IEEE Second International Conference on Data Stream Mining & Processing
August 21-25, 2018, Lviv, Ukraine

Image Contrast Enhancement Using a Modified Histogram Equalization

Sergei Yelmanov
Special Design Office of Television Systems
Lviv, Ukraine
sergei.yelmanov@gmail.com

Yuriy Romanyshyn[1,2]
[1]*Department of Electronics and Computer Technologies*
[1]*Lviv Polytechnic National University*
[2]*University of Warmia and Mazury*
[1]Lviv, Ukraine, [2]Olsztyn, Poland
yuriy.romanyshyn1@gmail.com

***Abstract*— The histogram equalization is the basic technology in image processing, which is widely used to increase the integral contrast of the image and is characterized by high efficiency. However, known techniques of histogram equalization have a number of disadvantages, the major one of which is a decrease in the contrast of small objects in the image. To address this disadvantage, a new technique of modified histogram equalization is proposed based on the assessment of the two-dimensional probability distribution of brightness in the image. A new method of increasing the contrast of the image based on the modified equalization of histogram is also proposed. The proposed technique of modified histogram equalization can be recommended to increase the image contrast in automatic mode in imaging and image processing.**

Keywords—image, contrast, histogram, modified equalization.

I. INTRODUCTION

The widespread use of modern digital technologies in image processing and image processing requires the solution of the task of effective improving of image quality in automatic mode [1, 2].

The histogram equalization is the basic techniques to enhance the image quality [3]. The histogram equalization technique and its modifications are widely used for images processing to increase integral contrast of image and are characterized by high efficiency [4]. However, known techniques of histogram equalization have a number of disadvantages. Their main disadvantage is a decrease in the contrast of small-sized objects and their details in the image.

To address this disadvantage, we propose a new technique of image enhancement based on the modified equalization of histogram.

In this work solves the task of increasing the efficiency of processing of multi-element images. The problem of increasing the image contrast based on histogram transformations is considered (Section II). A new technique of modified equalization of image histogram is proposed based on the assessment of the two-dimensional probability distribution of brightness (Section III). A new method of increasing the contrast of the image based on the modified equalization of histogram is also proposed.

Research of known and proposed methods of images processing is carried out by measuring the contrast for the results of processing test images (sections IV and V).

II. IMAGE CONTRAST ENHANCEMENT

Various approaches to enhance the contrast of image are known at present [1]. Techniques of processing in spatial domain using nonlinear statistical no-inertial transformations of brightness are of the greatest interest to the image processing in automatic mode and in real time mode [1, 3].

The most widely used method of image pre-processing is the linear stretching of the dynamic range of brightness to the range of its possible values [1]:

$$y_i = y_{\min} + \frac{y_{\max} - y_{\min}}{x_{\max} - x_{\min}} \cdot (x_i - x_{\min}), \qquad (1)$$

where x_{min}, x_{max} , y_{min}, y_{max} - minimum and maximum values of brightness for the source and processed images:

$$x_i, x_{\min}, x_{\max}, y_i, y_{\min}, y_{\max} \in [0,1]. \qquad (2)$$

Generally, it is assumed that $y_{min} = 0$, $y_{max} = 1$.

In [5], a method of nonlinear stretching of the dynamic range of images using the sigmoid function was proposed:

$$y_i = y_{\min} + \frac{y_{\max} - y_{\min}}{x_{\max} - x_{\min}} \cdot \frac{1}{1 + e^{-\alpha(x_i - \beta)}}, \qquad (3)$$

where α, β - parameters of the sigmoid function.

Another widely used approach to contrast enhancement is power law transformation, also known as gamma correction [1]:

$$y_i = y_{\min} + (y_{\max} - y_{\min}) \cdot \left(\frac{x_i - x_{\min}}{x_{\max} - x_{\min}} \right)^{\gamma}, \qquad (4)$$

where γ – exponent, parameter.

