Histogram Equalization Techniques For Image Enhancement

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Abstract
Various enhancement schemes are used for enhancing an image which includes gray scale manipulation, filtering and Histogram Equalization (HE). Histogram equalization is one of the well known imaget enhancement technique. It became a popular technique for contrast enhancement because this method is simple and effective. In the latter case, preserving the input brightness of the image is required to avoid the generation of non-existing artifacts in the output image. Although these methods preserve the input brightness on the output image with a significant contrast enhancement, they may produce images with do not look as natural as the input ones. The basic idea of HE method is to re-map the gray levels of an image. HE tends to introduce some annoying artifacts and unnatural enhancement. To overcome these drawbacks different brightness preserving techniques are used which are covered in the literature survey. Comparative analysis of different enhancement techniques will be carried out. This comparison will be done on the basis of subjective and objective parameters. Subjective parameters are visual quality and computation time and objective parameters are Peak signal-to-noise ratio (PSNR), Mean squared error (MSE), Normalized Absolute Error (NAE), Normalized Correlation, Error Color and Composite Peak Signal to Noise Ratio (CPSNR).

Keywords
Contrast enhancement, Histogram equalization, PSNR, MSE, NAE, CPSNR, Visual quality.

I. Introduction

Out of the five senses – sight, hearing, touch, smell and taste – which humans use to perceive their environment, sight is the most powerful. Receiving and analyzing images forms a large part of the routine cerebral activity of human beings throughout their waking lives. In fact, more than 99% of the activity of the human brain is involved in processing images from the visual cortex. A visual image is rich in information. Confucius said, "A picture is worth a thousand words." [1] 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. Whenever an image is converted from one form to other such as digitizing the image some form of degradation occurs at output.

A. Image Enhancement

Image enhancement is among the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is shown in Fig.1 in which when we increase the contrast of an image and filter it to remove the noise "it looks better." It is important to keep in mind that enhancement is a very subjective area of image processing. Improvement in quality of these degraded images can be achieved by using application of enhancement techniques.

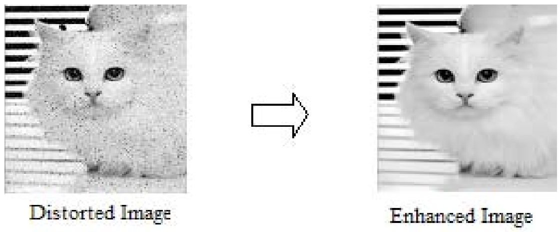

Fig.1: Image enhancement

B. Adaptive Histogram Equalization method

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.

C. 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.

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.

II. Background

One of the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New York. Introduction of the Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours. Specialized printing equipment coded pictures for cable transmission and then reconstructed them at the receiving end.

Some of the initial problems [2] in improving the visual quality of these early digital pictures were related to the selection of printing procedures and the distribution of intensity levels. Although the methods just cited involve digital images, they are not considered digital image processing results in the context of our definition because computers were not involved in their creation. Thus, the history of digital image processing is intimately tied to the development of the digital computer. In fact, digital images require so much storage and computational power that progress in the field of digital image processing has been dependent on the development of digital computers and of supporting technologies that include data storage, display, and transmission.

III. Implementation

Compare all these techniques on the basis of performance parameters in objective and subjective manner. These are the merits on the bases of that I will compare above defined techniques.

A. Contrast Limited Adaptive Histogram Equalization method:

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 neighbouring 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.

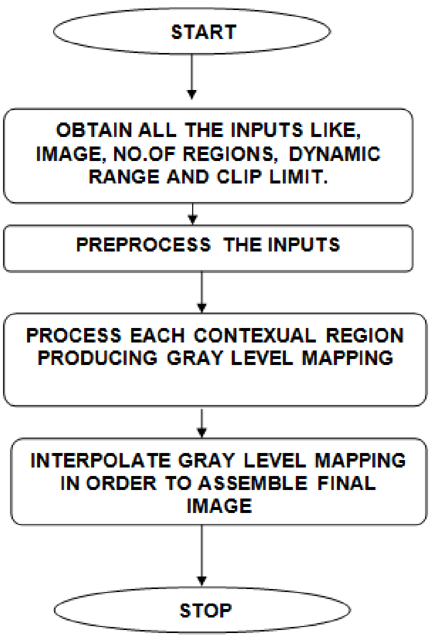

Fig.2: Flow chart for CLAHE

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

Algorithm Steps:

Suppose image X is segmented by a section with gray level of X=Xe and the two sub-images are Xl and Xu, so we have

$X = X_l \cup X_U$. Here $X_L = (X(i,j) | X(i,j) < Xe, \forall X(i,j) \in X)$

$(X(i,j) | X(i,j) \geq Xe, \forall X(i,j) \in X)$ ... (1)

It is obvious that sub image XL 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. The corresponding cumulative distribution function will be

$C_L(X_k) = \frac{1}{p}\sum_{i=0}^{k} pi$, k=0,1,……. e-1... (2)

$C_U(X_k) = \frac{1}{p-1}\sum_{i=e}^{l-1} pi$, k=e,e+1,..... L-1

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

$F_L(X_k) = X_0 + (X_{e-1} - X_0)c(X_k)$, k=0,1,….e-1... (3)

$F_U(X_k) = X_e + (X_{l-1} - X_e)c(X_k)$, k=e,e+1,...........L-1

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

$Y = \{Y(i,j)\} = f_L(X_L) \cup f_U(X_U)$ .... (4)

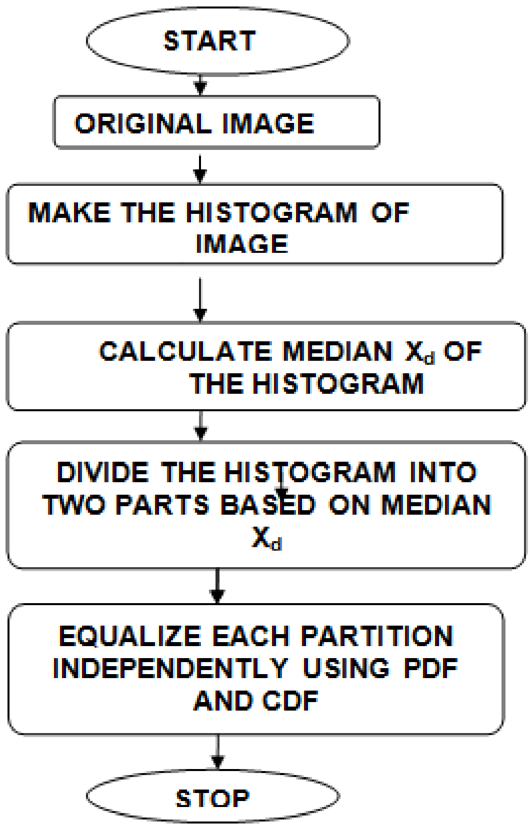

Fig.3: Flow chart for DSIHE

C. Dynamic histogram equalization for image contrast enhancement:

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 m_0, m_1, ..., 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 [m_0, m_1], the second one will take [m_1+1, m_2] 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

$Span_i = m_i - m_{i-1}$

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

where, $span_i$ = dynamic GL range used by sub-histogram i in input image.

m_i = i^{th} local minima in the input image histogram.

$range_i$ = 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 [i_{start}, i_{end}], then $i_{start} = (i-1)_{end} + 1$ and $i_{end} = i_{start} + range_i$. 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.

D. Metrics for Gray Scale Images:

1. Peak-signal-to-noise-ratio (PSNR):

PSNR is the evaluation standard of the reconstructed image quality, and is important measurement feature. PSNR is measured in decibels (dB) and is given by:

$$PSNR = 10\log\left(255^2 / MSE\right)$$

where the value 255 is maximum possible value that can be attained by the image signal. Mean square error (MSE) is defined as Where M*N is the size of the original image. Higher the PSNR value is, better the reconstructed image is.

2. Absolute mean brightness error (AMBE):

It is the Difference between original and enhanced image and is given as

AMBE= $|E(x) - E(y)|$

Where E(x)= average intensity of input image E(y)=average intensity of enhanced image

3. Contrast:

Contrast defines the difference between lowest and highest intensity level. Higher the value of contrast means more difference between lowest and highest intensity level.

4. 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.

