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Improving Images Quality by Combination of Filtering Methods

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ABSTRACT

The article deals with digital images which are corrupted by interfering signal representing random homogeneous or rare changes brightness of individual pixels. These changes matched Gaussian noise, impulse noise and their joint action. As usually to decreasing noises on the picture is used filtering. The known spatial and frequency filtering methods are leads to deteriorating sharpness images and recovering sharpness images are uses methods based on computing the second derivations, for example Laplacian. The main idea proposed approach is combined filtering methods and increasing sharpness. On the basis of quantitative criteria for estimation of quality and criteria of visual perception is studied rational combination of known types of filters. Several illustrative examples are presented that demonstrate the effectiveness of the proposed technique.

Keywords *- Composition, filtering, impulse noise, Gaussian noise, Laplacian, median, Wiener filtering*.

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I. INTRODUCTION

Digital images are widely used in various fields of human activity and requirements to their quality are rising every year. Image is a natural means of communication between man and machine in any systems of processing, analysis and control. Therefore the problem of visual perception, which arose a long time, but is still relevant today, is one of the main problems in image processing [1-5].

In practice often have to deal with images are distorted by noise, which show up as imposed on initial to additional image as a mask of pixels of random colors and intensities. Visually, it looks like set granules which have different sizes, randomly are located at the image and are distorts picture's show. Especially noise is noticeable on homogeneous or dark image areas [6-8]. We will consider additive noise here.

The most common types of noises are Gaussian noise and impulsive noise, and their combination [6-13]. Gaussian noise is formed right on the images as result digitized from photographs of a portrait and natural scenes in bad conditions photographing. It may happen, for example, because of poor lighting in the photograph, as a result of the presence of electronic emission in electrical circuits and so on. In turn impulsive noise is formed in communication channels because of transferring image. For example, as a result of poor contact on transmission lines, works of powerful switching devices, as well as the action of natural phenomena such as lightning in the process of image transmission wireless.

Any distortions, obstacles, signal noise worsens visual perception and image analysis, complicate their handling by different technical means. To reduce noise used filtering. Filtration images are the process that does not change the physical size of the original image, but removes certain components with desired properties. It is believed that the intensity (brightness) of each element (pixel) of the resulting image is formed from pixels intensities the some of its neighborhood. And as a term "filter" understands the system (including program), which solves the problem of filtering [9, 10]. Restoring image quality based on filtering involves the complete replacement of intensities of pixels with a sharp change of intensity compared with their neighborhood.

Much work has gone into evening up this trade-off [1-12]. The approach using modified anisotropic diffusion algorithm [1] limited by application it only for images corrupted Gaussian noise. Method proposed in [2] assumes filtering monochrome image by blending the ε-filtering and conventional unsharp masking. In this method there is difficulty in determination optimal value ε for noisy image. Image enhancement method at expense of high-pass filter is considered in [3]. Some idea in the high-resolution image [4] and wavelet [5] approach have also been proposed. Traditional and modern theoretical information about filtering can be found in works [6-8] renowned experts in the field of digital image processing. Practical software aspects solutions of problems in the field of digital image processing are described in [9, 10]. Different techniques quantify evaluation the quality of digital image processing are shown in [11-13].

Restoring image quality is important in science; methods for it constantly are being improved. They are widely used in art, medicine, industry, space. Also used in pattern recognition, automation detection of objects and many other processes. For transmission of images from different spacecraft by digital channels is required enormous flow of information. A frequent subject of scientific research and development are considered the methods to improving automation and recovering of medical images, and images that are distorted by electron microscopes, scanners, X-ray machines and so on. The problem of optimal filtration consists of search of such a procedure, which would allow us to achieve the best result.

The aim of this research is to study methods of filtering for images that corrupted by additive noises (Gaussian noise, impulse noise, their combination) in order to improve their quality by way minimizing noises; search best techniques for different models of noise.

II. PROBLEM FORMULATION

As in [6, 7] will represent elementary image v, observed as a continuous function of two spatial variables whose values are subject to some spatial energy of distribution lighting

$$E(v) = E(x, y)\,, \tag{1}$$

where $E(\cdot)$ – lighting energy distribution function, and x, y - spatial coordinates of the two-dimensional grid. In (1) v is a pixel. In reproducing systems instead of $E(\cdot)$ there is another function $E^*(v)$, which is the sum of information component and disturbing spatial signal $\chi(\cdot)$

$$E^*(v) = E(x, y) + \chi(x, y)\,. \tag{2}$$

Signal $\chi(\cdot)$ in (2) has a different physical nature, can be random and additive pulse signal. The main difference lies in the density and spatial distribution of its intensity. If the random signal has a uniform distribution on the image plane, it is treated as noise, which is analog random fluctuation in radio systems. Impulse noise is a single emission light energy values that on the image looks as isolated contrast points.

