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Contrast Enhancement using Recursive Exposure Boundary Calculation

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Abstract

In this paper, we presented annovel contrast enhancement method for underexposed and overexposed images using a boundary exposure value. The proposed method works well for all kinds of images. It is a combination of boundary exposure calculation, contrast stretching and histogram equalization method. This method divides the original histogram of image into four parts using proposed boundary exposure calculation. It suggests a new way of finding threshold for overexposed images which yields better results than the existing one.. The entropy measures indicate better quality of images in both cases. The method also is able to maintain the mean brightness better than the old method for both overexposed and underexposed images. The visual quality also describes the supremacy of proposed method over ESIHE method.

Key words

Contrast enhancement, Exposure boundary calculation, Histogram equalization. Introduction

I. Abstract

Image enhancement is a procedure of applying a transformation on the image so that the resulting image is better than the original for a definite application. The main objective of applying this technique is to get better the perception of information in images for visual examination or machine investigation, without any knowledge of the source degradation model. Image enhancement means as the perfection of an image appearance by increasing supremacy of some features or by decreasing uncertainty between different regions of the image. Image enhancement is one of the most interesting and visually appealing areas of image processing. Image enhancement is broadly divided into two categories i.e. spatial domain methods and frequency domain methods [2].

Various methods have been proposed for limiting the level of enhancement and for mean brightness preservation, most of which are obtained through modifications on histogram equalization (HE).

Firstly Kim introduced bi histogram equalization techniques for modified histogram. **BBHE** [5] divides the original histogram into two sub-histograms based on the mean brightness of the input image. Then HE is implemented independently in each sub-histogram. The mean brightness can be preserved by retaining the value of the original mean brightness. And "Quantized bi-histogram equalization" **(QBHE)** [6] use the average intensity value as their separating point for histogram sub division and equalization.

Wan & Chen in 1999 introduced Dualistic sub-image histogram equalization **(DSIHE)** [7].This method claimed that it is better than BBHE in terms of preservation of brightness and average information content (entropy) of an image. DSIHE divides the histogram into two sub histograms containing equal number of bins and the division is based on median value instead of mean brightness. Although BBHE and DSIHE are visually more pleasing than HE, these two techniques cannot adjust the level of enhancement and are not robust to noise which could be added problem when the histogram has spikes.

Chen &Ramli 2003 introduced Minimum mean brightness error bi-histogram equalization **(MMBEBHE)** [8]. MMBEBHE method was introduced for preserving the mean brightness "optimally". This method is an improvement on BBHE, which calculates the absolute mean brightness error (AMBE) for gray levels 0 to L-1 and bisects the histogram based on the intensity value X, which yields minimum AMBE. MMBEBHE suffers from slow runtime as a result of its highly complex implementation. Moreover, the minimal mean shift in the output does not always guarantee the visual quality of the enhanced image.

S. Chen and A. Ramli, in 2003 gave Recursive mean-separate histogram equalization **(RMSHE)** [9] and similar to this technique Sim et al. in 2007 introduced Recursive sub-image histogram equalization **(RSIHE)** [10]. RMSHE method recursively performs the BBHE in which the histogram is divided into two parts on the basis of average input brightness and BBHE is performed to each sub histogram independently. RSIHE algorithm performs the division of histogram based on median value of brightness instead of mean brightness. Finding the optimal value of iteration factor is a big challenge for producing significant enhancement results in RMSHE and RSIHE methods. Also these techniques do not provide mechanism for adjusting the level of enhancement.

Mary Kim and Chung, 2008 introduced Recursively separated and weighted histogram equalization **(RSWHE)** [11]. This method is introduced to improve the contrast while preserving brightness of the enhanced image. RSWHE consists of three modules. It first performs the histogram segmentation module that recursively separates an image histogram into two or more sub-histograms. The separating point can be either mean or median of the histogram. Then, it proceeds with the histogram weighting module, which modifies the sub-histograms by using a weighting process based on a normalized power law function. Lastly, HE module is applied to all sub-histograms separately. The RSWHE is considered as the leading state of- the-art method in brightness-preserving image enhancement.

However, the RSWHE tends to introduce unnatural enhancement to the processed image under some circumstances. Also the user-defined selection of recursion level prevents the RSWHE to yield optimal enhancement performance.Sengee, and Choi, proposed Weighted clustering histogram equalization **(WCHE)** in 2008[12]. WCHE method was introduced to preserve image brightness, improvecontrast, and enhance visualization without producing any undesired artifactsthrough over-enhancement. WCHE tends to lose pertinent image details because acluster with large groups of bins may equalize to a narrow dynamic range. Weighting mean separated sub-histogram equalization

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(WMSHE) [13] aims to achieve complete contrast enhancement for the small-scale detail. WMSHE begins with histogram segmentation by using weighted-mean value, and it then uses a piecewise transformation function to all sub histograms to accentuate on the enhancement of fine details in the image. However, the effort to bring out fine image details leads to the generation of noise artifacts, largely due to the enhancement noise components in the input image.

