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Problems of the Television Image Processing

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ABSTRACT: The article describes the most important issues is the formation of digital television images. Their basis improving the control of system for image processing. In addition, in the article considered the methods of numerical models and algorithms for solving problems of filtering various digital television images using Fourier and Wavelet methods. In this area, targeted scientific research is carried out: improving the method of classification. Selection of criteria for monitoring and evaluating image quality, methods for controlling image clarity at given values of medium-intensity pixels, creating algorithms for modeling the image processing process, methods for controlling the processes of ensuring the level of clarity of the TV image.

I. INTRODUCTION

Today, in the world in the field of information and communication technologies, close attention is paid to the control system for processing digital television images in video information systems. In the conditions of intensive improvement of modern information, one of the urgent problems is to improve the quality of television images and control the filtering processes from redundant information. In this direction, in the field of information and communication technologies in the leading countries of the world, there is an increasing demand and need to improve the methods of filtering and increasing the brightness of digital television images.

In the world, scientific research is being conducted to improve the quality level of digital television images, methods for modeling filtration processes and high-performance control systems in a number of priority areas. This areas including: the formation of mathematical models of filtration processes, improving the methods of wavelet, Fourier, Haar, Walsh-Hadamard, Karhunen. In improving the clarity and brightness of images based on linear and nonlinear differential equations. To create methods for eliminating additive, pulsed, and adaptive-Gaussian types of noise in images using additive and adaptive filtering. The methods of algorithms and software tools for introducing intra-frame and inter-frame image transformations; methods of adaptive method for controlling the brightness system using the Chebyshev matrix series; methods of gradient, static, and Laplace methods for image segmentation and dividing it into contours; formation of criteria and conditions for evaluating image quality.

Materials and methods

The mathematical model of the image processing process allows you to obtain the distribution of the brightness values of a digital image depending on the brightness of the objects of the working scene L_{obi} [1; 6-7-p.]

The components of the mathematical model are the working stage model F_{PC} , radiation receiver model F_{PI} mathematical model of analog-to-digital signal conversion. The mathematical model of neural network image signal processing F_i :

$$F_{AB} = \{F_{PC}, F_{PI}, F_{ADC}, F_0\}$$

$$F_{AB} = F_0 \left(F_{ADC} (F_{PI} (F_{PC} \left(L_{obj} (x_1, x_2) \right))) \right)$$

The mathematical model of the working stage allows you to get description of the digital image of the working stage as a function of the brightness of the objects of the working stage L_{obj} , it also makes it possible to determine the dependence of the image illumination on the brightness of the objects on the work stage [5; 1-13-p.].

Images obtained using video sensors are characterized by the presence of noise, which reduces the image quality and leads to some loss of information. Blurring occurs due to the imperfection of the transfer functions of all links of the optical signal conversion path. Each point in the observed scene is mapped to the image as a spot with an illumination distribution proportional to the point's scattering function [23; 146-147-p.] The output image is represented as the sum of the system's responses to each point in the scene. When the video sensor operates in real conditions, the scattering function is determined by the combined effect of lens diffraction, lens aberration and defocusing, image



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motion (including that caused by the movement of objects in the field of view), atmospheric conditions, etc. The final illumination of the working stage is denoted as

$$E_{img} = L_{obj} * \pi * \tau_c * \tau_{opt} * \frac{1}{1 + 4(\frac{f}{d}(1-m))^{-2}}$$

where L_{obj} - brightness of the radiation source; τ_c -refractive index of the medium; τ_{opt} optical system transmittance; f - focal length of the lens; D - focal length of the lens; $m = 1 - \frac{s_{img}}{f} < 0$ - lens magnification factor

[8; 254-255-p.].

A feature of video sensors is the raster structure of the generated image, which is due to the structure of photodetectors, which are a matrix of photosensitive cells (photodiodes or phototransistors). In the process of charge accumulation, photodetectors average the illumination of the primary image within each photosensitive area [36; 21-22-p.]. The signal value from the output of each receiver is determined as an integral over its area:

$$I(i,j) = \int_{i\cdot A+b/2}^{i\cdot A+b/2} \int_{i\cdot A-b/2}^{i\cdot A+b/2} E_{img}(x,y) dxdy$$

where i, j-accordingly, the number of the row and column of the photo detector matrix; A, b-the distance between the centers of the photosensitive elements and the size of these elements, respectively (we will assume that these distances are the same throughout the matrix, but not equal to each other); $E_{imp}(x, y)$ -the illumination of the image.

