Comparative Analysis of Various Image Enhancement Techniques

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Abstract

Image Enhancement is simple and most appealing area among all the digital image processing techniques. The main purpose of image enhancement is to bring out detail that is hidden in an image or to increase contrast in a low contrast image. Histogram equalization is one of the well known image enhancement technique. HE becomes a popular technique for contrast enhancement because this method is simple and effective. This paper represents review of some techniques in the area of image enhancement for brightness preservation as brightness preservation is in great demand in the consumer electronics field, when the image is effectively enhanced. Comparisons with the best available results are given in order to illustrate the best possible technique that can be used as powerful image enhancement. The performance of several established image enhancement techniques is presented in terms of different parameters like Absolute mean brightness error (AMBE), Peak signal to noise ratio (PSNR), Normalized absolute error (NAE), contrast, correlation and visual quality to make real-time image-processing applications more feasible and easier.

Keywords

Image enhancement, Histogram equalization, Brightness Preservation, histogram partition.

I. Introduction

Digital images play an important role both in daily life applications such as satellite television, magnetic resonance imaging, computer tomography as well as in areas of research and technology such as geographical information systems and astronomy [1].Whenever an image is converted from one form to other such as digitizing the image some form of degradation occurs at output. Improvement in quality of these degraded images can be achieved by using application of enhancement techniques The main purpose of image enhancement is to bring out details that are hidden in an image, or to increase the contrast in a low contrast image. Image enhancement produces an output image that subjectively looks better than the original image by changing the pixel's intensity of the input image. Generally, image enhancement enlarges the intensity differences among objects and background. There are many image enhancement techniques have been proposed and developed. One of the most popular image enhancement methods is histogram equalization (HE) [6]. HE becomes a popular technique for contrast enhancement because this method is simple and effective. HE technique can be applied in many fields such as in medical image processing, radar image processing, and sonar image processing. The basic idea of HE method is to re-map the gray levels of an image based on the image's gray levels cumulative density function. HE flattens and stretches the dynamic range of the resultant image histogram and as a consequence, it enhances the contrast of the image and gives an overall contrast improvement [4]. However, HE is rarely employed in consumer electronic applications such as video surveillance, digital camera, and television since HE tends to introduce some annoying artifacts and unnatural enhancement, including intensity saturation effect. One of the reasons to this problem is because HE normally changes the brightness of the image significantly, and thus makes the output image becomes saturated with very bright or dark intensity values. Hence, brightness preserving is an important characteristic needed to be considered in order to enhance the image for consumer electronic products [4]. In order to overcome the aforementioned problems, mean brightness preserving histogram equalization based techniques have been proposed in the literature. Generally, these methods separate the histogram of the input image into several sub histograms, and the equalization is carried out independently in each of the sub-histograms. This paper describes different image enhancement techniques for mean brightness preservation. All these techniques employ histogram equalization for their processing

II. Histogram Equalization

For a given image X, the probability density function (X_k) is defined as

$$p([\![X)]\!]^k = \frac{n^k}{n} \qquad (1)$$

For k = 0, 1, …, L – 1, where nk represents the number of times that the level X_k appears in the input image X and n is the total number of samples in the input image. Note that $p(X_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensity X_k. In fact, a plot of n_k vs. X_k is known histogram of X. Based on the probability density function, the cumulative density unction is defined as

$$c(x)\sum_{j=0}^{k} p(Xj) \qquad (2)$$

where $X_k = x$, for k = 0, 1, …, L – 1. Note that $c(X_{L-1}) = 1$ by definition. HE is a scheme that maps the input image into the entire dynamic range, (X_0, X_{L-1}), by using the cumulative density function as a transform function. Let's define a transform function f(x) based on the cumulative density function as

$$f(x) = X_0 + (X_{l-1} - X_0)c(x) \qquad (3)$$

Then the output image of the HE, Y = {Y(i, j)}, can be expressed as

$$Y = f(X) \qquad (4)$$

$$= \{f(X(i,j)) \mid \forall X(i,j) \in X\} \qquad (5)$$

The high performance of the HE in enhancing the contrast of an image as a consequence of the dynamic range expansion, Besides, HE also flattens a histogram. Base on information theory, entropy of message source will get the maximum value when the message has uniform distribution property. As addressed previously, HE can introduce a significant change in brightness of an image, which hesitates the direct application

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of HE scheme in consumer electronics. For instance, Fig. 1 and Fig. 2 shows original image arctic hare and the resultant image of the HE that are composed of 256 gray levels. Observe that here the equalized image is much darker than the input image. Observe also the unnatural enhancement in most part of the image. This is a direct consequence of the excessive change in brightness by HE when image has a high density over high gray levels.

