

## Image Enhancement using Histogram Approach

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### Abstract

*Image enhancement is the process used to enhance the image. There are various techniques of image enhancement which is broadly classified into two categories: Spatial domain and Frequency domain. Spatial domain methods operate directly on the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain method, the image is first transferred into frequency domain. It means that the Fourier transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then, the Inverse Fourier Transform is performed to get the resultant image. There are numerous techniques of image enhancement available in literature. In this paper, we will compare two histogram techniques: Histogram Equalization and Histogram Specification. We will implement and analyze the result of these two approaches in MATLAB using Image Processing Toolbox (IPT) and their performances will be evaluated on various images.*

### 1. Introduction

Image enhancement is the processing of image to enhance certain feature of an image. Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing better input for other automated image processing techniques. The principal objective of image enhancement is to modify attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. Image enhancement is used in the following cases: Removal of noise from image, enhancement of the dark image and highlight the edges of the objects in an image. The result is more suitable than the original image for

certain specific applications. Processing techniques are very much problem-oriented. For example, best techniques for enhancement of X-ray image may not be best for enhancement for microscopic images. There exist many techniques that can enhance a digital image without spoiling it. The enhancement methods can broadly be divided into the following two categories: Spatial Domain Methods and Frequency Domain Methods. Spatial domain methods which operate directly on pixels. In this method, the pixel values may be modified according to rules that depend on the original pixel value (local or point processes). Alternatively, pixel values may be combined with or compared to others in their immediate neighborhood in a variety of ways. Frequency domain which operate on the Fourier transform of an image. It modifies Fourier transform coefficient of an image. It takes Inverse Fourier Transform of the modified coefficient to obtain the enhanced image.

The work in this paper is organized as: In section II, we described the related work in the area of Histogram Processing. In section III, we discussed the Histogram which is used in the case of image enhancement. We analyze the Histogram Equalization and Histogram Specification techniques and their effects on different images. In section IV, we performed the experimental results and discussion based on these techniques. Finally, section V concludes the papers.

### 2. Related Work

J. Alex Stark [7] proposes a scheme for adaptive image contrast enhancement based on a generalization of histogram equalization (HE) useful for improving image contrast. He introduced a "cumulation function" which is used to generate a grey level mapping from the local histogram to achieve a wide variety of effects. Tzu-Cheng Jen et al. [15] introduced a generalized histogram equalization technique based on localized image analysis and design two measures  $f_1$  and  $f_2$  to measure local characteristics around each pixel, the global statistics of these two local measures are then recorded into an extended histogram and develop a procedure to generate suitable intensity

transfer functions for various applications, like contrast enhancement and shadow enhancement and provides a flexible and efficient way for image enhancement. Hojat Yeganeh [6] presents a novel approach for contrast enhancement based on histogram equalization (HE) and applies some preprocessing steps on the histogram corresponding to the image and then applies histogram equalization. He applied the proposed algorithm on a database which includes 220 normal images and results are promising. The proposed method has better results comparing with Bi Histogram Equalization (BHE) algorithm based on visual criterion and a mathematical criterion. Qian Wang [16] proposed a novel histogram mapping method i.e local-mean based strict pixel ordering method to overcome the problem that the histogram equalization can fail for discrete images. He uses a fast local feature generation technique to establish a combined histogram that represents voxels' local means as well as grey levels. Different sections of the combined histogram, separated by individual peaks, are independently mapped into the target histogram scale under the constraint that the final overall histogram should be as uniform as possible. By using this method, the speed of histogram equalization is dramatically improved, and the satisfactory enhancement results are also achieved. Takashi Kawakami [14] proposed a novel Histogram Equalization (HE) called mean preserving bi-histogram equalization (BBHE) method with variable enhancement and separation intensity degree to avoid the saturation effect. Finally, these two proposed methods are combined and control the enhancement degree by two parameters. Debashis Sen [3] introduced an automatic exact histogram specification technique which aims at information maximization and used it for global and local contrast enhancement of images. The desired histogram is obtained by first subjecting the image histogram to a modification process and then by maximizing a measure that represents increase in information and decrease in enhancing contrasts of grayscale images as demonstrated through visual assessment of results. Gabriel Thomas [4] proposes a new technique for specifying a histogram to enhance the image contrast and use them on segmentation approaches also. He emphasizes the flexibility of this image processing approach to do more than enhancing images. Dah-Chung Chang [2] presents a new ACE (adaptive contrast enhancement) algorithm, which uses contrast gains (CG's) to adjust the high frequency components of images and eliminates uses noise over enhancement and ringing artifacts in conventional approaches. Yu Wang [17] proposed a novel histogram equalization technique, equal area dualistic sub-image histogram equalization. First, the image is decomposed into two

