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Minimum mean brightness error contrast enhancement of color images using adaptive gamma correction with color preserving framework

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ABSTRACT

In this paper, we propose an efficient method to enhance contrast of digital images. Image contrast enhancement is a pre-processing step that improves efficiency of other image dealing applications such as computer vision and pattern recognition. The proposed method enhances contrast and brightness of given image using the gamma correction and weighted probability distribution of luminance pixels. Experiments results show that the proposed method is able to enhance contrast of all type of color images without much affecting its visual and color information.

1. Introduction

Insufficient contrast in back-light images reduce the ability of observer in analyzing the image. In many cases insufficient contrast may produce difficulties in subsequent processing. This insufficient contrast may occur due to various reasons such as presence of clouds in the captured scene, lack of operator expertise and inadequacy of the image capture device, etc. In the available literature we are giving introduction of various methods that are used for image contrast enhancement. These methods can be broadly divided into two categories they are, direct enhancement [2–4] and indirect enhancement [5–7]. In direct enhancement methods, the image contrast can be directly defined by a specific contrast term [2–4]. However, most of these metrics cannot simultaneously gauge the contrast of simple and complex patterns in images which contain both [4].

Histogram equalization (HE) based techniques fall under the category of indirect enhancement methods. These techniques attempt to enhance image contrast by redistributing the probability density [1]. Using these techniques [9–15] the intensities can be better redistributed within the dynamic range. Histogram equalization techniques [9–15] are popular due to their simplicity of implementation and computationally less expensiveness than other methods.

Although the HE based methods are widely used, in histogram equalization we do not have any mechanism to control the enhancement level, due to this sometimes output image may have over enhanced regions. Also HE could not effectively work, when the input image contains regions that are significantly darker or brighter than other parts of the image. Another problem with HE is, in theory it is clearly shown that mean brightness of histogram equalize image is always middle gray level; regardless the mean brightness of input image. This problem is known as the 'mean-shift' problem. In [8], K. Zuiderveld proposed a widely used method known as 'contrast limited adaptive histogram equalization' (CLAHE). The CLAHE method was able to reduce the over enhancement of contrast in the processed image but it was not capable in reducing the mean brightness change in the processed image. To solve the 'mean-shift' problem, Yeong-Taeg in [9] proposed 'brightness preserving bi-histogram equalization' (BBHE) where the image X is divided into two sub-images X_L and X_U based on mean X_M of brightness of input image and then equalize these two sub-histograms separately. Later Zhang in [10] proposed 'equal area dualistic sub-image histogram equalization' (DSIHE), though this approach also separates an input image into two sub-sections, the only difference between BBHE and DSIHE is, in later method the separation is based on the median value.

An extension of BBHE has been proposed by Chen and Ramli in [11], known as 'minimum mean brightness error bi-histogram

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equalization' (MMBEBHE). This method provides maximum brightness preservation. The MMBEBHE proposes to perform the separation based on the threshold level, which would yield minimum absolute mean brightness error [11]. The MMBEBHE is a useful tool to control the brightness difference between input and processed image. In [12], Chen and Ramli proposed another interesting method called 'recursive mean-separate histogram equalization' (RMSHE), here authors suggested recursive division of histograms, based on the local mean. In each recursive step existing sub-histogram is divided into two sub-histograms. After rth recursion the number of sub-histogram is 2^r, where number of recursion depends on choice of user. Also authors proved mathematically that as r increases, the mean brightness of processed image approaches towards the mean brightness of input image. Sim et al. in [13], improved DSIHE into 'recursive sub-image histogram equalization' based contrast enhancement (RSIHE), by introducing recursive segmentation in the similar manner as Chen and Ramil proposed in [12], this method is similar to RMSHE but it uses median values instead of mean values to divide histogram into sub-histograms.

Recently, S.C. Huang et al. [16], propose 'efficient contrast enhancement using adaptive gamma correction with weighting distribution' (AGCWD). This method is an automatic transformation technique that improves the brightness of dimmed images via the gamma correction and probability distribution of luminance pixels; also this method produces enhanced images of comparable or higher quality than those produced by other methods [16].

The organization of this work is as follows. After introducing about research background in Section 1, Section 2 describes the AGCWD method. Section 3 explains the proposed method in details. For evaluation of proposed method experimental results are shown in Section 4. Finally Section 5 summarizes and concludes the proposed work.

