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Image enhancement via Median-Mean Based Sub-Image-Clipped Histogram Equalization

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ABSTRACT

This paper presents a robust contrast enhancement algorithm based on histogram equalization methods named Median-Mean Based Sub-Image-Clipped Histogram Equalization (MMSICHE). The proposed algorithm undergoes three steps: (i) The Median and Mean brightness values of the image are calculated. (ii) The histogram is clipped using a plateau limit set as the median of the occupied intensity. (iii) The clipped histogram is first bisected based on median intensity then further divided into four sub images based on individual mean intensity, subsequently performing histogram equalization for each sub image. This method achieves multi objective of preserving brightness as well as image information content (entropy) along with control over enhancement rate, which in turn suits for consumer electronics applications. This method avoids excessive enhancement and produces images with natural enhancement. The simulation results show that MMSICHE method outperforms other HE methods in terms of various image quality measures, i.e. average luminance, average information content (entropy), absolute mean brightness error (AMBE) and background gray level.

1. Introduction

Contrast enhancement and brightness preservation are two prime focus areas of researchers in the field of consumer electronics products. Nowadays mobile phones have been widely used to take pictures in daily life. Mobile phones have limited hardware capability for digital photography. In this scenario, post-processing using software tools is needed to improve the quality of the acquired image. Histogram equalization (HE) is most extensively utilized contrast enhancement technique due to its simplicity and ease of implementation [1]. The idea behind HE is to flatten the probability distribution and stretching the dynamic range of gray levels, which in result improves the overall contrast of the image [2]. HE utilizes the cumulative density function (CDF) of image for mapping the gray levels of original image to the enhanced image. HE is not suitable for most consumer electronics applications such as TV, cameras etc., as it tends to change the mean brightness of the image to the middle level of the gray level range, which in turn produces annoying artifacts and intensity saturation effects. Various methods [2–6] have been suggested in literature to overcome the shortcomings in histogram equalization method. Kim [2] in 1997 was the first one to propose an algorithm named brightness preserving bi histogram equalization (BBHE) which preserves the mean brightness of the image and improves the contrast.

BBHE bisects the histogram based on the input mean brightness and equalizes the two sub histograms independently. In 1999 Wan et al. [3] proposed an algorithm named dualistic sub image histogram equalization (DSIHE) and claimed that it is better than BBHE in terms of preservation of brightness and information content (entropy) of the image. DSIHE separates the histogram based on median value instead of mean, which implies that each histogram contains almost equal number of pixels. Chen and Ramli introduced minimum mean brightness error bi-histogram equalization (MMBEBHE) for preserving the mean brightness "optimally" [4]. This method is an extension of BBHE, which iteratively calculates the absolute mean brightness error (AMBE) for gray levels 0 to $L-1$ and bisects the histogram based on the intensity value X_m, which yields minimum AMBE.

Chen and Ramli proposed another approach named recursive mean-separate histogram equalization (RMSHE) [5]. This technique iteratively performs the BBHE in which the histogram is divided into two parts based on the average input brightness and BBHE is performed to each sub histogram independently. Sim et al. [6] proposed a similar technique to RMSHE known as recursive sub-image histogram equalization (RSIHE). This technique performs

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the division of histogram based on the median value of brightness instead of mean brightness. Finding the optimal value of iteration factor is a big challenge for producing significant enhancement results. Kim and Chung [7] presented a method named Recursively Separated and Weighted Histogram Equalization (RSWHE) similar to RSIHE and RMSHE methods. In addition, RSWHE modify the histogram by weighting process using normalized power law function. These techniques do not provide a mechanism for adjusting the level of enhancement. Clipped histogram based techniques [8–10] were proposed as a solution for controlling the enhancement rate as well as preserving the original brightness. These methods control maximum value of the histogram by clipping histograms higher than the prespecified threshold. Different approaches are proposed for the determination of clipping threshold or plateau limit.

