A Comparative study of Image Enhancement using Histogram Approach

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ABSTRACT
This paper presents two methods of Image enhancement that improves the visual quality of image. In this paper, the authors compare two histogram techniques: Histogram Equalization and Histogram Specification. 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 specification is a technique to enhance certain regions of an image. A measure of enhancement (EME) based on contrast respect to transform is used as a tool for evaluating the performance of the enhancement techniques. The author implement and analyze the result of these two approaches based on EME using Image Processing Toolbox (IPT) and their performance evaluated on various images.

Keywords
Image Enhancement, Histogram equalization, Histogram Specification, EME.

1. INTRODUCTION
Image enhancement is the processing of image to enhance certain features 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 are operate directly on pixels. Frequency domain which operates on the Fourier transform of an image. The image enhancement can also be achieved using 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 [2]. An automatic exact histogram specification technique which aims at information maximization is also used for global and local contrast enhancement of images in which 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 [3]. This technique is also used on segmentation approach which emphasizes the flexibility of this image processing approach to do more than enhancing images [4]. A novel approach for contrast enhancement based on histogram equalization (HE) is also introduced and applies some preprocessing steps on the histogram corresponding to the image and then applies histogram equalization [6]. A "cumulation function"which is used to generate a grey level mapping from the local histogram to achieve a wide variety of effects is also used for image enhancement [7]. Numerous enhancement methods and some histogram processing techniques 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 [8]. A 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 [10]. The classical histogram specification technique is also extended 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 [11]. Image-dependent brightness preserving histogram equalization (IDBPHE) technique to enhance image contrast while preserving image brightness is also introduced [12]. Some annoying artifacts and unnatural enhancement due to Histogram Equalization is overcome by implementing different brightness preserving techniques and their Comparative analysis is done on the basis of subjective and objective parameters, Peak signal noise ratio (PSNR), Mean

squared error (MSE), Normalized Absolute Error (NAE), Normalized Correlation, Error Color and Composite Peak signal to Noise Ratio (CPSNR) [13]. To avoid saturation effect a novel Histogram Equalization (HE) called mean preserving bi-histogram equalization (BBHE) method with variable enhancement and separation intensity degree is also proposed [14]. Two measures $f1$ and $f2$ are also introduced 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 [15]. 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 is also proposed. By using this method, the speed of histogram equalization is dramatically improved, and the satisfactory enhancement results are also achieved [16-17].

This paper explains two approaches of image enhancement which includes Equalization and Specification techniques of Histogram method. This method gives better quality of image as compared to the original image. The evaluation and comparison are based on their respective EME values.

The work is organized as: In section 2, 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 3, we performed the experimental results and discussion based on Image Quality Measurement (EME) techniques. Finally, section 4 concludes the paper.

2. HISTOGRAM

Histogram is one of the fundamental techniques 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 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

$$h(r_k) = n_k \text{............ (1)}$$

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 (b) and its histogram

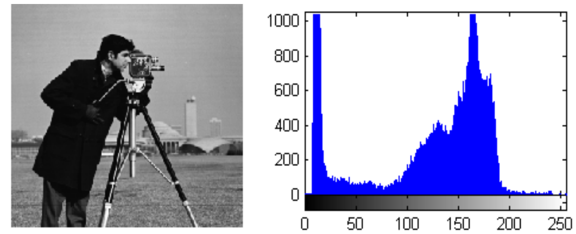


Fig 1: Image and its histogram

2.1 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

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

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.

2.2 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, it is assumed that *r* represents gray-level in an image and 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.

$$s = T(r) \text{ ………. (3)}$$

Where *r* represents original image, *s* represents processed image and $T(r)$ represents tansformed function on original image. This transformed function should satisfy two conditions: (1) $T(r)$is single valued and monotonically increasing on $0 \ll r \ll 1$ 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) $0 \ll T(r) \ll 1$ for $0 \ll r \ll 1$ i.e. processed image should have pixel value between minimum and maximum allowable range. From equation (3), we have

$$r = T^{-1}(s) \text{ ……….. (4)}$$

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, if $p_r(r)$ and $T(r)$ are known and $T^{-1}(s)$ are single valued and monotonically increasing then, the probability density function (PDF) of processed image is given by

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

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 $T(r)$. Consider a particular Transformation function.

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

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

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

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

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

From above equation, it is find that, if we take this particular Transform function which is Cumulative Distribution Function CDF) of r , then using this Transformation function , an image is generated which have uniform Probability Density Function (PDF) of intensity values of processed image which enhance the contrast of image. The probability of pixel having value r_k and the plot of $p(r_k)$ for different values of r_k , 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

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

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, some post processing have done so that all these s_k values are between 0 and 1 which can be dynamically mapped from 0 to 255 and mapping function given by

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

This value of s' will give intensity level in processed image from 0 to 255. Suppose r varies from 0 to 7 that is, r=0, 1, 2…….7 and similarly s=0, 1, 2 …….7. The value of $p_r(i)$ is given below. 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, Transformation function $T(r)$, which map the input image to the output image where the output image will be equalized. First we find the mapping function $T(r)$.