The above mentioned techniques do not provide mechanism for adjusting the level of enhancement. New class of techniques based on clipping of histogram was proposed as a solution for controlling the enhancement rate as well as preserving the original brightness. These methods control maximum value of histogram by clipping histograms higher than the pre specified threshold. These methods provide different approach for the determination of clipping threshold.

Weighted and Thresholded Histogram Equalization **(WTHE)** [14] and Gain- Controllable Clipped Histogram Equalization **(GC-CHE)** [4] are few examples of clipped histogram equalization technique. In order to obtain good enhancement these methods require user to manually set the parameter's value. To overcome this disadvantage another approach for histogram equalization has been introduced.Ooi introduced Bi-histogram equalization with plateau limit (BHEPL) in 2009[15]. BHEPL is introduced as one of the options for the system that requires a short processing time image enhancement. This method uses average intensity of the input image as the threshold to divide the input image histogram into two sub histograms. These two sub histograms are individually clipped using two different plateau limits. The plateau limits are defined as average of the number of intensity occurrences in both sub histograms separately. BHEPL clips each sub histogram using the mean of the corresponding occupied intensity in the sub-histogram.ESIHE [17] method is for low exposure gray scale images. The method calculates image intensity exposure to find underexposed images and then it finds exposure threshold to divide the image histogram into two sections. Next clipping threshold is computed to prevent over enhancement of image. The histogram equalization is performed on the clipped histogram to obtain enhanced output image.

II. Proposed Model

The proposed method involves three important steps: Recursive Exposure boundary calculation, Histogram Equalization of sub-histograms, Contrast stretching of each sub sections,

1. Recursive Exposure Boundary calculation

The exposure intensity is the measure of how much a image region is underexposed or overexposed. The value of exposure lies between (0,1). If exposure value is less than 0.5 than the image has more of underexposed region and if exposure value is greater than 0.5 than the image has more of overexposed region and therefore there is need of contrast enhancement in both the cases. [16] This intensity exposure helps in finding the exposure threshold limit for both overexposed and underexposed regions. The measure of exposure is calculated as given in (8):

$$e = \frac{1}{\mathrm{lmax}} \frac{\sum_{\mathrm{lmin}}^{\mathrm{lmax}} h(i) * i}{\sum_{\mathrm{lmin}}^{\mathrm{lmax}} h(i)} \qquad (8)$$

where e is intensity exposure, i is a gray level intensity, h(i) is no. of intensities at gray level i, lmin and lmax is minimum & maximum gray value of an image. Exposure Threshold limit is a parameter that gives the value of gray level boundary which divides the image into underexposed and over exposed sub images as shown in Fig 1. The value of this parameter for under exposed and overexposed image are calculated using (9) respectively:

$$X_2 = lmax \times e \qquad (2)$$

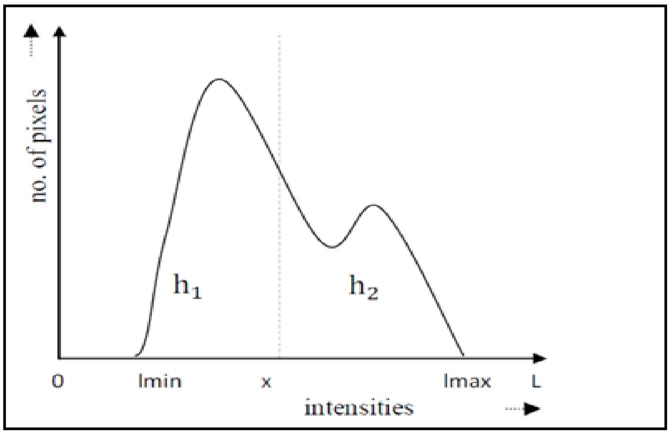

Fig. 1 : Setting of exposure threshold using proposed method

Now this X2 will be the lmax for next operation shown in eq 10

$$X_1 = X_2 \times e \qquad (3)$$

Recursively the same thing will be calculated for next two sub section like

$$X_3 = X_2 + (lmax - X_2) \times e \qquad (4)$$

Now there are four sub sections of histogram ranges from lmin - X_1, $X_1 - X_2$, $X_2 - X_3$ anf X_3- lmax.

2.2 Histogram Equalization of sub histogram

Consider all sub histogram as separate main histogram for a unique image. Let n_i be the number of occurrences of gray level *i*. The probability of an occurrence of a pixel of level *i* in the image is

$$p_x(i) = p(x = i) = \frac{n_i}{n}, \quad 0 \le i < L \qquad (5)$$

L being the total number of gray levels in the image (typically 256), *n* being the total number of pixels in the image, and $p_x(i)$ being in fact the image's histogram for pixel value i, normalized to [0,1].