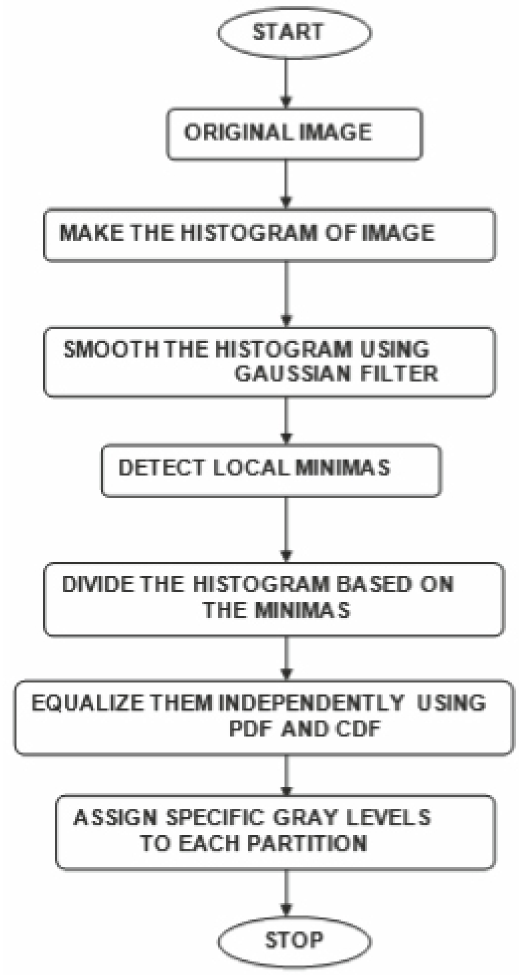

Fig. 4: Flow chart for DHE

IV. Tool to be used:

In this thesis for implementation of techniques MATLAB 7.0.2 version is used. In that image processing toolbox is used. MATLAB® is a high-performance language for technical computing.

V. Experimental Results

To verify the efficacy of the proposed method, obtained after following the Different enhancement Algorithms for gray scale images. After the comparison tables, a graphical representation has also been done for a quick analysis of results. All the techniques have been tested for all the assumed standard test images.In this paper three techniques are used for Gray Scale Image enhancement which are CLAHE, DSIHE and DHE.

A. Results of test image "Rice"

Fig.5 shows the visual quality of real image "Rice" and the enhanced image using three different image enhancement techniques. The performances of these techniques are evaluated in terms of PSNR, AMBE and Contrast.

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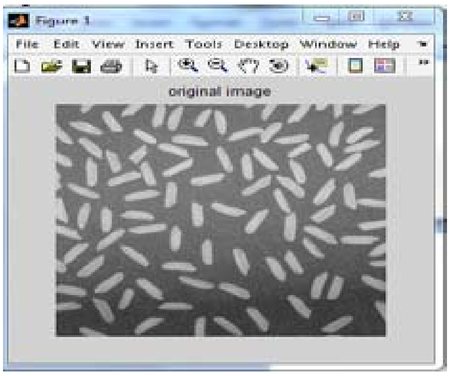
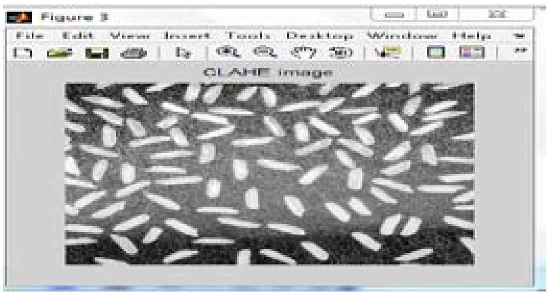
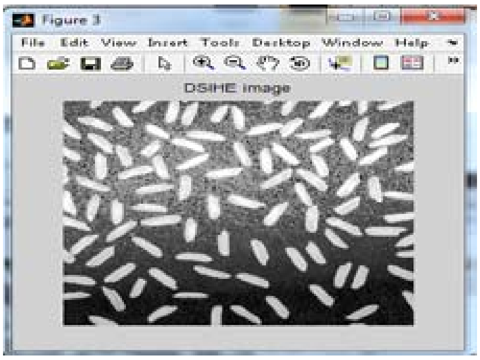


