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Image Enhancement using Improved Histogram Equalization

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Abstract: *The main aim of enhancement of an image is to apply some operation on the image in spatial or frequency domain so that the resultant image is more appropriate than the original image for a particular application. In this paper a method to enhance low contrast images in spatial domain is proposed. The method first applies power law to correct the image tone and then applies improved histogram equalization to reduce the problem of noise amplification as in histogram equalization. The performance is measured both quantitatively and qualitatively and the results reveal that method is better than the state-of-the-art and can be applied to many image processing and computer vision application.*

Keywords: Enhancement, Histogram Equalization, noise amplification.

I. INTRODUCTION

The process of contrast enhancement plays very important role in image processing to highlight the information that exists within low dynamic range of that gray level image. To improve the visual and comprehensible quality of an image, it required to perform some operations on the image like adjusting the contrast or elimination of noise present in the image [1]-[3]. Contrast enhancement is required normally when an image has a narrow range of intensity values. When the given image is either too dark or maybe too bright and no particular colors are visible; hence, the objects in the image cannot be identified and recognized. Contrast is the difference in luminance or color that makes an object distinguishable from other objects within the same field of view. Contrast enhancement changes the image value distribution to cover a wide range. There exist mainly two types of methods to improve the contrast of the image. First types of methods are called spatial domain methods and they directly operate on image pixels [4]. Second types of methods are called frequency domain methods [5]. For these methods the image is first converted to Fourier transform and then filters are applied to enhance the image or to remove the noise from the image. There are many reasons for the low contrast of an image. Poor lighting conditions, weather, the time at which the image is captured, quality of camera, resolution of the display device etc. The quality of the image can also be lost due to the compression of the image or document containing the image. Poor lighting conditions lead to poor quality images [6].

II. BACKGROUND

Many methods to improve the image quality are proposed in literature. Spatial domain methods are easy to implement and therefore are widely used. Depending upon the transformation function used, Contrast Enhancement methods can be further divided into linear and non-Linear [7]. The linear method includes Contrast-Stretching [8] transformation that uses Piecewise Linear functions while Non-linear method includes Histogram Equalization [9], Gaussian Stretch [10] etc. which uses Non-Linear transformation functions that are obtained automatically from the histogram of the input image [11]. Histogram Equalization is a very promising method for contrast improvement [12]. A disadvantage of the method is that it is indiscriminate. It may increase the contrast of background noise, while decreasing the usable signal [13].

III. THE PROPOSED METHOD

The first step in proposed method is to change the size of the image if the application requires the images of a given size. After that power law is applied. The general form of Power law transformation function is

$$s = c*r^{\gamma} \quad (1)$$

Where's' and 'r' are the output and input pixel values, respectively and 'c' and γ are the positive constants. power law curves with γ <1 map a narrow range of dark input values into a wider range of output values, with the opposite being true for higher input values.

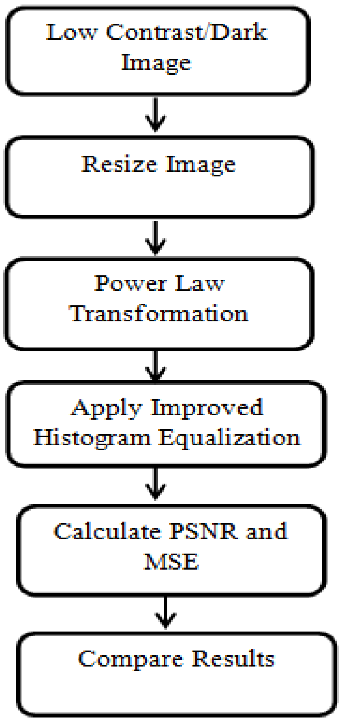


Figure 1: The proposed method model

After applying the power law the second step is to apply improved histogram equalization. The improved histogram step is applied to luminance channel of the image. For this purpose the RGB image is first converted to YUV color space. Y represents Luma component; U and V represent two chrominance components [14]. All the operations are applied on Y channel.

Algorithm:

Step 1: Divide the original intensity image into non-overlapping contextual regions. The total number of image tiles is equal to M × N, and 8×8 is a good value to preserve the image chromatic data.

Step 2: Calculating the histogram of each contextual region. The histogram places the value of each pixel $f[x,y]$ into one of L uniformly-spaced buckets $h[i]$.

$$h[i] = \sum_{x=1}^{N} \sum_{y=1}^{M} \begin{cases} 1, & if\ f[x,y] = i \\ 0, & Otherwise \end{cases} \quad (2)$$

Where L=2^8 and the image dimension is M×N.