equal area sub-images based on its original probability density function. Then, the two sub-images are equalized respectively. At last, the results after the processed sub-images are composed into one image. The simulation result indicates that the algorithm can not only enhance image information effectively but also keep the original image luminance well enough to make it possible to be used in video system directly. P. Rajavel [12] proposes image-dependent brightness preserving histogram equalization (IDBPHE) technique to enhance image contrast while preserving image brightness. The curvelet transform and histogram matching technique are used to enhance image. The proposed IDBPHE technique undergoes two steps. (i) The curvelet transform is used to identify bright regions of the original image. (ii) Histogram of the original image is modified with respect to a histogram of the identified regions. It enhances image contrast while preserving image brightness without any undesired artifacts. Md. Foisal [10] presents a new method of image enhancement that improves the visual quality of digital images as well as image that exhibits dark shadows due to limited dynamic range of imaging. In this paper non linear image enhancement technique is used in transform domain by the way of transform coefficient histogram matching to enhance image. Processing includes global dynamic range correction and local contrast enhancement which is able to enhance the luminance in the dark shadows keeping the overall tonality consistent with that of the input image. Logarithmic transform histogram matching is used which uses the fact that the relation between stimulus and perception is logarithmic. Komal Vij [8] reviews and summarizes some Histogram Processing Techniques for Image enhancement. Numerous enhancement methods have been proposed but the enhancement efficiency, computational requirements, noise amplification, user intervention, and application suitability are the common factors to be considered when choosing from these different methods for specific image processing application. Rajesh Garg [13] proposes various enhancement schemes used for enhancing an image which includes gray scale manipulation, filtering and Histogram Equalization (HE). The basic idea of HE method is to re-map the gray levels of an image. HE tends to introduce some annoying artifacts and unnatural enhancement. To overcome these drawbacks different brightness preserving techniques are used which and their Comparative analysis is done on the basis of subjective and objective parameters, Peak signal to-noise ratio (PSNR), Mean squared error (MSE), Normalized Absolute Error (NAE), Normalized Correlation, Error Color and Composite Peak Signal to Noise Ratio (CPSNR). Pavithra P [11] extends the classical histogram specification technique

by using a target image which is obtained by fusing multiple high resolution images. A set of Quality Metrics were identified to assess the quality of the output enhanced image. a) Effect of varying the number of target images on the quality of the output enhanced image b) Role of using different methods of fusion on the quality of the output enhanced image c) Category of the target image on the quality of the output enhanced image. If the input image is from a forest, whether in order to obtain an enhanced image, all target images has to be selected from the forest category d) Effect of preprocessing of target image on the quality of the output enhanced image.

### 3. Histogram

Histogram is one of the Fundamental Technique of Spatial Domain. Histogram processing is the act of altering an image by modifying its histogram. Common uses of histogram processing include normalization by which one makes the histogram of an image as flat as possible. This is also known as *contrast enhancement*. It considers the overall appearance of an image. It does not tell anything about

#### 3.1 Normalized Histogram

Histograms are frequently normalized by the total number of pixels in the image. It gives the global description of an appearance of an image and is very easily derived from original histogram. Assuming an image, a normalized histogram is given by

$$p(r_k) = \frac{n_k}{n}, K=0, 1, 2 \dots L-1 \quad (2)$$

This equation is related to probability of occurrence of  $r_k$  in the image. Where  $p(r_k)$  gives an estimate of the probability of occurrence of gray level  $r_k$  and  $n$  is the total number of pixels in digital image. The sum of all components of a normalized histogram is equal to 1.