In addition to the useful signal, there are noises in the system. The noise in the image is an additive component. Hence, the brightness distribution in a noisy image $I_{noise}(i, j)$ we write it as follows:

$$I_{noise}(i,j) = I(i,j) + Q(i,j),$$

where O(i, j) – a random variable corresponding to the pixel noise, which includes shot, thermal, fixed-line noise, etc.

1. The study of the structure of the modified lead-tin-base bronze

Reasoning from theoretical premises, the main consequence of nanopowder introduction into the melt should be refinement of the macro- and microstructure, as the powder particles must serve as nuclei of new grains. Figures 1 and 2 show photos of the microstructure of cast samples from the bronze of the lead-tin bronze grade, both modified by SDP of aluminium oxide and without modifier addition. The phase composition of the bronze under study represented in photos of the microstructure is a solid solution of tin in copper, lead inclusions and eutectoid inclusions based on electron compound.

In most modern matrices, the output pixel value is the voltage, so it is necessary to take into account the transmission coefficient of the photo detector k, which determines the voltage change at the output of the radiation receiver and depends on the circuit implementation of the pixel. Then the pixel output will be:

$$U(t) = k \cdot I_{noise}(i, j).$$

If the matrix consists of digital pixels, in this case, the image is sampled by spatial coordinates and quantized by brightness values directly on the pixel, while the sampling is provided by the structural organization of the pixel matrix. In most of the digital sensors considered, 2^8 =256 quantization levels are used to represent the halftone image [10; 4-5-c.]. However, the use of ADCs that provide a quantization step less than the noise value does not seem appropriate, since increasing the bit depth of the ADC will only allow you to more accurately digitize the noise, and at the same time complicate the pixel scheme.

The analog-to-digital conversion ensures that the discrete reference is matched U(t) code value N(t). The

quantitative relationship for a moment in time is determined by the relation: $N(t) = U(t) / \Delta U \pm dN(t)$,

where dN(t) - conversion error at this step, ΔU - the quantization step.

At the output of the ADC, we get a bit code that determines the brightness of the image pixel with the coordinates

$$Y[i, j] = U(i, j, \Delta t) / \Delta U \pm dN(i, j, \Delta t),$$

$$\lim_{\substack{i=1..m \\ j=1..m}}$$



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where Δt – the sampling step.

Thus, we get a matrix description of the image in the form

$$Y = \begin{bmatrix} y(1,1) & y(1,2) & . & y(1,l) \\ y(2,1) & y(2,2) & . & y(2,l) \\ . & . & . & . \\ y(m,1) & y(m,2) & . & y(m,l) \end{bmatrix}, u\pi$$

$$Y = \begin{bmatrix} y_{11} & y_{12} & y_{13} & ... & y_{1l} \\ y_{21} & y_{22} & y_{23} & ... & y_{2l} \\ y_{31} & y_{32} & y_{33} & ... & y_{3l} \\ ... & ... & ... & ... \\ y_{m1} & y_{m2} & y_{m3} & ... & y_{ml} \end{bmatrix}.$$

The process of subsequent digital processing of the image signal depends on the operations used:

$$O = f(Y(i, j),),$$

$$\lim_{\substack{i=1...n\\i=1..m}}$$

where Y - image matrix, O - the image obtained as a result of processing; $\langle M \rangle$ - multiple processing operations, f - functional dependence, which in the case of sequential propagation of a signal in a neural network filtering structure is defined as a set of mappings:

$$S_{1}: (F_{i,j}, C_{1}) \to Q_{1})$$

$$S_{2}: (F_{i,j}, C_{2}) \to Q_{2})$$

$$S_{n}: (F_{i,j}, Q_{1} \dots, Q_{n-1}, C_{n}) \to Q_{n})$$

where S1, S2, ..., Sn-multiple mappings; Q1, Q2, ..., Qn-the result of processing by the corresponding layer of the neural network, C1, C2, ..., Cn-the operations performed (in general, they may be different). In that case Qn, it is the result of transformations and represents the brightness matrix of the processed image.

