Image Quality Enhancement using Balanced Histogram Equalization

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Abstract

The Image processing is a method of converting images into digital form and applies some operations on it to achieve an enhanced image or to extract some meaningful information from it. The histogram for an image is the representation of the number of pixels elements that can have every value of colors. In a grey scale image, it is generally represented as a graphic of the grey values, and in RGB images. In this paper, Balanced Histogram Equalization technique is applied over an image and it is analysed that the histogram equalization really depends on the initial distribution of intensity values. If they are concentrated on one side of the histogram, equalization will stretched it to cover the whole range and enhance the contrast of an image.

Keywords : Digital Image, Balanced Histogram Equalization, Image Enhancement

1 Introduction

1.1 Digital Image

An image is a kind of analog or digital in nature. A digital image is a representation that is stored on a computer. It is digitized in computer that means it has been changed into a sequence of numbers which computer can understand. A digital image is a discrete space collected of small surface elements which is pixel. The each element contains a value or a set of value codings that the intensity level at each position. A digital image can be obtained with a great number of different units such as a digital camera, an MRI machine or any other kind of devices with a sensor able to capture light intensity.

Because of its discrete nature, the concept used to process digital image rely on discrete domain, even if the analogy with the continuous domain is possible [1].

The stored image in computer occupies space in memory. The image can have following sizes of memory [2]:

8 bit size : A common sample format is 8 bit integers, 8 bit integers can only represent 256 discrete values which is $2^8 = 256$. So, brightness levels are quantized into these levels.

12 bit size : The images with detail both in shadows and highlights which is high dynamic range images having 8 bits 256 discrete values does not provide enough precision to store an accurate image.

16bit size : The TIF and PNG image formats supports mostly 16 bit size. Many image processing and manipulation programs perform the operations on 16 bit when working on 8 bit image to keep away from quality loss in processing.

1.2 Types of Digital Images

There are two types of digital images namely Vector and Raster image.

1.2.1 Vector Image :

When a picture is made of using lines, curves, rectangles and circles; such images are called vector images. This is one way to describe an image using numbers is to declare its contents using position and size of geometric forms and shapes.

1.2.2 Raster (Bitmap) Images

The Bitmap or raster images are generally *Digital photographs*. This is the most common form to represent natural images and other forms of graphics that are rich in detail. The Bitmap image is normally how graphics is stored in the video memory of a computer [3-5]. The expression bitmap refers to how a given pattern of bits in a pixel maps to a specific color.

A bitmap images take the shape of an array, in which the value of each element is called a pixel element, that correspond to the color of that portion of the image [6-8]. In the image, each horizontal line in the image is called a scan line.

1.3 Image Processing

The Image processing is a method of converting an image into digital form and applies some operations on it to get an enhanced image or to extract some meaningful information from it [9, 14]. The following methods are applied over an image in image processing:

1.3.1 Image Compression

The Bitmap images uses a lot of memory so the image compression technique reduces the amount of memory needed to store an image. For an image instance, a 2 mega-pixel or 8bit RGB image occupies 1600 x 1200 x 3 bytes which is equivalent to 5760000 bytes or 5.5 megabytes. This is the uncompressed size of the image.

The term compression ratio is the ratio between the compressed image and the uncompressed image. For an image of 512 kb, jpeg file, the compression ratio would be 0.5 mb : 5.5 mb which is treated as 1:11.

a. Loss less compression

The image can also be losslessly compressed. The repetition and predictability is used to represent all the information using less memory. The original image may be restored. One of the easiest lossless image compression methods is run length encoding. The algorithm Run length encoding, encodes consecutive similar values as one token in a data stream.

b. Lossy Compression

The Lossy image compression methods take advantage of the human vision ability to hide imperfection and the fact that some types of information are more important than others. The changes in luminance are for instance having more significant by a human observer than change in hue [12-14].

