A Comparative Investigation of Different Image Enhancement Techniques Using Histogram Equalization

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Abstract: ***To Improve contrast and preserving brightness is the most important task when enhancing the quality of a digital image by using histogram equalization technique. A number of brightness preserving techniques are developed and applied in digital images. Each technique has its own degree of excellence. Only one technique cannot be used in all types of digital image. Image can be clicked in different environment and conditions. So, on the basis of the quality of image, a specific technique is selected. But how to select the right technique to enhance the quality of image is the important question. To solve the problem, in this paper the most useful and popular techniques are compared on the basis of certain parameters so that the most suitable technique can be sorted out for the image of interest. Therefore, four such techniques based on Histogram Equalization viz CHE (Conventional Histogram Equalization), BBHE (Brightness Preserving Bi-Histogram Equalization), DSIHE (Dual Sub-Image Histogram Equalization) and MMBEBHE (Minimum Mean Brightness Error Bi-HE), are compared. For quantitative comparison four mathematical quantities i.e. PSNR, MSE, Entropy and AMBE are measured.***

Keywords: Histogram Equalization, Thresholding Technique, Brightness, PSNR, MSE, Entropy, AMBE.

1. Introduction

Imagine a situation where CCTV cameras are installed inside and outside a jewelry shop. Some thief, with mask on their face, come in a car and enter into the shop. They rob the shop and run away. Now to catch them red handed the police need to check the cctv footage of outside camera to look for the number plate of the car. We know that sometimes due to improper light condition or too much light the area of interest is not very visible. In these situations, a powerful technique called "Image Enhancement" is used to improve the quality of image and make it more visible. This was just one example; the image enhancement techniques are used in many such applications where the clear visibility of digital image is required. Therefore, Image Enhancement is a very important and challenging area in image processing. It is a very useful method to enrich the visual quality of the image. Many image enhancement techniques have been discovered for such purpose in the spatial domain and frequency domains. In spatial domain image pixels are examined and their values are changed to obtain the desired enhancement whereas in frequency domain techniques, the frequency transform domain coefficients are modified [1]. Each of these techniques has their own advantages over one another. For effective and desired result the most suitable technique must be used. In this paper CHE (Conventional Histogram Equalization), BBHE (Brightness Preserving Bi-Histogram Equalization) [2], DSIHE (Dual Sub-Image Histogram Equalization) [3] and MMBEBHE (Minimum Mean Brightness Error Bi-HE) [4] are compared. All these techniques are based on the principle of splitting of histogram in two or more parts and then equalize them separately. To enhance Digital Images, Histogram Equalization is very simple and most widely used Image Enhancement Technique [5]. The Histogram of a digital image with intensity levels in the range [0, L-1] is a discrete function h(rk) = nk, where rk is kth intensity value and nk is the number of pixels in the image with intensity rk. The operation of HE is achieved by rearranging the gray levels of the image based on the probability distribution of the input gray levels [6]. But the drawback of histogram equalization is that it just scattered the pixels in entire grey level range. After HE each gray level has almost equal number of pixels and therefore for all types of images the mean is fixed as the middle gray level. Due to this the contrast of those images whose background is either very bright or very dark, changes exceedingly.

To keep the mean near its original position is very important to enhance the quality of image as desired. Hence, to overcome this issue some techniques are developed by researchers to enhance contrast and at the same time to preserve brightness also. These techniques are Brightness Preserving Bi-histogram Equalization (BBHE), Dualistic sub-image histogram equalization (DSIHE) and Minimum Mean Brightness Error Bi-histogram Equalization (MMBEBHE). In BBHE the histogram of input image is divided into two equal parts based on input mean. The input mean is called threshold point. Each part is then equalized separately and the above problem of brightness preservation is resolved [7]. In DSIHE input image's histogram is separated in two parts from the point where each part has equal area or image pixels. MMBEBHE is the novel extension of BBHE that provides maximum brightness preservation. These techniques are upgraded version of conventional histogram equalization, which utilize separate equalizations of sub-images obtained by decomposing the input image [8].

