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An Adaptive Image Enhancement Technique Preserving Brightness Level Using Gamma Correction

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Abstract

In this paper, we will discuss the development of the image enhancement techniques and their application in the field of image processing .The principle objective of image enhancement techniques is to process an input image so that the resultant image is more suitable than the original image for specific application. Traditional global histogram equalization usually causes excessive contrast enhancement while local histogram equalization may cause block effect. To overcome these problems, a new method for image contrast enhancement is developed. The novelty of the proposed method is that the weighted average of the histogram equalized, gamma corrected and the original image are combined to obtained the enhanced processed image .The proposed algorithm not only achieve contrast enhancement but also preserves the brightness level. Experimental results show that the proposed algorithm has good performance on enhancing contrast and visibility for a majority of images.

Index Terms: Digital image processing, Image Enhancement, Spatial Domain Technique, Histogram equalization, Gamma Correction.

1. Introduction

Image enhancement, which is one of the significant techniques in digital image processing, plays an important role in many fields, such as medical image analysis, remote sensing, high definition television, hyper spectral image processing, industrial X-ray image processing, microscopic imaging etc. Image enhancement is a processing on image in order to make it more appropriate for certain applications [1]. It is mainly utilized to improve the visual effects and the clarity of the image or to make the original image more conducive for other automated processes. Generally an image may have poor dynamic range or distortion due to the poor quality of the imaging devices or the adverse external conditions at the time of acquisition and so on.

The contrast enhancement is one of the commonly used image enhancement methods. Many methods for image contrast enhancement have been published and widely used which can be broadly categorized into two groups: direct methods and indirect methods. Among the indirect methods, the histogram modification techniques have been widely utilized because of its simplicity and explicitness, in which the histogram equalization (HE) is one of the most frequently, used technique. The fundamental principle of Histogram equalization is to make the histogram of the enhanced image to have approximately uniform distribution so that the dynamic range of the image can be fully exploited. However the original HE always causes several problems:

- It lacks of adjustment mechanism to control the level of the enhancement and cannot make satisfying balance on the details between bright parts and dark parts.
- It may over enhance or generate excessive noise to the image in certain applications.
- It may sometimes dramatically change the average brightness of the image.

Various methods have been published to limit the level of contrast enhancement in HE. Most of them are carried out through modifications on the HE. For instance, in the Brightness preserving Bi- Histogram Equalization (BBHE) [2], two separate histograms from the same image are formed and then equalized independently, where the first one is the histogram of intensities that are less than the mean intensity and the second one is the histogram of intensities that are greater than the mean intensity. BBHE can reduce the mean brightness variation. In Dualistic Sub-image Histogram Equalization (DSIHE) [3], two separate histograms are created according to the median gray intensity instead of the mean intensity. Although DSIHE can maintains the brightness and entropy better both DSHE and BBHE cannot adjust the level of enhancement and are not robust to noise. Consequently, several problems will emerge when there are spikes in the histogram. The Recursive Mean Separation Histogram Equalization (RMSHE) [4] enhances image by iterating BBHE. The mean intensity of the output image will converge to the average brightness of the original image when the iteration increases. Accordingly the brightness of the enhanced image to the original image can be maintained much better. Although the methods mentioned above can often increase the contrast of the image, these approaches usually bring some undesired effects. Overall the traditional global histogram equalization (GHE) will cause excessive enhancement, and the local histogram equalization (LHE) sometimes will bring block effect [5]. In order to overcome these problems an image contrast enhancement algorithm based on the weighted average of histogram equalization and gamma correction is proposed in this paper, in which the level of contrast enhancement can be controlled by adjusting the weighting coefficients. The proposed algorithm not only avoids the excessive enhancement and makes the contrast enhancement adjustable, but also maintain the brightness level. The rest of this paper is organized as follows: Section II provides a brief discussion of histogram equalization. Section III, presents our proposed method in detail. In Section IV, the efficiency of the proposed method is examined by comparing the experimental results obtained by the use of proposed method and the state of art technique. Finally Section V presents the conclusion and the future scope of the proposed method.

