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An Experimental Study of the Performance of Histogram Equalization for Image Enhancement

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***Abstract*—** Histogram equalization is one of the image enhancement techniques which has gained widespread popularity nowadays. It is a spatial domain histogram manipulation technique which mainly deals with brightness value remapping for recovering the lost contrast. In this paper an experimental study of the performance of histogram equalization technique on images has been done using matlab. Image multiplication and image division techniques are done on images in such a way that by adjusting the respective constant values, the contrast of the image is been made poor. To recover the lost contrast and the image back, the technique of histogram equalization is used and a comparison of the resultant image with original image and an analysis of the performance of this technique is done. The appearance of the images get enhanced by histogram equalization. The method uses the principle of stretching out the grey levels of the less contrast, darker image thereby producing a uniformly distributed flat histogram and a more contrast clear image.

***Keywords*—** Histogram manipulation; Pixel; Remapping; Histogram equalization; Image enhancement; Contrast; Brightness

I. INTRODUCTION

Image enhancement is a technique in which the original image is processed so that the resultant image is more suitable than the original image, that is, image is enhanced. An enhancement algorithm is one that gives better quality images for some particular application which can be done by either increasing the image contrast or suppressing the noise[1][2]. Spatial domain and frequency domain are two classifications of image enhancement techniques. Spatial domain method directly operates on the pixel, where as frequency domain method operates on the Fourier transform of an image which then transform it back to the spatial domain. Spatial domain technique is broadly classified as point operation, mask operation and global operation. In point operation, each pixel is modified by an equation that is not dependent on other pixel values. The point operation is represented by g(x,y)=T[f(x,y). Here f(x,y) is the original image and T is transformation applied to it to get a new modified image g(x,y). Here general equation remains the same while T changes. Brightness modification, contrast modification and histogram manipulation are the three types of point operation. Brightness adjustment deals with the pixels of the image. By adding a constant value to each pixel of image, the brightness of the image can be increased and by subtracting a constant value from each pixel of image, the brightness of the image can be decreased. That is, g(x,y)=f(x,y)+k and g(x,y)=f(x,y)-k. Similarly, by scaling all the pixels of the image by a constant, the adjustment of the contrast can be done. That is, g(x,y)=f(x,y)*K.

II. HISTOGRAM MANIPULATION

The other widely used point operation is histogram manipulation apart from brightness and contrast modification. Nowadays, histogram manipulation has gained widespread popularity among digital photography, medical imaging and remote sensing applications. Modification of histogram of the image is done in order to improve the visual quality of the image[2]. In histogram manipulation, representation of the number of occurrences of gray level in the image against gray level values is been done. The plotting of histogram can be done either by representing gray level on x-axis and number of pixels in each gray level on y-axis or by representing grey level on x-axis and the probability of occurrence of that grey level on y-axis.\

That is, $P(r_k) = \frac{n_k}{n}$ where, r_k is the k th grey level, n_k is the number of pixels in the k th grey level and n is the total number of pixels in the image. Generally, 0 is used to represent black and 1 is used to represent white. Information about image contrast and brightness is obtained from the histogram plot. So by modifying the histogram of an image, the brightness of the image can be improved[2][4]. The histogram of an image is analyzed based upon brightness and contrast of the image. If the

histogram of the image is dark, the pixels of the image move towards the lower gray level region. If the histogram of the image is bright, the pixels of the image move towards the higher gray level region[3]. The histogram will not be equally spread if it is a low contrast image. The histogram will be equally spread if it is of high contrast. Linear stretching and histogram equalization are the two methods of histogram manipulation. In linear stretching, the dynamic range of the image is increased while the shape of the histogram is not altered. The linear stretching technique cannot be used for applications that require a flat histogram. This can be done by using histogram equalization[5][8]. The gray level in the image is evenly spread out in case of histogram equalization. That is, the gray levels in an image is evenly distributed across their range. Histogram equalization is a sophisticated non-linear mapping technique in which a re-assigning of intensity values of pixels of input image is done so that in the output image a uniform distribution of pixel intensities is obtained.

Thus we will get a flat histogram for the output image. The technique stretches the contrast of high histogram regions and compresses the contrast of low histogram regions. This type of image enhancement technique is having varied application in different areas, the most important area being the medical field[[3]6][7]. The contrast of the medical images can be pre-processed using this technique. The other commonly used areas include speech recognition, image texture synthesis, satellite image processing, etc.

III. ALGORITHM FOR HISTOGRAM EQUALIZATION

A. The algorithm for histogram equalization is as follows:

a) The number of pixels is plotted against the gray level values.

b) The probability distribution function (PDF) and cumulative distribution function (CDF) of the number of pixels against the gray levels is calculated.

c) Each value of CDF is multiplied by the number of gray levels.

d) The values obtained in step c is rounded off to the nearest value

IV. MATHEMATICAL CALCULATION

A. The mathematical calculation based on the algorithm given above is done as following:

Table I. Gray level v/s Number of pixels

Gray level	0	1	2	3	4	5	6	7
No of Pixels	50	0	50	0	50	0	50	0

Total number of grey levels (L)=8

Table II. Probability and Commutative density functions

Gray level	**n_k (n=200)**	**PDF $P_r(r)=n_k/n$**	**CDF $S_k=\sum P_r(r)$**	**$(L-1)*s_k = 7*s_k$**	**Rounding off**
0	50	0.25	0.25	1.75	2
1	0	0	0.25	1.75	2
2	50	0.25	0.50	3.5	4
3	0	0	0.5	3.5	4
4	50	0.25	0.75	5.25	5
5	0	0	0.75	5.25	5
6	50	0.25	1	7	7
7	0	0	1	7	7