2. Quality Measures

Mean Square Error (MSE):

MSE is used to assess the image quality. The lower the value of MSE the better will be the image quality. Assuming that N is the total number of pixels in the input and output image, MSE (Mean Squared Error) is calculated through equation [9]:

$$\text{MSE} = \frac{\sum_i \sum_j |X(i,j) - Y(i,j)|^2}{N}$$

Peak Signal To Noise Ratio (PNSR)

PSNR is calculated to quantitatively assess the degree of contrast enhancement. The greater the value of PSNR the better will be the image quality. It is important to keep PSNR high to avoid the generation of non-existing artefacts in the output image [9].

Based on MSE, PSNR is then defined as below:

$$\text{PSNR} = 10\log_{10}\frac{(L-1)^2}{MSE}$$

Entropy:

Entropy is chosen as a measure of the details reflected by image. Low entropy indicates that little information can be derived from the image. So entropy provides a comparison of images results from different technique and decides which provides the most details. It is a useful tool to measure the richness of details in the output image [9].

For a given PDF p, entropy Ent [p] is computed as follows. In general, the entropy is a useful tool to measure the richness of the details in the output image.

$$Ent[p] = -\sum_{k=0}^{L-1} p(k)\log_2 p(k)$$

Absolute Mean Brightness Error (AMBE):

AMBE is used to measure image brightness. It is defined as the absolute difference between the input and the output mean. For an input image X and output image Y it is given as:

AMBE = |Xm - Ym|

Where
Xm - Mean of input image.
Ym - Mean of output image.
Lower AMBE implies better brightness preservation. So the lower the AMBE the better will be the image quality [4].

3. Image Thresholding

In this technique, the pixels below a threshold value say m are assigned gray scale value 0 and above or equal to threshold value is assigned gray scale value 255. The selection process is usually called thresholding.

S= 0 if r < m
= 255 if r ≥ m

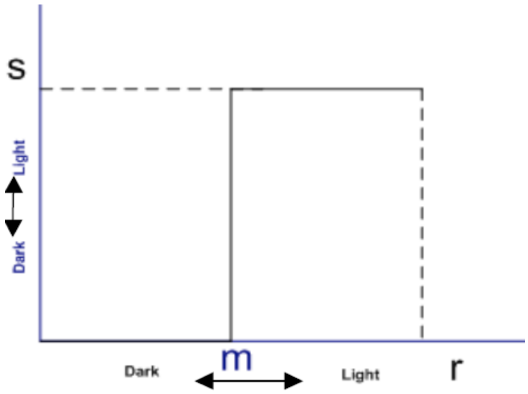
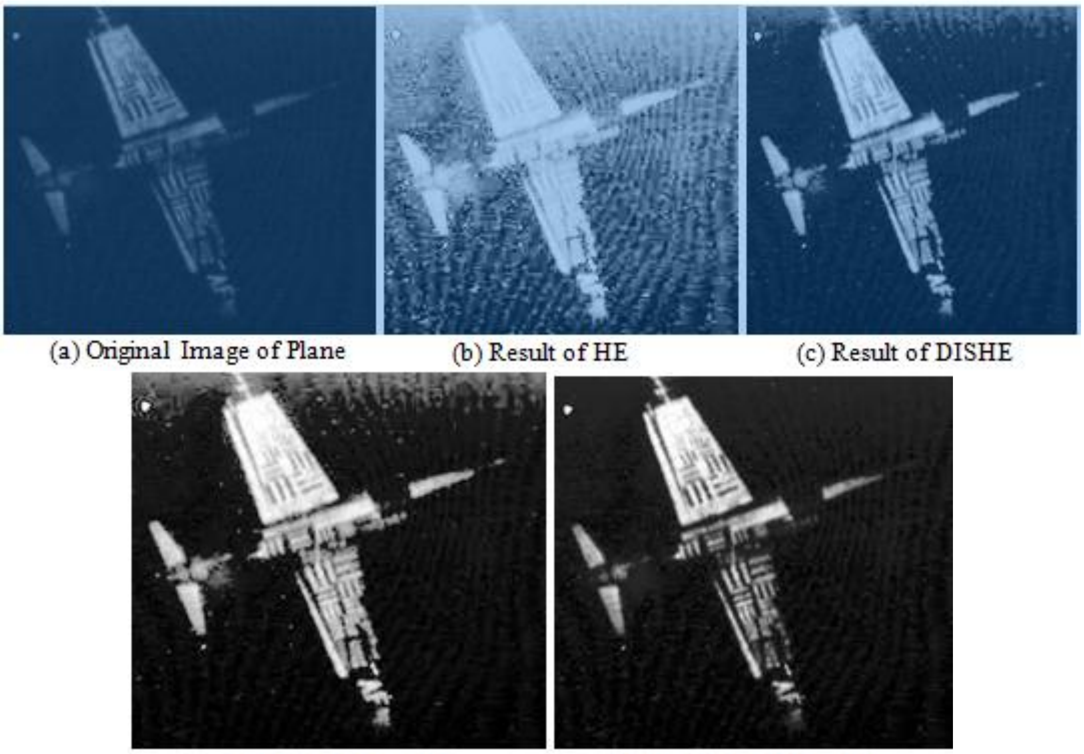