2. Histogram Enhancement

Histogram of a digital image shows global appearance of dark, bright, low contrast or high contrast image. It is a graph of the frequency of occurrence of each gray level in an image. Gray histogram of an image is a one-dimensional discrete function, which can be represented as follows:-

$$h(k) = n_k \tag{1}$$

in which n_k is the number of pixels with the gray value of k in image F(i, j) . Consequently, the probability density function (PDF) can be obtained according to equation (1)

$$p_s(s_k) = {}^{n_k}/_{n} \quad o \le s_k \le 1, k = 1,2..n-1 \tag{2}$$

where s_k (k= 0,1,2... n-1) denotes the k th gray-level of F(i, j) and n is the total number of pixels in the image. Therefore, the cumulative distribution function (CDF) can be obtained by utilizing the gray-scale transform.

$$\mathrm{t_k} = E_h(\mathrm{s_k}) = \sum_{i=0}^{k} \left(\frac{\mathrm{ni}}{\mathrm{n}}\right) = \sum_{\mathrm{i=0}}^{\mathrm{k}} \mathrm{p_s}\ (s_i\ ) \tag{3}$$

The Pixels with the intensity of s_k in the input image are mapped to the corresponding pixels with the intensity of t_k in output image according to (3). Theoretically the gray-scale or the probability density function of an image will produce a perfectly equalized histogram through such a mapping mechanism.

However the gray-scale and the probability density function may not be exactly uniform in practical applications because of the discrete nature of the pixel intensities. As a result, pixels with a high probability of gray level may be over enhanced and pixels with a lower probability of gray level may be lack of enhancement or even be removed. Therefore, HE always enhances the background of an image excessively and decreases the saturation of the small area with most interesting.

3. Proposed Algorithm

In order to overcome the problems caused by direct HE an adjustable weighted average contrast enhancement algorithm is proposed in this paper. Firstly the exponential function ie adaptive gamma correction function is adopted for nonlinear smooth transform of an image. Then an adjustable weighting algorithm is proposed to improve the effects of image enhancement by HE.

Basic steps for the proposed algorithm are as follows:-

- Step-1 Image Acquisition
- Step-2 RGB to Gray Scale Conversion
- Step-3 Histogram Extraction of original image
- Step-4 Obtain Histogram Equalized Image
- Step-5 Obtain Adaptive Gamma Corrected image
- Step-6 Fusion of original image, Histogram equalized image and Gamma corrected image for final image enhancement.
- Step-7 Performance measurement of the proposed method by absolute mean brightness error (AMBE) and Entropy.

A. Improved exponential transform enhancement:

To compensate for the limitations of previous methods, a technique must be developed which creates a balance between high levels of visual quality and low computational costs. In this paper a hybrid HM method is proposed to accomplish this goal by efficiently combining the TGC and THE methods. A normalized gamma function can be used to modify the histogram to provide multi-equalizations with brightness preservation. In the proposed method we directly utilized cdf and applied a normalized gamma function to modify the transformation curve without losing the available histogram of statistics. Consequently, the lower gamma parameter generates a more significant adjustment. This observation led us to employ a compensated cdf as an adaptive parameter, which modifies the intensity with a progressive increment of the original trend [12]. The proposed adaptive gamma correction (AGC) is formulated as follows:

$$T(l) = l_{max}(1/l_{max})^{\gamma} = l_{max}(1/l_{max})^{1-\mathrm{cdf(l)}} \qquad (4)$$

The AGC method can progressively increase the low intensity and avoid the significant decrement of the high intensity.

Finally the gamma parameter based on cdf of Equation (4) is given as follows:

$$\gamma = 1 - \mathrm{cdf(l)} \qquad (5)$$

B. Weighted average algorithm

Due to the unexpected results caused by directly using Histogram equalization, in this paper, Histogram equalized, gamma corrected and the original image are combined to achieve a better enhancement results.

In the proposed algorithm the enhanced histogram $h^{\sim}$ can be viewed as a solution of a triple criteria optimization problem [9]. The goal of the proposed HE algorithm is to find a histogram that is as close to the histogram by using Histogram equalization (h_{eq}) and the histogram by using exponential transformation (h_{log}) as possible and make the residual histogram $h^{\sim} - h_i$ as small as possible.