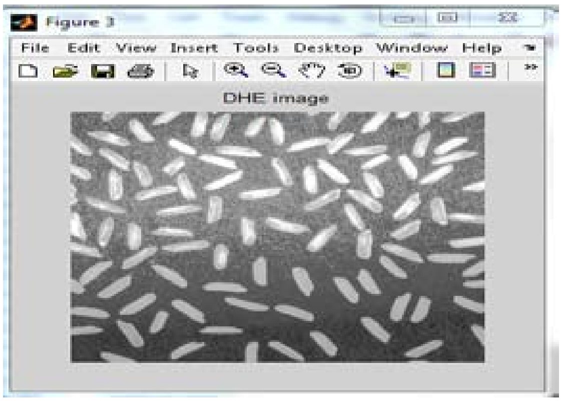
a) Original Image



b) CLAHE Image



c) DSIHE Image

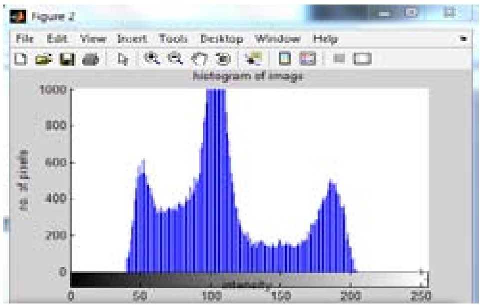


d) DHE Image

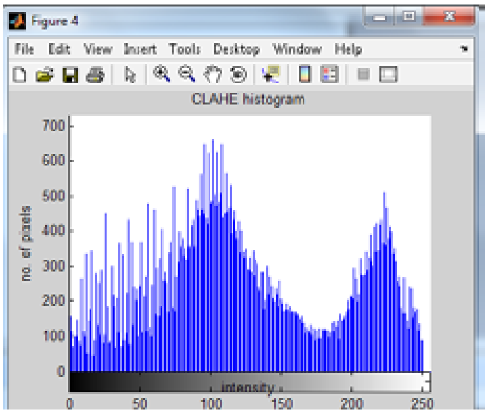
Fig. 5: Enhanced Result of real image as shown in image a, b, c, d.

B. Histograms of test image "Rice" for different enhancement algorithms

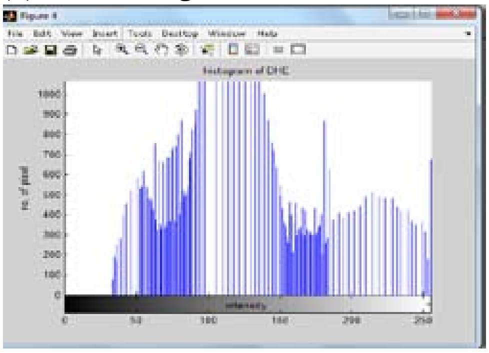
Fig.6 shows respective Histograms of test image "rice" using Different image enhancement techniques.



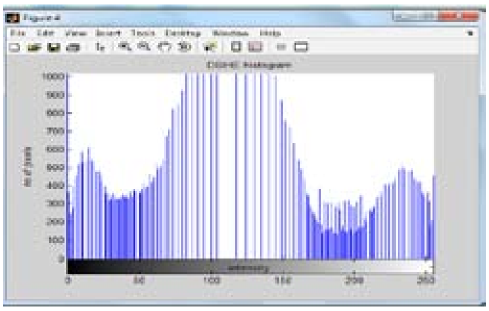
(a) Histogram of Image



(b) CLAHE Histogram



(c) Histogram of DHE



(d) DSIHE Histogram

Fig. 6: Equalized Histograms for Image "Rice" as shown in image a, b, c, d as original, CLAHE, DHE, DSIHE Respectively.

Table 1: Comparison of Various Parameters for "Rice" Image:

Parameter Technique	AMBE	Contrast	PSNR
CLAHE	13.8521	23.5878	0.0366
DSIHE	4.9081	33.8767	0.0327
DHE	13.0886	12.1438	0.1107

Anyone can make comparison of parameter AMBE (Absolute mean brightness error) for different image enhancement techniques. The value of AMBE should be as small as possible which indicates that difference between original and enhanced image should be minimum. Therefore in terms of AMBE, DSIHE technique gives best results as AMBE is taken in negative. Now considering PSNR, CLAHE gives better output as it is cleared from the formula that PSNR should be as high as possible so that noise content should be lower than signal content.

VI. Conclusion and Future Scope

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) Algorithm has been implemented and compared. The Performance of all these Methods has been analyzed and a number of Practical experiments of real time images have been presented. 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 both for Gray Scale Images and colour Images. Particularly, for colour images there are not many performances measurement parameter considered. So, new parameters can be considered for the evaluation of enhancement techniques. New colour models can also be chosen for better comparison purpose. Optimization of various enhancement techniques can be done to reduce computational complexity as much as possible.

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