The histogram equalization is the most well-known standard procedure in image processing [1, 4]:

$$y_i = y_{\min} + (y_{\max} - y_{\min}) \cdot \int_0^{x_i} p(x)dx, \qquad (5)$$

where $p(x)$ - distribution of brightness.

However, the discussed methods (1), (3)-(5) of image enhancement and their modifications have several significant disadvantages.

The main disadvantage of the known methods of image enhancement by histogram equalization is a decrease in the contrast of small-sized objects.

To address these disadvantages, we propose a new method of modified equalization of histogram based on the assessment of the two-dimensional probability distribution of brightness.

III. PROPOSED METHOD

We propose a new approach to the modified equalization of histogram on the basis of the assessment of the two-dimensional probability distribution of brightness.

A new method of image processing based on the modified equalization of histogram is also proposed.

Image enhancement is carried out by the modified histogram equalization based on the assessment of the two-dimensional probability distribution of brightness in image.

Proposed method is an adaptive transformation in the form:

$$y_i = \alpha \cdot \int_0^1 \int_0^1 \omega(x_k, x_n) \cdot \varphi_{x_i}(x_k, x_n)\, dx_k dx_n , \quad (6)$$

where $\omega(x_k, x_n)$ – two-dimensional density distribution of the brightness; $\varphi_{x_i}(x_k, x_n)$ - weight function; α - normalizing coefficient, multiplier.

The weight function $\varphi_{x_i}(x_k, x_n)$ (6) characterizes the measure of proximity between two values of brightness x_i and x_k (or x_n) on a preset interval (x_k, x_n) of brightness and is defined as:

$$\varphi_{x_i}(x_k, x_n) = \begin{cases} 0, & if\ x_k > x_i \wedge x_n > x_i \\ \dfrac{\rho(x_k, x_i)}{\rho(x_k, x_n)}, & if\ x_k \le x_i \wedge x_n > x_i \\ \dfrac{\rho(x_n, x_i)}{\rho(x_n, x_k)}, & if\ x_k > x_i \wedge x_n \le x_i \\ 1, & if\ x_k \le x_i \wedge x_n \le x_i \end{cases}, \quad (7)$$

where $\rho(x_k, x_i)$ - measure of proximity for two values x_k and x_i of brightness.

Normalizing coefficient α (6) is equal to:

$$\alpha = \left[\int_0^1 \int_0^1 \omega(x_k, x_n)\, dx_k dx_n \right]^{-1} . \quad (8)$$

Expressions (6) - (8) define the proposed method of modified histogram equalization in general terms.

To demonstrate the proposed technique of modified histogram equalization let's assume that the assessment of two-dimensional distribution for the brightness has the form:

$$\omega(x_k, x_n) = p(x_k)^{\gamma} \cdot p(x_n)^{\gamma}, \quad (9)$$

where $p(x_k)$ – distribution of brightness of source image, γ – parameter.

Assume also that the measure $\rho(x_k, x_i)$ of proximity for two brightness values is defined as:

$$\rho(x_i, x_k) = |x_i - x_k| . \quad (10)$$

Expressions (6)-(8) and (9)-(10) define the proposed method to increase the image contrast using modified equalization of image histogram.

Research of known and proposed methods of image enhancement by histogram transformation are carried out in Sections IV and V.

IV. RESEARCH

Research was carried out by measuring the contrast of test images and the results of their processing using contrast metrics and expert estimates of perceived contrast.

The processing of the source images was carried out using six different methods:

1) linear stretching (1) [1], α = 0.01 (1%);
2) nonlinear stretching using sigmoid funktion (3) [5];
3) gamma correction (4) [1], y_{mean} = 0.5;
4) histogram equalization (5) [1, 4];
5) BBHE [6];
6) modified histogram equalization (6)-(10).

The four source images are shown in Fig. 1, Fig. 3, Fig. 5 and Fig. 7. The results of processing for the source images with using earlier considered methods are shown in Fig. 2, Fig. 4, Fig. 6 and Fig. 8.

