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Adaptive contrast enhancement using modified histogram equalization

K. Santhi[a,*], R.S.D. Wahida Banu[b]

[a] K. S. Rangasamy College of Technology, Tiruchengode 637215, Tamilnadu, India
[b] Government College of Engineering, Salem 636011, Tamilnadu, India

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ABSTRACT

Adapted enhancement controlled contrast using adjusted histogram is developed to minimize the problems of over enhancement, saturation artifacts and change in mean brightness with conventional histogram equalization. The input image's histogram is first divided into four sub-histograms based on its median. A clipping process based on the input image mean is applied. Then each partitioned histogram is equalized independently. A contrast enhancement rate is devised in order to achieve the varying contrast for output images. The proposed algorithm is proved to produce better enhanced images than the contemporary techniques in terms of contrast per pixel and structural similarity index.

1. Introduction

Due to portability and easy implementation, the digital camera has become an additional feature embedded in cell phones by many manufacturers. However, the qualities of the images captured using a cell phone camera is usually poor as a result of low contrast [3]. In a dark room or during night time, the lack in natural light-sources leads to poor and lowly contrasted images. To overcome this problem, recently LEDs are used for dark environments. However, the lighting from LEDs of capturing devices is insufficient to brighten the course between the image and the images capturing device which are at a longer distance. As a result, the images captured produce annoying artifacts for low contrast [5].

Histogram equalization (HE) is a popular technique for enhancing image contrast, is to map the gray levels based on the probability distribution of the input image gray levels. HE flattens and stretches the dynamic range of an image histogram and gives an overall contrast improvement [7]. HE has been used in all fields like Medical, Radar, Satellite and Microstructure image processing. The HE is available in most image processing packages such as Adobe Photoshop [12], National Institutes of Health Image [8] and Lispix [13]. But the enhanced image tends to have unnatural enhancement and intensity saturation artifacts due to the error in brightness because of mean-shifting due to HE [11]. In the recent years, many researchers have proposed several useful algorithms to solve the problems of HE [4,9,10,14,15,20]. Generally these contrast enhancement using HE can be divided into two partitioned histogram equalization or dynamic partitioned histogram equalization (DPHE). One important thing of DPHE is assigned to a new enhanced dynamic range instead of using the original dynamic range [2,18]. Its partition is based on mean or median values. The mean preserving bi-histogram equalization with neighborhood metrics has been proposed to overcome the saturation effect. First, an original image histogram is created using the distinction neighborhood metric and it is divided into 2040 sub bins. Second, the histogram is separated into two sub-histograms, which are equalized independently [17].

Recently, Range Limited Bi-Histogram Equalization for Image Contrast Enhancement (RLBHE) has been developed [1]. This method divides the input histogram into two independent sub-histograms by a threshold which is used to separate the object from the background that minimizes the intra class variance. Then the range of the output image is calculated to yield minimum absolute mean brightness error between the original and equalized image.

This article presents an Adapted Contrast Enhancement using Modified Histogram (ACMHE). The main objective of contrast enhancement is to process an image in order to get a better result that is more suitable than that of the original image. Therefore the proposed method divides the histogram into four parts based on the median brightness. The enhancement rate parameter plays an important role in ACMHE. Simulation results showed that this proposed algorithm is more suitable to enhance the contrast and to maintain the brightness. Structural similarity index and contrast per pixel are used to analyze the image quality. This paper

* Corresponding author. Tel.: +91 9843281823.
E-mail address: santhik@ksrct.ac.in (K. Santhi).

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is organized as follows: Section 2 deals with histogram equalization, Section 3 describes the proposed work, Section 4 presents the quality measurement tools. Simulation results are given in Section 5 and finally, the conclusion is provided in Section 6.

2. Histogram equalization

Let, $X = \{X(i,j)\}$ denote a digital image, where $X(i,j)$ represents the gray level of pixel (i,j) composed of L discrete gray levels, denoted as $\{X_0, X_1, \ldots, X_{L-1}\}$ and $X(i,j) \in \{X_0, X_1, \ldots, X_{L-1}\}$. For a given image X, the Probability Density Function (PDF) $p(X_k)$ is defined as:

$$p(X_k) = \frac{n_k}{n} \tag{1}$$

for $k = 0, 1, \ldots, L-1$, where n_k represents the number of pixels that have the value of k and n is the total number of samples in the input image. Note that $p(X_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensity X_k. A plot of n_k vs X_k is known as the histogram of $X(i,j)$. Based on the, image's PDF, its Cumulative Density Function (CDF) as:

$$c(X) = \sum_{j=0}^{k} p(X_j) \tag{2}$$

where $k = 0, 1, \ldots, L-1$. Note that $c(X_{L-1}) = 1$ by definition. Histogram equalization is a scheme that maps the input image into the entire dynamic range, (X_0, X_{L-1}) by using the cumulative density function as a transform function [4]. That is, let us define a transform function $f(x)$ based on the cumulative density function as:

$$f(x) = X_0 + (X_{L-1} - X_0)c(x) \tag{3}$$

then the output image of the histogram equalization, $Y = \{Y(i,j)\}$ can be expressed as:

$$Y = f(x) = \{f(X(i,j)) / \forall X(i,j) \in X\} \tag{4}$$

where (i,j) are the spatial coordinates of the pixel in the image.

3. Adaptive contrast modified histogram equalization (ACMHE)

Adaptive controlled contrast using modified histogram (ACMHE) which is proposed in this paper consists of six steps:

1. Average difference metrics
2. Clipping process
3. New gray point array distribution
4. Histogram equalization
5. Enhancement rate controlling process
6. Adjusting the level of enhancement.

The details of each step are described in the following subsections.

3.1. Average difference metrics

Histogram of original image is divided into two sub-histograms. For separating point, median values are used to divide the two sub-histograms into two smaller associate-histograms and totally four sub-histograms are obtained. In the input histogram, the minimum and maximum intensity values (0,255) are used to set as the separating points. Each and every separating point can be calculated by the Eqs. (5–8):

$$q_1 = 0.2\{R_{\text{width}} \times R_{\text{height}}\} \tag{5}$$

$$q_2 = 0.4\{R_{\text{width}} \times R_{\text{height}}\} \tag{6}$$

$$q_3 = 0.6\{R_{\text{width}} \times R_{\text{height}}\} \tag{7}$$

$$q_4 = 0.8\{R_{\text{width}} \times R_{\text{height}}\} \tag{8}$$

where q_1, q_2, q_3 and q_4 are the total number of pixels in the input image histogram intensities set to 0.2, 0.4, 0.6 and 0.8 respectively. R_{width} and R_{height} represent the width and the height of the input image.

3.2. Clipping process

In order to overcome the unnatural and over enhancement of processed image, clipping process is used. For this automatic clipping process, the self-adaptive plateau HE for the infrared image contrast enhancement is proposed. This algorithm may fail to detect local peak detection for classical images. So, a modified-SPAHE [13] was introduced to locate median value of the non-empty bins as the clipping threshold T_c. In this proposed work, to minimize computational complexity, average numbers of intensity values were taken for implementation.

3.3. New gray point array distribution

Partition based histogram equalization methods perform the enhancement process in each sub-histogram which are between two separating points. Thus the sub-histograms may not ensure the balance space in each sub-histogram for sufficient contrast enhancement because contrast enhancement obtained in a narrow stretching space is less significant. This phenomenon particularly occurs when the side of the sub-histogram is narrow. Consequently, the processed image tends to suffer from loss of image details and intensity saturation artifacts [3]. To balance the enhancement space for each sub-histogram, a novel gray level dynamic range method is employed in this proposed method.

$$\text{Dynamic range} = \frac{\text{Gray level spans}}{\text{Total no. of pixels}} \tag{9}$$

$$Span_r = q_{r+1} - q_r \tag{10}$$

$$Factor_r = Span_r \times (\log_{10} Q_r)^{\delta} \tag{11}$$

where $span_r$ in (10) is the dynamic gray level used by rth sub-histogram in the input image, q_r is the rth separating point, Q_r is the total number of pixels in rth sub histogram and δ is the amount of emphasis, which is the adjusted parameter. In the input image, its dynamic range of the gray levels is '0' i.e. $\delta = 0$. In this moment, the image details will be at a loss. Then the value of δ is important and it is discussed in next subdivision.

$$Range_r = \frac{Factor_r}{\sum_{k=1}^{n} factor_k} \times (L-1) \tag{12}$$

where $k = 0, 1 \ldots, n$ (12). In the rth sub-histogram the new dynamic range is allocated from $[r_{\min}, r_{\max}]$, where

$$r_{\min} = (r-1)_{\max} + 1 \tag{13}$$

$$r_{\max} = r_{\min} + range_r \tag{14}$$

The $r_{\min}$ represents minimum intensity value of new dynamic range. $range_r$ states the gray level range for ith sub-histogram in the output image.

3.4. Histogram equalization

After obtaining the dynamic range as in Eq. (9), the new ranges are found in all sub histograms. At last, each sub-histogram is equalized independently. The rth histogram is assigned at a gray level