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IMAGE ENHANCEMENT TECHNIQUES BASED ON HISTOGRAM EQUALIZATION

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ABSTRACT
Histogram equalization (HE) is one of the common methods used for image enhancement. Histogram equalization (HE) has proved to be a simple and effective image contrast enhancement technique. This paper presents a review of new forms of histogram for image enhancement. The major difference among the methods in this family is the criteria used to divide the input histogram.

INTRODUCTION
The main purpose of image enhancement is to enhance or improve the quality of image with the minimum amount of MSE. Various enhancement techniques are used for this purpose both in spatial domain and frequency domain. This paper emphasizes mainly on spatial domain technique of image enhancement. The histogram equalization is the most commonly used technique for contrast enhancement and brightness preservation of the image. There are various techniques used to equalizes the given image's histogram such as BBHE, DSHIE, MMBEBHE, BBPHE, CLAHE,BHEGF. In all these technique the image have to first decomposed and then the histogram of each part generated from the decomposition is equalized. That is also known as the segmentation of an image into various sub-images[9]. Most images require only object enhancement while retaining the background, especially when these two parts are well-separated. However, the background is always over-enhanced owing to extremely high density as compared to objects, and thus objects are insufficiently enhanced. The brightness preserving bi-histogram equalization (BBHE) was proposed to preserve the image brightness by decomposing the image into two based on the input mean. The sub-images are then independently equalized and combined into the output image. the dualistic sub-image histogram equalization (DSHIE) to segment the image into two based on a CDF of 0.5 instead of the mean value so that the output image can yield the highest entropy based on information theory. The BBHE is improved by minimum mean brightness error bi-histogram Equalization (MMBEBHE) where the image is decomposed based on the grey level that yields minimum absolute mean error between the input and output images. However, the shift of background brightnessis still obvious for these methods. In this Letter, a method using nonlinear histogram equalization, namely background brightness preserving histogram equalization (BBPHE), is proposed not only to enhance the image contrast, but also to preserve the background brightness [8]. Adaptive Histogram Equalization (AHE) It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image. Contrast Limited Adaptive Histogram Equalization (CLAHE) CLAHE differs from ordinary AHE in its contrast limiting. CLAHE was developed to prevent the over amplification of noise.Histogram equalization is one of the most common technique used for contrast enhancement[4]. While stretching the contrast of an image, it results in the degradation of brightness of the image. To overcome this hurdle a method known as Bi-Histogram equalization was introduced to preserve the brightness level of the output image [9].

IMAGE ENHANCEMENT
Image enhancement techniques improve the quality of an image as perceived by human. Generally image enhancement techniques are used to get detail that is obscured, or to highlight certain features of interest in image. In image enhancement process one or more attributes of image are modified [2]. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image. Whenever an image is converted from one form to other such as digitizing the image some form of degradation occurs at output [4].
Image enhancement techniques may be grouped as either subjective enhancement or objective enhancement. Subjective enhancement techniques may be repeatedly applied in various forms until the observer feels that the image yields the details necessary for particular application.

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On the other hand objective image enhancement corrects an image for known degradation. This enhancement is not repeatedly applied but it is applied only once based on the measurement taken from the system.[7]
Image enhancement can also be categorized into two main and broad categories. They are as follows:

i. **Spatial Domain Technique**:
Spatial domain refers to the Image Plane itself and approaches in this categories are based on direct manipulation of pixels in an image. Histogram equalization techniques are one of the spatial domain image enhancement techniques, which has form the basis in this paper. This technique refers to the aggregate of the pixels composing an image. This process will be denoted by the expression given below.

$$A(x, y) = T(f(x, y)) \qquad (1)$$

Where f(x,y) is input image , g(x, y) is processed image and T is an operator on f, given g(x ,y) = A(x, y).

ii. **Frequency Domain Technique**:
Frequency domain processing techniques are based on modifying the Fourier transform of an image [2]
The paper is organized as follows: HE for digital input image is reviewed together with their mathematical formulation and BBHE, DSIHE, MMBEBHE, BBPHE in section III. Contrast Limited Adaptive Histogram Equalization (CLAHE) will be presented in section IV. Section V. includes the Brightness Bi-Histogram Equalization Technique Using Gaussian Filter. Paper concludes with Section VI containing discussion of various Histogram Equalization techniques

HISTOGRAM EQUALIZATION

A very popular technique for image enhancement is histogram equalization (HE). This technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images. The operation of HE is performed by remapping the gray levels of the image based on the probability distribution of the input gray levels. It flattens and stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement [3].