To measure the contrast of images, the no-reference metrics of contrast were used:

1) complete integral weighted contrast [7]:

$$C_{gen}^{wei_1} = \int_0^1 \int_0^1 \frac{|x_i x_j - \bar{x}|}{x_i x_j + \bar{x}}\, p(x_i)\, p(x_j)\, dx_i dx_j , \quad (11)$$

where $\bar{x}$ - average value of brightness for the initial image.

2) generalized weighted contrast [8]:

$$C_{gen}^{wei_2} = \int_0^1 \int_0^1 \frac{|x_i - x_j|}{x_i + x_j}\, p(x_i)\, p(x_j)\, dx_i dx_j , \quad (12)$$

3) generalized integral linear contrast [8]:

$$C_{gen}^{lin} = \int_0^1 \int_0^1 \frac{|x_i - x_j|}{x_{\max} - x_{\min}}\, p(x_i)\, p(x_j)\, dx_i dx_j , \quad (13)$$

4) incomplete integral weighted contrast [8]:

$$C_{inc}^{wei} = \int_0^1 (x - \bar{x})/(x + \bar{x})\, p(x) dx , \quad (14)$$

5) incomplete integral linear contrast [9]:

$$C_{inc}^{lin} = \int_0^1 \left| \frac{x-\bar{x}}{x_{mpv}} + \frac{1}{2} - \left| \frac{x-\bar{x}}{x_{mpv}} - \frac{1}{2} \right| \right| p(x)dx\,, \quad (15)$$

where x_{mpv} - maximum possible value of brightness.

The results of measuring the integral contrast for test images and for results of their processing are shown in Fig. 9, Fig. 10, Fig. 11 and Fig. 12. Analysis of results of the research is carried out in Section V.

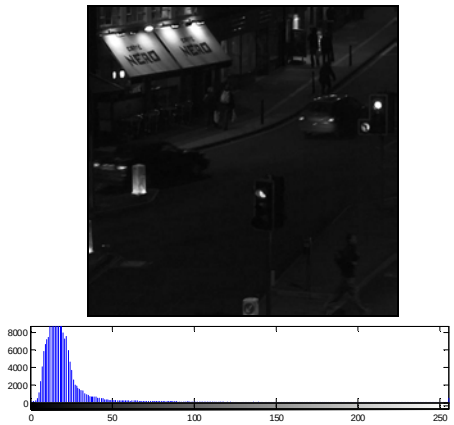


Fig. 1. The source image A.

A1. linear stretching, α=0,01 A2. sigmoid stretching

A3. gamma correction A4. histogram equalization

A5. BBHE A6. proposed technique

Fig. 2. Processed images.

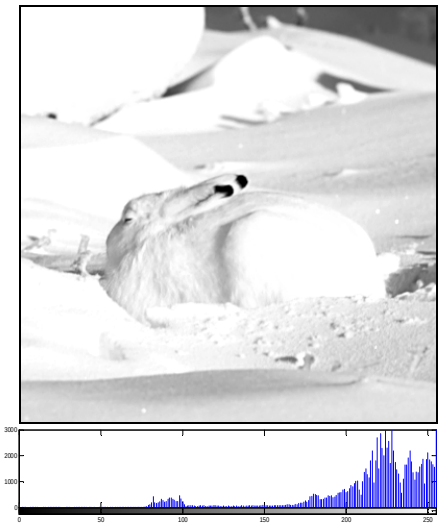
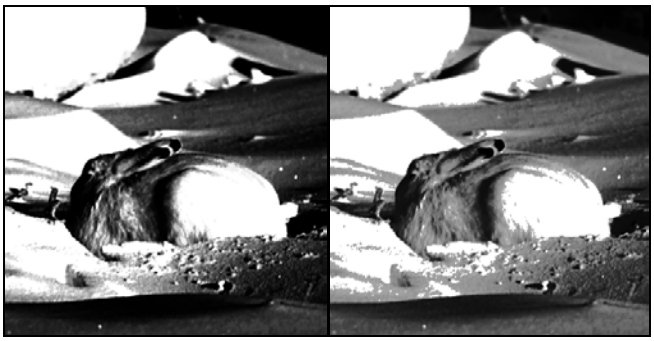
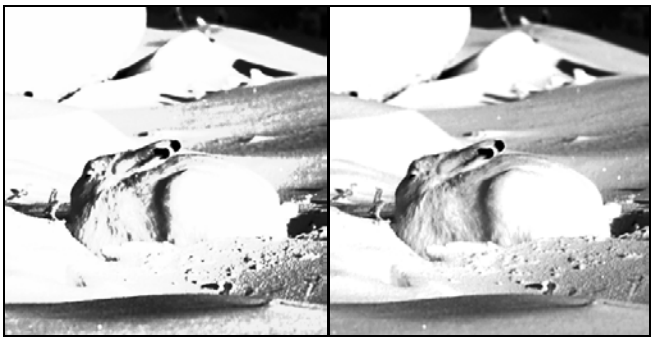