Given the task of filtering we will be presented it in the form specified transformation F, which approximates v as close to perfect as well accordance with the specified standard or metric for accuracy of reproduction

$$\hat{E}(v) = F[E^*(v)]\,. \tag{3}$$

In (3) $\hat{E}(\cdot)$ is a result of filtering individual pixel. Improving the overall shot is dependent on improving each element of v, because filtering techniques uses procedures serial processing pixel in image. The easiest way to suppress noise is simple linear filtering, which for the acquisition of pixel image has a form product of the coefficients f_i operator F with the elements e_i pictures v

$$\hat{E}(v) = \sum_{i=1}^{K} f_i e_i^*(v)\,, \tag{4}$$

where $i = \overline{1, K}$. In literature about processing digital images [6-10] the filter that performs the operation (4), called a mask, which is applied to the image, and filtering – processing by mask, which looks like a geometric table (matrix), i.e. $K = \zeta \times \xi$. The filter is the mask that moves sequentially from the initial to the final point picture by some algorithm viewing.

The problem is considered in this paper in determining the filtering methods for practical tasks when the original image was damaged Gaussian, pulse and their joint action.

III. METHODS OF FILTERING

If images have smooth transitions in luminance, the most popular are smoothing filters. The processing image has effect noise reduction by this type of filters. Because the image processing element and its neighborhood is covered by a mask, so it is advisable to conduct averaging by spatial filter for whole picture. General formula weighted averaged filtering on the mask $\zeta \times \xi$ for the original image size of $M \times N$ is [7]

$$\hat{E}(x,y) = \frac{\sum_{i=K-\xi/2}^{K+\xi/2} \sum_{j=K-\zeta/2}^{K+\zeta/2} f(\xi,\zeta) e^{*}(x+i, y+j)}{\sum_{i=-\xi/2}^{\xi/2} \sum_{j=-\zeta/2}^{\zeta/2} f(i,j)} . \tag{5}$$

Algorithm (5) applies to image elements $x = 0, 1, ..., M - 1$, $y = 0, 1, ..., N - 1$. The size of mask must be chosen at $3 \le K \le 15$. Effective averaging method to reduce noise at low light levels is known in astronomy [7]. Equation

$$F = \frac{\| f_{\xi\zeta} \|}{\sum_{i=-\xi/2}^{\xi/2} \sum_{j=-\zeta/2}^{\zeta/2} f(i,j)} , \tag{6}$$

where $\| f_{\zeta\ \xi} \|$ – matrix size $\zeta \times \xi$ is a spatial filter [7]. The simplest type averaging filter, which is used for suppressing noise in the picture, calculates the arithmetic mean the elements of mask. Refurbished image $\hat{E}(x,y)$ by averaged mask determinates sizes ζ and ξ. This equation (6) transformed into

$$F(\xi,\zeta) = (\xi \cdot \zeta)^{-1} I , \tag{7}$$

where I – matrix, its size $\zeta \times \xi$ with elements equal 1 [14]. Thus, if the filter looks like a square mask with parameters $\xi = \zeta = 3$, it will

$$F(3,3) = 1/9 \begin{vmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{vmatrix} . \tag{8}$$

Filter (7), (8) is called the arithmetic mean, it does not cause the shift average brightness of processed image and noise exclusion is achieved by smoothing.