Fig. 1: Original image of arctic hare

Fig. 2: Result of HE of image arctic hare

Note that the HE maps its input gray to a gray level, which is proportional to cumulative density up to the input gray level regardless of the input gray level.

III. Techniques based on brightness preserving histogram equalization

Brightness preserving histogram transform is a hot topic in the consumer electronics society for the purpose of avoiding annoying artifacts. This section describes five important image enhancement techniques which make use of the HE method with the purpose of brightness preserving.

A. Contrast Limited Adaptive Histogram Equalization:

This is an extension to traditional Histogram Equalization technique. It enhances the contrast of images by transforming the values in the intensity image I. Unlike HISTEQ, it operates on small data regions (tiles), rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the specified histogram. The neighboring tiles are then combined using bilinear interpolation in order to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited in order to avoid amplifying the noise which might be present in the image.

Algorithm Steps:

1. Obtain all the inputs:
Image, Number of regions in row and column directions, Number of bins for the histograms used in building image transform function (dynamic range), Clip limit for contrast limiting (normalized from 0 to 1).
2. Pre-process the inputs:
Determine real clip limit from the normalized value if necessary, pad the image before splitting it into regions.
3. Process each contextual region (tile) thus producing gray level mappings. Extract a single image region, make a histogram for this region using the specified number of bins, clip the histogram using clip limit, create a mapping (transformation function) for this region.
4. Interpolate gray level mappings in order to assemble final CLAHE image. Extract cluster of four neighboring mapping functions, process image region partly overlapping each of the mapping tiles, extract a single pixel, apply four mappings to that pixel, and interpolate between the results to obtain the output pixel; repeat over the entire image.

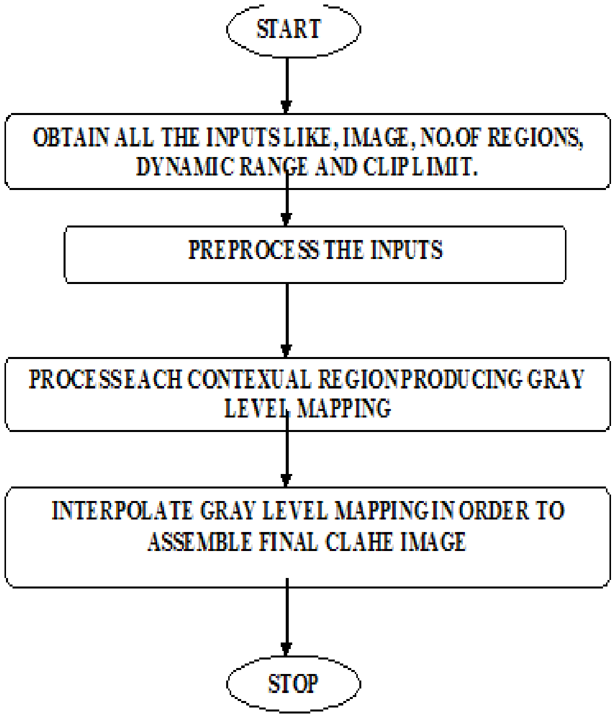

Fig. 3: Flow chart for CLAHE

B: Equal area Dualistic sub-image histogram equalization method:

This is a novel histogram equalization technique in which the original image is decomposed into two equal area sub-images based on its gray level probability density function. Then the two sub-images are equalized respectively. At last, we get the result after the processed sub-images are composed into one image. In fact, the algorithm can not only enhance the image visual information effectively, but also constrain the original image's average luminance from great shift. This makes it possible to be utilized in video system directly.

Algorithm Steps:

1. Suppose image X is segmented by a section with gray level of X=Xe and the two sub-mages are XL and Xu, so we have X=XL ☐ XU. Here

$XL = (X(i,j)|X(i,j) < Xe, \forall X(i,j) \in X)$

$$XU = (X(i,j)|X(i,j) \geq Xe, \forall X(i,j) \in X) \quad (2.1)$$

2.It is obvious that sub image X_L is composed by gray level of $\{X_0, X_1, \ldots\ldots\ldots X_{e-1}\}$, while sub image X_U is composed of $\{X_e, X_{e+1}, \ldots\ldots\ldots\ldots X_{l-1}\}$. The aggregation of the original images' gray level distribution probability is decomposed into $\{p_0, p_1, \ldots\ldots\ldots p_{e-1}\}$ and $\{p_e, p_{e+1}, \ldots\ldots\ldots\ldots p_{l-1}\}$ correspondingly.