Table III. Old gray level v/s New gray level

Old gray level	**Equivalent no of pixels**	**New gray level**
0	50	2
1	0	2
2	50	4
3	0	4
4	50	5
5	0	5
6	50	7
7	0	7

Table IV. Histogram equalization

Gray level	0	1	2	3	4	5	6	7
No of Pixels	0	0	50	0	50	50	0	50

V. RESULTS AND DISCUSSIONS

Study of performance of histogram equalization technique is been done on two standard images. The standard images used are Cameraman and Barbara. The contrast of the images is made poor by using arithmetic operations on the images by varying the constant values applied. The arithmetic operations used on the images are image multiplication and image division. That is, multiplication of the image by a constant value less than 0.4, results in a darker image. Similarly, division of the image by a constant value greater than 4, results in a darker image. As the contrast of the image decreases, the details of the image becomes less clear and less visible. The image in fact becomes a dark image. The original clear image can be recovered back by using the histogram equalization method. The histograms of the original image, the darker image and the histogram equalized image are plotted using matlab. From the histograms, it is observed that the histogram of darker image is skewed towards the lower end region of the

gray scale, thus compressing all the detail information of the images. The histogram of the equalized image retains all the lost contrast back, thereby making the image more clear. The technique uses the principle of re-mapping the pixel values. The resultant histogram is uniformly distributed as the gray levels are evenly stretched out at the dark end. For an experimental study, image multiplication is used to reduce the image contrast in Cameraman image while for Barbara image, image division is used to reduce the contrast. To both these less contrast dark image sets obtained, equalization technique is applied using matlab. From the results it is observed that the resultant images obtained are of more contrast and clear. Also from the histogram of the resultant images it is clear that the pixel values are evenly distributed throughout the gray level.

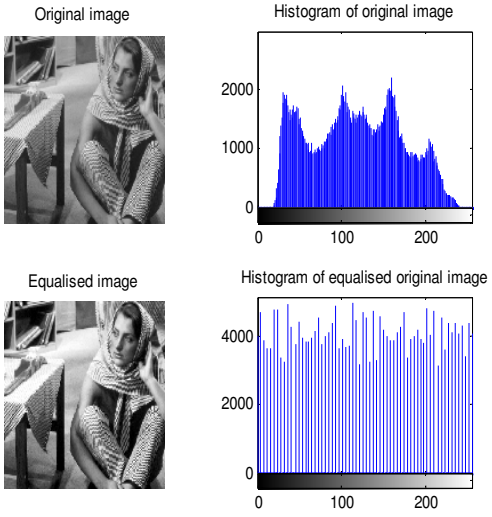

Fig.1 Original image (Barbara) and its histogram

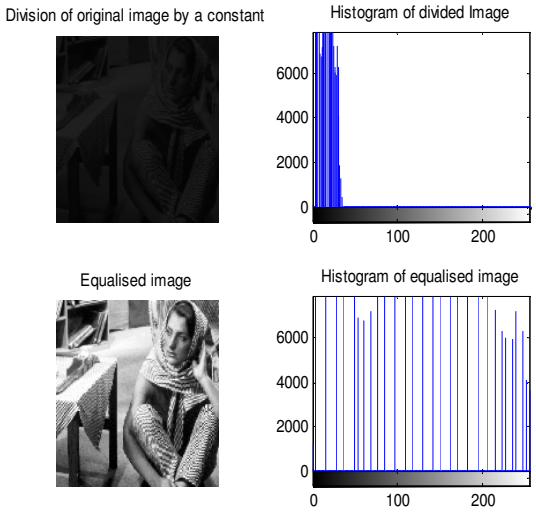

Fig 2. Histogram equalization of darker image

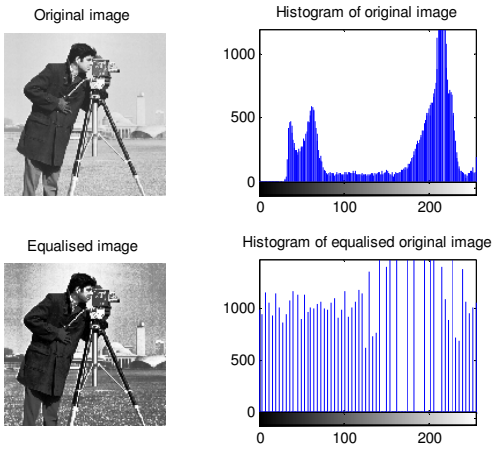

Fig 3.Original image (Cameraman) and its histogram

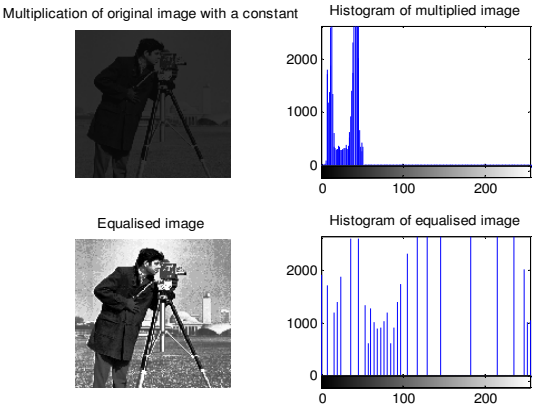

Fig 4.Histogram equalization of darker image

VI. CONCLUSION

This paper emphasizes on the study of the concept of manipulation of histogram of the image to improve its visual contrast. The histogram manipulation technique used in this paper for study is histogram equalization. The technique is used on two standard images and the quality of the resultant image is been analyzed based upon the contrast improvement.

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