A Review of various Global Contrast Enhancement Techniques for still Images using Histogram Modification Framework

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Abstract : **This paper presents the evaluation and comparison of some popular image contrast enhancement algorithms using Histogram modification framework. Histogram based techniques is one of the important digital image processing techniques which can be used for image enhancement. Histogram based techniques is mainly based on equalizing the histogram of the image and increasing the dynamic range corresponding to the image. Histogram equalization is widely used in different ways to perform contrast enhancement in images. As a result, such image creates side-effects such as washed out appearance and false contouring due to the significant change in brightness. To overcome this weakness, we proposed a new method based on Histogram modification framework that works well with still images, and it enhances the images without making any loss in image details.**

Keywords: **Contrast enhancement, Histogram equalization, Dynamic histogram specification, Histogram modification, Global Contrast enhancement**

I. INTRODUCTION

Contrast enhancement is an important area in image processing for both human and computer vision. It is widely used for medical image processing and as a preprocessing step in speech recognition, texture synthesis, and many other image/video processing applications [1] -[4]. There are several reasons for an image/video to have poor contrast: the poor quality of the used imaging device, lack of expertise of the operator, and the adverse external conditions at the time of acquisition. These effects result in under-utilization of the offered dynamic range. As a result, such images and videos may not reveal all the details in the captured scene, and may have a washed-out and unnatural look. Contrast enhancement targets to eliminate these problems, thereby to obtain a more visually pleasing or informative image or both. Different methods have already been developed for this purpose [5] - [15].

A very popular technique for contrast enhancement of images is Histogram Equalization (HE) [4] - [7]. It is the most commonly used method due to its simplicity and comparatively better performance on almost all types of images. HE performs its operation by remapping the gray levels of the image based on the probability distribution of the input gray levels [5]. Generally, we can classify these methods in two principle categories – global and local histogram equalization [6]. 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] 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. Nonetheless, most of the time, these methods produce an undesirable checkerboard effects on enhanced images [4].

Histogram Specification (HS) [4] is another method that takes a desired histogram by which the expected output image histogram can be controlled. However specifying the output histogram is not a smooth task as it varies from image to image. A method called Dynamic Histogram Specification (DHS) is presented in [9], which generates the specified histogram dynamically from the input image. This method can preserve the original input image histogram characteristics. However, the degree of enhancement is not that much significant.

Some researches have also focused on improvement of histogram equalization based contrast enhancement such as Mean Preserving Bi-histogram Equalization BBHE [13], Equal area Dualistic Sub-image Histogram Equalization (DSIHE) [7] and Minimum Mean Brightness Error Bi-histogram Equalization (MMBEBHE) [8]. 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 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) [3] is another improvement of BBHE. However, it also is not free from side effects. N.S.P. Kong [16] proposed Sub Regions Histogram Equalization (SRHE) for sharpening the images. M. Sundaram et al. [17] proposed a method called Histogram Modified local contrast enhancement for mammogram images.

The aforementioned contrast enhancement techniques perform well on some images but they can create problems when a sequence of images is enhanced, or when the histogram has spikes, or when a natural looking enhanced image is strictly required. In addition, computational complexity and controllability become an important issue when the goal is to design a contrast enhancement algorithm for consumer products. In summary, our goal in this paper is to obtain a visually pleasing enhancement method that has low-computational complexity and works well with both video and still images. To overcome the aforementioned problems we have proposed a GCE Histogram modification algorithm in this paper.

The rest of the paper is organized as follows. Section II gives some of the existing HE methods, and the proposed method is described in Section III. Some experimental results are shown in Section IV and a short concluding remark is given in Section V.

II. HE TECHNIQUES

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

A. Global Histogram Equalization (GHE)

Contrast of images is determined by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. The histogram provides information for the contrast and overall intensity distribution of an image. 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

$$S_k = C(r_k) = \sum_{i=0}^{k} p(r_i) = \sum_{i=0}^{k} \frac{n_i}{n} \quad (1)$$

where $0 \leq s_k \leq 1$ 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). The result image of HE is enhanced in contrast. However, it also has unnatural look because of over enhancement in brightness.