As a result, the optimization problem can be formulated as a weighted sum of the three objective functions:

$$\min\left|\left|h - h_i\right|\right| + k\left|\left|\mathrm{h} - \mathrm{h}_{\mathrm{eq}}\right|\right| + \lambda\left|\left|\mathrm{h} - \mathrm{h}_{\mathrm{log}}\right|\right| \quad k, \lambda \epsilon[0, \infty] \quad (6)$$

in which κ and λ are weighting coefficients for different objective functions. The enhanced histogram $h^{\sim}$ can be obtained as follows:

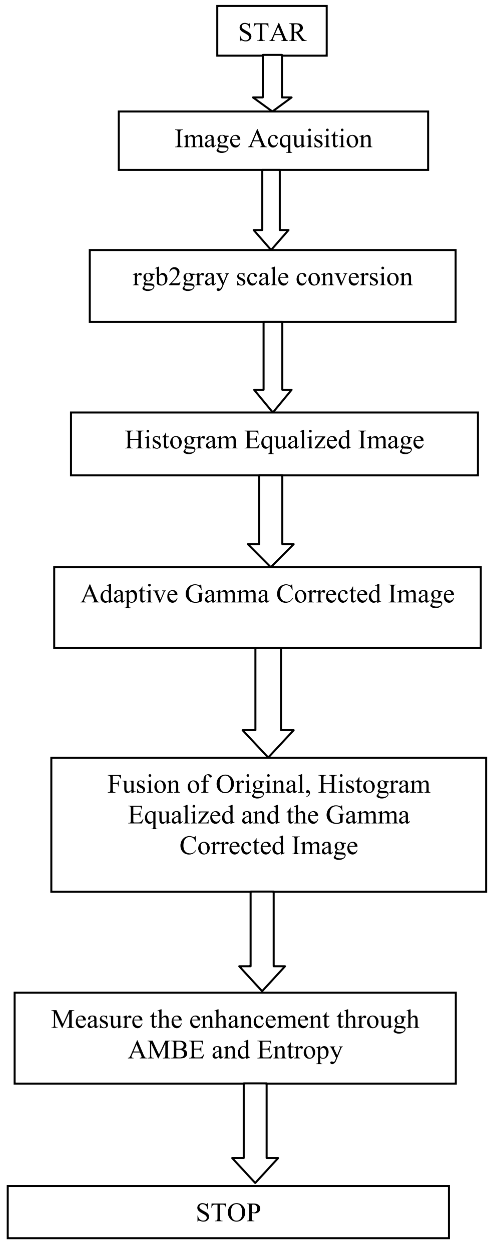
$$h^{\sim} = \frac{h_i + k * h_{eq} +, \lambda * h_{log}}{1 + \lambda + k} \quad (7)$$

$$h^{\sim} = \left({}^{1}/_{1 + \lambda + k}\right) * h_i + \left({}^{k}/_{1 + \lambda + k}\right) * h_{eq} + \left({}^{\lambda}/_{1 + \lambda + k}\right) * h_{log} \quad (8)$$

It is observed from (8) that, the modified histogram turns out to be a weighted average of the three histograms. It turns to be the original histogram when κ = λ = 0. Therefore different levels of image enhancement can be achieved by the proposed method [9]. In summary the block diagram of the proposed enhancement can be illustrated as shown in the fig:-

Flow Graph of the Proposed Algorithm:

Figure illustrate the proposed method in the pictorial form, the algorithm starts with the image acquisition, this image is converted into gray image with the matlab command "rgb2gray" then the histogram equalized image is obtained by the "histeq" command in matlab and then the proposed gamma corrected image is obtained and at last the three images that are the original image ,histogram equalized image and the gamma corrected image are combined with weighted function discussed earlier and obtain the enhanced image .