Table 1. Mapping of input image to output image using function $T(r)$.

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

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

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.

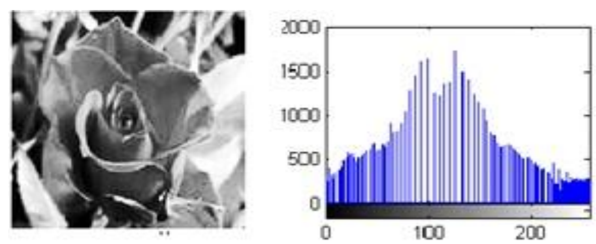


Fig 2. Image & its histogram after equalization

2.2.1 Limitation

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

2.3 Histogram Specification

It is also called *Histogram Matching*. The histogram equalization (HE) is not suitable for iterative image manipulation. If we enhance only certain region of the histogram then, we use histogram specification. We have the input image, then the target histogram is specified, we 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

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

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

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

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

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

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
   $$s_k = \sum_{i=0}^{k} \frac{n_i}{n} \ \ldots\ldots\ldots\ldots\ldots\ldots (16)$$
3. Obtain transformation function G from given
   $$v_k = G(z_k) = \sum_{i=0}^{k} p_z(z_i) = s_k \ .. (17)$$
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'.

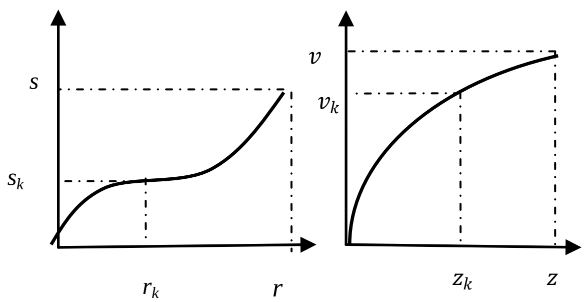


Fig 3. a) Forward Transformation b) Inverse transformation

We have to find out,

$$s_k \longrightarrow r_k \longrightarrow z_k \longrightarrow z_k$$

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

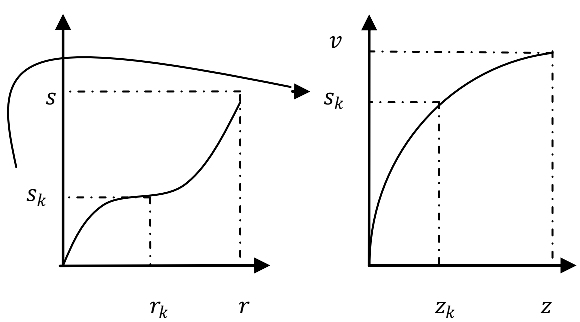


Fig 4. Iterative procedure to find out s_k from z_k

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.

$$v_k = G(z_k) = s_k \ \ldots\ldots\ldots\ldots (18)$$

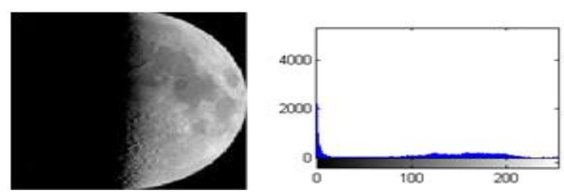
$$G(z_k) - s_k = 0$$

Here z_k is nearly equal to $\hat{z}$. It should satisfy $G(\hat{z}) - s_k \geq 0$. So, we increment value of $\hat{z}$ by 1 iteratively unless that condition met. For example, suppose $v \ and \ z$ varies from 0 to 7 that is, v =0, 1, 2, …………..7 and z = 0,1,2……………..7. The value of $p_r(r)$ is given. The probability when intensity value is 0, $p_r(0)$ = 0. Similarly, $p_r(1) = p_r(2) = 0.1$, $p_r(3) = 0.3$, $p_r(4)$, $p_r(5) = 0$, $p_r(6) = 0.4$, $p_r(7) = 0.1$. The value of Target Histogram, $p_z(z)$ will be $p_z(0) = 1, p_z(1) = 0.1, p_r(2) = 0.2, p_z(3) = 0.4, p_z(4) = 0.2$, $p_z(5) = 0.1$, $p_z(6) = p_r(7) = 0$ and we have to find out mapping function from $r \ to \ z$.