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 (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.

Figure: 1(a) Original image (b) GHEed image

B. Local Histogram Equalization (LHE)

While GHE takes into account the global information and cannot adapt to local light condition, Local Histogram Equalization (LHE) performs block-overlapped histogram equalization [6], [10]. 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. Though LHE cannot adapt well to partial light information [9], still it over-enhances some portions depending on its mask size. Figure 2(a) shows the results of applying LHE to Figure 1(a). In Figure 2(a), the background noises are much enhanced depending on the block size.

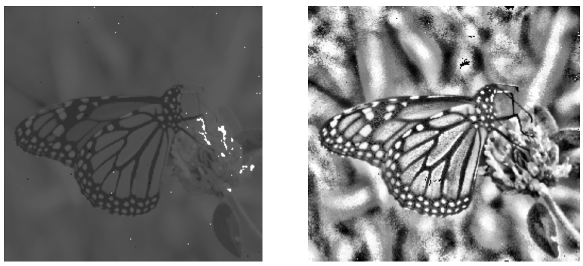

Figure:2(a) LHEed image (b) DHSed image

C. Histogram Specification (HS)

Histogram specification is a technique that transforms the histogram of one image into the histogram of another image. This transformation can be easily accomplished by recognizing that if instead of using an equally spaced ideal histogram (as in histogram equalization), one is specified explicitly. Histogram specification is applied when we want to transform the histogram of image into a specified histogram to achieve highlighted gray level ranges.

$$v_k = C(z_k) = \sum_{i=0}^{k} p(r_i) = s_k \qquad (2)$$

where k = 0, 1, 2, …, L-1. Note that, 's_k' and 'v_k' represent the CDFs of histograms of the input image and the specified histogram respectively.

D. Dynamic Histogram Specification

This approach selects some Critical Points (CP) from the image histogram. Then based on these CPs and other components of the histogram, it creates a specified histogram. Then HS is applied on the image based on this specified histogram. Dynamic Histogram Specification (DHS) enhances the image keeping some histogram characteristics since the specified histogram is created from the input image histogram. However, as it does not change the dynamic range, the overall contrast of the image is not much enhanced. Moreover, sometimes it causes some artifacts in the images. Figure 2(b) shows the results of applying DHS to Figure 1(a).

E. Dynamic Histogram Equalization

In spite of processing the whole histogram with the transformation function at a time, Dynamic histogram equalization (DHE) divides it in to a number of sub-histograms until it ensures that no dominating portion is present in any of the newly created sub-histograms. Then a dynamic Gray Level (GL) range is allocated for each sub-histogram to which its gray levels can be mapped by HE. This is done by distributing total available dynamic range of gray levels among the sub histograms based on their dynamic range in input image and Cumulative Distribution Function (CDF) of histogram values.

Figure 3(b) shows the results of applying DHE to figure3(a). As a result, there will be no significant loss in image details.

Figure:3 (a) Original image (b) DHE image

III. GCE HISTOGRAM MODIFICATION ALGORITHM

Histogram-based contrast enhancement techniques utilize the image histogram to obtain a single-indexed mapping T[n] to modify the pixel values. In HE and other histogram-based methods, mapping function is obtained from the histogram or the from the modified histogram. HE finds a mapping to obtain an image with a histogram that is as close as possible to a uniform distribution to fully exploit the dynamic range. The normalized histogram P[n] of an image gives the approximate Probability Density Function (PDF) of its pixel intensities. Then, the approximate Cumulative Distribution Function (CDF), C[n], is obtained from P[n]. The mapping function is a scaled version of this CDF. HE uses the image histogram to obtain the mapping function; whereas, other histogram-based methods obtain the mapping function via the modified histogram. The mapping function in the discrete form is given as

$$T[n] = \left\lfloor (2^B - 1)\sum_{i=0}^{n} P[j] + 0.5 \right\rfloor \qquad (3)$$

where B is the number of bits used to represent the pixel values, and n ε [0, 2B - 1]. Although the histogram of the processed image will be as uniform as possible, it may not be exactly uniform because of the discrete nature of the pixel intensities.