$$F(i,j) = \sum_{n_1, n_2} \sum_{n_1, n_2} h(n_1, n_2) \cdot y(i - n_1, j - n_2), \quad (n_1, n_2) \in D,$$

Let's define the filtering procedure as follows: $n_1 n_2$ where $h(i, j; n_1, n_2)$ filter coefficients that depend on the brightness values of the input image; and in the general case

$$0 \le i \le m, 0 \le j \le l, 0 \le n_1 \le m, 0 \le n_2 \le l.$$

If you make a restriction:

$$D = \{ (n_1, n_2) : abs(y(i - n_1, j - n_2) - y(i, j)) \le \sigma \}$$

we get the operation of weighted averaging of window samples whose values differ from the brightness value of the central pixel. This approach allows you to select coefficients depending on the characteristics of the processing window and to adapt to changes in the characteristics of the working scene.

From the point of view of image analysis, the ideal filter completely filters out noise without distorting the shape of the contours. This requirement is controversial, so the choice of a filter to implement in a practical machine vision system is determined by what is more important in a particular task, as well as the limitations imposed on computing tools.

As noise models, we will consider Gaussian noise and pulse noise.

The probability distribution, which is given by the density function of the distribution:

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{(x-\mu)^2}{2\sigma^2}}$$

where is the parameter $\mu-$ the average value (mathematical expectation) of a random variable and indicates the

coordinate of the maximum of the distribution density curve, and σ^2 – the variance is called the normal distribution, as well as the Gaussian distribution. The noise of the optoelectronic path of the video sensor is affected by a significant number of independent factors that can introduce positive and negative deviations with equal error, regardless of the nature of these random factors.

The normal distribution depends on two parameters-the offset and the scale [2; 3-4-s.]. The values of the parameters correspond to the values of the average (mathematical expectation) and the spread (standard deviation).



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The pulse noise is described by the relation

$$g(x,y) = (1-p)f(x,y) + p \cdot i(x,y).$$

where i(x, y) – pulse noise model, a binary parameter that takes the values 0 and 1.



Figure 2. Pulse distribution

The most common criterion used to evaluate the quality of image processing is the minimum mean square error criterion. In relation to filtering, we write its expression in the form:

$$E\left\{\left[x(i,j) - \sum_{(i_1,j_1)\in S} \sum a(i_1,j_1) * y(i-i_1,j-j_1)\right]^2\right\} = \min_{a(.)},$$

where E – the symbol of mathematical expectation. Finding the optimal filter is to determine its impulse response in such a way that the average square of the error $\varepsilon(i, j) = x(i, j) - x^*(i, j)$, expressing the difference between the signal x(i, j) and the rating $x^*(i, j)$, generated by the filter, was minimal.

The noise level is estimated using the peak signal-to-noise ratio (PSNR). The peak signal-to-noise ratio is determined by the ratio between the maximum possible signal value and the power of the noise that distorts the signal values. PSNR it is measured on a logarithmic scale in decibels. We define this ratio in terms of the root-mean-square error, which for images I and K size $m \times n$, one of which is considered a noisy approximation of the other,

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} \left| I(i, j) - K(i, j) \right|^{2}.$$

PSNR defined as:

$$PSNR = 10\log_{10}\left(\frac{MAX_I^2}{MSE}\right) = 20\log_{20}\left(\frac{MAX_I}{\sqrt{MSE}}\right),$$

calculated as:



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where MAX_I – the maximum value accepted by the image pixel. When the pixel brightness is limited to 8 bits, $MAX_I = 255$.

Consider systems of grid five-point equations of the form [7; 37-38-p.]

$$-a_{ij}z_{i-1,j} - b_{ij}z_{i,j-1} - c_{ij}z_{i+1,j} - d_{ij}z_{i,j+1} + e_{ij}z_{ij} = f_{ij}$$
(1.1)

approximating two-dimensional boundary value problems on rectangular grids (or topological equivalent to rectangular ones). The equations are considered in the internal nodes of the computational domain with indexes

$$=1,2,...,I,$$
 $j=1,2,...J_i,$

where J_i — the number of internal nodes on the the grid line. It is assumed that in the near boundary nodes, the coefficients and the right-hand sides of equations are determined taking into account the boundary conditions (for example, if the nodes (i-1, j) and (i, j-1) external, then $a_{ii} = b_{ii} = 0$).