The variant of rectangular averaging filter which has all nonzero elements are filters containing some zero elements. If you organized a mask that contains zero elements on the edges, the non-zero elements are formed on the plane circle. That filter called circular averaging filter, its have a mask as

$$F(\xi,\zeta) = 1/12 \begin{vmatrix} 0 & 1 & 1 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 1 & 1 & 0 \end{vmatrix} . \tag{9}$$

In practice, found widespread use filters that hasn't identical weights and such that components are decreasing relatively of its center. This approach is implemented in the Gaussian filter [7, 10]. His weight function has the form

$$F(c,\sigma) = ce^{-0.5\left(\frac{d}{\sigma}\right)^2} , \tag{10}$$

where c – a scale factor, d – the coordinates of view window, σ – distribution parameter. The mask size 5×5 for (10) can be represented in the integer form with the parameters $c = 85$, $\sigma = 1.5$

$$F(85,\ 1.5) = \begin{vmatrix} 1 & 2 & 3 & 2 & 1 \\ 2 & 4 & 5 & 4 & 2 \\ 3 & 5 & 7 & 5 & 3 \\ 2 & 4 & 5 & 4 & 2 \\ 1 & 2 & 3 & 2 & 1 \end{vmatrix} . \tag{11}$$

Parameters in (11) selected such as minimal element mask had a value equal 1.

Median filter have a sliding window with even or odd number elements [7-10]. The median discrete sequence a_1, a_2, ..., a_P is element $a_{P/2}$, if P – odd item and $P/2$ a number that is between items $a_{(P-1)/2}$ and $a_{(P+1)/2}$. If P is even, the choice is in favor of $a_{(P-1)/2}$ or $a_{P/2}$. The logic of median filter is in separate image elements in increasing brightness and selecting the middle element order. It is clear that as a result of this approach average mean values do not change, but will only suppressed ejection brightness that match unipolar or bipolar pulsed noise.

To sort can be applied any sorting algorithm by splitting enter into two sequences, then it recursively applied to each half (see also [9, p. 182].) The value of the reconstructed image median filtering at an arbitrary point (x, y):

$$\hat{E}(x,y) = \begin{cases} \hat{E}(x,y), \text{ if } |\hat{E}(x,y)| \le |\hat{E}(x_м, y_м)|, \\ \hat{E}(x_м, y_м) \text{ otherwise.} \end{cases} \quad (12)$$

In (12) x_m, y_m – coordinates of the median. Median filtering does not affect for Gaussian noise.

The basic idea to minimizing the noise level in the image was proposed Wiener, which consists of minimizing the mean square deviation of reconstruction from the reference image [6 - 10]

$$\theta^2 = \min_{\substack{0 \le x \le M-1, \\ 0 \le y \le N-1}} (E(x,y) - \hat{E}(x,y))^2 . \quad (13)$$

According to this result the filtering on optimal criterion (13) is an expression

$$F(u,v) = \frac{1}{H(u,v)} \frac{|H(u,v)|^2}{|H(u,v)|^2 + R} , \quad (14)$$

where $H(u, v)$ – distorting transfer function in the plane u, v (frequency representation), $|H(u, v)|^2 = H^*(u, v) \cdot H(u, v)$, $H^*(u, v)$ – complex-conjugate show for $H^*(u, v)$, and R – the ratio of the energy spectra of noise and signal. Fourier transform these functions is unknown therefore this ratio is replaced the some constant. The main limitation of use (14) for arbitrary pictures associated with unknown mathematical description of the function $H(u, v)$ and a choice constant R. In result (14) is also a mask, which imposed on the image, but only in the frequency plane.

One of the most effective approaches to improving detail is detection changes the boundaries of the brightness on images. For this can be used the methods based on calculation the second derivative, they are isotropic relatively transformations (rotation) images. These methods include Laplacian [6 - 8]. But this method may lead to the separation boundary image where there is a sharp change in brightness and suppress regions with mild change it. In order to restore the original image is superimposed on the original image Laplacian

$$\hat{E}(x,y) = \begin{cases} \hat{E}(x,y) - \nabla^2 \hat{E}(x,y), \text{ if } f(0,0) < 0, \\ \hat{E}(x,y) + \nabla^2 \hat{E}(x,y), \text{ if } f(0,0) \ge 0, \end{cases} \quad (15)$$

where $f(0, 0)$ – a central element of the mask, and ∇^2 – Laplacian function $\hat{E}(\cdot)$ whose coefficients to mask 3 × 3 determined from formula

$$\nabla^2 \hat{E}(x,y) = [\hat{E}(x+1,y) + \hat{E}(x,y+1) + \hat{E}(x-1,y) + \hat{E}(x,y-1)] - 4\hat{E}(x,y). \quad (16)$$

The coefficients in (16) can be changed by adding diagonal elements and a corresponding change in coefficient of $f(0,0)$, and multiplying the left and right sides (16) at a constant factor.