Figure 1: Image Thresholding

In most applications of image processing, gray levels belonging to the target are considerably contrary from the gray levels belong to the background. Thresholding then becomes a simple but effective tool to separate objects from the background [10]. Some Examples are document image analysis, where the aim is to obtain printed characters; symbols, graphical content or musical scores, where lines legends and characters are to be found; scene processing, where an object is to be detected. The output of the thresholding operation is a binary image.

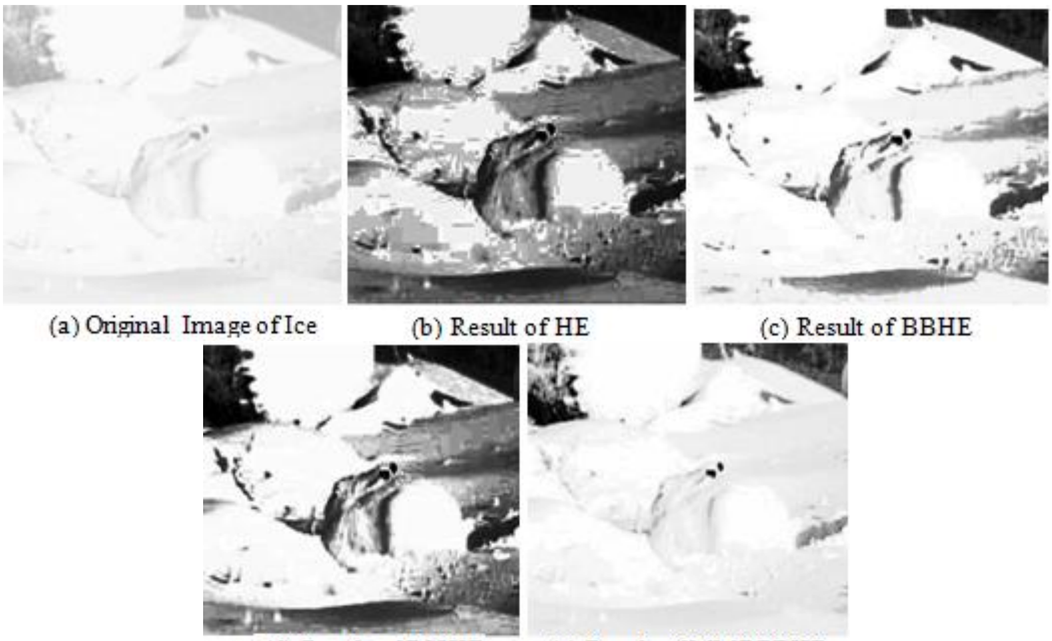
4. Result and Discussion

The previous sections described methods which use Histogram Equalization for preserving the brightness of gray-level images and also enhance the contrast. Now Figures below shows for the input images, the output images. These methods are experimented on 2 images. Four quality measures have been used to access the image quality. Here, the goals are: brightness preserving and contrast enhancement. So AMBE is used to assess the degree of brightness preservation, while MSE, PSNR and Entropy are calculated to quantitatively assess the degree of contrast enhancement. In addition, to assess contrast enhancement qualitatively, output images are visually inspected and see if it keep back an image which is quite natural. So first we assess these techniques qualitatively and then quantitatively. The main aim of the qualitative assessment is to see if the output image is visually reasonable to eyes and has an inherent appearance. In order to demonstrate the performance of the proposed algorithm, simulation results of HE, BBHE, DISHE and also MMBEBHE for images Ice and Plane.