Fig. 3. The source image B.

B1. linear stretching, α=0,01 B2. sigmoid stretching



B3. gamma correction B4. histogram equalization



B5. BBHE B6. proposed technique

Fig. 4. Processed images.

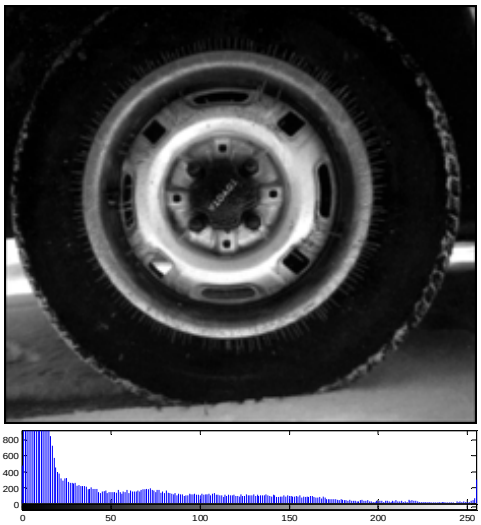


Fig. 5. The source image D.

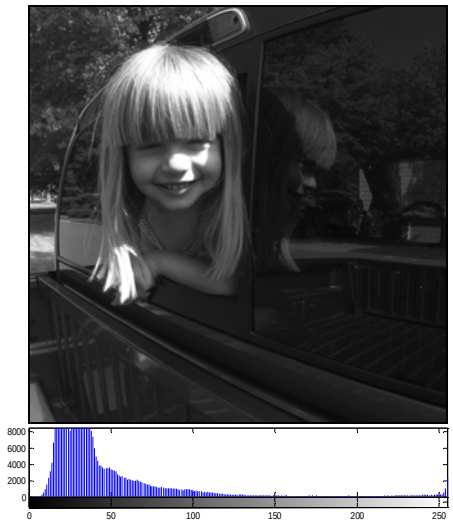
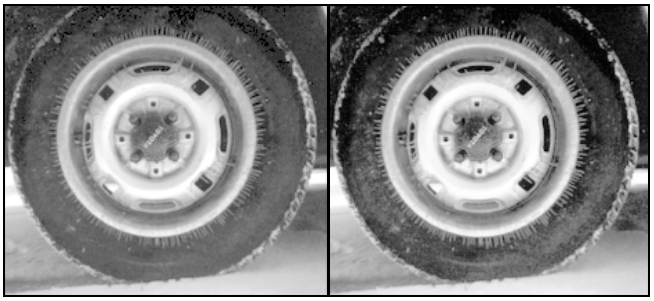
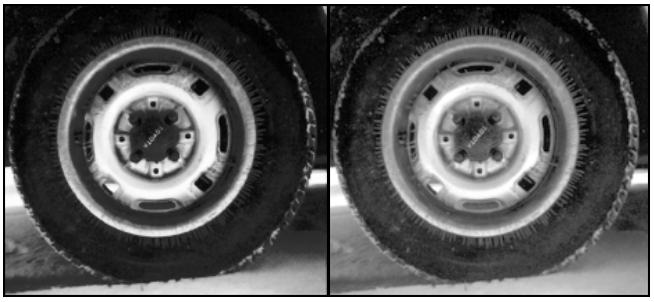


Fig. 7. The source image E.