Consider an input image A having total pixels n and K grey levels. The input probability
Density function (PDF), $p(X_k)$, is defined as

$$p(X_k) = \qquad (2)$$

for$k = 0, 1, \ldots, K-1$, n_k is the total pixels at X_k level and $X_k\{X_0, X_1, \ldots, X_{K-1}\}$. The input cumulative density function (CDF), $c(X_k)$, is then obtained by

$$c(X_k)= \qquad (3)$$

By definition, $c(X_{K-1})= 1$. The transform function is obtained from theinput CDF by

$$f(X_k)= X_0 + (X_{K-1} - X_0)c(X_k) \qquad (4)$$

The output image of the HE, B, can then be expressed as

$$B=f(X_k) \qquad (5)$$

For a normal grey-scale image, K=256 and k=0, 1, . . ., 255. For processing, an image is always normalized into the range [0, 1]. [8]

Histogram equalization technique does not preserve the brightness of images, so because HE technique is a global operation. When brightness preservation is important and necessary, this property is not a desirable one in certain applications [7].

A. Conventional Histogram Equalization (CHE):

Histogram equalization technique enhances the contrast of an image but it tends to change the brightness of image that means it does not preserve the brightness of images so because CHE stretches higher density grey levels more than low density grey levels[7].

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B. The Brightness Preserving Bi-histogram Equalization (BBHE):

BBHE firstly separate the input image's histogram into two based on its mean one having range from minimum gray level to mean and the other ranges from mean to maximum gray level. Next it equalizes the two histograms independently.

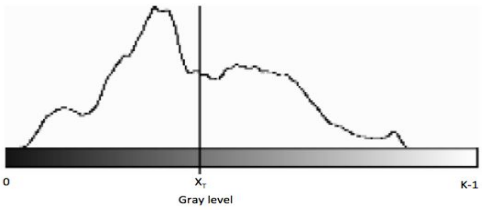

Figure1.Bi-histogram equalization.

The histogram with range from 0 to *K- 1* is divided into two parts, with separating intensity X_T. This separation produces two histograms. Thefirst histogram has the range of 0 to X_T, while the secondhistogram has the range of X_{T+1} to *K -1*[1]. It has been analyzed both mathematically and experimentally that this technique is capable to preserve the original brightness to a certain extend [7].

C. Dualistic Sub-image Histogram Equalization(DSHIE):

Following the same basic ideas used by the BBHE method of decomposing the original image into two sub-images and then equalize the histograms of the sub-images separately. The dualistic sub-image histogram equalization (DSHIE) to segment the image into two based on a CDF of 0.5 instead of the mean value so that the output image can yield the highest entropy based on information theory[8]. it is shown that the brightness of the output image O produced by the DSIHEmethod is the average of the equal area level of the image I and the middle gray level of the image, i.e., K / 2 . the brightness of the output image generated by the DSIHE method does not present a significant shift inrelation to the brightness of the input image, especially for the large area of the image with the same gray-levels (represented by small areas in histograms with great concentration of gray levels), e.g., images with small objects regarding to great darker or brighter backgrounds[1].

D. Minimum Mean Brightness Error Bi-histogram Equalization (MMBEBHE):

BBHE is improved by minimum mean brightness error bi-histogram Equalization this method can preserve brightness better than BBHE and DSIHE. Still following the basic principle of the BBHE and DSIHE methods of decomposing an image and then applying the HEmethod to equalize the resulting sub-images independently. The main difference between the BBHE and DSIHE methods and the MMBEBHE one is thatthe latter searches for a threshold level l_t that decomposes the image *I* into two sub-images *I* $[0, l_t]$ and *I* $[l_t +1, K - 1]$, suchthat the minimum brightness difference between the input image and the output image is achieved, whereas the former methods consider only the input image to perform the decomposition.