#### 3.2 Histogram Equalization

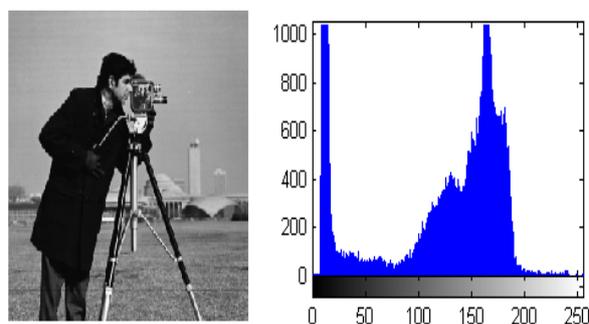
Histogram Equalization is a technique that generates a gray map which changes the histogram of an image and redistributing all pixels values to be as close as possible to a user –specified desired histogram. Histogram equalization allows for areas of lower local contrast to gain a higher contrast. Initially, we assume that  $r$  represents gray-level in an image and we assume that the pixel values are continuous and normalized in the range  $[0, 1]$  where 0 represents black pixel and 1 represents white pixel. In discrete domain, we consider pixel values from 0 to  $L-1$  where  $L$  is the number of discrete gray-level in image.

$$s = T(r) \quad (3)$$

contents of an image. The Histogram of digital image with the intensity levels in the range  $[0, L-1]$  is a discrete function, which is given by

$$h(r_k) = n_k \quad (1)$$

Where  $r_k$  is the intensity value,  $n_k$  is the number of pixels in the image with intensity  $r_k$  and  $h(r_k)$  is the histogram of the digital image with gray Level  $r_k$ . If we plot these number of pixels values  $r_k$  against the intensity values of those pixels, then this plot is called histogram. Figure (1) shows the original image and its histogram.



(a) Image (b) and Its histogram  
**Figure 1: Image and its histogram**

Where  $r$  represents original image,  $s$  represents processed image and  $T(r)$  represents transformed function on original image. This transformed function should satisfy two conditions: (1)  $T(r)$  is single valued and monotonically increasing on  $0 << r << 1$  i.e. it should maintain intensity order of an image where a dark pixel in original image should be dark in processed image and white pixel should be white. It means processed image should be in the range  $[0, 1]$ , (2)  $0 << T(r) << 1$  for  $0 << r << 1$  i.e. processed image should have pixel value between minimum and maximum allowable range. From equation (3), we have

$$r = T^{-1}(s) \quad (4)$$

Now, the inverse transformation function will also satisfy above two conditions. To achieve Inverse Transform function, histogram follows following Mathematical procedure: We assume Normalized intensity values in the range  $[0, 1]$  where  $p_r(r)$  represents Probability Density Function (PDF) of  $r$  and  $p_s(s)$  represents Probability Density Function (PDF) of  $s$ . Where  $r$  is the intensity value in original image and  $s$  is the intensity value in processed image. From elementary probability theory, we know if  $p_r(r)$  and  $T(r)$  are known and  $T^{-1}(s)$  is single valued and monotonically increasing. Then, the probability density function (PDF) of processed image is given by

$$p_s(s) = p_r(r) \cdot \left| \frac{dr}{ds} \right|_{r=T^{-1}(s)} \quad (5)$$

All the histogram processing techniques try to modify probability density function (PDF) that is  $p_s(s)$  so that

image gets a particular application which is obtained through Transformation function  $T(r)$ . Let's consider a particular Transformation function

$$s = T(r) = \int_0^r p_r(w)dw \tag{6}$$

And  $0 \ll r \ll 1$ . The equation (6) gives the cumulative distribution function (CDF) of  $r$ . If we take  $T(r)$  of this form then it satisfy both particular conditions and then we compute

$$\frac{ds}{dr} = p_r(r) \tag{7}$$

By substituting value of equation (7) in equation (5), we get

$$p_s(s) = p_r(r) \left| \frac{dr}{ds} \right| = p_r(r) \cdot \frac{1}{p_r(r)} = 1 \tag{8}$$