Step 3: Histogram of each tile is clipped with a calculated clip limit. For a contextual region of size 'M' rows and 'N' columns and 'L' being the number of histogram bins, clip-limit CL is given by,

$$CL = \begin{cases} 1 & \text{if } \frac{\propto MN}{L} < 1 \\ \frac{\propto MN}{L} & \text{else} \end{cases} \quad 0 < \propto \leq 1 \quad (3)$$

Step 4: Calculate the cumulative distribution function.

$$CDF[j] = \sum_{i=1}^{j} h[i] \quad (4)$$

Step 5: Scale the input image using the cumulative distribution function to produce the output image.

$$g[x,y] = \frac{CDF[f[x,y]] - CDF_{min}}{(N \times M) - CDF_{min}} \times (L-1) \quad (5)$$

Where CDFmin is the smallest non-zero value of the cumulative distribution function.

Step 6: Use bilinear interpolation to rejoin the tiles.

IV. EXPERIMENTAL RESULTS

All the experiments are done in Python 3.7. The images are selected from Google randomly. Figure 2 to 5 show the visual results that reveal that the proposed method works better than the state-of-the-art methods. Table 1 and table 2 show the quantitative results in the terms of Peak Signal to Noise Ratio (PSNR) and Mean Square Error (MSE) respectively.


(a) Test Image (b) Contrast Stretching


(c)Histogram Equalization (d) Proposed Method

Figure 2: Visual Performance Evaluations


(a) Test Image (b) Contrast Stretching

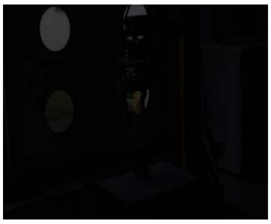
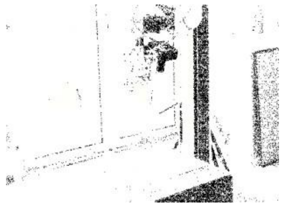

(c)Histogram Equalization (d) Proposed Method

Figure 3: Visual Performance Evaluations

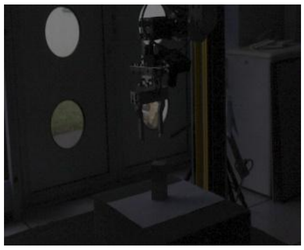

(a) Test Image (b) Contrast Stretching


(c)Histogram Equalization (d) Proposed Method

Figure 4: Visual Performance Evaluations

(a) Test Image (b) Contrast Stretching

(c)Histogram Equalization (d) Proposed Method

Figure 5: Visual Performance Evaluations

Both visual and quantitative results reveal that the proposed method is better than the state-of-the- art. The methods works best for the very dark images as it can be seen in figure 4 and figure 5. The method also works well for color images as shown in figure 1.

Increased PSNR and decreased MSE values in case of proposed methods show that method is also improved in terms of quantitative evaluation.

Table 1: Quantitative Performance Evaluation: PSNR

Image	*Contrast Stretching*	*Histogram equalization*	*Improved Histogram equalization*
Test_img1	27.78	27.77	28.28
Test_img2	27.98	27.72	29.62
Test_img3	29.96	30.67	30.84
Test_img4	27.38	27.36	30.71
Test_img5	28.40	27.83	30.35
Test_img6	25.35	28.44	38.19
Test_img7	32.24	30.12	34.45
Test_img8	30.12	29.02	40.28

Table 2: Quantitative Performance Evaluation: MSE

Image	*Contrast Stretching*	*Histogram equalization*	*Improved Histogram equalization*
Test_img1	108.41	108.28	96.52
Test_img2	108.26	109.75	70.95
Test_img3	85.56	95.65	77.41
Test_img4	119.22	119.17	55.10
Test_img5	93.79	106.94	59.94
Test_img6	34.09	92.95	19.86
Test_img7	80.89	78.08	53.09
Test_img8	110.21	106.34	87.26

V. CONCLUSION

It can be concluded that the proposed method works better than the state-of-the art. The power law proves promising to reproduce the colors and the improved histogram equalization is responsible the brightness and contrast adjustment. Moreover the method proves better for both gray scale and color images. In this method the values of gamma in power law transformation are taken manually. An automatic method can be found in future that can choose the value of gamma itself.

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