Abdullah-Al-Wadud et al. [11] proposed a new class of histogram partitioning named as dynamic histogram equalization (DHE). The DHE partitions the original histogram based on local minima and then, assigns a new dynamic range to each sub-histogram. The major drawback of this method is that it remaps the histogram peaks by allocating new dynamic range, which significantly changes the mean brightness. Ibrahim and Kong [12] proposed a method brightness preserving dynamic histogram equalization (BPDHE) similar to DHE, which is extension of the DHE. BPDHE applies Gaussian-smoothing filter before the histogram partitioning process is carried out. The BPDHE uses the local maxima as the separating point rather than the local minima used in DHE. Ibrahim and Kang claimed that the local maxima are better for mean brightness preservation. Sheet et al. [13] proposed a modification of the BPDHE technique named as Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE). This method uses Fuzzy histogram computation for smoothing operation of histogram before partitioning of image into sub histograms. The authors of BPDFHE method proved the superiority of the algorithm in terms of less computational time and brightness preservation. These dynamic methods are suitable only for the images having significant peaks in the histograms. Quadrants Dynamic Histogram Equalization (QDHE) method was proposed by Ooi and Isa [14] for better contrast enhancement. QDHE partitions the histogram into four sub-histograms using the median value of intensity and then clips the histogram according to the mean of intensity occurrence of the input image and finally a new dynamic range is assigned to each sub-histogram before each sub-histogram is equalized. Ooi and Isa [15] also proposed Adaptive Contrast Enhancement Methods with Brightness Preserving which comprised of two methods named as dynamic quadrants histogram equalization plateau limit (DQHEPL) and bi-histogram equalization median plateau limit (BHEPL-D). DQHEPL is extension of RSIHE, divides the histogram into four sub histograms, and then assigns a new dynamic range and finally implements clipping process. BHEPL-D is the extension of the BHEPL except that it clips the histogram using the median of the occupied intensity. Chang and Chang [16] presented a simple approach for contrast enhancement named as Simple Histogram Modification Scheme (SHMS). This method modifies the histogram by changing the values of two boundary values of the support of the histogram.

A new method named as background brightness preserving histogram equalization (BBPHE) [17] was proposed by Tan et al. The partition method used by BBPHE is based on background levels and non-background levels range. After partition, each sub-image is equalized independently, and then combined into the final output image. It is claimed that the background levels are only stretched within the original range, hence, the over enhancement can be avoided by BBPHE. Singh and Kapoor [19] proposed Exposure based Sub Image Histogram Equalization (ESIHE) method for enhancement of low exposure images where the image exposure threshold is used for sub dividing image.

Although various techniques were proposed to cater specific problem of contrast enhancement a new robust algorithm is being proposed here which addresses problems of preservation of mean brightness, entropy and control on the enhancement rate simultaneously. This algorithm also puts emphasis on natural enhancement of images. The authors believe that the MMSICHE technique that achieves the multiple objectives of entropy maximization, brightness preservation and control over enhancement is a better approach to natural image enhancement.

This paper is organized as follows: Section 2 describes the proposed MMSICHE method. Section 3 gives experimental results, and Section 4 concludes the paper.

2. Median-Mean Based Sub-Image-Clipped Histogram Equalization

This section, presents the algorithm of MMSICHE. The algorithm consists of three steps, namely median and mean calculation, Histogram Clipping and Histogram Subdivision & Equalization. Following subsections present description of each step of the algorithm.

2.1. Median and mean calculation

The median of the image is denoted as an intensity value X_e where the cumulative density function is 0.5 [3]. Two mean intensity values (X_{ml} and X_{mu}) are calculated for two individual sub histogram divided based on median value. The values of X_e, X_{ml} and X_{mu} are calculated before histogram clipping process. Eq. (1) computes the total number of samples N for a given image

$$N = \sum_{k=0}^{L-1} h(k) \tag{1}$$

$h(k)$ is histogram of image and L is total number of gray levels. For calculating X_e consider a variable $z(k)$ as computed in (2)

$$z(k) = z(k-1) + h(k) \quad \text{for} \quad k = 0, 1, \ldots, L-1 \quad \text{and} \quad z(0) = h(0) \tag{2}$$

Median variable can be calculated as per (3) using (1) and (2)

$$X_e = k \quad \text{where} \quad z(k) \geq \frac{N}{2} \tag{3}$$

Eqs. (4) and (5) expresses the calculation of mean variables X_{ml} and X_{mu}

$$X_{ml} = \sum_{k=0}^{X_e-1} P_l(k) \times k \tag{4}$$

$$X_{mu} = \sum_{k=X_e}^{L-1} P_u(k) \times k \tag{5}$$

where $P_l(k)$ and $P_u(k)$ are individual PDF of two sub histograms divided based on median. Eqs. (6) and (7) depict the calculation of these PDFs

$$P_l(k) = \frac{h(k)}{N_l} \quad \text{for} \quad k = 0, 1, \ldots, X_e - 1 \tag{6}$$

$$P_u(k) = \frac{h(k)}{N_u} \quad \text{for} \quad k = X_e, X_e + 1, \ldots, L - 1 \tag{7}$$

N_l and N_u are total numbers of pixels in the lower and upper histogram respectively.