FUZZY ALGORITHM FOR ADAPTIVE IMAGE CONTRAST INCREASING НЕЧЕТКИЙ АЛГОРИТМ АДАПТИВНОГО ПОВЫШЕНИЯ КОНТРАСТОВ ИЗОБРАЖЕНИЙ

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Abstract: A fuzzy algorithm for adaptive enhancement of image contrasts is considered, which is a characteristic of how wide the spread of the colors of image pixels is. The greater the spread of the pixel color values, the greater the contrast of the image. The main disadvantages of images, in most cases, are distorted brightness characteristics and low contrast. Therefore, the work is devoted to improving the contrasts of the image and converting the image to this form, which makes them more contrasting and, accordingly, more informative.

Keywords: Brightness, contrast, mathematical expectation, entropy, standard deviation, histogram length function.

1. Introduction

Brightness is a characteristic that determines how much the colors of pixels differ from black. For example, if a digitized photograph was taken in sunny weather, then its brightness will be significant. On the other hand, if the photo was taken in the evening or at night, then its brightness will be low [1].

Contrast is a measure of how widely the colors of the pixels in an image vary. The greater the variation in the pixel color values, the greater the contrast in the image.

By analogy with the terms of the theory of probability, it can be noted that brightness is, as it were, the mathematical expectation of the sample values, and contrast is the variance of the sample values [2].

Brightness and contrast can be considered not only for the entire image, but also for individual fragments. Thus, the concepts of local brightness and local contrast arise.

The main disadvantages of images, in most cases, are distorted brightness characteristics and low contrast.

Therefore, the main goal of improvement methods is to transform images to such a form, which makes them more contrasting and, accordingly, more informative [1]. Quite often, the image contains distortions in certain local areas, which are caused by light diffraction, imperfections in optical systems, or rosofocusing. This leads to the need to perform local transformations on the image. In other words, this adaptive approach makes it possible to select informative areas in the image and process them accordingly. Methods of adaptive transformation of local contrast meet the stated requirements [1-2]. For this, the following designations are used:

$F,\ f(x,y)$ - original image and its element with (x,y) coordinates, respectively;

$C(x,y)$ - contrast of an image element with coordinates (x,y);

$G(C(x,y))$ - converted contrast value $C(x,y)$;

$\varepsilon,\sigma,\mathrm{h}$ - characteristics of local neighborhoods (ε - entropy, σ - standard deviation, h - histogram length function);

$g(x,y)$ - element of the processed image with coordinates (x,y).

Disadvantage of the original handwritten image is that the image is low contrast, which makes it difficult to analyze the image. Therefore, first, the operation of stretching the image histogram to the maximum allowable range is performed. Further, the contrasting of the studied image is carried out. This leads to an improvement in the visual quality of handwritten images.

Consider an image F of size M×N pixel, the presence of a gray levelrin the range between 0 and L-1. When applying a fuzzy set for image processing, they are treated as an array of fuzzy singletones. Each element of the array points to a membership value $\mu_F(f(x,y))$ gray level $f(x,y)$, corresponding to the (x,y) th pixel, in accordance with the predefined image properties such as brightness, sharpness, uniformity [3-6].

As a generalization of this approach, we introduce the following representation of an image in a fuzzy environment.

The image F described in a fuzzy medium has the form $F = \left\{ \left\langle f(x,y),\ \mu_F(f(x,y)) \right\rangle \middle| f(x,y) \in \{0,...,L-1\} \right\}$,

where $x \in \{1,...,M\}$, $y \in \{1,...,N\}$, $\mu_F(f(x,y))$ denote, respectively, the degree of belonging (x,y)-th pixel to set in accordance with the properties of the image.

Function μ_F correspond to belonging to many components of the image. Fuzzy set image processing techniques provide a flexible mathematical framework to cope with "quality" properties such as image contrast in the ambiguity and fuzziness conditions often found in digital images.

In terms of fuzzy image processing, the question that naturally arises when trying to define a fuzzy set of pixel brightness can be formulated as follows: “how can we determine the belonging of a function of gray levels to describe an image in a fuzzy set, or more understandable with human perception:“ how bright is gray level and how can we be sure that it is so bright? "

Uncertainty in images comes from various factors. They affect our confidence in deciding whether a pixel is "gray" or "sharp" and therefore introduce some doubts about the corresponding point.

2. Algorithm for adaptive enhancement of image contrast.

1. Normalization:

$$u(x,y) = l\,\frac{f(x,y) - f_{\min}}{f_{\max} - f_{\min}}.$$

2. Fuzzification:

$$\mu_F^i(x,y) = \frac{1}{1 + \dfrac{u(x,y) - c_i}{\sigma_f}},\ \ i = \overline{1,k}.$$

3. Clarification of fuzzification:

$$\mu_F^i(x,y) = \begin{cases} 2(\mu_F^i(\mathrm{x},\mathrm{y}))^2, & 0 \le \mu_F^i(\mathrm{x},\mathrm{y}) \le \dfrac{1}{2}, \\ 1 - 2(1 - \mu_F^i(\mathrm{x},\mathrm{y}))^2, & \dfrac{1}{2} < \mu_F^i(\mathrm{x},\mathrm{y}) \le 1. \end{cases}$$

4.A fuzzy histogram of a digital image is determined by a sequence $h_F(f)$ with $f \in \{0,...,L-1\}$
:

$$h_F(f) = \left\| \left\{ \left\langle (x,y),\ \mu_F(f) \right\rangle \middle| x \in \{1,...,M\},\ y \in \{1,...,N\} \right\} \right\|,$$

where $\|\cdot\|$ denotes the number of elements in a fuzzy set.