IV. COMPOSITION FILTERING METHODS

Each filtering method has its limitations. Yes, smoothing, or averaging filters are effective for Gaussian noise, decrease noise, but leads to defocusing images, median filtering is effective for impulsive noise, but does not affect Gaussian noise. Wiener's filtering is effective when fully known about distorting function and power of the signal and noise. In practice when working with images we deal with a specific effect of blending different types of noise and absolutely no information about the types of noises and their parameters. Therefore there is a need the selection consistency of parameters of filters and their combined use to achieve the best result for the solution of complex image enhancement tasks.

Mathematically, the expression composition comprises a sequential application of the above mentioned methods, namely to converting of result image will look like

$$\hat{E}(v) = F_l\Big(F_{l-1}\Big(\ldots(F_1(E^*(v)))\Big)\Big), \quad (17)$$

where l – number conversion, l = 1, 2, ..., and generalized conversion operator written as

$$F = F_1 \circ F_2 \circ \ldots \circ F_l . \quad (18)$$

The approach based on (17), (18) does not involve the use one type conversion, that is, $F_l \neq F_{l-1}$, the use of which may depend on the tasks that treats. Their quality must match certain criteria.

V. CRITERIA EVALUATION OF IMAGE QUALITY

Quality rating restored image can be evaluated by criteria such as: mean square error (MSE), peak signal / noise ratio (PSNR) and structural similarity index (SSI).

The most universal tool used to assess the quality of images within the quantitative methods, – is a method of calculating a mean square error

$$\varepsilon = \sqrt{\frac{1}{M \cdot N}\sum_{i=1}^{M}\sum_{j=1}^{N}(v_{i,j} - \bar{v}_{i,j})^2} , \quad (19)$$

where $\bar{v}$ – intensity pixel (i, j) reference image. As is known [12], this measure is useful for determining the quality of image filtering at damaged it impulse noise. If image had a slight deterioration "snow", "moire", it would not convenient criterion, therefore of its own use is impractical.

Peak signal / noise ratio is calculated by formula

$$PSNR = 10\lg\left(\frac{L_{\max}}{\varepsilon_{\max}}\right). \quad (20)$$

In (20) value L_{max} – the maximum pixel intensity level, measured in all channels with representation 8-bit intensity each channel. The measure (20) has the most flaws that MSE, its advantage is a much smaller amount of computation, especially when there are previously calculated by (19) the maximum value of the ε.

Recently, the most common is a measure of structural similarity image that was first proposed by Wang in [11] for comparison halftone image and its relevance was confirmed [2, 13]. The similarity computation based on the correlation properties of the image. The value of the criterion SSI calculated by the formula:

$$SSI = \left(\frac{\sigma_{xy}}{\sigma_x\sigma_y}\right)\left(\frac{2\overline{XY}}{(\bar{X})^2 + (\bar{Y})^2}\right)\left(\frac{2\sigma_x\sigma_y}{\sigma_x^2 + \sigma_y^2}\right), \quad (21)$$

where

$$\bar{X} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}x_{ij}, \;\; \bar{Y} = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}y_{ij} , \quad (22)$$

$$\sigma_x^2 = \frac{1}{(M-1)(N-1)}\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{ij} - \bar{X})^2 , \quad (23)$$

$$\sigma_y^2 = \frac{1}{(M-1)(N-1)}\sum_{i=1}^{M}\sum_{j=1}^{N}(y_{ij} - \bar{Y})^2 , \quad (24)$$

$$\sigma_{xy} = \frac{1}{(M-1)(N-1)}\sum_{i=1}^{M}\sum_{j=1}^{N}(x_{ij} - \bar{X})(y_{ij} - \bar{Y}) , \quad (25)$$

where $X = \{x_{ij}\}$ and $Y = \{y_{ij}\}$ elements compared images. The first part of the expression (21) is the correlation coefficient between the images *X* and *Y*. The second part describes the similarity average values of intensities of the two images. The third part describes the similarity of expression contrasts images are compared. Methods based on these estimates, well suited for images with white noise. The value of this criterion is in the range $0 < SSI \leq 1$ and more values correspond to better similarity (filtering).

Fig. 1 shows examples of images original image (a) and distorted one of different levels noise (b), (c). Criteria (19), (20) confirm their unfitness for evaluation. Yes, distorted image (b): ε = 14,5, *PSNR* = 24.9 dB for distortion image (a): ε = 15,5, *PSNR* = 24.3 dB. Both distorted images are not much difference values of ε, PSNR, but they aren't sensitive enough to evaluation.

