

# Adaptive Equalization Algorithm for Image Based on Histogram

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**Abstract**—The classical histogram equalization algorithm is not perfect in its over extending low gray layers, which produces over emphasized images and in its weakness in changing gray level, which leads to the lost of details in image. For enhancing the algorithm, the paper introduces an adaptive equalization algorithm that involves the process of dealing with image by using classical histogram equalization before mapping the image by linear function so as to ensure a large gray area for brightness adjustment. In order to verify the actual effect of this improved algorithm, arrange targeted experiments . The experimental results show that the image processed by improved algorithm has better contrast than original image. At the same time, also make the details of some of the background had better retention and well restrain the phenomenon of over-stretched. By comparison, the enhanced algorithm is highly adaptive and it can effectively improve the classical algorithm in terms of image contrast and visual effects.

**Keywords**- *Histogram; Classical equalization algorithm; Adaptive equalization algorithm ; Gray-scale transformation ; Digital image processing*

## I. INTRODUCTION

Gray-scale transformation is an important means to image enhancement in digital image processing<sup>[1]</sup>, the principle is to change the distribution of gray levels of the original image by using a variety of function transformation , then we can achieve the desired treatment effect . Using the histogram equalization algorithm is an important means to achieve gray scale conversion . Histogram equalization is a common method for image processing, it is the basic for image enhancement ,compression and recognition . Using histogram equalization can make the image which has smaller gray level ranges distributing uniform<sup>[2-4]</sup> , this algorithm can also be achieved to enhance the image, to improve the overall contrast and achieve better visual effect . Nevertheless, there are some shortcomings to the classical algorithm , these mainly reflected the following aspects : (1) Overstretching , in particular, the original

image having more pixels of the gray level is excessively enhanced, while also increasing the noise. (2) Losing some details , image pixels having a gray level less are combined in the transform , thus leading to some of the edges and details of the image are missing .(3) Lack of adaptive mechanisms can not achieve on-demand processing, image transformation is not conducive to the realization of automation . In order to solve the above problems, this paper proposes an adaptive equalization algorithm, and can achieve better treatment results .

## II. THE PRINCIPLE OF HISTOGRAM EQUALIZATION ALGORITHM

Histogram refers to the probability density distribution of each gray level in the image<sup>[5-6]</sup> , the gray dynamic range of image after histogram equalization treatment can increase , thus enhances the image contrast.

Set  $r$  represents the gray image to be processed, its value is  $[0, L-1]$ , and  $r=0$  represents black,  $r=L-1$  indicates white. Set  $s$  represents the gradation-converted,  $T(r)$  represents the transformation function, then the following equation as<sup>[7]</sup>:

$$s = T(r), 0 \leq r \leq L-1 \quad (1)$$

(1) need to satisfy two conditions: (a)  $T(r)$  is a monotonically increasing function on the interval  $r$  .(b) when  $0 \leq r \leq L-1$ , then  $0 \leq T(r) \leq L-1$ .

Let  $p_r(r)$  and  $p_s(s)$  denote the probability density function of  $r$  and  $s$ , then

$$p_s(s) = p_r(r) \left| \frac{dr}{ds} \right| \quad (2)$$

$$\text{Assume } s = T(r) = (L-1) \int_0^r p_r(w) dw \quad (3)$$

$$\text{Then } \frac{ds}{dr} = \frac{dT(r)}{dr} = (L-1) \frac{d}{dr} \left[ \int_0^r p_r(w) dw \right] = (L-1) p_r(r) \quad (4)$$

(4) is substituted into the formula(3) formula was:

$$p_s(s) = p_r(r) \left| \frac{1}{(L-1)p_r(r)} \right| = \frac{1}{L-1}$$

Where  $0 \leq s \leq L-1$  (5)

(5) shows that obtained by the transform probability density function  $p$  is a uniform distribution function, Its function diagram is shown in Fig .1:

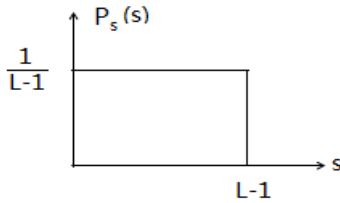


Figure 1. The function diagram of  $p_s(s)$

For digital image processing, since we are using a discrete value, so we can use probability values, respectively, the cumulative summation alternative probability density function and integration. The Probability of the image gray level  $r_k$  appear is<sup>[8-10]</sup>:

$$p_r(r_k) = \frac{n_k}{MN}, \quad k = 0, 1, 2, \dots, L-1 \quad (6)$$

Where  $MN$  is the total number of pixels in the image,  $n_k$  is the number of pixels of  $r_k$ ,  $L$  is the number of gray levels of the image. In this paper, we using an 8-bit image that is  $L = 256$ , The graph  $p_r(r_k)$  is the histogram of image. The corresponding formula (3) in the form is:

$$s_k = T(r_k) = (L-1) \sum_{j=0}^k p_r(r_j) = \frac{(L-1)}{MN} \sum_{j=0}^k n_j$$

$$k = 0, 1, 2, \dots, L-1 \quad (7)$$

Where  $k$  represents the gray levels of the digital image,  $n_j$  represents the numbers of pixel on the gray layer of image, Transform  $T(r_k)$  is called histogram equalization<sup>[10]</sup>.

Now through a simple example to illustrate the principle of histogram equalization. Suppose a size of 3 bits 64\*64 image ( $L=8$ ) of the gray level as shown in Table 1[10].

TABLE I THE SIZE OF THE 64\*64 PIXEL GRAY LEVEL DIGITAL IMAGE DISTRIBUTION

$r_k$	$n_k$	$p_k(r_k) = n_k / MN$
0	790	0.19
1	1023	0.25
2	850	0.21
3	656	0.16
4	329	0.08
5	245	0.06
6	122	0.03
7	81	0.02

The histogram equalization transform function value using the type (7), as follows:

$$s_0 = 7 \sum_{j=0}^0 p_r(r_j) = 7 p_r(r_0) = 1.33$$

$$s_1 = 7 \sum_{j=0}^1 p_r(r_j) = 7 p_r(r_0) + 7 p_r(r_1) = 3.08$$

Similarly, there is  $s_2 = 4.55$ ,  $s_3 = 5.67$ ,  $s_4 = 6.23$ ,

$$s_5 = 6.65, s_6 = 6.86, s_7 = 7.00.$$

Because the value of  $S$  is produced by accumulating for probability values, therefore it should be approximately closest integer, These are the values of the histogram equalization:

$$s_0 = 1.33 \rightarrow 1, s_1 = 3.08 \rightarrow 3, s_2 = 4.55 \rightarrow 5$$

$$s_3 = 5.67 \rightarrow 6, s_4 = 6.23 \rightarrow 6, s_5 = 6.65 \rightarrow 7$$

$$s_6 = 6.86 \rightarrow 7, s_7 = 7.00 \rightarrow 7$$

It can be seen from (6) that,  $p_r(r_k)$  gave an estimate for the probability of occurrence in a gray level image. In other words, the histogram shows the distribution of gray value. We can change the shapes of the histogram to enhance the image contrast. This method is based on probability theory.

Histogram equalization is one of the most common methods. Fig .2 to 5 are the images of different effects and its corresponding histogram.

