomes more accessible, and the regulated flight of objects allows you to identify and prevent dangerous situations.

The approach proposed in the work of applying the spatio-temporal model of objects of observation and highlighting smoke areas allows us to solve the problem of detecting moving objects (smoke, flames) in the absence of a priori information, combining further moving areas of the images of objects to obtain hazard information.

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