From above equation, we find that, if we take this particular Transform function which is Cumulative Distribution Function CDF) of  $r$ , then using this Transformation function, we generate an image which have uniform Probability Density function (PDF) of intensity values of processed image which is going to enhance the contrast of image. The probability of pixel having value  $r_k$  in an image and the plot of  $p(r_k)$  for different values of  $r_k$ , we define histogram of an image. Histogram Equalization makes use of this histogram to find out transformation function between intensity levels of original image and processed image and that transform function is given by

$$s_k = T(r_k) = \sum_{i=0}^k \frac{n_i}{n} = \sum_{i=0}^k p_r(r_i) \tag{9}$$

Where the minimum value of intensity is 0 and maximum value of intensity is 1 but in Digital image minimum intensity value of an image is 0 and maximum are 255. For practical implementation, we have to do some post processing so that all these  $s_k$  values which we get between 0 and 1 which can be dynamically mapped from 0 to 255 and mapping function given by

$$s' = \text{Int} \left[ \frac{s-s_{min}}{1-s_{min}} \times (L - 1) + 0.5 \right] \tag{10}$$

This value of  $s'$  will give intensity level in processed image from 0 to 255 and can be shown with an example. Suppose  $r$  varies from 0 to 7 that is,  $r=0, 1, 2, \dots, 7$  and similarly  $s=0, 1, 2, \dots, 7$ . The value of  $p_r(i)$  is given. The probability when intensity value is 0,  $p_r(0)=0$ . Similarly,  $p_r(1) = p_r(2) = 0.1, p_r(3) = 0.3, p_r(4) = p_r(5) = 0, p_r(6) = 0.4, p_r(7) = 0.1$ .

Given this histogram of input values, we want to find the Transformation function  $T(r)$ , which will map the input image to the output image where the output image will be equalized. For this, first we will find the mapping function  $T(r)$ .

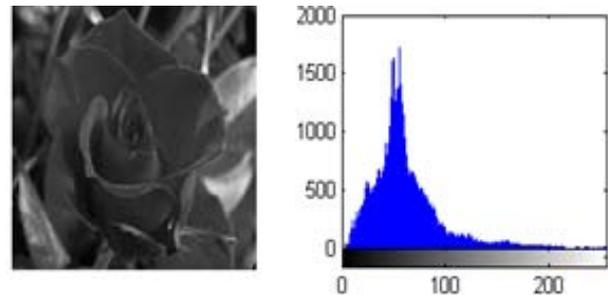
By using  $s'$ , it is scaled from 0 to 7. Therefore,  $r$  and  $s'$  give the corresponding mapping between the given intensity value and output intensity value. So, by using histogram equalization, the histogram will be enhanced so that image will be improved.

**Table 1.**

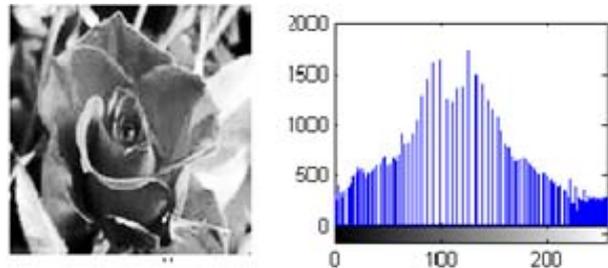
$r$	$p_r(r)$	$T(r) = \sum_{i=0}^r p_r(i) = s_k$	$s'$
0	0	0	0
1	0.1	0.1	1
2	0.1	0.2	2
3	0.3	0.5	4
4	0	0.5	4
5	0	0.5	4
6	0.4	0.9	7
7	0.1	1.0	7

$$s' = \text{Int} \left[ \frac{s-s_{min}}{1-s_{min}} \times 7 + 0.5 \right] \tag{11}$$

The result are shown in figure.



(a) Before equalization



(b) After equalization

**Figure 2 . Histogram before equalization, histogram after equalization**

### 3.2.1 Limitation

In Histogram Equalization, the probability density functions (PDF) of intensity value of equalized image are ideally uniform distribution. Theoretically, we will get uniform distribution but practically, it is not possible because in discrete image, many of pixel values may not be present.