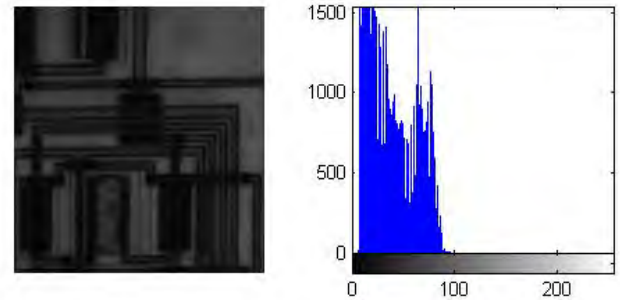


Figure 2. Dark image and its histogram

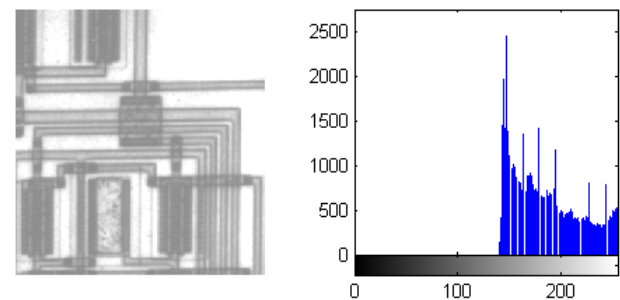


Figure 3. bright image and its histogram

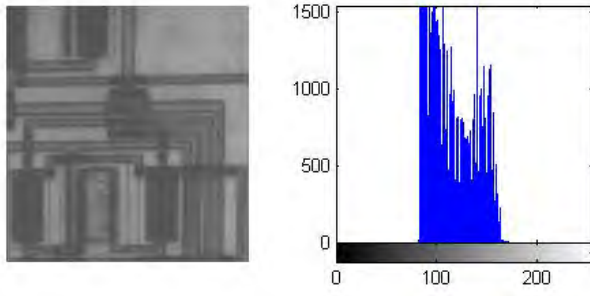


Figure 4. low dynamic range image and its histogram

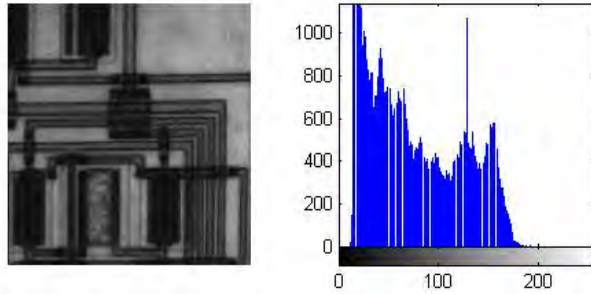


Figure 5. normal image and its histogram

It Can be clearly seen by comparison, gray level range in the dark image is very narrow and mainly concentrated in the low gray level; gray level range in the bright image is mainly concentrated in the high gray level; For the same reason, gray level range in the grey image is mainly concentrated in the middle gray level because of the narrow range of gray level and the small dynamic range; The normal image, which has a large dynamic and distributed homogeneously range gray level, could clearly be showed in detail and well enough of contrast.

Based on this theoretical analysis, which we have analyzed above. Histogram equalization can achieve the purpose of image enhancement by histogram processing. The basic idea of this method is to transform the histogram of original image into uniform distribution. The method could increases the dynamic range of the pixel gray level values and achieve the purpose of enhancing the overall effect of image contrast.

### III. IMPROVING HISTOGRAM EQUALIZATION ALGORITHM

Because the histogram theory come from continuous function , but the digital image processing is discrete values, which Easily lead to get an approximation value when in the histogram transformation. So these Can easily lead to the quantization error and some of the low gray level of images are merged, so cause to Loss some of gray information of the image . To overcome the above reasons brought defects, many scholars proposed correction algorithm, As the literature [3] algorithm is more complex, [5] algorithms are not flexible, need to histogram specification or Computationally intensive, etc. When performing histogram equalization, Since the amounts of pixels in image low gray layer are so much that cause to combine into a higher gray level. In order to

achieve the desired results, this paper made the following improvements: First, process the image histogram equalization, Then all the pixels of the processed image was transformed by a special function, Finally, adjust the brightness compensation coefficient, So that the image having high contrast. The special function like this:

$$T_k = \frac{(L-1) - \alpha X_{\min}}{X_{\max} - X_{\min}} (X_k - X_{\min}) + \alpha X_{\min}$$

$$\text{Where } k = 0, 1, 2, \dots, L-1, \quad 0 \leq \alpha \leq 1 \quad (8)$$

Where  $T_k$  is a gray value after the conversion of the final image,  $X_{\min}$  and  $X_{\max}$  are the minimum and maximum values respectively, after the first image equalization ,  $X_k$  is a pixel gray value;  $\alpha$  is the brightness adjustment coefficient. the coefficient  $\alpha$  can be appropriately adjusted so that the image having a good contrast. In order to make the improved algorithm has better adaptability, I control the value of  $\alpha$  by the slider using MATLAB GUI technology, Use the slider to slide dynamically observation image visual effect. Through a lot of experiments , the phenomenon of low gray layer combined Can well be control when  $\alpha = 0.3$  .At the same time, it can better show the details of the original image , reduce the excessive stretching and loss detail information and others .then we can set  $\alpha = 0.3$  as the brightness adjustment coefficient. Thus, the improved algorithm can not only greatly reduce the amount of computation but also easily to implement.