(a) Original Image of Plane (b) Result of HE (c) Result of DISHE
(d) Result of DSIHE (e) Result of MMBEBHE

Here Image Plane is chosen as the representative of images with low mean brightness (dark background). Notice that unpleasant artefacts (noise in white color) due to excessive increment in brightness in the image from HE (fig. b), BBHE (fig. c), and DSIHE (fig. d) is not seen at all in the results of MMBEBHE (fig. e). The simulation results clearly show that the MMBEBHE algorithm outperforms the typical histogram equalization in points that it preserves the mean brightness of a given image. While enhancing the contrast, and consequentially it results in more natural enhancement.



(a) Original Image of Ice (b) Result of HE (c) Result of BBHE
(d) Result of DSIHE (e) Result of MMBEBHE

Image Ice is chosen as the representative of images with high mean brightness (bright background). Observe that resulting images of HE (fig. b), BBHE (fig. c) and DSIHE (fig. d) have mean brightness much darker compared to the original image and hence, results in unnatural contrast enhancement. Result from MMBEBHE (fig. e) clearly shows that the proposed algorithm has increased the brightness preservation (brighter mean brightness) and yielded a more natural enhancement.

A. Assessment of Contrast Enhancement

Table 1 shows values of MSE and Table 2 shows values of PSNR of different image and for different techniques.

Table 1: Mean Square Error (MSE)

Image	HE	BBHE	DSIHE	MMBEBHE
Ice	17567	4030	9028	**1180**
Plane	1387	1980	2224	**748**

We know that the greater the PSNR, the better the image quality and the lower the value of MSE better is the image. MMBEBHE method makes the highest scores in all test images for MSE and PSNR. A matrix of entropy values are given in Table 3. In general, the higher the entropy is, the richer details and information the image holds.

Table 2: Peak Signal to Noise Ratio (PSNR)

Image	HE	BBHE	DSIHE	MMBEBHE
Ice	5.68	12.07	8.57	**17.41**
Plane	6.7	15.16	14.66	**19.38**

A careful examination of the entropy values reveals that HE method produces good comparative results in both images.

Table 3: Entropy

Image	HE	BBHE	DSIHE	MBEBHE
Ice	**6.89**	5.84	6.54	5.35
Plane	**7.83**	6.45	6.52	6.27

B. Assessment of Brightness preservation

Table I shows a matrix of AMBE values, where rows correspond to 2 test images and columns correspond to 4 HE-based methods. Here, MMBEBHE method produces the minimum values for AMBE for both images.

Table 4: Absolute Mean Brightness Error (AMBE)

Image	HE	BBHE	DSIHE	MBEBHE
Ice	111	31	72	**12.748**
Plane	97	17	20	**6.64**

For this image BBHE gives the lower AMBE. MMBEBHE gives the best results. Based on these observations, we can say that MMBEBHE method is the best brightness preserving method.

5. Conclusion

It is noticed that the cases, such as in Plane and Ice images where the background is completely dark or bright, that are not handled well by HE, BBHE and DSIHE. These images generally require higher degree of brightness preservation to avoid annoying artifacts. MMBEBHE provides better brightness in these cases. The main idea lies on separating the histogram using the threshold level that would yield minimum Absolute Mean Brightness Error (AMBE). The ultimate goal behind the MMBEBHE is to allow maximum level of brightness preservation in Bi-Histogram Equalization to avoid unpleasant artifacts and unnatural enhancement due to excessive equalization while enhancing the contrast of a given image as much as possible. MMBEBHE demonstrate comparable performance with HE, BBHE and DSIHE both by quantitatively and qualitatively.

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