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A MODERATE HISTOGRAM EQUALIZATION METHOD FOR IMAGE ENHANCEMENT

ABSTRACT

The traditional histogram equalization and most of its variants usually suffer from different artifacts such as washed out appearance, checkerboard effect and unnatural look due to over or under enhancement of some parts of an image. We propose a moderate histogram equalization to enhance the contrast of the different parts of an image ensuring a soothing appearance with no severe side effect. Experimental results also advocate for the superiority of the proposed method over the other currently available variants of histogram equalization.

KEYWORDS: Image Enhancement, Contrast, Dynamic Range, Histogram Equalization, Artifacts.

INTRODUCTION

The field of image enhancement targets at producing a clearer view of the details in an image. It plays an important role to the image or video display systems for human vision. It also works as a preliminary step in many image/video processing systems and applications such as medical image processing and pattern/texture analysis [1-3].

Among the many contrast enhancement techniques proposed so far in the research community, histogram equalization (HE) [4-7] is one of the most popular techniques. It is the most commonly used method due to its simplicity and comparatively better performance on almost all types of images. Different variants of the original HE techniques have also been proposed in the recent years. Global Histogram Equalization (GHE) [4] 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. If there are some gray levels in the image with very high frequencies, they dominate the other gray levels having lower frequencies. 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 causes significant contrast loss for other small ones. Local histogram equalization (LHE) [4] 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 along with the image features. To get rid of the high computational cost, another approach is to apply non-overlapping block based HE. Nonetheless, most of the time, these methods produce an undesirable checkerboard effects on enhanced images [4].

There are also some proposals that partition image histogram into different parts and then equalize each part independently. Mean preserving bi-histogram equalization (BBHE) [5], equal area dualistic sub-image histogram equalization (DSIHE) [8] and minimum mean brightness error bi-histogram equalization (MMBEBHE) [9], [10] are few among these techniques. BBHE 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 method uses entropy value for histogram separation. MMBEBHE 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. Recursive Mean-Separate Histogram Equalization (RMSHE) [9] is another improvement of BBHE. However, it also is not free from side effects [7]. And the enhancements are not visible in some histogram partitions that have small dynamic gray level ranges.

We propose a Moderate Histogram Equalization (MHE) technique in this paper to overcome the aforementioned problems and produce a sooth looking overall enhancement of every part of an image. The proposed MHE employs a partitioning operation over the input image to chop it into some blocks so that they have no dominating component in them. Then each image block goes through the calculations of HE and generates a mapping of gray levels. These mappings are finally combined together to form the final gray level mapping, which is applied on the whole image. Thus, a better overall contrast enhancement is gained by MHE eliminating the possibility of the low histogram components being compressed that may cause some part of the image to have washed out appearance. Moreover, MHE ensures consistency in preserving image details and is free from any severe side effect. The experimental results on several images also demonstrate such excellent performances of the MHE.

The rest of the paper is organized as follows. Section II gives some of the existing methods, and the proposed MHE is described in Section III. Section IV presents some experimental results of applying MHE and some other method on different images, and then section V concludes the paper.

RELATED WORKS

In this section, we review some of the existing HE approaches in brief. Here we discuss about GHE, LHE and some methods based on histogram partitioning.

Global Histogram Equalization (GHE)

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

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

where $0 \le s_k \le 1$ and k = 0, 1, 2, …, L-1.

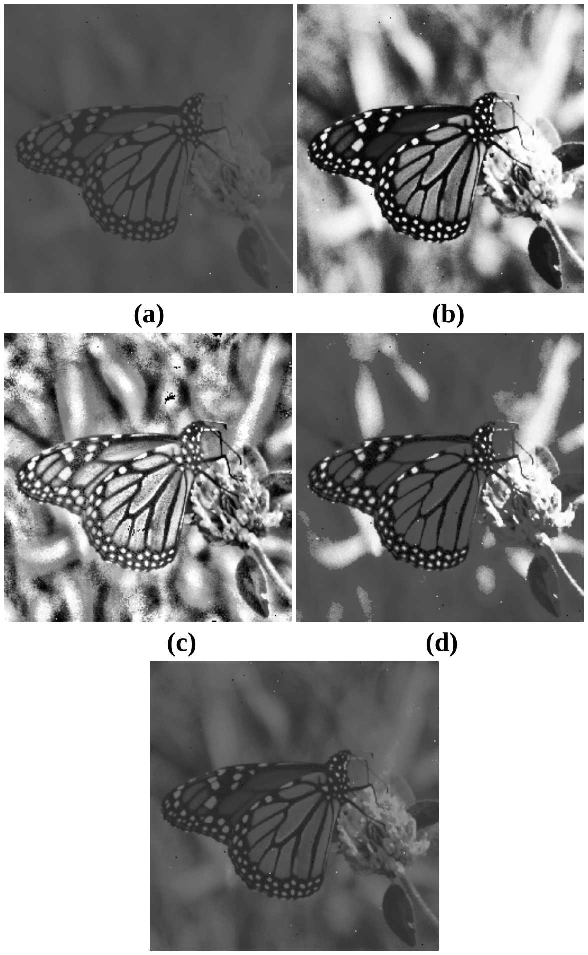
In (1), n_i represents the number of pixels having gray level r_i, n is the total number of pixels in the input image, and $P(r_i)$ represents as the Probability Density Function (PDF) of the input gray level r_i. Based on the PDF, the Cumulative Density Function (CDF) is defined as $C(r_k)$. This mapping in (1) is called Global Histogram Equalization (GHE) or Histogram Linearization. Here s_k can easily be mapped to the dynamic range of [0, L-1] multiplying it by (L-1).