### IV. EXPERIMENTAL SIMULATION AND ANALYSIS

MATLAB 10 is used to simulate in this paper, For some low gray scale image, using improved algorithm to achieve image enhancement, and analyzing the results about processing , to be compared with the results of traditional histogram equalization processing. Original image and its histogram are shown in Fig .6.

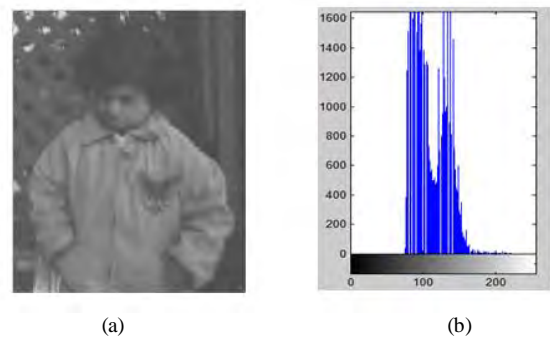


Figure 6. Original image and its histogram

Fig .6 (a) is the image, which gray level distribution presents high in middle part and low at both ends. Fig .6 (b) is its histogram. As can be seen from Fig .6 (a), the image contrast of the background and characters is not obvious. Some background information is not clear. The main reason is the fewer number of pixels in the low gray level at both ends. The distribution of histogram is uneven.

Image after histogram equalization and its histogram are shown in Fig .7.

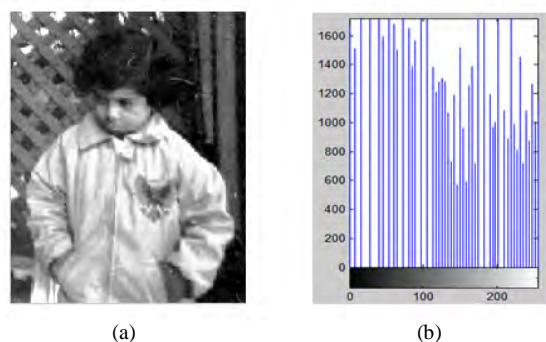


Figure 7. Image after histogram equalization and its histogram

Fig .7 (a) showing effect after classical histogram equalization , Fig .7 (b) is the corresponding histogram. From (a) can be seen brightness and contrast of the entire image has been significantly improved, But the phenomenon of over-stretched and lost some of the details was occurred. Through the histogram analysis we can find the reason for this phenomenon , Low gray level image both ends have emerged over consolidation and improve other phenomena, so that the distribution of the middle of the high gray layer is too fragmented, leading to some of the details were too stretched and lost. Image processed by self-adaptive algorithm and its histogram are shown in Fig .8.

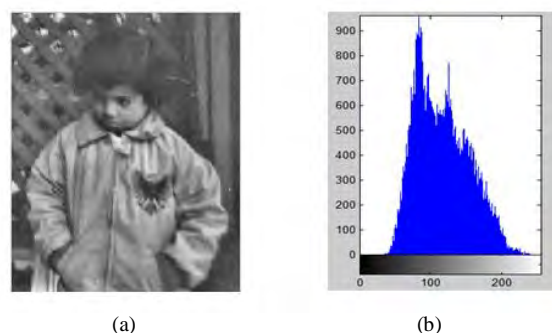


Figure 8. Image processed by self-adaptive algorithm and its histogram

Fig .8 (b) is the corresponding histogram. It Can be clearly seen by comparison, the image processed by improved algorithm has better contrast than original image. At the same time, also make the details of some of the background had better retention and well restrain the phenomenon of over-stretched. Through the histogram contrast can be found, the pixel gray level distribution is close to uniform distribution, to achieve a balanced treatment of the objective.

## V. CONCLUSION

Experimental results show that the improved adaptive histogram equalization algorithm in this paper can make up the shortage of the traditional histogram equalization processing. By comparison, the enhanced algorithm is highly adaptive and it can effectively improve the classical algorithm in terms of image contrast and visual effects.

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