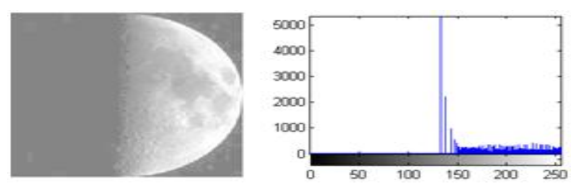
Table 2. Mapping of r to z using function $G(z)$

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

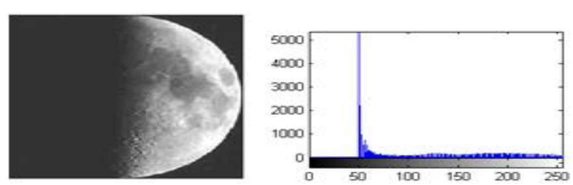
First, we have to map from $r \ to \ s$, then $s \ to \ z$.For that, we have the find out the minimum value of z.



(a) Before histogram equalization



(b) After histogram equalization



(c) After histogram specification

Fig 5. Comparison between Histogram Equalization and Histogram Specification

2.4 Performance measure of enhancement (EME)

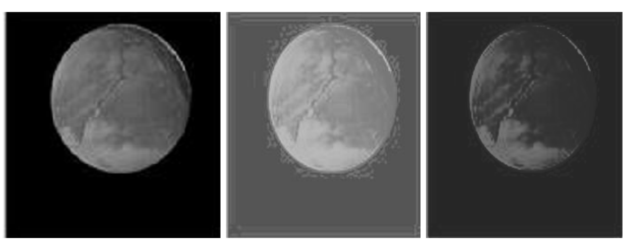
Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or a machine. The improvement in images after enhancement is difficult to measure. In practice, there are different methods to measure image performance. EME is one of such method to measure the quality (or contrast) of images and can be calculated as:

$$EME\ \alpha_1 k_1 k_2{}^{(\emptyset)} = \frac{1}{k_1 k_2} \sum_{l=1}^{k_1} \sum_{k=1}^{k_2} 20ln \frac{I^w \max k, l(\emptyset, par)}{I^w \max k, l(\emptyset, par) + c}$$

Where an image $x(n,m)$be split into $k_1 k_2$ blocks, $\emptyset$ is a given classical orthogonal transform, $\propto$ is an enhancement parameter, $I^w\ max{:}\,k,l$ and $I^w\ min{:}\,k,l$ are the maximum and minimum intensity value in a given block and c is a small constant equal to 0.0001 to avoid dividing by 0. $EME\ \alpha_1 k_1 k_2{}^{(\emptyset)}$ is called measure of enhancement or contrast measure with respect to transform $\emptyset$.

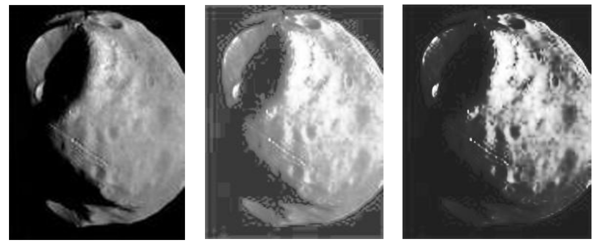
3. RESULTS AND DISCUSSIONS

For darker image, the histogram spread on the left side while for brighter image, it is on right side. Better the image, better the histogram. For enhancement of poor contrast image, Histogram Equalization techniques is used. But in certain specific situation, the background is almost washed out. In such cases, Histogram Specification is the best approach. In Histogram Specification, the target histogram which was specified was obtained using Histogram Equalization. The authors have taken different set of images and compare the results of both methods. It has observed that the contrast of background is more cleared and detailed in histogram specification as compare to histogram equalization.
The experimental results are shown in Table 3 using different images.



(i)Earth

(ii) Flower



(iii) Marsmoon

(iv) Cameraman

(v) Leaf

Fig 6. (a) Original image (b) Histogram equalization (c) Histogram specification

Table 3. EME of original image, histogram equalized image and histogram specification image.

Image	Original image	Histogram Equalization	Histogram Specification
Earth	3.4392	3.2910	5.4313
Flower	9.0342	13.9999	14.0115
Marsmoon	5.8159	5.3077	6.3651
Cameraman	10.2968	13.0249	15.2700
Leaf	10.3795	10.9957	13.2694

Table (3) gives quantitative measure of image enhancement with respect to EME as a measure of enhancement. From table (3) it has observed that original Flower image has EME value of 9.0342. After histogram equalization, EME becomes 13.9999 and after applying histogram specification increases to 14.0115 which is higher than others. Also for other images the both histogram equalization and histogram specialization gives better results for image enhancement and the resultant images becomes clearer than the original. The contrast of background of

Histogram Specification is more detailed as compare to histogram Equalization.

4. CONCLUSION

In this paper, the author analyzes two image enhancement techniques based on spatial domain approach. Histogram Equalization 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, input image has given, and then the target histogram is specified, image has processed in such a way that the histogram of the processed image will be close to the target image. The author evaluated and compared these two methods based on their EME values. The experimental results show that Histogram Specification is better than Histogram Equalization because the images are more cleared and the background is more detailed.

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