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A Novel Brightness Preserving Histogram Equalization Technique for Image Contrast Enhancement

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Abstract: ***A histogram is a graphical representation of the distribution of data in an image. It is an estimate of the probability distribution of a continuous variable (quantitative variable). Histogram Equalization is a contrast enhancement technique in the image processing which uses the histogram of image. However histogram equalization is not the best method for contrast enhancement because the mean brightness of the output image is significantly different from the input image. There are several extensions of histogram equalization has been proposed to overcome the brightness preservation challenge. Contrast enhancement using brightness preserving bi-histogram equalization (BBHE) which divides the image histogram into two parts based on the input mean and median respectively then equalizes each sub histogram independently. This research paper aims at providing the results of the algorithms of image enhancement techniques like Brightness Preservation Bi-Histogram Equalization (BBHE), Brightness Preserving Dynamic Histogram Equalization (BPDHE) and Combined Approach and determine the best one for image enhancement. The comparison of these techniques is done on the basis of different applications like medical imaging, consumer electronics etc. and for evaluation of these techniques, various performance parameters are calculated like Mean Square Error (MSE), Normalized Absolute Error (NAE), Correlation, Peak Signal to Noise Ratio (PSNR) and Correlation for gray scale images. These are the objective measures of evaluation and the subjective evaluation is done on the basis of Visual Quality of the images. All the enhancement techniques are implemented using MATLAB-2015 and its image processing toolbox. Enhancement techniques are applied on images of different size like 512×512, 256×256, etc and from different application fields like real images, medical images and consumer electronics images.***

Keywords: histogram equalization, image enhancement, mean square error, peak signal to noise ratio

1. Introduction

The contrast enhancement technique is used with an objective to obtain a new enhanced image with a uniform histogram. This can be achieved by using the normalized cumulative histogram as the grey scale mapping function. The intermediate steps of the histogram equalization process are the histogram and the normalized cumulative histogram. Using the normalized cumulative histogram as a color table of the original image, we obtain the histogram equalized image. The histogram of an image represents the relative frequency of occurrence of gray levels within an image. It also represents the probability of such an occurrence. With a narrow distribution of gray levels, the contrast in the image will be low and the dynamic range limited. Hence, a good gray level assignment scheme would be to expand the intensity range to fill the whole dynamic range available. The probability of occurrence of all gray levels should be equal or uniform. In histogram equalization, the goal is to obtain a uniform histogram distribution for the output image, so that an optimal overall contrast is perceived. It increases the local contrast of images when the usable data of the image is represented by close contrast values.

By using the histogram equalization, the intensities can be better distributed on the histogram. This allows for areas of lower local contrast to gain a higher contrast without affecting the global contrast. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. The effect of promising HE on an image is to produce a uniform distribution of gray levels in an image. The equalization process spreads out the peaks in an image and while compressing the range of intensities in regions of the histogram that have relatively few pixels. The histogram represents the relative frequency of occurrence of the various gray levels in an image. Equalization provides a way to enhance minor intensity variations in an apparently uniform image-method to emphasize dim features.

2. Literature Survey

Adaptive Histogram Equalization (AHE) was proposed by *Charles W. Kurak Jr. in 1997* [1]. It is an excellent contrast enhancement method for both natural images and medical and other initial non visual images. In medical imaging, its automatic operation and effective presentation of all contrast available in the data make it a competitor to the standard contrast enhancement method, interactive intensity windowing. For certain class of images, intensity windowing has no significant advantages in local contrast presentation in any contrast range, while AHE has advantages of being automatic and reproducible, and requiring the observer to examine only a single image. In AHE, the method involves applying to each pixel the histogram equalization mapping based on the pixels in a region surrounding that pixel (its contextual region). That is, each pixel is mapped to intensity proportional to its rank in the pixels surrounding it. But the basic method is slow.

Brightness Preserving Bi-Histogram Equalization (BBHE) was proposed by *Yeong-Taeg Kim in 1997* [2]. This method divides the image histogram into two parts. In this method, the separation intensity X_T is presented by the input mean brightness value, which is the average intensity of all pixels that construct the input image. After this separation process, these two histograms are independently equalized. By doing this, the mean brightness of the resultant image will lie between the input mean and the middle gray level. Histogram equalization is widely used for contrast enhancement in a variety of applications due to its simple function and effectiveness. This technique is used to overcome the drawback of HE. The resulting equalized sub images are bounded by each other around the input mean. It will be shown mathematically that the proposed algorithm preserves the mean brightness of a given image significantly well compared to typical histogram equalization while enhancing the contrast and, thus, provides much natural enhancement that can be utilized in consumer electronic products.