3.The corresponding cumulative distribution function will be

$$CL\,(X_k) = \frac{1}{p}\sum_{i=0}^{k} pi, \quad k=0,1,\ldots\ldots\ e-1 \quad (2.2)$$

$$CU\,(X_k) = \frac{1}{p-1}\sum_{i=e}^{l-1} pi, \quad k=e,e+1,\ldots\ldots\ L-1 \quad (2.3)$$

4. Based on the cumulative distribution function, the transform functions of the two sub images' histogram are equalized below.

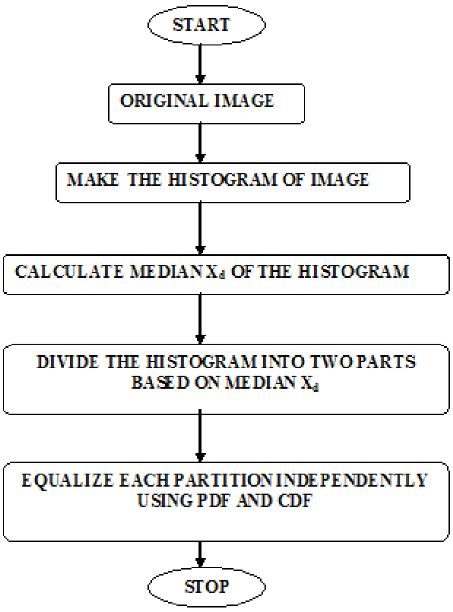

Fig. 4: Flow chart for DSIHE

$FL(X_k) = X_0 + (X_{e-1} - X_0)c(X_k)$, $k=0,1,\ldots.e-1$ $FU(X_k) = X_e + (X_{l-1} - X_e)c(X_k)$, $k=e,e+1,\ldots\ldots L-1$ 5. At last result of dualistic sub image histogram is obtained after the two equalized sub images are composed into one image. Suppose Y denotes the processed image then

$Y=\{Y(i,j)\}= fL(X_L)$ ☐ $fU(X_U)$

C. Dynamic histogram equalization for image contrast enhancement:

It employs a partitioning operation over the input histogram to chop it into some sub histograms so that they have no dominating component in them. Then each sub-histogram goes through HE and is allowed to occupy a specified gray level range in the enhanced output image. Thus, a better overall contrast enhancement is gained by DHE with controlled dynamic range of gray levels and eliminating the possibility of the low histogram components being compressed that may cause some part of the image to have washed out appearance.

Algorithm Steps:

1. Histogram Partition

DHE partitions the histogram based on local minima. At first, it applies a one-dimensional smoothing filter of size 1 x 3 on the histogram to get rid of insignificant minima. Then it makes partitions (sub-histograms) taking the portion of histogram that falls between two local minima (the first and the last non-zero histogram components are considered as minima). Mathematically, if m0, m1, ..., mn are (n+1) gray levels (GL) that correspond to (n+1) local minima in the image histogram, then the first sub-histogram will take the histogram components of the GL range [m0, m1], the second one will take [m1+1, m2] and so on. These histogram partitioning helps to prevent some parts of the histogram from being dominated by others.

2. Gray Scale Allocation

For each sub-histogram, DHE allocates a particular range of GLs over which it may span in output image histogram. This is decided mainly based on the ratio of the span of gray levels that the sub-histograms occupy in the input image histogram. Here the straightforward approach is

Spani= mi-mi-1

$$rangei = \frac{spain_i}{\sum span_i} * (L-1)$$

where,

spani = dynamic GL range used by sub-histogram i in input image.

mi = ith local minima in the input image histogram.

rangei = dynamic gray level range for sub-histogram i in output image.

The order of gray levels allocated for the sub-histograms in output image histogram are maintained in the same order as they are in the input image, i.e., if sub-histogram i is allocated the gray levels from [istart, iend], then i_{start} = (i-1)end + 1 and $i_{end} = i_{start}$ + rangei. For the first sub-histogram, j, $j_{start} = r_0$.