1.4 Histogram Equalization

The histogram for an image is the representation of the number of pixels elements that can have every value of colors. In a grey scale image, it is generally represented as a graphic of the grey values, and in RGB images. The representation is done with three graphic, each for every color component (Red, Green and Blue). To avoid dependence between the number of pixels or the number of quantization levels and the size of the histogram, typically the histogram axis are normalized in between 0 and 1. One of the ways to compare histograms is suggested in [17]. This distance is a factor of similarity between two vectors. In between 0 and 1, with 0 being the histogram, if nothing and 1 appear if they are of the same [15-16].

2.0 Objective

The Histogram equalization is as a contrast enhancement technique. The main objective of the research work is

- To obtain a new enhanced image with a uniform histogram
- Comparative study with earlier image processing techniques
- Obtain the improvement in accuracy for histogram equalization

3.0 Literature Review

Many researchers argued that Histogram equalization (HE) is a simple and an easy method to enhance the contrast and improve the image quality [17]. Since 2014 raised several concerns about contrast problem and suggested Brightness preserving Bi-Histogram Equalization in order to enhance the contrast. The average intensity value was applied as a separating point to differentiate between a dark area and bright area. The above finding contradicts the study.

The author presented that a median intensity value is more accurate as the separating point compared to the average intensity. These results were contradicted that suggested the minimum mean brightness between original and output image as the separating point is more specific and accurate compared to the BBHE and Dualistic Sub Image Histogram Equalization [18]. Research conducted [19] proposed a new improvement in histogram equalization known as Quadrant Dynamic Histogram Equalization. The first step in this technique was to divide the histogram into four sub-quadrant histograms based on the median value of the original image. After normalizing each sub-histogram, finally, the image was equalized.

A major advantage of QDHE is that it's enhanced the image without any intensity saturation, noise amplification, and over-enhancement. In [20], presented a new method based on Plateau level equation, namely Bi-Histogram Equalization with a Plateau Level. The main objective of this paper is to improve the BBHE technique in term of processing time. The process of this method also involved mean brightness preserving histogram equalization method with a clipped histogram equalization method. However, interestingly, this is contrary to a study conducted [21]. They suggest an extension method of BBHE based on the Neighbourhood Metric. This method involved a few steps: First, a large histogram was divided into the subregion using Neighbourhood Metric. Second, based on mean, the histogram of the original image was separated into two sub-regions and process independently. The results enhanced the local contrast and preserved the brightness of the original image.

In a unlike study [22], explained a new approach to solving the illumination problem on the face images using Histogram Equalization (HE). The technique is based on the combination of gamma correction and the Retinal filter's compression function. The Retinal filter is a new enhancement method, and the result was effective compared to the three conventional enhancement methods which are histogram equalization, gamma correction and log transformation. In another study, proposed a Background Brightness Preserving Histogram Equalization method based on non-linear Histogram equalization (HE).

Following table shows the comparison of different histogram equivalization techniques applied by researchers for image processing.

Table 1 : Comparison of different histogram equivalisation techniques

Technique	Advantages	Disadvantages
LAHE	Offers an excellent enhancement of image contrast	Computationally very slow, requires a high number of operations per pixel
Histogram expansion	Simple and enhance contrast of an image	If there are gray values that are physically for apart from each other in the image, then this method fails.

Par sectioning	Easy to implement	Better suited to hardware implementation
Odd sectioning	Offers good image contrast	Has problems with histograms which cover almost the full gray scale
Cumulative histogram equalization	Has good performance in histogram equalization	Requires a few more operations because it is necessary to create the cumulative histogram

4.0 Histogram Equalization on Colored Image

A color image is a digital array of pixel containing color information in the form of 255 x 255 x 255 points. Each image can be decomposed into three different layers according to the three color channels which are encoded with Red, Green and Blue. For any instance, an eight bit color images encode the Red & Green channel with 3 bits and the blue with 2 that could encode 256 different color combinations.

Moreover, performing histogram equalization on components of Red, Green and Blue independently enhance the images. At the end of this analysis, it can be noticed that the histogram of before and after histogram equalization of an image which is obtained by performing histogram equalization on the components (Red, Green and Blue) independently.