It is also possible to enhance the contrast without using the histogram. Black stretching and white stretching are simple but effective techniques used in consumer-grade TV sets. Black stretching makes dark pixels darker, while white stretching makes bright pixels brighter. This produces more natural looking black and white regions; hence, it enhances the contrast of the image. The algorithm for the proposed method is given below.

Algorithm**:**

Step 1: Read the given input image

Step 2: Generate the image histogram 'm_i' using the mapping function in (3)

Step 3: Choose the initial value of contrast enhancement parameter.

Step 4: Compute the modified histogram 'g_m' using

$$g_m = \frac{m_i + \varphi u}{1+\varphi} = \left(\frac{1}{1+\varphi}\right) m_i + \left(\frac{\varphi}{1+\varphi}\right) u \qquad (4)$$

where 'm_i' is the input image histogram, 'u' is the uniform histogram and 'φ' is the contrast enhancement parameter

Step 5: Find the mean and variance of the modified sub image for local contrast Enhancement

Step 6: Check the quality of the modified image using Quality enhancement measures such as Peak Signal to Noise Ratio (PSNR)

Step 7: If the quality of the modified image is not satisfied, adjust the value of contrast enhancement parameter, Repeat the steps 4 to 6.

Step 8: Otherwise, display the final contrast enhanced output image.

IV. EXPERIMENTAL RESULTS

The performance of the various HE based methods were tested on standard images Bottle, Village, Cameraman, blood1, rice etc. All of these images are with size of 512 X 512 pixels. To compare the performance, the same images are enhanced with the contemporary enhancement techniques GHE, LHE, BBHE, Histogram Specification (HS), Dynamic HS, DHE and RSWHE. For all these methods, the performance is measured qualitatively in terms of human visual perception and quantitatively by using the widely used metric Peak Signal to Noise Ratio (PSNR) for measuring contrast enhancement. The PSNR values for different images are given in Table I. The line graph representation for different HE methods is shown in figure 4. It is evident from the figure that the proposed method provides better contrast enhancement than the existing HE methods.

TABLE I
PSNR VALUES OF DIFFERENT HE METHODS

Image / Method	**Bottle**	**Village**	**Aircraft**	**Girl**
GHE	12.6802	17.4201	10.213	13.012
LHE	10.2425	15.9034	9.3489	12.034
BBHE	18.4981	22.3012	14.2416	14.6891
HS	28.4092	26.8436	17.6872	20.3632
DHS	13.0012	19.0291	11.2991	13.7981
DHE	30.6489	34.5226	23.7401	21.7709
RSWHE	33.0279	35.0209	23.9758	23.9024
proposed	35.8978	35.9894	23.1980	30.5960

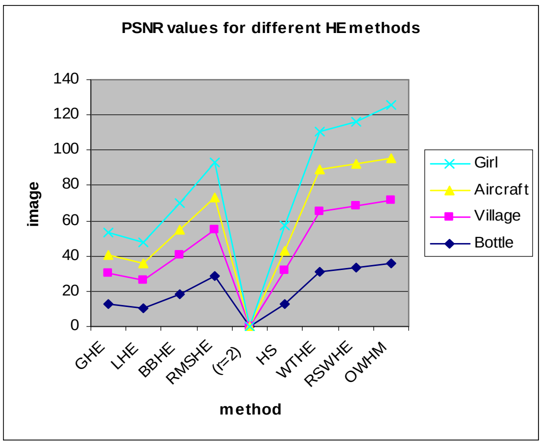

Figure: 4. PSNR values for different HE Methods using line graph

V. CONCLUSION

This paper presents a new method for contrast enhancement in still images for better perception. Moreover, the method is simple and computationally effective that makes it easy to implement and use in real time systems.