### 3.3 Histogram Specification

It is also called *Histogram Matching*. The histogram equalization (HE) is not suitable for iterative image manipulation. If we want to enhance only certain region of the histogram then, we will use histogram specification. We have the input image, then the target histogram is specified, we have to process the image in such a way that the histogram of the processed image will be close to the target image. From given image, we have

$$p_r(r_k) = \frac{n_k}{n} \quad (12)$$

The target histogram which is given by  $p_z(z_k)$ . But we do not have any image correspond to target histogram. From equation (12), we get

$$s_k = T(r_k) = \sum_{i=0}^k \frac{n_i}{n} = \sum_{i=0}^k p_r(r_i) \quad (13)$$

$$z_k = v_k = G(z_k) = \sum_{i=0}^k p_z(z_i) = s_k \quad (14)$$

$$z_k = G^{-1}(s_k) \quad (15)$$

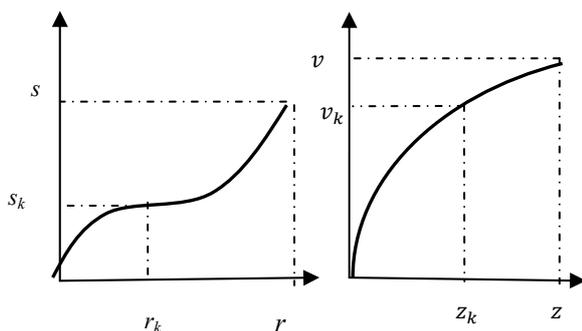
We can find out  $G^{-1}$  by using Iterative procedure as follows:

1. Obtain histogram of the given image.
2. Precompute a mapped level  $s_k$  from each level  $r_k$

$$s_k = \sum_{i=0}^k \frac{n_i}{n} \quad (17)$$

3. Obtain transformation function G from given  $v_k = G(z_k) = \sum_{i=0}^k p_z(z_i) = s_k$  (18)
4. Precompute  $z_k$  for each level of  $s_k$  using iterative scheme.

For each pixel in the original image, if the value of the pixel is  $r_k$ , map this to its corresponding level  $s_k$ , then map  $s_k$  into the final level  $z_k$  using precomputed values. So, histogram specification gives the mapping from  $r$  to  $z'$ .

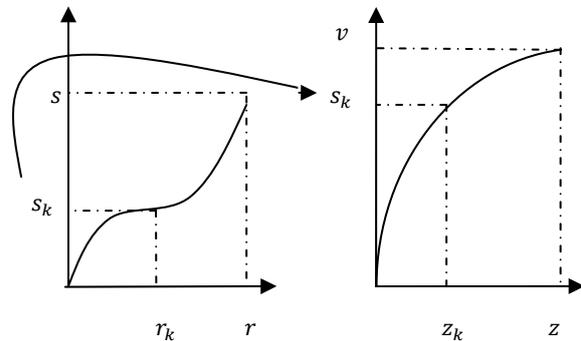


a) Forward Transformation b) Inverse Transformation  
**Figure 3.**

We have to find out,

$$s_k \rightarrow r_k \rightarrow z_k \rightarrow v_k$$

But the problem is that  $z_k$  is unknown. So, this will find out with the help of  $G^{-1}$ .



**Figure 4. Iterative procedure to find out  $s_k$  from  $z_k$**

We know  $r_k$ , we can easily find  $s_k$  from  $r_k$  by using  $S = T(r)$ . After that we will set  $v_k = s_k$  and thus find out  $z_k$  from this  $s_k$  or  $v_k$ . Sometimes, analytically, it is not possible to find this. But in discrete domain, both these transformation function  $s = T(r)$  and  $v = G(z)$  can be implemented in the form of arrays.

$$v_k = G(z_k) = s_k \quad (19)$$

$$G(z_k) - s_k = 0$$

We assume  $z_k$  is nearly equal to  $\hat{z}$ . It should satisfy

$$G(\hat{z}) - s_k \geq 0.$$

So, we will increment value of  $\hat{z}$  by 1 iteratively unless that condition met. For example, suppose  $v$  and  $z$  varies from 0 to 7. i.e.

$$v = 0, 1, 2, \dots, 7 \text{ and } z = 0, 1, 2, \dots, 7.$$

The value of  $p_r(r)$  is given. The probability when intensity value is 0,  $p_r(0) = 0$ .