(a) (b) (c)

Fig. 1. Images "Newton" which damaged of noise with a different levels

Fig. 2 shows photos of land surface with different levels distorting noise a) - the original image, b) and c) various levels distorted noise. Compare images b) and c) with a) similarity criteria allowed us to obtain the following results *MSE* = 66 and *MSE* = 177 respectively.

(a) (b) (c)

Fig. 2. Images of the earth's surface distorted with different levels of noise

VI. COMPARISON OF FILTERING METHODS

To analyze the quality of image restoration Fig. 3, (b) that damaged different types of noises. For this image carried out studies of various types of filters: rectangular and circular averaging, Gauss and the median, of Wiener filter and Laplacian.

Modeling acting filters performed at MathLab [10], where there is ample opportunity for choosing filtering functions. Ratings and quality of the restored image was conducted by the criteria of (19) – (25).

In Fig. 3 source images are modeling, first of which (a) – is reference, and (b) – is combinations of two types of noise (Gaussian and impulse).

(a) (b)

Fig. 3. Images for modeling: (a) original image, (b) images, damaged impulse noise and Gaussian noise

(a) (b)

(c) (d)

(e) (f)

(g) (h)

Fig. 4. The results of processing damage image with impulse and gauss noises.

Results filtration distorted image Fig. 3, (b) are shown in Fig. 4. The results filtering images of damaged impulsive and gauss noise by averaging rectangular filter (a), a circular averaging filter (b), Gaussian low-pass filter (c), median filter (d), the Wiener filter (e), Wiener filter and median filter (f), and combine median and Wiener filter (g), and combine median and Wiener filter and Laplacian filtering are given on Fig. 4 and its evaluation by criteria (17) – (23), listed in the table. 1.

Table 1
Quality assessment damaged image different types of filtering

Method filtering	***MSE***	**PSNR, dB**	**SSI**
Unfiltered images	*1009.6344*	*18.0892*	*.1878*
Rectangular averaging	253.5656	24.0899	.4905
Circular averaging	402.0649	22.0878	.7261
Gaussian	251.6443	24.1229	.6592
Median	136.6863	26.7736	.7143
Wiener	264.0385	23.9141	.5708
Wiener and median	153.701	26.264	.782
Median and Wiener	129.3133	27.0144	.8679
Median, Laplacian and Wiener	121.2247	27.2949	.875

Analysis Fig. 4 and data in Table 1 is showing that the best results removing noise from images Fig. 3, b) at visual criterion filtering and calculations that was obtained by complex using median, Wiener and Laplacian filtering. These results confirm high value of SSI criterion, which for this case is equal 0.875. The high value of the SSI have also filtering by circular averaging, median filter, which takes the value of $SSI \approx 0,73$ and $SSI \approx 0,71$ respectively. Quality at *SSI* and *PSNR* not give unique interpretation for these types filters, although complex application filters are given positive results for quality indicators: PSNR – takes the maximum value, which corresponds to 27 dB, and *MSE* – minimum, $MSE=121,22$.

The main result of the study is a complex application filtering by median, Wiener Laplacian and that can be interpreted as combined method. Combination of these three methods has the best performance by criteria (19)-(25).

VII. CONCLUSION

Photographing, X-ray photographs and old photos may be damaged as a result of its obtaining or preservation. Damages have a different nature, but they appear as blur pictures, "snow", "moire" bands that reduce the quality of picture.

The results of studies of the effectiveness of different types of filtering criteria such as mean square error, peak signal to noise ratio and structural similarity images for photo damaged Gaussian noise, which makes images blurry and impulse noise, which causes deviation of brightness of individual pixels, show that the priority of structural similarity and peak signal to noise ratio as indicators of quality.

Based on the analysis found that the best method for imaging the noise is Gaussian Wiener filter, and best reduces the level of impulse noise median filtering. The best result in image processing with the combination of these two types of noise was obtained by combination of three methods – median, Wiener filtering and Laplace. Future research plans directed to study high-resolution methods and color images and subjectively evaluation using paired comparison for output and etalon images.

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Biographies and Photographs

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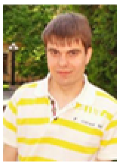

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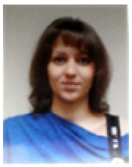

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