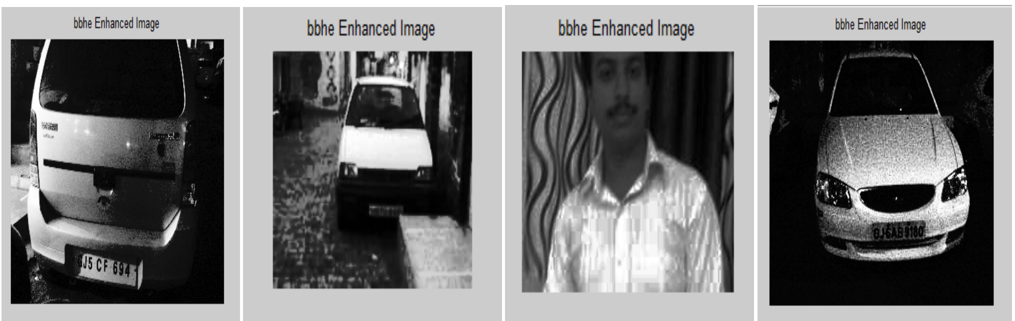


4. Simulation Results

In this section, a group of images are taken to evaluate the performance of the proposed image enhancement algorithms. Three image enhancement algorithms are carried out in these experiments: Histogram equalized algorithm, the brightness preserving bi-histogram equalization [BBHE] and the proposed method. Figures show the results of image enhancement methods:

Four test images (a) CAR1 (b) CAR2 (c) ANKIT (d) CAR 3

Histogram Equalized Image



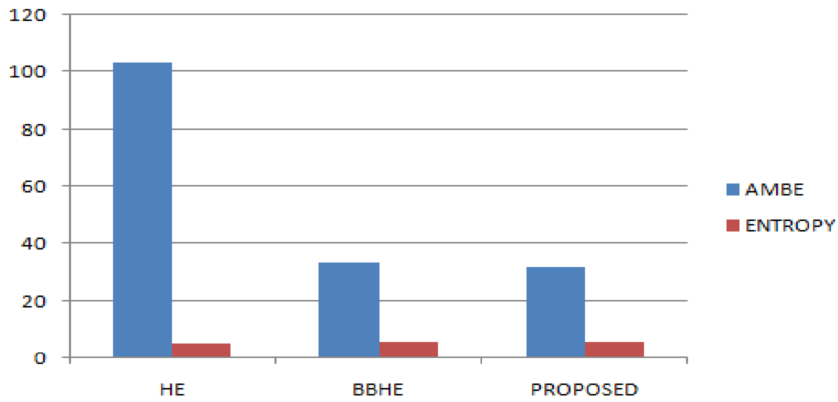
BBHE Equalized Image

Final proposed Image

In this paper, two quantitative objective measures are the Absolute Mean Brightness Error (AMBE) and the discrete entropy are adopted. AMBE is the absolute difference of input and output mean [11] while the discrete entropy is used to measure the details of an image. The quantitative measurements of the three image enhancement algorithms are listed in Table. Generally, the higher value of discrete entropy indicates a richer detail in an image. Therefore, higher value of discrete entropy in enhancement is expected in the image enhancement also the smaller values of AMBE shows that the average intensity of the input and the output images are similar, and that represent the corresponding method preserves the mean brightness of the image. It is observed from the tables that, the proposed algorithm can achieve a higher discrete entropy value and the smaller AMBE value, indicating the proposed method enhance the contrast of the image while preserving the brightness level.

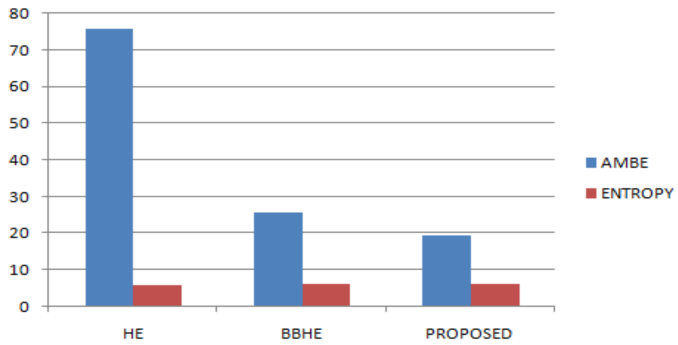
Comparison of AMBE, Entropy of CAR 1 image

