A Modified Histogram Equalization for Contrast Enhancement
Preserving the Small Parts in Images

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Summary
Histogram equalization is a very popular technique for image contrast enhancement. However, it at times produces a washed-out appearance of the small details present in an image. In this paper, a modified contrast enhancement technique based on conventional histogram equalization algorithm is proposed. This technique modifies the accumulations in the histogram bins of an image before applying the equalization process so that it performs the enhancement of the image without making any loss of details in it. This method outperforms other present approaches by enhancing the contrast well without introducing washed out appearance, checkerboard effects or any such undesirable artifacts.

Key words:
Contrast enhancement, histogram equalization, washed-out appearance, image details.

1. Introduction
Many image/video processing applications use a contrast enhancement as a preprocessing step. Different contrast enhancement methods have already been developed which make use of simple linear/non-linear gray level transformation functions as well as complex analysis of different image features. Among them, histogram equalization (HE) [1-5] is a very popular technique for contrast enhancement of images. HE is the most commonly used method due to its simplicity and good performance on almost all types of images. HE remaps the gray levels based on the probability distribution of the input gray levels in an image [6].

Different approaches of applying histogram equalization are found in the literature. Global Histogram Equalization (GHE) [1] uses the histogram information of the entire input image for its transformation function. Though this global approach is suitable for overall enhancement, it fails to adapt with the local brightness features of the input image. The gray levels with very high frequencies (number of occurrences) dominate over the other gray levels having lower frequencies in an image. In such a situation, GHE remaps the gray levels in such a way that the contrast stretching becomes limited in some dominating gray levels having larger image histogram components, and it causes significant contrast loss for other small ones. Local histogram equalization (LHE) [1] can get rid of such problem. It uses a small window that slides through every pixel of the image sequentially and only the block of pixels that fall in this window are taken into account for HE and then gray level mapping for enhancement is done only for the center pixel of that window. Thus, it can make remarkable use of local information also. However, LHE requires high computational cost and sometimes causes over-enhancement in some portion of the image. Another problem of this method is that it also enhances the noises in the input image. To get rid of the high computational cost, another approach is to apply non-overlapping block based HE [1]. Nonetheless, most of the time, these methods produce undesired checkerboard effects.

Different variants of histogram equalization are also available. These variants aims at improving the performance of the traditional HE. Examples of such variants include mean preserving bi-histogram equalization (BBHE) [4], equal area dualistic sub-image histogram equalization (DSIHE) [7], minimum mean brightness error bi-histogram equalization (MMBEHE) [6, 8], etc. BBHE [4] separates the input image histogram into two parts based on input mean. After separation, each part is equalized independently. This method tries to overcome the brightness preservation problem. DSIHE [7] method uses entropy value for histogram separation. MMBEBHE [6, 8] is the extension of BBHE method that provides maximal brightness preservation. Though these methods can perform good contrast enhancement, they also cause more annoying side effects depending on the variation of gray level distribution in the histogram [9]. Recursive Mean-Separate Histogram Equalization (RMSHE) [6] is another improvement of BBHE. However, it also is not free from side effects. Moreover, such approaches may not ensure good enhancements of all the partitions [10]. The difference in the degrees of enhancements of different parts may create undesired artifacts in the image.

We have proposed a modified histogram equalization (MHE) technique in this paper to overcome the aforementioned problems. Unlike histogram equalization where higher histogram components dominate the lower
parts, the proposed MHE employs a modification operation over the input histogram to reduce the accumulations of the higher histogram bins so that they may not be dominating. Thus, a better overall contrast enhancement is gained by MHE eliminating the possibility of the low histogram components to be compressed that may cause some part of the image to have washed out appearance.

The rest of the paper is organized as follows. Section 2 presents the HE process along with the shortcomings, and then the proposed MHE. Section 3 presents some experimental results of applying MHE and some other methods, and Section 4 concludes the paper.

2. The Proposed Approach

In this section, we first present the procedure of the traditional global histogram equalization (GHE), and then propose the modified histogram equalization (MHE) to overcome the shortcomings faced by the GHE.

Suppose that an image \( f(x, y) \) is composed of discrete gray levels in the dynamic range of \([0, L-1]\). The transformation function \( C(r_k) \) used by the GHE is defined as

\[
s_k = C(r_k) = \sum_{i=0}^{k} P(r_i) = \sum_{i=0}^{k} \frac{n_i}{N},
\]

where \( 0 \leq s_k \leq 1 \) and \( k = 0, 1, 2, \ldots, L-1 \).