Moreover, $h_F(f)$ is the frequency of occurrence of the "about g" brightness level. However, because of its definition, the fuzzy histogram fails to be a probability density function.

5. The normalized histogram is determined:

$$\tilde{h}_F(f) = \frac{h_F(f)}{\sum_{f=0}^{L-1} h_F(f)},$$

where $f \in \{0,...,L-1\}$.

6.Let f - be a singleton that defines the discrete intensity of the image, $h_F(f(x,y))$ - corresponding histogram values. n -th moment $f(x,y)$ relative to the average value of the brightness of the elements of the local neighborhood W. is defined by the formula [7]:

$$M_n(f) = \sum_{(x,y)\in W} \left(f(x,y) - \frac{\sum_{i=1}^{k} f_i(x,y)\cdot \mu_F^i(x,y)}{\sum_{i=1}^{k} \mu_F^i(x,y)} \right)^n h_f(f(x,y)).$$

7. Determine the measure of contrast based on the following expression [8]:

$$C(x,y) = 1 - \frac{1}{1 + k\frac{\sum_{j=1}^{n}[f_j - M[f_j]]^2 \mu_j}{\sum_{j=1}^{n}\mu_j}}. \qquad (1)$$

$C(x,y)$, according to expression (1), is equal to zero for neighborhoods with constant intensity and unity for large values $\sigma^2(L)$. This property of expression (1) fully meets the requirements for determining local contrast.

8. The fuzziness measure F can be defined by analogy with the Shannon entropy in the form [4]:

$$\varepsilon(\mu_F) = -a\sum_{i=1}^{n}\{\mu_F(f_i)\ln\mu_F(f_i) + [1-\mu_F(f_i)]\ln[1-\mu_F(f_i)]\},$$

9. Non-linear local contrast transformation is performed $C(x,y)$.

$$C^*(x,y) = C(x,y)^{\alpha_{\min} + (\alpha_{\max}-\alpha_{\min})(\varepsilon(x,y)-\varepsilon_{\min})/(\varepsilon_{\max}-\varepsilon_{\min})^s}.$$

Here the minimum $\alpha_{\min}$ and maximum $\alpha_{\max}$ exponent values α. The adaptation consists in the formation of an additional term to $\alpha_{\min}$ by determining it based on the entropy of the values ε of the brightness of the elements of the sliding neighborhood.

10. The image is restored by defining a new brightness value $g(x,y)$ element with coordinates (x,y). To do this, we use an expression that is determined from formula (1):

$$g(x,y) = \overline{f}(x,y) + \left(\frac{C^*(x,y)*n*m}{1-C^*(x,y)} - \sum_{\forall(x,y)\in W_2-W_1} \left(\frac{\sum_{i=1}^{k} f_i(x,y)\cdot\mu_F^i(x,y)}{\sum_{i=1}^{k}\mu_F^i(x,y)} - f(x,y) \right)^2 h_F(f(x,y)) \right)^{0,5}.$$

3. Computational experiment

We repeat the described procedure for each image element.

The proposed method uses a statistical determination of local contrasts, which takes into account texture characteristics such as uniformity, roughness and graininess. Therefore, this method is recommended for processing images that contain small details (Fig. 1).

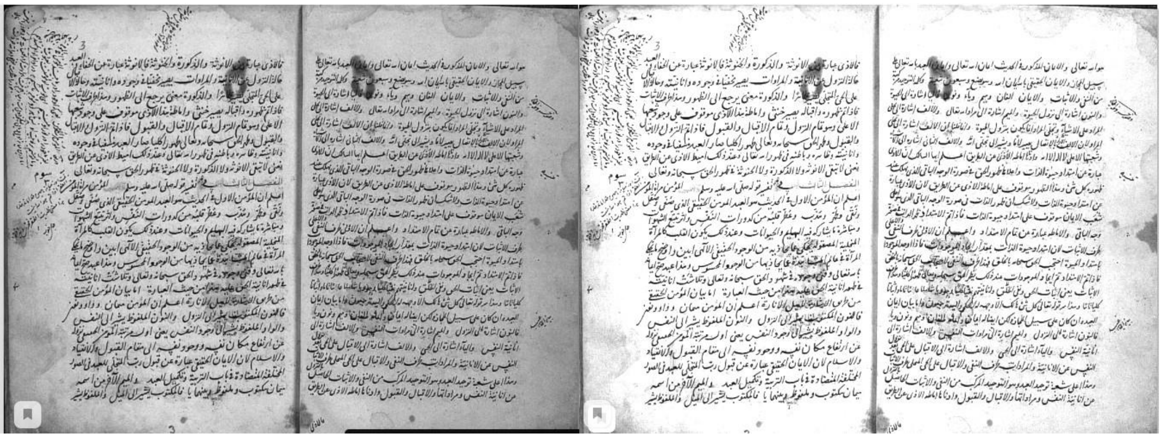

Figure: 1. Image processing by the method of power transformation of local contrasts using the known and statistical expressions for their determination:
alfa = 0.01

4. Conclusion

Proposed expression for the modified power transformation makes it possible to more clearly identify various types of local image neighborhoods and adaptively enhance their contrast depending on the values of the local characteristics of these neighborhoods [9].

The contrast enhancement method is effectively used in processing a wide class of images. Taking into account the characteristics of the moving neighborhoods, it is possible to identify areas of the image by the level of contrast and respond accordingly. This achieves finer processing of small parts. However, images must meet two requirements. They should not contain a large number of pulsed emissions and dark or light areas of a large area. Indeed, in the first case, this can lead to inadequate calculation of the histogram length function, and in the second, to ineffective contrast enhancement. Therefore, if the image does not meet the above requirements, it should be filtered or gradation correction.

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