All coefficients in will be considered non-negative and have the property of diagonal predominance. In other words, the matrix of a system written in vector form as

$$Az = f$$
where $z = fz = \{z_{ij}\}, f = \{f_{ij}\}, \text{ is } M - \text{ the matrix.}$

Introducing sub vectors z_i dimensions J_i representing the values of the grid function on i grid lines, a system of equations can be represented as

$$-L_{i} z_{i-1} + D_{i} z_{i} - U_{i} z_{i+1} = f_{i}, i = 1, 2, \dots, I, \quad L_{1} = U_{1} = 0$$
(1.3)

Here $D_i = \{-b_{ij}, e_{ij}, -d_{ij}\}$ square tri diagonal M - order matrices J_i , and $L_i U_i$ - in general, rectangular matrices that have one non-zero element on their news q_i on C_i second inclusion.

that have one non-zero element on their rows a_{ij} or c_{ij} accordingly.

The matrix of our system can be written in the form.

$$A = D - L - U = \begin{vmatrix} D_1 - U_1 \\ -L_i & D_i - U_i \\ 0 & 0 \end{vmatrix},$$

where $D = \{D_i\}, L$ and U – respectively, block-diagonal, lower and upper triangular matrices. We will also additionally assume the symmetry of the matrix A, $D = D^1, L = U^1$, where stroke means transpose.

To solve the system of equations (1.1)-(1.3), we consider the iterative method of conjugate gradients $r^n = f - Az^n$, $\overline{z}^n = K^{-1}r^n$, $p^0 = \overline{z}^0$,

$$z^{n+1} = z^n + a_n p^n, \ a_n = \frac{(\mathbf{r}^n, \overline{z}^n)}{(Ap^n, \mathbf{p}^n)},$$

$$p^{n+1} = \overline{z}^{n+1} + \beta_n, \ p^n, \ \beta_n = \frac{(\mathbf{r}^{n+1}, \overline{z}^{n+1})}{(\mathbf{r}^n, \overline{z}^n)},$$
with a pre-conditioning matrix
$$K = (\mathbf{G} - L)\mathbf{G}^{-1}(\mathbf{G} - U)$$
(1.5)

Here $G = \{G_i\}$ - a block-diagonal matrix whose blocks are G_i the essence of the tape matrices and are determined from the recurrent relations $G_1 = D_1, G_i = D_i - L_i (G_{i-1}^{-1})^{(p)} U_{i-1} - \theta S_i, i = 2, 3, ..., I,$ (1.6) where p = 0, 1, 3, ... odd number, $0 \le \theta \le 1$ — iterative "compensating" parameter, $(G_{i-1}^{-1})^{(p)}$ — the "ribbon part" of the matrix with the width of the strip p, and S_i — a diagonal matrix calculated using the equality

$$S_{ie} = L_i \left[\mathbf{G}_{i-1}^{-1} - (\mathbf{G}_{i-1}^{-1})^{(p)} \right] e$$
(1.7)

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in which e denotes a vector with unit components.

Note that if p = 0 (this implies $(G_{i-1}^{-1})^{(p)} = 0$), then $G_i = D_i - \theta S_i$ and the resulting algorithm can be considered as a generalization of the method of block symmetric sequential upper relaxation with "compensation" or similar to it in the implementation of the alternately triangular method [7;5-6-c.] and explicit methods of variable directions [8; 4-5-c.].

II. CONCLUSION

The implementation of methods (1.4) - (1.7), which we will call implicit due to the fact that the matrices are no longer diagonal, contains at least two noteworthy algorithmic aspects. The first is a non-classical linear algebra problem-calculating the tape part of a matrix that is the inverse of the tape matrix. As it was shown in [8; 18-19-p.], its solution is easily carried out with the help of counter runs.

As a result, to find each of the matrices G_i not $p^2 J_i$, the number of operations that are bypassed is proportional to $p^2 J_i$, moreover, these calculations need to be performed only once before starting iterations.

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