A Dynamic Histogram Equalization for Image Contrast Enhancement

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***Abstract*--A smart contrast enhancement technique, Dynamic Histogram Equalization (DHE), is proposed. It takes control over traditional Histogram Equalization for appropriate contrast enhancement of images without introducing any severe side affects such as washed out appearance, over-enhancement of some features and noises, checkerboard effects etc.**

I. INTRODUCTION

A very popular technique for contrast enhancement of images is histogram equalization (HE) [2]-[6]. A variety of HE techniques are proposed. In Global Histogram Equalization (GHE), at times the contrast stretching becomes limited in some dominating (larger) histogram components and causes significant contrast loss for other small ones. Fig. 1(b) shows an example of loss of details and washed out appearance (in the flower). Local histogram equalization (LHE) [2], [6] requires high computational cost and sometimes causes over-enhancement in some portions of the image. In Fig. 1(c), background noises are much enhanced.

Histogram Specification (HS) takes a desired histogram by which the expected output image histogram can be controlled. A Dynamic Histogram Specification (DHS) [7] generates the specified histogram dynamically from the input image. Fig. 1(d) shows the effect of DHS on an image. Since there are some white pixels (salt noises) in the image, their contributions will be present in the specified histogram. That is why the noises are emphasized here and some portions of the flower have become white.

Bi-Histogram Equalization (BBHE) [5] separates the input image histogram into two parts based on input mean. Then each part is equalized independently. Recursive Mean-Separate Histogram Equalization (RMSHE) [1] proposes to partition the histogram more than once. Fig. 1(e) shows a result of applying RMSHE with two levels of partitioning. The actual effect is depicted in Fig. 2. 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 Fig. 1(e).

To overcome the aforementioned problems we propose a dynamic histogram equalization (DHE) technique in this paper. It eliminates the possibility of the low histogram components to be compressed, which may cause some parts of the image to have washed out appearance. Moreover, DHE is free from any severe side effects such as checkerboard effects, over-enhancing noises etc.

II. DYNAMIC HISTOGRAM EQUALIZATION (DHE)

The total technique can be divided in three parts--partitioning, allocating GL ranges and applying HE.

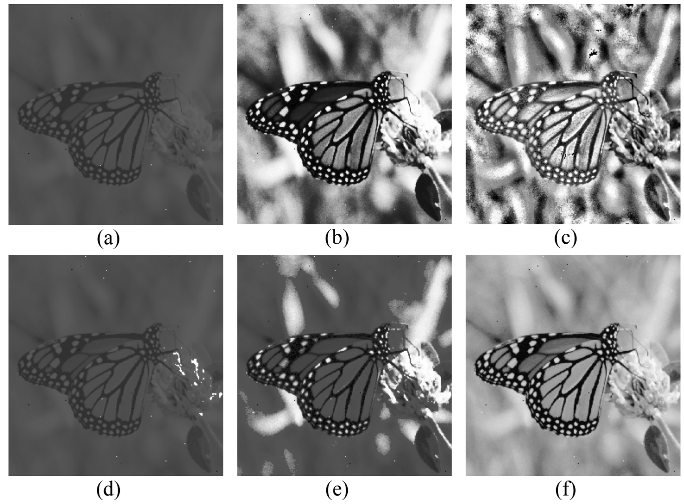

Fig. 1. (a) Original image, (b) GHEed image, (c) LHEed image using 32x32 blocks, (d) DHSed image, (e) RMSHEed image with $r = 2$, (f) DHEed image with $x = 0$.

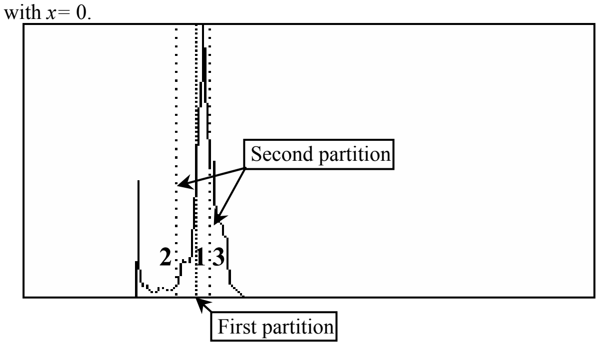

Fig. 2. Histogram of image in Fig. 1(a). Dotted lines show portioning ($r = 2$) (1 denotes the first, and 2,3 denote the 2nd partitioning).

A. Histogram Partition

DHE divides image histogram into sub-histograms until it ensures that no dominating portion is present in these sub-histograms. If m_0, m_1, …, m_{n-1} are n GLs that correspond to n local minima in the image histogram, then the ith sub-histogram takes histogram components of the GL range [m_i, m_{i+1}]. One example of partitioning is presented in Fig. 3(a). Mean, μ, and standard deviation, σ, of histogram components are calculated for each sub-histogram. If the number of GLs having frequencies within ($\mu - \sigma$) to ($\mu + \sigma$) is more than 68.3% of the total number of GLs of a sub-histogram, then we may consider it to have a normal distribution of frequencies [8] and there is no dominating portion. Otherwise, DHE splits the sub-histogram into three smaller sub-histograms by partitioning it at GLs having histogram components ($\mu - \sigma$) and ($\mu + \sigma$). One such instance is illustrated in Fig. 3(b). Then the sub-histograms are then taken into the same test of domination and re-split if necessary.