Quantized Bi-Histogram Equalization was proposed by *Yeong-Taeg Kim in 1997* [3]. As an effort to overcome drawback of typical HE, for extending the applications of the Histogram equalization in consumer electronic products, bi-histogram equalization is capable of preserving the mean brightness of an image while it performs contrast enhancement. The essence of the bi-histogram equalization is to utilize independent histogram equalizations separately over two sub images obtained by decomposing the input image based on its mean. In is a simplified version of the bi-histogram equalization, which will be referred to as the quantized bi-histogram equalization. The proposed algorithm provides much simple hardware structure than the bi-histogram equalization since it is based on the cumulative density function of a quantized image. Thus, the realization of bi-histogram equalization in hardware can be much feasible, which leads to versatile applications in the field of consumer electronics.

Multipeak Histogram Equalization with Brightness Preserving (MPHEBP) was proposed by *K. Wongsritong in 1998* [4]. In this scheme, the histogram is first smoothed with one dimensional smoothing filter. Then, the histogram is divided based on the local maximums of the smoothed histogram. From here, the number of sub-histograms is dependent to the number of the local maximums. Each sub-histogram is then independently equalized using histogram equalization. Wongsritong et al claimed that the performance of MPHEBP in maintaining the mean brightness is better than BBHE.

Brightness Preserving Dynamic Histogram Equalization was proposed by *Haidi Ibrahim, Nicholas Sia Pik Kong (BPDHE) in 2007* [5]. This method is actually an extension to both MPHEBP and DHE. Similar to MPHEBP, the method partitions the histogram based on the local maximums of the smoothed histogram. However, before the histogram equalization taking place, the method will map each partition to a new dynamic range, similar to DHE. As the change in the dynamic range will cause the change in mean brightness, the final step of this method involves the normalization of the output intensity. So, the average intensity of the resultant image will be same as the input. With this criterion, BPDHE will produce better enhancement compared with MPHEBP, and better in preserving the mean brightness compared with DHE. In most cases, BPDHE successfully enhance the image without severe side effects, and at the same time, maintain the mean input brightness.

It consists of five steps:
1) Smooth the histogram with Gaussian Filter.
2) Detection of the location of local maximums from the smoothed histograms.
3) Map each partition into a new dynamic range.
4) Equalize each partition independently.
5) Normalize the image brightness.

Brightness Preserving Dynamic Histogram Equalization for Image Contrast Enhancement for Color Images was proposed [6] by *Haidi Ibrahim, Nicholas Sia Pik Kong in 2008*. This method is actually an extension to both MPHEBP and DHE. Similar to MPHEBP, the method partitions the histogram based on the local maximums of the smoothed histogram. However, before the histogram equalization taking place, the method will map each partition to a new dynamic range, similar to DHE. As the change in the dynamic range will cause the change in mean brightness, the final step of this method involves the normalization of the output intensity. So, the average intensity of the resultant image will be same as the input. With this criterion, BPDHE will produce better enhancement compared with MPHEBP, and better in preserving the mean brightness compared with DHE.

3. Techniques for Implementation

3.1 Brightness Preserving Bi-Histogram Equalization

This method divides the image histogram into two parts. In this method, the separation intensity X_T is presented by the input mean brightness value, which is the average intensity of all pixels that construct the input image. After this separation process, these two histograms are independently equalized. By doing this, the mean brightness of the resultant image will lie between the input mean and the middle gray level. Histogram equalization is widely used for contrast enhancement in a variety of applications due to its simple function and effectiveness. This is a novel extension of HE to overcome such drawback of the histogram equalization.

The essence of the proposed algorithm is to utilize independent histogram equalizations separately over two sub images obtained by decomposing the input image based on its mean with a constraint that the resulting equalized sub images are bounded by each other around the input mean. It will be shown mathematically that the proposed algorithm preserves the mean brightness of a given image significantly well compared to typical histogram equalization while enhancing the contrast and, thus, provides much natural enhancement that can be utilized in consumer electronic products. It preserves the mean brightness of a given image significantly well compared to typical histogram equalization while enhancing the contrast.