Figure 1(b) shows that GHE provides a significant improvement in image contrast, but along with some artifacts and undesirable side effects such as washed out appearance in the gray levels of the flower. In (1), larger values of n_k cause the respective gray levels to be mapped apart from each other forcing the mappings of the smaller n_k values to be condensed in a small range with the possibility of duplications. This is the main source of such side effects and loss of image details.

Local Histogram Equalization (LHE)

While GHE takes into account the global information and cannot adopt to local light condition, Local Histogram Equalization (LHE) performs block-overlapped histogram equalization [4], [6]. LHE defines a sub-block and retrieves its histogram information. Then, histogram equalization is applied for the center pixel using the CDF of that sub-block. Next, the sub-block is moved by one pixel and sub-block histogram equalization is repeated until the end of the input image is reached.

LHE cannot adapt well to partial light information [11]. It also over-enhances some portions depending on its mask size. Figure 1(c) shows the results of applying LHE to Fig 1(a). In Figure 1(c), the background noises are much enhanced depending on the block size. Actually, using a perfect block size that enhances all part of an image is not an easy and smooth task to perform.



(a) (b)

(c) (d)

(e)

Figure 1. A set of images showing results of applying different enhancement approaches. (a) Original image (b) GHEed image (c) LHEed image using 32x32 blocks (d) RMSHEed image with r = 2 (e) MHEed image using 32x32 blocks.

Histogram Partitioning Approaches

As mentioned earlier, BBHE tries to preserve the average brightness of the image by separating the input image histogram into two parts based on input mean and then equalizing each of the parts independently. DSIHE partitions the image based on entropy. RMSHE proposes to partition the histogram recursively more than once. Figure 1(e) shows a result of applying RMSHE with two level (r = 2) of partitioning. The actual effect is depicted in Figure 2 [7]. Here the portion of histogram between partition 2 and 3 cannot expand much, while the outside region expands so much that creates the unwanted artifacts in Figure 1(e). This is a common drawback of most of the existing histogram partitioning approaches since they keep the partitioning point fixed through the entire process [7].

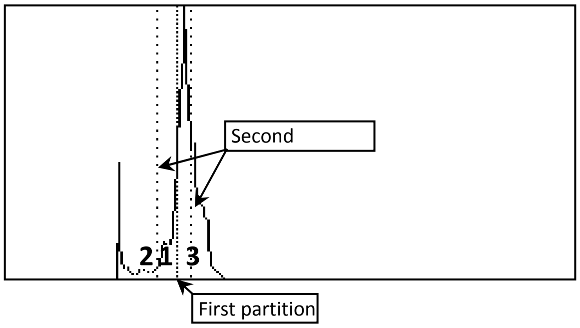


Figure 2. Partitioning histogram of image in Figure 1(a) using RMSHE. Dotted lines show portioning (r = 2) (1 denotes the first, and 2, 3 denote the 2nd partitioning).

THE PROPOSED MODERATE HISTOGRAM EQUALIZATION (MHE)

Among the existing histogram equalization approaches, Global Histogram Equalization (GHE) and Local Histogram Equalization (LHE) are the two extremes. On one hand, GHE considers the intensities of all the pixels in an image to create a mapping function that yields an overall enhancement of the image. However, though it maintains the relative intensities of the pixels, it includes a potential risk of ignoring/suppressing the small local details. Local Histogram equalization, on the other hand, considers local only the information of the pixels in a defined block, and hence, local details are enhanced independently irrespective of the overall appearance of the whole image. Especially, the relative intensities among the pixels in different blocks may not be maintained. In this paper, we propose a Moderate Histogram Equalization (MHE) to exploit and combine the good points of both these approaches.

The proposed MHE can be divided into three phases— partitioning the image, generating intensity mappings for local enhancement and the combination of the local mappings to generate the final mapping to be used in generating the output image.

Image Partitioning

In traditional HE, such as GHE, the highly occurring intensities may dominate over the other intensities in the image. Hence, to protect the local details of an image from being dominated by the more frequently occurring intensities in that image, LHE, as mentioned earlier, makes some overlapped blocks. However, the number of blocks becomes very high, and it needs much computation to calculate the intensity mappings using histogram equalization for all the blocks.

The proposed MHE divides the whole image into some non-overlapping blocks. Hence, the number of blocks is much minimized. It ensures less computation than the LHE. While the number of histogram equalization calculations in LHE is equal to the number of pixels in an image, it is equal to the number of blocks in MHE.