2. The AGCWD method

As mentioned earlier in [16], S.C. Huang et al. proposes 'efficient contrast enhancement using adaptive gamma correction with weighting distribution', (AGCWD). The AGCWD method can progressively increase the low intensity and avoid the significant decrement of the high intensity. The AGCWD method applies the weighting distribution (WD) function to slightly modify the statistical histogram and lessen the generation of adverse effects. The WD function is formulated as:

$$pdf_w(l) = pdf_{\max}\left(\frac{pdf(l) - pdf_{\min}}{pdf_{\max} - pdf_{\min}}\right)^{\alpha}, \quad (1)$$

where α is the adjusted parameter, $pdf_{\max}$ is the maximum pdf of the statistical histogram, and $pdf_{\min}$ is the minimum pdf. Based on Eq. (1) the gamma parameter is given as:

$$\gamma = 1 - cdf(l), \quad (2)$$

where cdf is resultant cumulative distribution function calculated after normalizing pdf_w. The adaptive gamma correction (AGC) used by S.C. Huang et al. in [16] is given as:

$$T(l) = (L-1)\left(\frac{l}{L-1}\right)^{\gamma} = (L-1)\left(\frac{l}{L-1}\right)^{1-cdf(l)}, \quad (3)$$

where $(L-1)$ is the maximum intensity value of the image. It is clear that slight increase in $cdf(l)$ will cause drastic change in intensity value l of the processed image.

3. The proposed method

The resultant cdf curve of AGCWD [16] method is shown in Fig. 1.

It is clear from Fig. 1 that for $\alpha = 1.2$ and $\alpha = 0.8$ the resultant transformation curve is not increasing smoothly. To prove our this claim (in $image_1$ for transformation curve $\alpha = 1.2$) we have marked two intervals on x-axis (x_1, x_2); (x_3, x_4) and their corresponding intervals on y-axis (y_1, y_2); (y_3, y_4). The small interval (x_1, x_2) is transformed to sufficiently large interval (y_1, y_2) and in this case sufficient weights will be assigned to Eq. (3). However on the other hand due to non-smooth nature of the curve the large interval (x_3, x_4) is transformed to a small interval (y_3, y_4) and hence weights for a large interval will be not sufficiently large. This may also lead to loss of information in processed image.

To solve this problem and to make the resultant transformation curve to be smoothly increasing with sufficient color preservation; we proposed a new method called 'adaptive gamma correction with color preserving framework' (AGCCPF). The proposed method uses two-steps processing; initially it enhances contrast and brightness of given image using modified probability distribution of luminance pixels followed by the gamma correction. In second step it uses a color preserving framework for color restoration.

The objective of all histogram based contrast enhancement methods is to transform the histogram of an input image closer

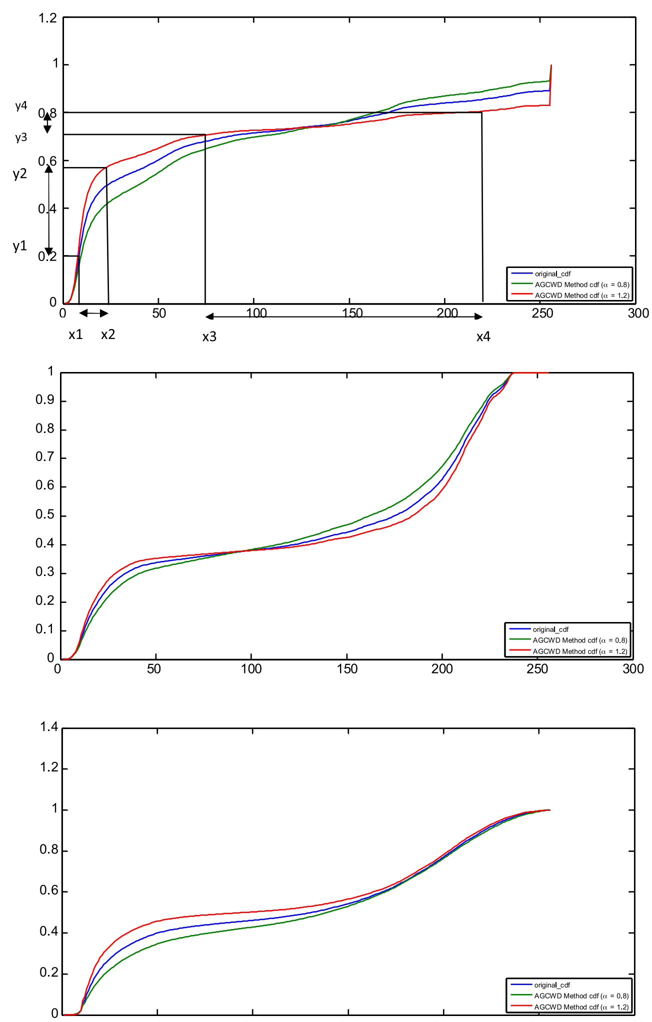

Fig. 1. Resultant transformation curve of AGCWD method, after applying weighting distribution function on $image_1$, $image_2$ and $image_3$. Here x-axis shows gray level of image and y-axis shows corresponding cumulative distribution function at each gray level.