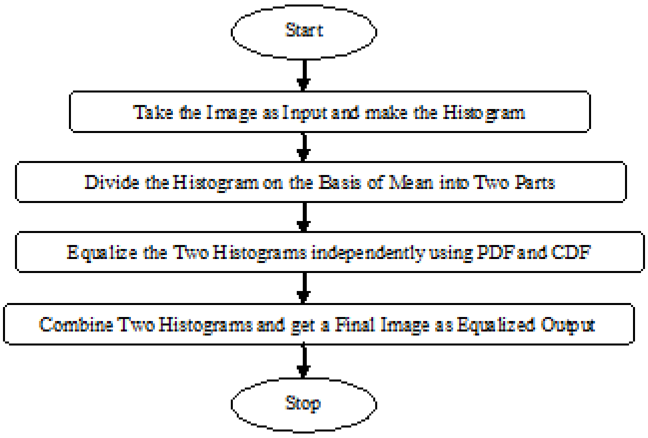

Figure 1: BBHE algorithm

The ultimate goal behind the BBHE is to preserve the mean brightness of a given image while enhancing the contrast of a given image. Output mean of the BBHE for a given analog image having symmetric distribution, which indicates that the BBHE is capable of preserving the mean brightness of a given image.

3.2 Brightness Preserving Dynamic Histogram Equalization

Brightness preserving dynamic histogram equalization (BPDHE), which is an extension to HE that can produce the output image with the mean intensity almost equal to the mean intensity of the input, thus fulfills the requirement of maintaining the mean brightness of the image. It consists of five steps.

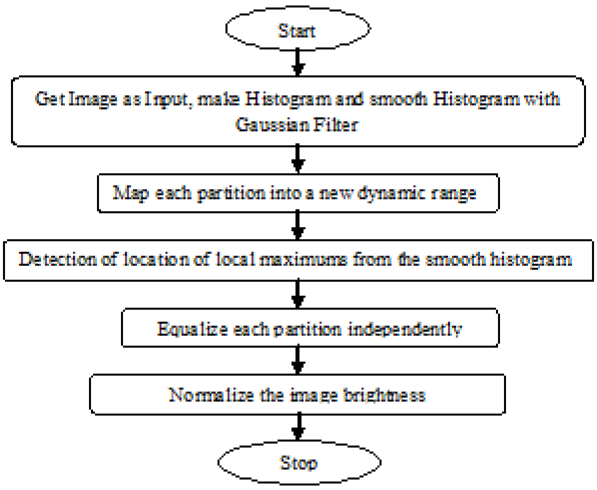

Figure 2: BPDHE algorithm

3.3 Combined Approach for BBHE and BPDHE

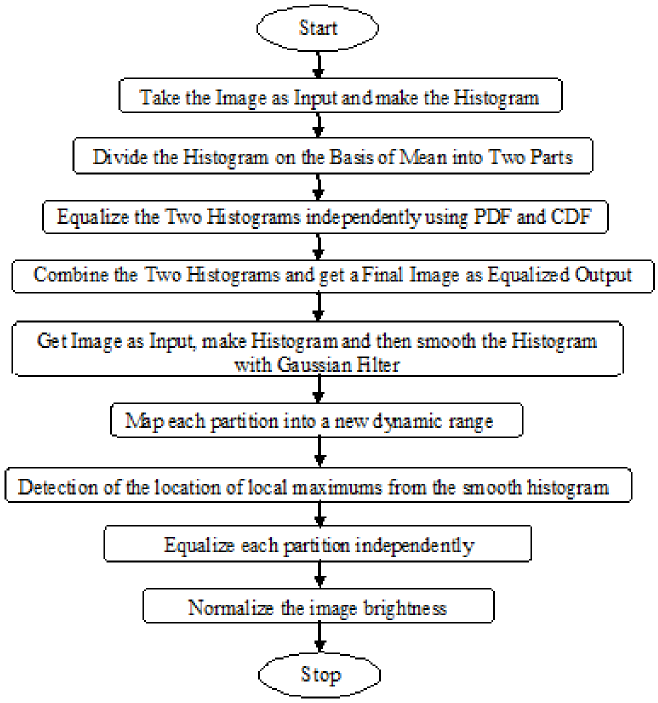

Figure 3: Combined algorithm for image contrast enhancement

4. Parameters used for Evaluation of Image Enhancement Techniques

For the objective measurement of any algorithm for image enhancement, there are various parameters on the basis of which performance of the algorithms is evaluated. The different parameters which are used to check the performance are as follows.

(i) Mean Square Error (MSE)

$$\text{MSE} = \frac{1}{MN}\sum_{j=1}^{M}\sum_{k=1}^{N}\left(x_{j,k} - x'_{j,k}\right)^2 \qquad (4.1)$$

where, M and N are rows and columns, respectively of the image. $x_{j,k}$ is the original image and $x'_{j,k}$ is the corresponding output image. The MSE should be less, which means that the pixel intensity of the input and output image should be as close as possible.