REFERENCES

[1] S. C. Pei, Y. C. Zeng, and C. H. Chang, "Virtual restoration of ancient Chinese paintings using color contrast enhancement and lacuna texture synthesis," IEEE Transactions on Image Processing, Vol. 13, pp. 416–429, 2004.

[2] A. Torre, A. M. Peinado, J. C. Segura, J. L. Perez-Cordoba, M. C.Benitez, and A. J. Rubio, "Histogram equalization of speech representation for robust speech recognition," IEEE Transactions on speech Audio Processing, Vol. 13, pp. 355–366., 2005

[3] S. D.Chen, and A. R. Ramli, "Contrast enhancement using recursive mean-separate histogram equalization for scalable brightness preservation", IEEE Transactions on Consumer Electronics, Vol. 49, No. 4, pp.1301-1309, 2003

[4] R. C. Gonzalez, "Digital Image Processing", 2nd Edition, Addison-Wesley, 1992

[5] K. Jain, "Fundamentals of digital image processing," Englewood Cliffs, NJ, Prentice-Hall, 1989

[6] J.Y. Kim, L.S. Kim and S.H. Hwang, "An advanced contrast enhancement using partially overlapped sub-block histogram equalization," IEEE Transactions on Circuits and Systems for Video Technology, Vol.11, pp. 475 –484, 2001

[7] Y. Wang, Q. Chen and B. Zhang, , "Image enhancement based on equal area dualistic sub-image histogram equalization method," IEEE Transactions on Consumer Electronics, Vol. 45, No. 1, pp. 68–75, 1999

[8] S. D. Chen, and A. R. Ramli, "Minimum mean brightness error bi-histogram equalization in contrast enhancement," IEEE Transactions on. Consumer Electronics, Vol. 49, No. 4, pp.1310–1319, 2003

[9] C.C. Sun, S.J. Ruan, M.C. Shie, and T. W. Pai, "Dynamic contrast enhancement based on histogram specification," IEEE Transactions on Consumer Electronics, Vol. 51, No. 4, pp. 1300–1305, 2005

[10] Z. Y. Chen, B. R. Abidi, D. L. Page, "Gray-level grouping (GLG): An automatic method for optimized image contrast enhancement—Part I: The method", IEEE Transactions on Image Processing, vol. 15, No. 8, pp.2290-2302, 2006

[11] Q. Wang and R. K. Ward, "Fast image/video contrast enhancement based on weighted thresholded histogram equalization," IEEE Transactions on Consumer Electronics, vol. 53, no. Vol. 53, No. 2, pp. 757-764, 2007

[12] Y. T. Kim, "Contrast Enhancement using Brightness Preserving Bi Histogram Equalization", IEEE Transactions on Consumer Electronics , Volume 43, Issue 1. pp. 01 –08, 1997

[13] S. Agaian, B. Silver and K. Panetta, "Transform coefficient histogram based image enhancement algorithms using contrast entropy," IEEE Transactions on Image Processing, vol. 16, No. 3, pp. 741–758, 2007

[14] A. Polesel, G. Ramponi and V. Mathews, "Image enhancement via adaptive unsharp masking," IEEE Transactions on Image Processing, vol. 9, No. 3, pp. 505–510, 2000

[15]. Haidi Ibrahim and N.S.P. Kong, "Image sharpening using Sub-Regions Histogram Equalization", IEEE Trans. Consumer Electron., Volume 55, Issue 2, pp: 891-895, 2009

[16] M. Sundaram, K. Ramar, N. Arumugam and G.Prabin, "Histogram modified local contrast enhancement for mammogram images", Applied soft computing, Elsevier, Volume11,pp.5809-5816,2011