B. Gray Level Allocation

The deciding factor for GL range of ith sub-histogram is--

$$factor_i = span_i * \left(\log F_i\right)^x . \quad (1)$$

where, $span_i = m_{i+1} - m_i + 1$ and F_i is total frequency of GLs in ith sub-histogram. x determines how much emphasis should be given on Fs. In most un-enhanced images, the dynamic range of GLs is low. There using *span* alone (x = 0) is sufficient. In other cases, x should be given some value.

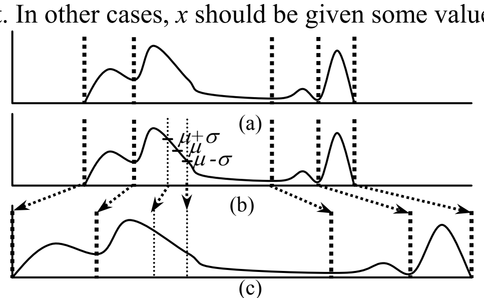

Fig. 3. A pictorial view of DHE

The range of GLs allocated to the ith sub-histogram is--

$$range_i = \frac{factor_i}{\sum_{k=0}^{n-1} factor_k} * (L-1) . \quad (2)$$

where, L = total number of available GLs.

If ith sub-histogram is allocated GLs [i_{start}, i_{end}], then i_{start} = $(i\text{-}1)_{end}$ + 1 and i_{end}= i_{start} + $range_i$. An example allocation is shown in Fig. 3(c).

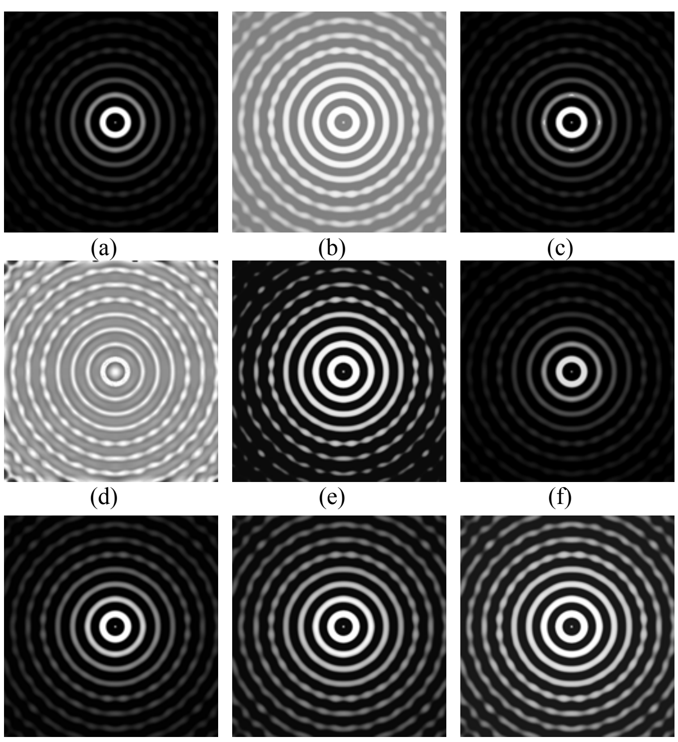

Fig. 4. Simulation results. (a) Original image (b) GHEed image (c) DHSed image (d) LHEed Image using block size 32x32 (e) RMSHE with one level of recursion (f)-(i) DHEed image with x value 0, 1, 3, 5 respectively.

C. Histogram Equalization

Conventional HE is applied to each sub-histogram, but its mapping to output image is allowed to confine within the allocated GL range that is designated to it.

DHE prevents over/under enhancements of any portion of the image. Allocating non-overlapping gray level ranges to sub-histograms guarantees that no two GLs from different sub-histograms map to the same GL, which prevent significant loss in image details. The sequential assignment and freedom from domination of any portion ensure not having any unpleasant jump in neighboring GLs. DHE ensures that no particular gray level will have, as a whole, multiple mappings in output histogram. It ensures no blocking effect.

III. EXPERIMENTAL RESULTS

Fig. 1 shows the original image along with simulation results from GHE, LHE, DHS, RMSHE and DHE. Here DHE shows better and smooth enhancement of the image.

Another simulation result is shown in Fig. 4. Here GHE has increased average brightness instead of increasing the contrast. The DHS has not improved the contrast of this image rather introduces white spots in the second ring. LHE has created some artifacts in black regions. Here RMSHE gives the best result with r =1. However, the outer rings are not visible. DHE performs much better role with different values of x. It is clear from Fig. 4(f)-(i) that with increase of x, the different concentric rings' brightness are increasing and making the edges sharp, but without introducing any artifacts.

IV. CONCLUSION

We have proposed a new approach for contrast enhancement of images, which takes control over traditional HE. The amount of control is decided dynamically based on the characteristics of original image histogram. Experimental results show that the proposed DHE can enhance images significantly without causing any severe side effect on images.

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