(ii) Peak Signal to Noise Ratio (PSNR)

$$\text{PSNR} = 10\log_{10}\frac{255^2}{MSE} \qquad (4.2)$$

Peak Signal to Noise Ratio should be as large as possible which means that the content of signal in the output is large and the noise is less. Since it is peak signal to noise ratio that's why the value of the signal is considered as maximum which is 255 (for gray scale images the gray scale ranges from 0 – 255).

(iii) Normalized Absolute Error (NAE)

$$\text{NAE} = \frac{\sum_{j=1}^{M}\sum_{k=1}^{N}\left| x_{j,k} - x'_{j,k} \right|}{\sum_{j=1}^{M}\sum_{k=1}^{N}\left| x_{j,k} \right|} \qquad (4.3)$$

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where, $x_{j,k}$ is the original image and is the corresponding output image $x'_{j,k}$. Normalized Absolute Error is the normalized absolute error, so it should be minimum showing that the difference between the input image and the output image is less.

(iv) Correlation

The value of each pixel in a correlation image is a measure of how well the target image matches the searched image at that point.

5. Results

This section of paper aims at providing the results of the algorithms of image enhancement techniques like Brightness Preservation Bi-Histogram Equalization (BBHE), Brightness Preserving Dynamic Histogram Equalization (BPDHE) and Combined Approach which have been described in previously and determine the best one for image enhancement. The comparison of these techniques is done on the basis of different applications like medical imaging, consumer electronics etc. and for evaluation of these techniques, various performance parameters are calculated like Mean Square Error (MSE), Normalized Absolute Error (NAE), Correlation, Peak Signal to Noise Ratio (PSNR) for gray scale images. All the enhancement techniques are implemented using MATLAB-2015 and its image processing toolbox.

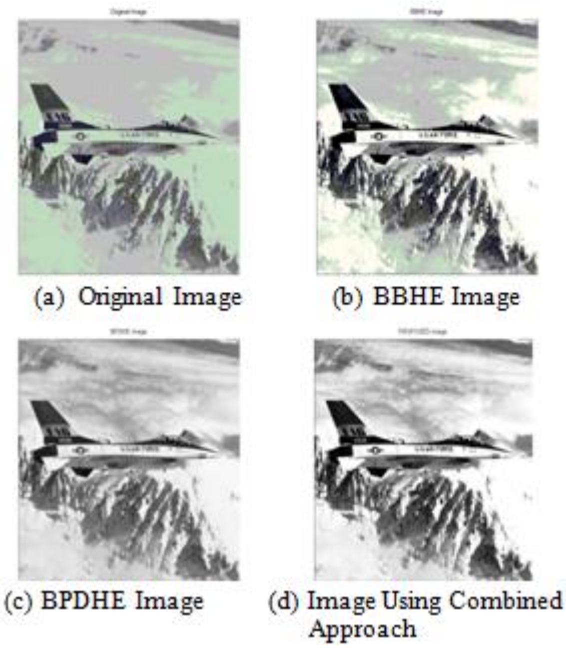

Figure 4: Results of aircraft image

Table 5.1: Comparison of parameters for "aircraft" image

Parameter Technique	MSE	PSNR	Correlation	NAE
BBHE	613.773	20.250	0.017	0.101
BPDHE	275.146	23.735	0.008	0.077
PROPOSED	189.492	25.354	0.005	0.059

Figure 5: Results of barabara image

Table 5.2: Comparison of parameters for "barbara" image

Parameter Technique	MSE	PSNR	Correlation	NAE
BBHE	955.971	18.326	0.0643	0.230
BPDHE	31.414	33.159	0.0021	0.027
PROPOSED	2.837	43.602	0.0001	0.010

6. Conclusion and Future Work

There are various techniques for enhancing the image. After implementing some of the techniques, which all are based on the histogram equalization, it is concluded that the enhancement of any image is application dependent. From the tables shown above, it is concluded that proposed methodology is better than Brightness Preserving Dynamic Histogram Equalization and Brightness Preserving Bi-Histogram Equalization techniques in terms of Mean Square Error (MSE), Correlation, Peak Signal to Noise Ratio (PSNR), Normalized Absolute Error (NAE) for different images. The visual quality of the images using proposed methodology is better as compared to others.

In future, for the enhancement purpose, more images can be taken. Also the different other techniques can also be compared to check the consistency of the proposed method. Also the new modification in the proposed technique is also beneficial for the enhancement purposes. Also the optimization of various techniques can be done to reduce the complexity as much as possible.

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