Let us also define the cumulative distribution function corresponding to p_x as

$$cdf_x(i) = \sum_{j=0}^{i} p_x(j) \quad (6)$$

which is also the image's accumulated normalized histogram.
We would like to create a transformation of the form $y = T(x)$ to produce a new image $\{y\}$, with a flat histogram. Such an image would have a linearized cumulative distribution function (CDF) across the value range, i.e.

$$cdf_y(i) = iK \quad (7)$$

for some constant K. The properties of the CDF allow us to perform such a transform it is defined as

$$cdf_y(y') = cdf_y(T(k)) = cdf_x(k) \quad (8)$$

where$k$ is in the range [0,L). Notice that T maps the levels into the range [0,1], since we used a normalized histogram of {x}. In order to map the values back into their original range, the following simple transformation needs to be applied on the result:

$$y' = y \cdot (\max\{x\} - \min\{x\}) + \min\{x\} \quad (9)$$

2.3 Contrast stretching of each sub section.

Once we calculate the X_1, X_2 and X_3 , after that we will stretch the contrast of each section separately by following way,
Using eq 12, contrast will be stretched of first sub section which ranges from lmin - X_1 . Here P_x is the current pixel on which contrast stretching is applied and S_x the modified pixel.

$$S_x = \frac{P_x - lmin}{X_1 - lmin}\,(lmax) \quad (10)$$

Same concept is applied on subsection two , three and four where contrast stretched modified pixels are calculated by eq. 11, 12 and 13 respectively.

$$S_x = \frac{P_x - X_1}{X_2 - X_1}\,(lmax) \quad (11)$$

$$S_x = \frac{P_x - X_2}{X_3 - X_2}\,(lmax) \quad (12)$$

$$S_x = \frac{P_x - X_3}{lmax - X_3}\,(lmax) \quad (13)$$

Finally all mapped or modified pixels will be replaced by all current pixels. This modified image will be called contrast stretched image which is nothing but the output of the proposed scheme.

III. Experimental Result and Analysis

This section shows the comparison and simulation results of the proposed method with the ESIHE method. We demonstrate the effectiveness and accuracy of the proposed approach with experimental results and discuss the performance of our algorithm. The simulation has been implemented in Matlab 2013 environment. We have taken many gray level test images of different types of categories i.e. images that are underexposed or overexposed. We will discuss experimental results and comparison separately for both kinds of images. Quantitative analysis is also done together with qualitative analysis.

3.1 Experimental Results for Overexposed Images

The experimental results of the proposed method the intensities are completely occupying all the histogram bins for overexposed images together with underexposed images which fails while using ESIHE method. The exposure threshold lies in between minimum and maximum value of histogram for all type of images. The algorithm automatically classifies images as underexposed or overexposed and divides the image histogram into two regions using the exposure threshold.

The analysis of visual results for all images tested shows the high picture quality of the proposed method compared to ESIHE method in terms of contrast enhancement, control on over enhancement and reduction in brightness error. In Fig 2. ocean image, the image produced using proposed method is more enhanced and is more equalized as compared to ESIHE method. The histogram of enhanced image uses more histogram bins for histogram equalization. This can be proved from the cumulative density function graph. Fig. 3(i) is the CDF graph for image enhanced from ESIHE method and Fig. 3(ii) is the CDF graph for image enhanced from proposed approach.

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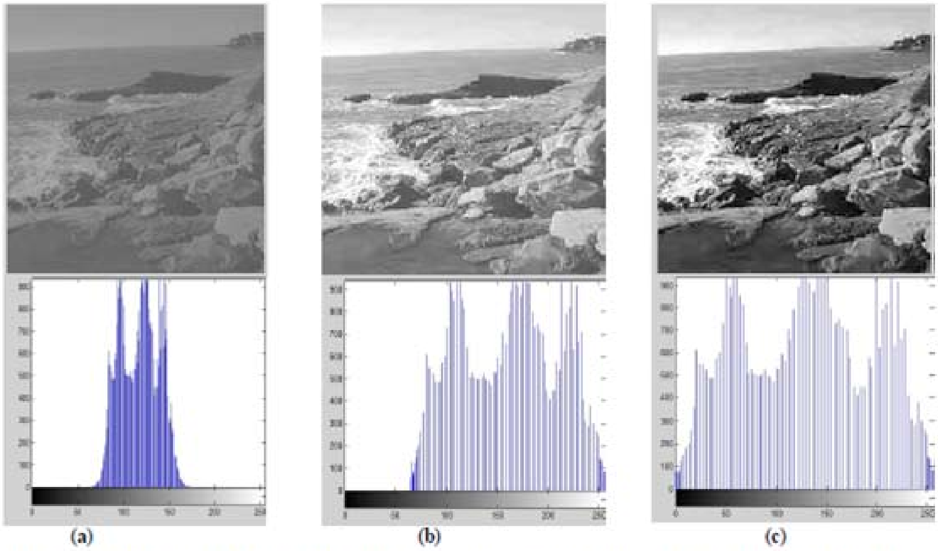