Once the input image is decomposed by the threshold Level l_t, each of the two sub-images *I* $[0,l_t]$ and *I* $[l_t+1, K-1]$ has its histogram equalized by the classical HE process, generating the output image[1].

E. Background Brightness Preserving Histogram Equalization (BBPHE):

The density of background levels is normally much higher than the other levels, especially for plain images, the total density of background levels can be more than half of the total pixels. Therefore, BBPHE decomposes the input image into sub-images based on background levels and non-background levels range. After that, each sub-image is equalized independently, and then combined into the final output image. In this way, the background levels are only stretched within the original range, hence, the over enhancement can be avoided. Also, although other sub-images contain only comparatively low density grey levels, BBPHE is able to expand them into a wider range due to normalization. Hence, this will provide adequate enhancement on the image.

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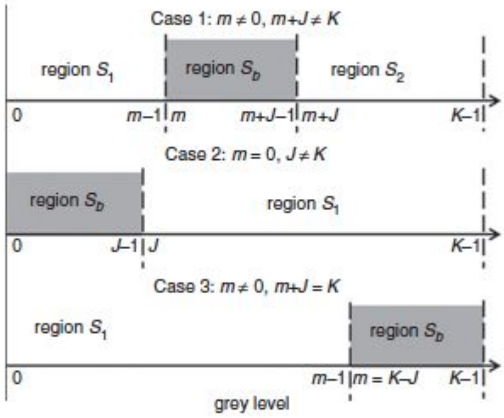

Figure 2 Decomposition of image into sub-images based on background levels for different cases

Consider an input image A having global background in a continuous range of *J* grey levels between the input *K* grey levels, where

J<K, and there are *m* levels before the background levels, hence there are *K-m -J* levels after the final background level X_{m+J-1}. Let X_b be the background level, the image is then divided into three sub-images S_1, S_2,and $S_b$as

$A=S_1S_bS_2$ (6)

where$S_1 = \{X \leq X_{m-1}\}$, $S_b = \{X_m \leq X \leq X_{m+J-1}\}$,

$S_2 = \{X_{m+J} \leq X \leq X_{K-1}\}$,$m$ 0,$m + J$K, and $Xb\{X_m, Xm+1, . . . , X_{m+J-1}\}$.

$S_1$and $S_2$are the sub-images of non-background levels, and S_b is the sub-image of background levels. The PDFs of the sub-images S_1, S_2,and S_b are then defined as

$p_1(X_k)=$ (7)

for$k = 0, 1, ...,m - 1$,

$p_b(X_k) =$ (8)

for$k =m, m + 1, . . ., m + J -1$, and

$p_2(X_k)=$ (9)

for k = m + J ,m + J + 1, . . . , K − 1, where n_k is the respective total of pixels at X_k grey level in each sub-image, and n_1, n_2, and n_b are the respective total of pixels in S_1, S_2,and S_b .The respective CDFs arethen obtained by

$c1(X_k) =$ (10)
$cb(X_k) =$ (11)
$c2(X_k) =$ (12)

In fact, $c_1(X_{m-1}) = c_b(X_{m+J-1}) = c_2(X_{K-1}) = 1$. Similar to the CHE,the transform functions of S_1, S_2,and $S_b$can be separately defined as

$f_1(X_k) = X_0 + (X_{m-1} - X_0)c1(X_k)$ (13)
$f_b(X_k) = X_m + (X_{m+J-1} - X_m)cb(X_k)$ (14)
$f_2(X_k) = X_{m+J}+ (X_{k-1} - X_{m+J})c2(X_k)$ (15)

The output image B can be expressed as

$B = f1\ fb\ f2$ (16)

The above calculations are for Case 1 where the background levels lie within the full grey level range. There are two special cases where the

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background level either starts from X_0 or ends at X_{k-1}, then the input image is decomposed into two sub-images S_l and S_b instead of three. The output image $B = fl\ \ fb$ is obtained by similar steps to Case1 but with different boundary conditions as in the following:

Case 2: A=S_b S_l, where $S_b = \{X \leq X_{J-1}\}$, S_l= $\{X_J \leq X \leq X_{K-1}\}$,$m = 0$, $J\ K$, and X_b starts from X_0, hence, X_b[$\{X_0, X_1, \ldots, X_{J-1}\}$