D1. linear stretching, α=0,01 D2. sigmoid stretching



D3. gamma correction D4. histogram equalization



D5. BBHE D6. proposed technique

Fig. 6. Processed images.

E1. linear stretching, α=0,01 E2. sigmoid stretching

E3. gamma correction E4. histogram equalization

E5. BBHE E6. proposed technique

Fig. 8. Processed images.

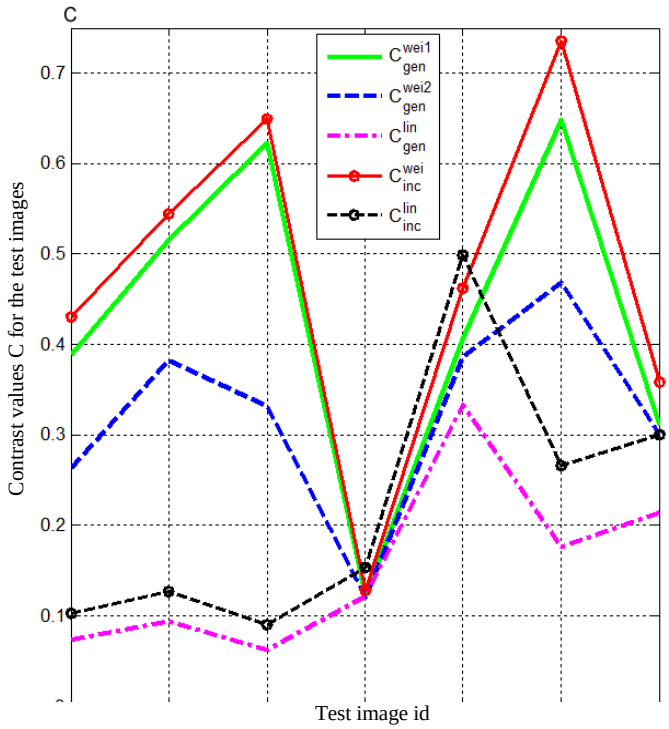


Fig. 9. Contrast for processed images

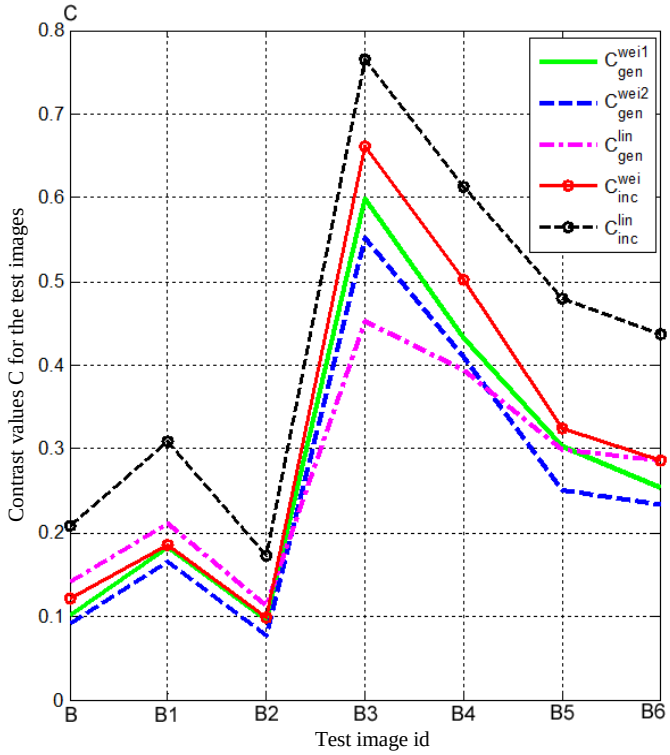


Fig. 10. Contrast for processed images

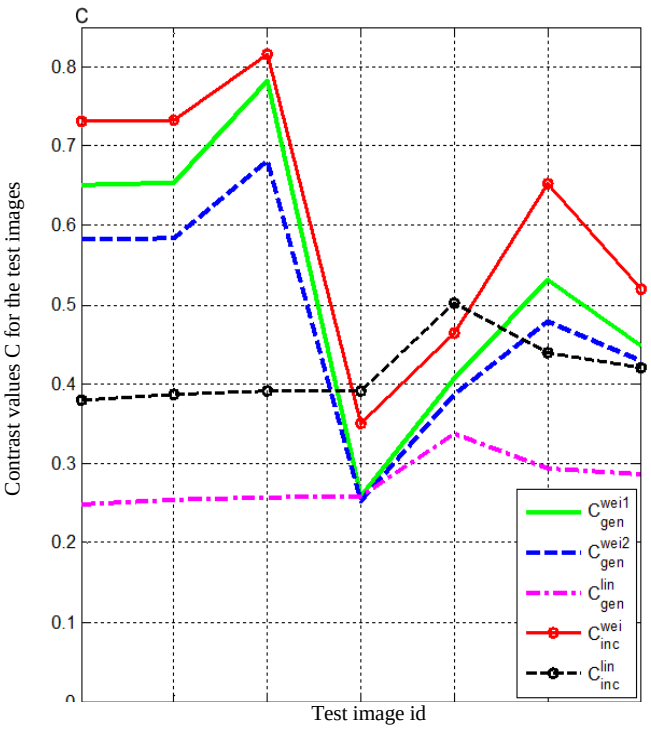


Fig. 11. Contrast for processed images

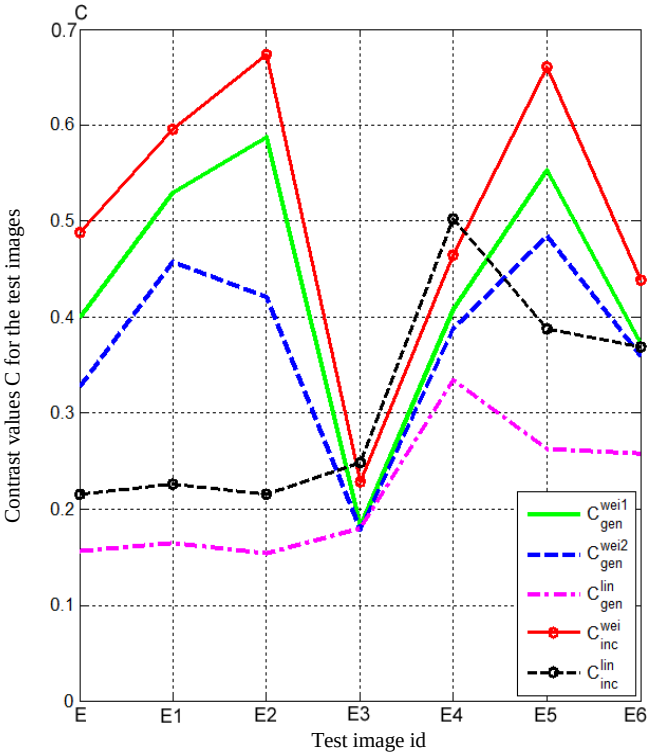


Fig. 12. Contrast for processed images

V. Discussion

The methods of image enhancement by histogram transformation are widely used for images processing to increase their integral contrast and are characterized by high efficiency.

The techniques of image processing by histogram equalization (5) provide the most effective enhancement of image contrast and are widely used to improve the image quality.

At present, histogram equalization is the basic technique of image enhancement.

However, known techniques of histogram equalization have a number of disadvantages that substantially limit their practical use in the automatic mode.

The main disadvantages of the known methods of image enhancement by histogram equalization are an overly increase in the contrast of large-sized objects in the image.