3. Histogram Equalization

Conventional HE is applied to each sub-histogram, but its span in the output image histogram is allowed to confine within the allocated GL range that is designated to it. Therefore, any portion of the input image histogram is not allowed to dominate in HE.

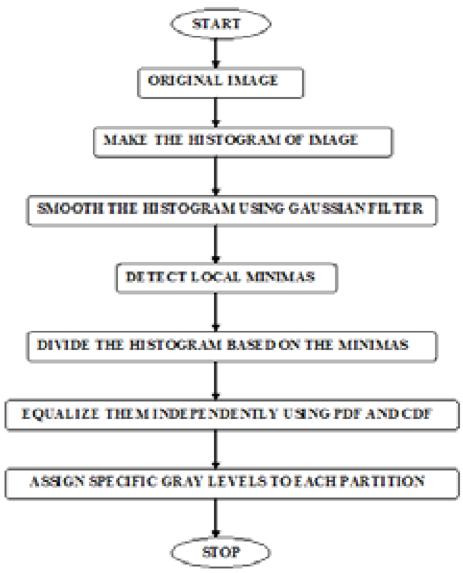

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Fig. 5: Flow chart for DHE

IV. Experimental Results:

In this section we make a comparison between Histogram Equalization[1]and Adaptive Histogram Equalization[12] by implementing these methods in Matlab(7.0.2). Following parameters considered for comparison.

Error Color(EC)

The error color is used to estimate the color distortion of the image. EC describes the differences between two images in terms of color. The greater value of EC means the more visible difference two images. It is defined as:-

$$EC = \frac{\sum_{j=1}^{M}\sum_{k=1}^{N}\left(X(j,k) - \hat{X}(j,k)\right)}{M \times N \times 3}$$

Composite Peak Signal to Noise Ratio (CPSNR):

Performance metric CPSNR, for color images, is the average of mean-square errors(MSEs) of the enhanced color components. It is defined as:

$$CPSNR = 10\log_{10}\left(\frac{255^2}{\frac{1}{3}MSE}\right)$$

Visual Quality

By looking at the enhanced image, one can easily determine the difference between the input image and the enhanced image and hence, performance of the enhancement technique is evaluated.

Table1: Comparison of various parameters for image

Parameter	Error Color	CPSNR
CLAHE	0.0982	38.7964
DSIHE	0.0890	37.9468
DHE	0.0880	37.8422

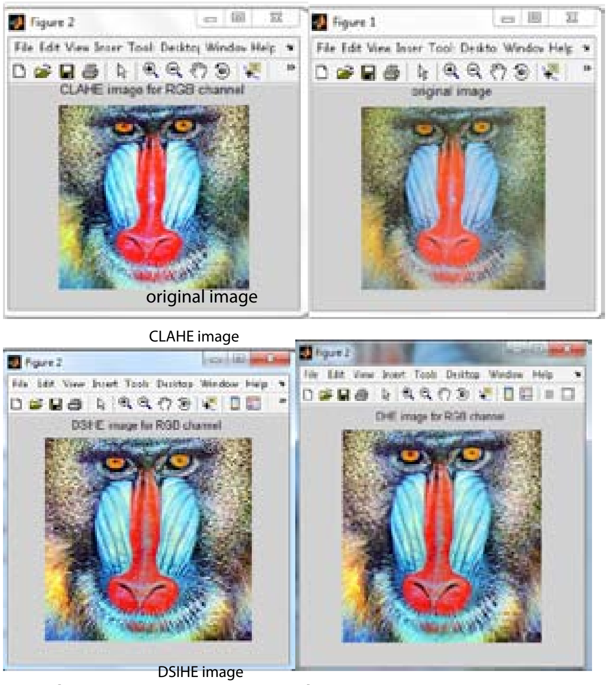

Fig. 6: Enhanced results of real image (a) original image (b) CLAH Equalized image (c) DHE Equalized image (d) DSIH Equalized image

5. Conclusion and future work

In this paper, a frame work for image enhancement based on prior knowledge on the Histogram Equalization has been presented. Many image enhancement schemes like Contrast limited Adaptive Histogram Equalization (CLAHE), Equal area dualistic sub-image histogram equalization (DSIHE), Dynamic Histogram equalization (DHE) algorithms has been implemented and compared. From the experimental results, it is found that all the three techniques yields Different aspects for different parameters.

In future, for the enhancement purpose more images can be taken from the different application fields so that it becomes clearer that for which application which particular technique is better for color Images.

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