Computers and Electrical Engineering 000 (2017) 1–15

Contents lists available at ScienceDirect

Computers and Electrical Engineering

journal homepage: www.elsevier.com/locate/compeleceng

Linearly quantile separated weighted dynamic histogram equalization for contrast enhancement☆

Bhupendra Gupta*, Tarun Kumar Agarwal

Indian Institute of Information Technology, Design & Manufacturing Jabalpur, MP, India 482005

ARTICLE INFO

Article history:
Received 23 May 2016
Revised 13 January 2017
Accepted 13 January 2017
Available online xxx

Keywords:
Histogram equalization
Image contrast enhancement
Power law function
Histogram weighting
Quantiles
Brightness preservation

ABSTRACT

Contrast-enhancement is a prerequisite of various image-processing and computer-vision applications. When we employ contrast-enhancement tools based on histogram equalization, the mean-shift problem commonly arises. In this work, we propose a new approach to contrast enhancement which overcomes the mean-shift problem. In the proposed approach, we suggest a quantile-based division of the histogram of a given image, which can be used across the entire spectrum of grey level for contrast-enhancement. Due to its non-recursive nature, the proposed approach is computationally less expensive than many other methods. Experimental results show that the proposed method performs better than other existing methods available in related literature. Further, this method preserves image brightness more accurately and takes less time as compared to prevailing state of art approaches.

1. Introduction

Image contrast enhancement is one of the most important issues in the field of digital image processing. The aim of image contrast enhancement is to bring out the hidden details in the given low contrast image.

In general contrast enhancement tools enlarge the intensity difference between the objects and their background. This enlargement in intensity differences can be achieved by stretching more frequent grey levels to a greater extent. Histogram equalization (HE) is one of the simplest and widely accepted methods to serve this purpose. Although, HE produces an overall enhancement by stretching the dynamic range of the input image histogram, it cannot adapt to local contrast of the input image because it uses only global information. In HE, there is no mechanism to control the level of enhancement at local level due to this there is saturation (over enhancement) in bright regions and also a significant contrast losses at other small regions of the processed image [1].

To overcome this limitation, adaptive histogram equalization methods are proposed by various researchers, [2–8]. In adaptive histogram equalization, the initial input image is discretized into rectangular sub-blocks, and then histogram equalization is perform on each sub-block. This method is suitable for improving the local contrast and preserves the local details of the input image.

Another disadvantage of HE is that the mean brightness of the output image is always the middle grey level, instead of the mean brightness of the input image [9]. Hence, HE is not suitable for consumer electronics products, where preserving

☆ Reviews processed and recommended for publication to the Editor-in-Chief by Area Editor Dr. E. Cabal-Yepez.
* Corresponding author.
E-mail addresses: gupta.bhupendra@gmail.com (B. Gupta), tarunag04@gmail.com (T.K. Agarwal).

http://dx.doi.org/10.1016/j.compeleceng.2017.01.010

the input image brightness is essential. Many methods have been proposed by various researchers to deal with this mean shift problem in the output image.

Initially, in 1997, Kim proposed a method known as BBHE (Brightness Preserving Bi-histogram Equalization) [9] to preserve the mean brightness of the image. In this method, Kim divided the input histogram into two sub-histograms based on the mean grey level of the input image. Then, histogram equalization is performed independently on each of the sub-histogram. Also, in [9] Kim analytically proved that the mean brightness of output image lies between mean brightness of input image and middle grey level, and thereby reducing the saturation effect and other annoying artefact on the output image. In BBHE, Kim divided the histogram on input image based on the mean grey level intensities of the image.

In 1999, Wang et.al. proposed DSIHE (Equal Area Dualistic Sub Image Histogram Equalization) [10]. This method is similar to the BBHE, except that the division of histogram into two sub-histogram is based on the median value instead of the mean value of the input image. In median based division, each sub-histogram contains the same number of pixels. In [10] authors claimed that DSIHE gives better results in comparison to BBHE in terms of preserving an image's brightness and entropy.

Later, Chen and Ramli proposed another method MMBEBHE (Minimum Mean Brightness Error Bi-histogram Equalization) for maintaining the mean brightness of an image [11]. This method is also an extension of BBHE, but unlike BBHE it determines the histogram partition threshold in such a way that it minimizes the mean brightness difference between the input image and the processed image.

