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 (MMBEBHE) [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

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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

$$s_k = C(r_k) = \sum_{i=0}^{k} P(r_i) = \sum_{i=0}^{k} \frac{n_i}{n}, \qquad (1)$$

where $0 \le s_k \le 1$ 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).

(a) (b)

Fig. 1. The result of applying the GHE method on an image. (a) Original image (b) GHEed image

GHE usually provides a significant improvement in image contrast, but along with some artifacts and undesirable side effects such as washed out appearance. In Eq. 1, larger values of n_i cause the respective gray levels to be mapped apart from each other that ensures good enhancement. However, the mapping of the gray levels having smaller n_i values are forced to be condensed in a small range that makes less enhancement in such gray levels. Moreover, rounding errors may also occur in the transformation such gray levels when the output gray levels are quantized into integer values. In such cases, there is the possibility mapping more than one input gray levels to the same output gray level that leads to the loss of image details. These two phenomena are the main sources of the washed out appearances in the output image. Fig. 1 shows an example of such effect. Here the gray levels of the flower have a washed-out appearance. Fig. 2. presents the corresponding histogram of the input image. The small accumulations in the right-most tail of the histogram come from the gray levels present in the flower region of the image. These are too small that the other big components of the histogram dominate them, and it results in a washed out effect.

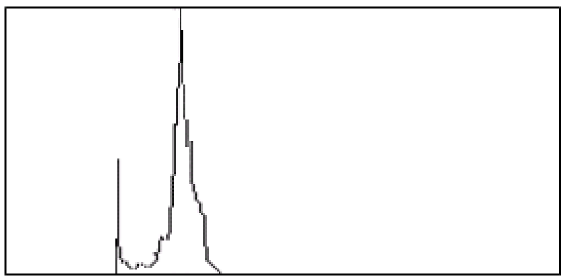

Fig. 2. The of the image in Fig. 1(a).

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

$$n_i = \min(n_i, m), \qquad (2)$$

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.

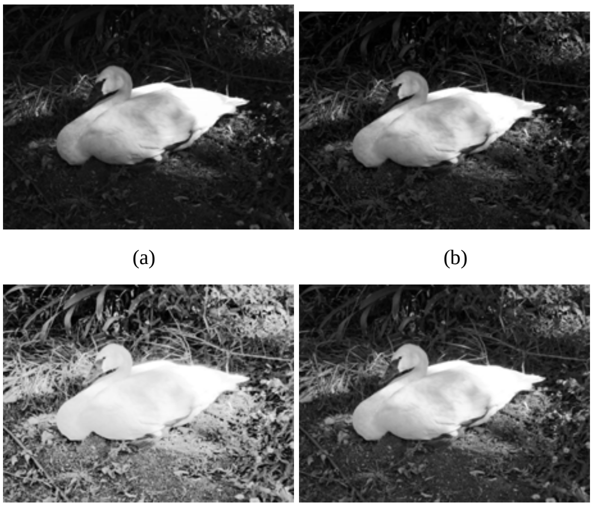

Fig. 3. Enhanced outputs of different methods using the *swan* image. (a) Original image, (b) RMSHEed image (r = 2), (c) GHEed image, (d) MHEed image.

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.

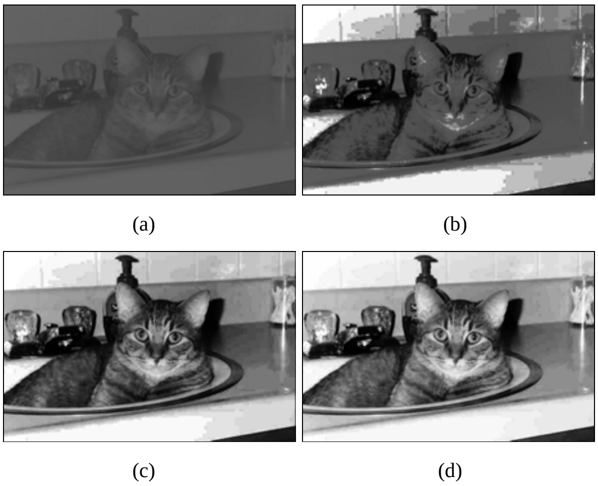

Fig. 4. Enhanced outputs of different methods using the *cat* image. (a) Original image, (b) RMSHEed image (r = 2), (c) GHEed image, (d) MHEed image.

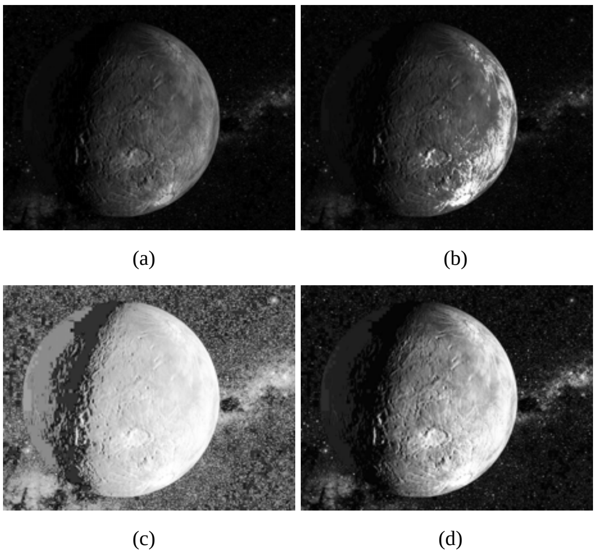

Fig. 5. Another set of enhanced outputs of different method. (a) Original image, (b) RMSHEed image (r = 3), (c) GHEed image, (d) MHEed image.

In Fig. 4, the RMSHE does not provide a good enhancement of contrast of the image. Moreover, both GHE and RMSHE have created some unwanted artifacts

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.

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