In Eq. 1, \( n_i \) represents the number of pixels having gray level \( r_i \), \( N \) is the total number of pixels in the input image, and \( P(r_i) \) represents as the Probability Density Function (PDF) of the input gray level \( r_i \). Based on the PDF, the Cumulative Density Function (CDF) is defined as \( C(r_k) \).

Here \( s_k \) can easily be mapped to the dynamic range of \([0, L-1]\) multiplying it by \( (L-1) \).

Our key focus in the proposed modified histogram equalization (MHE) is to eliminate the domination of higher histogram components on lower histogram components in the image histogram for a better enhancement of the image features. To do so we shorten the bigger histogram bins before applying the equalization process of Eq. 1. The whole MHE can be divided into two parts: modifying the dominating bins in the histogram and applying equalization.

2.1 Elimination of Domination

The smaller bins in the histogram of an image lacks proper enhancement due to the domination of the larger values in Eq. 1. Hence, to preserve the small details of an image, we propose to modify the image histogram before applying the equalization process. The modification of the histogram is done according to

\[
n_i = \min(n_i, m),
\]

where \( m \) is a threshold value to control the modification.
where \( n_i \) represents the number of pixels having gray level \( r_i \), and \( m \) is the mean of the accumulations in the non-zero histogram bins.

The modification by Eq. 2 shortens the histogram bins having the accumulations higher than the mean of the bins. This helps to prevent the possible domination of these bins during the equalization process.

2.2 Equalization

After the modification done by Eq. 2, the traditional HE is applied on the modified histogram using Eq. 1. The modification of histogram bins prevent under (as well as over) enhancement of some parts of an image. Hence, a very good overall enhancement is achieved for the whole image that produces a soothing look of the image without incurring any of the common artifacts produced by the traditional equalization approaches.

2. Experimental Results

We have applied the proposed MHE as well as other different equalization methods found in the literature to see the comparative performances of the enhancement approaches.

In Fig. 3, we can observe that GHE has increased the overall brightness of the image. It has not enhanced the contrast that much. Moreover, it has produced washed out effects in some portion of the image. RMSHE, using \( r = 2 \), has not provided a noticeable improvement in the contrast of the image. On the other hand, MHE provides a good overall enhancement. The body of the swan is enhanced, and the background is also enhanced. Moreover, it does not increase the brightness of the image too much. This is due to the reason that the enhancement in the dominating gray levels are controlled in MHE though the modification step. Furthermore, MHEed output is also free from any washed-out appearance.

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In Fig. 5, another set of enhanced outputs of different methods. (a) Original image, (b) RMSHEed image (\( r = 3 \)), (c) GHEed image, (d) MHEed image.

In Fig. 5, another set of enhanced outputs of different methods. (a) Original image, (b) RMSHEed image (\( r = 3 \)), (c) GHEed image, (d) MHEed image.
on the background. The proposed MHE, on the other hand, provides good enhancement with a very soothing appearance.

Fig. 5 also demonstrate a set of experimental outputs produced by the different enhancement approaches. It also advocate for the MHE due to its superior performance as compared to the other methods.

4. CONCLUSION

A modification of the traditional histogram equalization technique has been proposed for contrast enhancement of low contrast images. The proposed MHE enhances the image without making any loss in image details. Moreover, the method is very simple and computationally effective to be implemented in any practical system.

References


M. Abdullah-Al-WADUD was born in Galania, Brahmanbaria, Bangladesh. He received his B.S. degree in Computer Science and M.S. in Computer Science and Engineering from the University of Dhaka, Bangladesh in 2003 and 2004, respectively. In 2009, he completed his PhD in Computer Engineering from Kyung Hee University, South Korea. He served as a lecturer in Faculty of Sciences and Information Technology, Daffodil International University, Bangladesh, and in Faculty of Sciences and Engineering, East West University, Bangladesh, in 2003 and 2004, respectively. Currently he is working as an Assistant Professor in the Department of Industrial and Management Engineering, Hankuk University of Foreign Studies, South Korea. His research interest includes image enhancement, medical image processing, pattern recognition, sensor and ad hoc networks.