Similarly,

$$p_r(1) = p_r(2) = 0.1, p_r(3) = 0.3, p_r(4) = p_r(5) = 0, p_r(6) = 0.4, p_r(7) = 0.1.$$

$$\text{The value of Target Histogram, } p_z(z) \text{ will be } p_z(0) = 1, p_z(1) = 0.1, p_z(2) = 0.2, p_z(3) = 0.4, p_z(4) = 0.2, p_z(5) = 0.1, p_z(6) = p_z(7) = 0$$

We have to find out mapping function from  $r$  to  $z$ . First, we have to map from  $r$  to  $s$ , then  $s$  to  $z$ . For that, we have to find out the minimum value of  $z$ . For that we have to find out the minimum value of  $z$ .

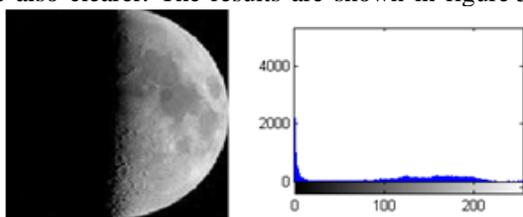
The mapping is showing in table 2.

**Table 2.**

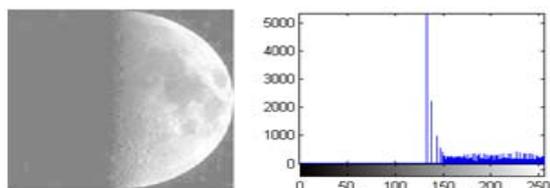
$r$	$p_r(r)$	$T(r) = \sum_{i=0}^r p_r(i) = S_k$	$t'$	$t$	$p_z(z)$	$G(z)$
0	0	0	0	0	0	0
1	0.1	0.1	1	1	0.1	0.1
2	0.1	0.2	2	2	0.2	0.3
3	0.3	0.5	3	3	0.4	0.7
4	0	0.5	3	4	0.2	0.9
5	0	0.5	3	5	0.1	1.0
6	0.4	0.9	4	6	0	1.0
7	0.1	1.0	5	7	0	1.0

#### 4. Results and Discussions

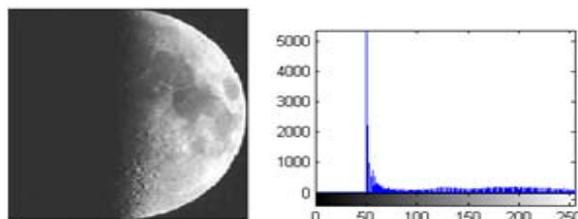
For darker image, the histogram will be spread on the left side while for brighter image, it will be on right side. Better the image better will be the histogram. For enhancement of poor contrast image, we can use the Histogram Equalization techniques. But in certain specific situation, the background is almost washed out. In such cases, we can use the Histogram Specification methods. In Histogram Specification, the target histogram which was specified was obtained using Histogram Equalization. On comparing two images, it is analyzed that in case of Histogram Specification the contrast of background is much more and details are also clearer. The results are shown in figure 5.



(a) Before histogram equalization



(b) After histogram equalization



(c) After histogram specification

**Figure 5. Comparison between Histogram Equalization and Histogram Specification**

#### 5. Conclusion

In this paper, we analyze two image enhancement techniques based on spatial domain approach. In Histogram Equalization, we generates a gray map which changes the histogram of an image and redistributing all pixels values to be as close as possible to a user-specified desired histogram. Histogram equalization allows for areas of lower local contrast to gain a higher contrast. In Histogram Specification, we have the input image, then the target histogram is specified, we have to process the image in such a way that the histogram of the processed image will be close to the target image. The result shows that Histogram Specification is better than Histogram Equalization as it makes details and background in the image clearer, in some specific situation.

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