Generating Intensity Mappings

We generate an intensity mapping to enhance the local details in every block. Note that we make the mappings only; the out image is not generated at this stage.

To make the local enhancements, we apply the traditional HE on every block. However, applying HE independently on the non-overlapped blocks may lead to blocking effects at the block-boundaries. MHE minimizes the probable blocking effects partly during the generation of intensity mappings (the possibility of blocking effect it fully minimized during the combination phase explained later).

Suppose that the maximum and minimum pixel intensities of a block b are b_{max} and b_{min}, respectively. Also suppose that the mapping

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$b_m(x)$ generated by the HE applied on this block maps these intensities to b_{Hmax} and b_{Hmin}, respectively. The proposed MHE remaps the dynamic range [b_{Hmax}, b_{Hmin}] of the output gray levels back to the dynamic range [b_{max}, b_{min}]. The mappings for the intensities in the dynamic ranges [0, b_{min}) and (b_{max}, L) are set to 0. This process of MHE maintains the relative intensities among the neighboring blocks.

Combining the Intensity Mapping

Generating the output image using the intensity mappings calculated for each block may lead to blocking effects. In MHE, we combine the mappings together to make a final mapping for all the pixels in the image. The final mapping maps an intensity value x to y using Eq. 2.

$$y = \frac{\sum_{i=1}^{n} \begin{cases} b_m^i(x) & x \in [b_{\min}^i, b_{\max}^i] \\ 0 & Otherwise \end{cases}}{\sum_{i=1}^{n} \begin{cases} 1 & x \in [b_{\min}^i, b_{\max}^i] \\ 0 & Otherwise \end{cases}} \qquad (2)$$

where n is the total number of blocks.

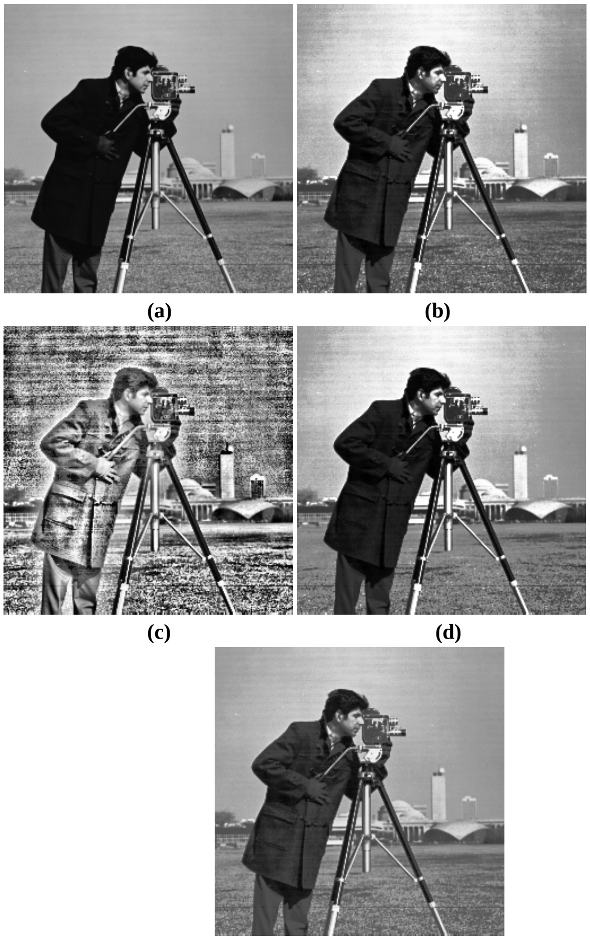
Eq. 2 calculates the average of the mappings of an intensity in all the blocks. The output image is then generated using this mapping. This prevents any possibility of blocking effects. It also maintains overall brightness of the image.

EXPERIMENTAL RESULTS

We have applied some previous algorithms and the proposed algorithm on various images to compare the enhancement abilities.

Figure 1 shows the original image along with simulation results from GHE, LHE, RMSHE and MHE. Here MHE has given better and smooth enhancement of the image without enhancing the noises or causing any undesired artifact.

In Figure 3, GHE has improved some parts of the image. However, the contrast is not that pleasing. Moreover, it has added artifacts to the sky. RMSHE has also done similar effects to the sky. The LHE has enhanced the image too much to maintain a natural look. Here also MHE shows a better enhancement than the others.



(a) **(b)**

(c) **(d)**

(e)

Figure 3. A set of images showing results of applying different enhancement approaches. (a) Original image (b) GHEed image (c) LHEed image using 32x32 blocks (d) RMSHEed image with r = 2. (e) MHEed image using 32x32 blocks.

CONCLUSION

In this paper, we have proposed an enhancement approach to make a better look of low contrast images. The proposed MHE enhances the image without making any loss in image details or annoying artifacts in the image. Moreover, the method is simple and computationally effective that makes it easy to implement and use in real time image or video displays.

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