Again, in 2003, Chen and Ramli proposed a scheme named as RMSHE (Recursive Mean Separate Histogram Equalization) for image contrast enhancement [12]. This method is a generalization of BBHE. In RMSHE, a recursive division of the histogram into sub-histograms takes place. This division of the histogram into sub-histograms is based on local mean values. The number of the sub-histogram after rth recursion is 2^r, where r is a natural number and depends upon user choice.

Another method, RSIHE (Recursive Sub-Image Histogram Equalization) is proposed by Sim et.al. in 2007 [13]. This method is similar to the RMSHE. This method also recursively subdivides the histogram into two or more sub-histograms on the basis of median value instead of the mean value. It is claimed by authors that RSIHE gives better results in comparison to RMSHE.

In 2008, Kim et.al. suggested a method known as RSWHE (Recursive Separated and Weighted Histogram Equalization) [14]. This method is exactly similar to RMSHE or RSIHE, the only difference is that, in RSWHE, normalized power law function is applied. In [14] authors applied this method for both recursive mean (RSWHE-M) and recursive median (RSWHE-D).

In 2007, Wadud et.al. [15] proposed a new method DHE (Dynamic Histogram Equalization) for contrast enhancement of an image without making any loss of details of an input image. DHE, partitions the image histogram based on local minima and assigns specific grey level ranges for each partition before equalizing them separately.

An extension of DHE is proposed by Ibrahim et. al. [16] named as BPDHE (Brightness Preserving Dynamic Histogram Equalization for image contrast enhancement). In BPDHE 1-dimension Gaussian filter is used for smoothen the histogram of the input image. Then, input image histogram is partitioned on the basis of local maximum. Similar to DHE, this method also maps each sub-histogram into a new dynamic range. The BPDHE method produces better results in terms of mean brightness preservation and contrast enhancement as compared to DHE.

Two other interesting methods are proposed by Khan et.al. [17] and Huynh-The et.al. [18]. These methods also perform histogram segmentation before applying histogram equalization. In [17], the authors proposed decomposition of the input histogram into multiple sub-histogram by taking mean or median values as thresholds. In [18], Huynh-The et.al. used within class variance for decomposition of the input histogram into multiple sub-histogram.

More recently, Tiwari et.al. [19], suggested a non-recursive nature approach HSQHE for the sub-division of input histogram, based on the Quantile value of the intensity distribution. The main advantage of this approach is its non-recursive nature, which makes this approach faster than the other approaches. Also the Quantile based division of histogram provides equal weights to the entire spectrum of grey level to play its role in enhancement process. Few other methods for enhancement of contrast in dimmed light and grey scale images are proposed in [20–22].

In every previously mentioned method, quality of the enhancement is based on the choice of number of division of histogram into sub-histograms. Although every method uses a different criterion for dividing input histogram into sub-histogram, they have a common drawback that number of sub-histograms is decided manually by the user. Hence, final enhancement is not optimal as it depends on the choice given by the user. Also, in most of the cases user can choose only 2^r number of sub-histograms, (where $r = 1, 2, 3, \ldots$ depending on the choice of user), i.e., a user cannot divide input histogram in to 3,5,6 sub-histogram. This drawback of existing methods motivated us to design a method that provides automatic selection (depending upon the histogram of the input image) of a number of sub-histogram for the optimal enhancement of contrast.

In this paper, we propose a new method LQSWDHE (linearly quantile separated weighted dynamic histogram equalization), which is an extension of DHE, BPDHE, and HSQHE. This method subdivides the histogram of input image on the basis of quantiles. Then each sub-histogram is mapped to a new dynamic range, which is similar to DHE or BPDHE. Further, a normalized power law function followed by HE is applied on each sub-histogram separately and finally normalization of the processed image is performed.

Organization of this paper is as: Section 2 describes the proposed method LQSWDHE in detail. Section 5 describe metrics which we use to evaluate the performance of the proposed method. Section 4 presents experimental results and comparison of results with the other standard methods and then the paper concludes in Section 5.

Please cite this article as: B. Gupta, T.K. Agarwal, Linearly quantile separated weighted dynamic histogram equalization for contrast enhancement, Computers and Electrical Engineering (2017), http://dx.doi.org/10.1016/j.compeleceng.2017.01.010