The efficiency of techniques of linear stretching (1), non-linear stretching using the sigmoid function (3) and gamma correction (4) for images enhancement depends significantly on the distribution of image brightness and the values of parameters of the transformation function which significantly limits the use of these methods.

The use of modified equalization of histogram based on the assessment of the two-dimensional probability distribution of brightness allows increasing the efficiency of contrast enhancement.

The proposed method for image processing by modified equalization of histogram increases the contrast of small-sized objects and the integral contrast for all test images.

VI. Conclusion

At present, the solution of the task of enhancement of image quality with an acceptable level of computational costs is urgent as never before.

The histogram equalization is currently the basic technique of image processing.

The technique of histogram equalization and its modifications are widely used for images processing to increase image contrast and are characterized by high efficiency.

Histogram equalization techniques provide an effective increase of the generalized contrast and enhance the objective quality of the image.

However, known techniques of histogram equalization have a number of disadvantages that limit their use for image processing in the automatic mode.

Their main disadvantages are an overly increase in the contrast of large-sized objects and also a decrease in the contrast of small-sized objects in the image.

To address these disadvantages, a new technique of modified histogram equalization was proposed.

The proposed technique of modified histogram equalization is based on the assessment of the two-dimensional probability distribution of brightness.

To demonstrate the possibilities of the proposed technique, a new method to increasing the integral contrast of complex monochrome images based on the modified equalization of histogram was proposed.

The proposed method provides an effective increase in the contrast of small objects in the image, and also increases the integral contrast of the complex multi-element image as a whole.

The research of the proposed method of modified equalization of histogram was carried out.

The research was carried out by analyzing the results of the measurement of integral contrast for monochrome test images that were processed using the known and proposed methods of image enhancement.

To measure the integral contrast of the test images, the metrics of contrast were used.

The proposed technique of modified histogram equalization provides effective enhancement of image quality and can be recommended to increase the integral contrast in imaging and image processing in automatic mode.

References

[1] R. C. Gonzalez, R. E. Woods, S. L. Eddins, Digital image processing using MATLAB, Prentice-Hall, Inc., NJ, USA, 2003.

[2] R.J. Kosarevych, B.P. Rusyn, V.V. Korniy, T.I. Kerod, “Image Segmentation Based on the Evaluation of the Tendency of Image Elements to form Clusters with the Help of Point Field Characteristics”, Cybernetics and Systems and Analysis, vol.51, issue5, 2015, pp.704-713.

[3] R. Ghabousian, N. Allahbakhshi, “Survey of Contrast Enhancement Techniques based on Histogram Equalization,” Int. J. Rev. Life Sci., vol. 5, no. 8, pp. 901–908, 2015.

[4] R. Hummel, “Image enhancement by histogram transformation,” Comp. Graph. Image Process., vol. 6, pp. 184–195, 1977.

[5] N. Hassan and N. Akamatsu, "A new approach for contrast enhancement using sigmoid function", International Arab Journal of Information Technology, vol. 1, no. 2, pp. 221-225, 2004.

[6] Y. Kim, "Contrast enhancement using brightness preserving bi-histogram equalization", IEEE Transactions. Consumer Electronics, Vol. 43, No. 1, pp. 1-8, 1997.

[7] V.F. Nesteruk, V.A. Sokolova, “Questions of the theory of perception of subject images and a quantitative assessment of their contrast”, Optiko-electronic industry. - 1980. – no. 5. - pp. 11-13.

[8] S. Yelmanov, Y. Romanyshyn, "A Method for Rapid Quantitative Assessment of Incomplete Integral Contrast for Complex Images", in Proceedings of 14th Int. Conf. on Advanced Trends in Radioelectronics, Telecommunications and Computer Engineering (TSET’2018), Lviv - Slavske, Ukraine (2018).

[9] R.A. Vorobel, Loharyfmichna obrobka zobrazhen' [Logarithmic Image Processing], Naukova Dumka (2012), Kyiv, Ukraine.