Figure 2 (a) Above: Original image of ocean Below: its histogram (b) Above: Image modified using ESIHE method Below: HE using ESIHE (c) Above: Image modified using Proposed Method Below: HE using Proposed method

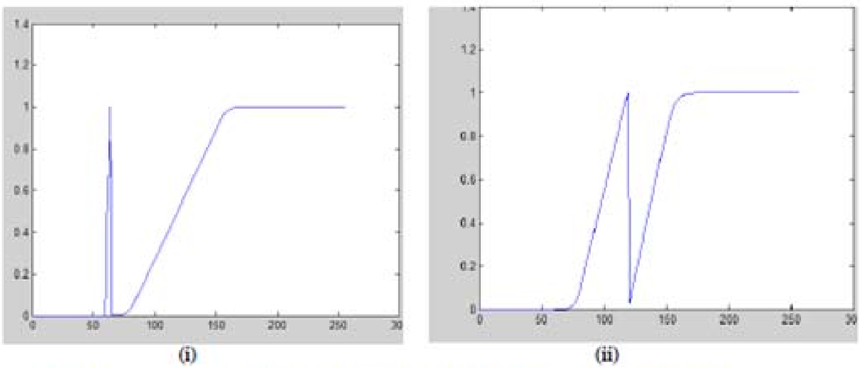

Figure 3 (i) CDF graph for ESIHE method (ii) CDF graph for Proposed Method

3.2 Experimental Results for Underexposed Images

The analysis and result evaluation is also done for underexposed images. The old method and pro osed method produce almost equivalent good enhancement results but some differences can be evaluated from few images. Fig. 4 (b) shows some white patches over the pumpkin where as Fig 4(c) proposed enhancement removes those white patches and produce a quality image which is more natural.

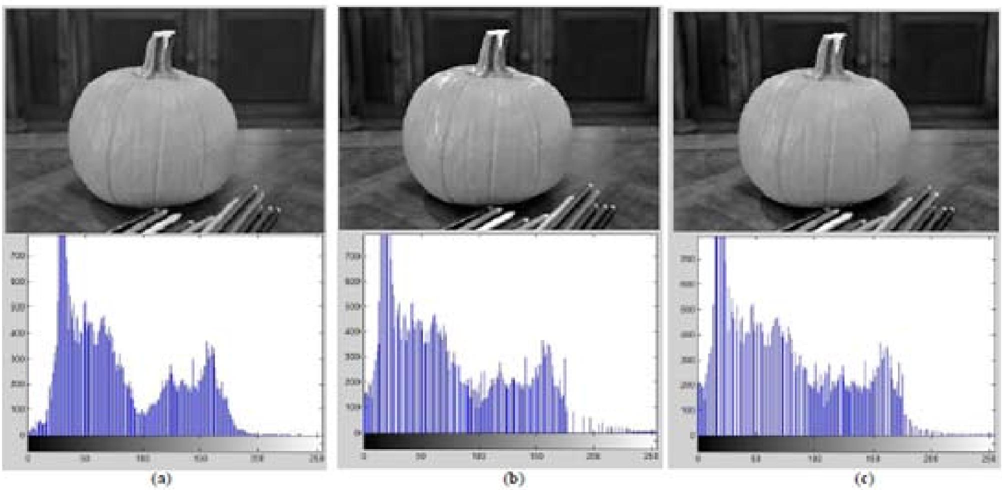

Figure 4 (a) Above: Original image of pumpkin Below: its histogram (b) Above: Image modified using ESIHE method Below: HE using ESIHE (c) Above: Image modified using Proposed Method Below: HE using proposed method

IV. Conclusion

In this paper, we presented an enhancement of ESIHE method for contrast enhancement of underexposed and overexposed images using an exposure value. The proposed method works well for all kinds of images. It is a combination of boundary exposure calculation , contrast stretching and histogram equalization method. It suggests a new way of finding threshold for overexposed images which yields better results than the existing one. Clipping of sub-histograms using two clipping thresholds controls the rate of enhancement and leads to natural appearance of output image. Experimental results show the supremacy of proposed method over ESIHE method for underexposed and overexposed images. The entropy measures indicate better quality of images in both cases. The method also is able to maintain the mean brightness better than the old method for both overexposed and underexposed images. The visual quality also describes the supremacy of proposed method over ESIHE method.

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