METHODS	AMBE	ENTROPY
HE	103.1952	5.3189
BBHE	33.3039	5.6696
PROPOSED	32.0272	5.7908



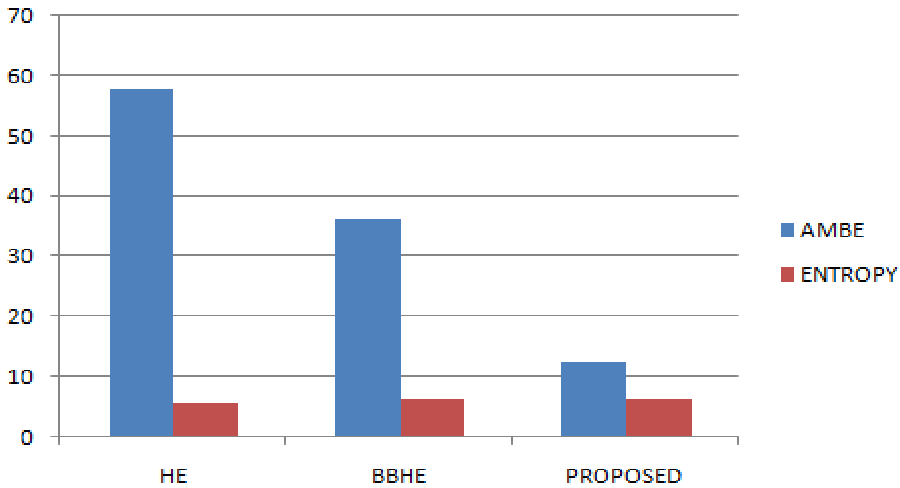
METHODS	AMBE	ENTROPY
HE	75.9876	5.7826
BBHE	25.7482	6.4070
PROPOSED	19.4567	6.4214

Comparison of AMBE, Entropy of CAR 2 image



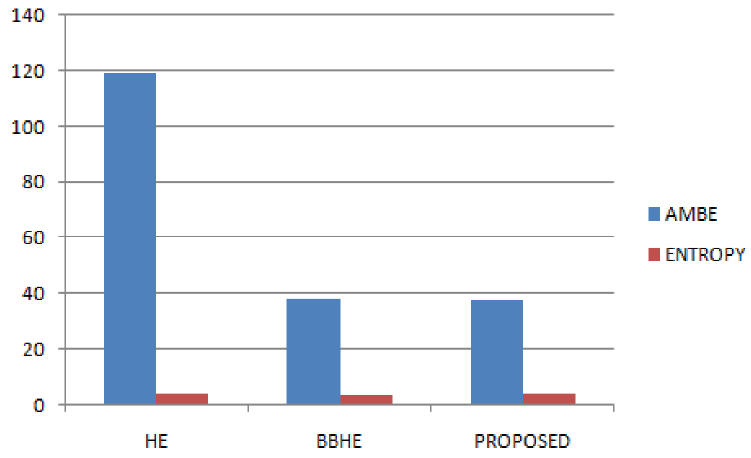
Comparison of AMBE, Entropy of ANKIT image

METHODS	AMBE	ENTROPY
HE	57.746	5.6674
BBHE	36.1739	6.3079
PROPOSED	12.5615	6.4159



Comparison of AMBE, Entropy of CAR3 image

METHODS	AMBE	ENTROPY
HE	119.571	4.0566
BBHE	38.064	3.9478
PROPOSED	37.7787	4.3016



5. Conclusion

This work proposed a method of image enhancement based on histogram equalization and adaptive gamma correction. Image enhancement is one of the most important image processing technologies which are necessary to improve the visual appearance of the image or to provide a better transform representation for future automated image processing such as image analysis, detection, segmentation and recognition. This research work adopts a scheme for enhancing the image contrast. The novelty of the proposed technique is that, the weighted average of histogram equalization, exponential transformation and the original image are combined and the level of the contrast improvement is adjustable by changing the weighting coefficients. The method has been implemented on four different images to check experimental results. AMBE and Entropy is then calculated to measure the performance of the proposed algorithm. It is observed from the experimented results that the proposed method not only enhances the visual quality of the image but also preserves the brightness level.

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