Case 3: $A = S_l\ S_b$, where S_l= $\{X \leq Xm-1\}$, $S_b = \{X_m \leq X \leq X_{m+J-1}\}$ $m\ 0$,$m + J = K$, and X_b ends at X_{K-1}, hence, $X_b\{X_m, X_{m+1}, \ldots, X_{m+J-1}\}$

In this paper BBPHE technique is compared to the CHE, BBHE, DSIHE and MMBEBHE for evaluation. However, BBPHE outperforms the other four where the background brightness is well preserved. This can be seen by comparing the histograms, where the backgroundlevels in are excessively stretched in the other four methods, causing over-enhancement. The proposed BBPHE solves this problemby maintaining the background levels in the same intervals, and hence is able to adequately expand the non-background levels[8].

CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION(CLAHE)

CLAHE differs from ordinary AHE in its contrast limiting. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization can give rise to This is achieved by limiting the contrast enhancement of AHE.

This method consist the following steps:

1. **Obtain all the inputs:**

Image, Number of regions in row and Column directions, Number of bins for the histograms used in building image transform function (dynamic range), Clip limit for contrast limiting (normalized from 0 to 1)

2. **Pre-process the inputs:**

Determine real clip limit from the normalized value if necessary, pad the image before splitting it into regions

3. **Process each contextual region (tile) thus producing gray Level mappings:**

Extract a single image region, make a Histogram for this region using the specified number of bins, clip the histogram using clip limit, create mapping for this region

4. **Interpolate gray level mapping in order to assemble final CLAHE image:**

Extract cluster of four neighboring mapping Functions, process image region partly overlapping each Of the mapping tiles, extract a single pixel, apply four Mappings to that pixel, and interpolate between the results to obtain the output pixel; repeat over the entire image[4].

BRIGHTNESSBI-HISTOGRAM EQUALIZATION TECHNIQUE USING GAUSSIAN FILTER

When we enhance an image by using contrast enhancement techniques, it also enhances the noise in the signal that causes the blurriness in the output image.The BHEGF method reduces this drawback and provides more accurate and realistic results. In BHEGF the input image is decomposed into sub–images by using the threshold gray level which is selected on the basis of image mean gray level. Then apply the HE method on each of the sub – image's histogram to map the values into the new dynamic range and normalizes the brightness of the image. There is an enhancement also in the noise of the image, so for the reduction of the noise and to obtain the more accurate information. In this paper, the comparative studies has done among the performance of the four most prominently used filters along with contrast enhancement and brightness preservation. The filters used in this paper are Median filter, Gaussian filter, Average filter and Motion filter along with the multi – histogram equalization technique

This method consist the following steps:

- Decomposing the image into sub images using its threshold value.

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- Stretches the contrast and preserve the brightness of the image by using histogram equalization which flattens and stretches dynamic range of histogram of the image .
- Filtering process can be done using median filter on the stretched image.
- Now apply the Gaussian filter to reduce the Gaussian noise .
- Further apply average filter to the stretched image .
- Lastly apply motion filter to the stretched image.
- At the last step compare the results and brightness measurements come from the above filters and multi histogram equalization technique on the basis of brightness count , MSE count and PSNR values. This paper conclude that the Gaussian filter gives much better results in comparison to all other filters in the case of satellite images when applied with BBHE . In other words the MSE count is much lesser with Gaussian filter compared to other one and it also gives a very good PSNR count. This will be very good results with both gray scale and color images [9].

DISCUSSION

The main objectives of contrast enhancement include enhancing the objects while simultaneously maintaining the background brightness. In this Letter, a new histogram equalization method by decomposing the input image based on the background and non-background levels .This method is capable of enhancing the objects while preserving the background brightness. The comparative study of Histogram Equalization based methods shows that The BBPHE can preserve the background brightness better than HE,CHE BBHE, DSIHE, MMBEBHE.
Another image enhancement schemes like Contrast limited Adaptive Histogram Equalization (CLAHE), CLAHE techniques provide very good result for medical image Enhancement and face identification methods based on CLAHE[4].As the contrast enhancement enhances the image , it also enhances the noise in the signal that causes the blurrness in the output image. The BHEGF method reduces this drawback and provides more accurate and realistic results..

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