Steps to be performed:

1. Convert RGB image into HSI Image
2. Obtain the 'Intensity Matrix' from the HSI Image matrix
3. Perform Histogram Equalization on the intensity Matrix
4. Update the Intensity Matrix from the HSI Image matrix with the histogram equalized Intensity matrix
5. Convert HSI Image back to RGB Image

The steps are involved in performing histogram equalization :

1. Find the frequency of each pixel value
2. Draw a matrix $A = \begin{bmatrix} 1 & 4 & 2 \\ 5 & 1 & 3 \\ 1 & 2 & 4 \end{bmatrix}$ with number of bins = 5
3. The matrix depicted pixel value 1 at 3 times. The pixel value 2 at 2 times and so on.
4. Find the probability of each frequency. The probability of pixel value 1 occurs = frequency (1) / Number of pixels which is 3/9
5. Obtain the cumulative histogram of each pixel. The cumulative histogram of 1 = 3. Cumulative histogram of 2 = cumulative histogram of 1 + frequency of 2 = 5. Similarly Cumulative histogram of 3 = cumulative histogram of 2 + frequency of 3 = 5 + 1 = 6

6. Now calculate the final value of each pixel by multiplying number of bins and round of the values (1 = 3/9)*5 = 1.6667. The final value for bin 1 is 2.

In the above procedure, *n* bin is the number of bins chosen to perform the histogram and min & max the two values for the range of the histogram. The above procedure returns a vector containing the relative frequencies associated to the histogram. The core of the function is the computation of the histogram in number of pixels and then in relative frequency respecting the range and the number of bins.

5. Methodology

The proposed method first transforms the image into its digital form. Then it is converted into gray scale image. After convertion in gray scale image, the gray level is distributed in the whole image with the adjustment of colour intensity. After this procedure, balanced histogram algorithm is applied over the image. The working procedure of the proposed system is as given below :

5.1 Image Transformation

An operator or function that takes an image as an input image and produces an image as an output image. Depending on the transform function, the input and output images can appear entirely different and have different interpretations. A number of methods are exist like Fourier transforms, Principal Component Analysis and various spatial filters, are of frequently used image transformation procedures.

An image transform can be applied to an image to convert it from one domain to another domain. Viewing an image in domains such as frequency enables the identification of features that may not be as easily detected in the spatial domain.

The familiar image transforms include:

Radon Transform - used to reconstruct images from fan-beam and parallel-beam projection data
Wavelet Transform - used to perform discrete wavelet analysis, denoise, and fuse images
Hough Transform - used to find lines in an image
Discrete Cosine Transform - used in image and video compression
Discrete Fourier Transform - used in filtering and frequency analysis

5.2 Transformation of Gray level

There are two ways of transforming gray level in an image, which are linear transformation and non-linear transformation.

5.2.1 Linear Transformation

A *linear transformation* of an image is a function that maps each pixel gray level value into another gray level at the same position according to a linear function.

The input argument is a gray level

$f = f(m,n)$ at location (m,n)

and the output is a new gray level

$g = g(m,n)$ defined at the same position (m,n).

Linear mappings have the form $g(m,n) = T[f(m,n)]$ such that

$$T[af(m, n) + bf(j, k)] = ag(m, n) + bg(j, k) \quad (1)$$

However, affine transformations are more useful and they are just a linear transformation followed by a translation, such as the equation of a line, $y = ax + b$, where a is the *slope* and b is the *y-intercept*. These are often called linear and so we will also. For images gray level transformations these take the form

$$g(m,n) = af(m,n) + b \quad (2)$$

Figure presents a linear transformation that maps the gray levels of an input image {f(m,n)} into the gray levels of an output image {g(m,n)}. In this case the transformation dilates the input domain from a subinterval of minimum to maximum gray levels for the original image, $[f_{min}, f_{max}]$, onto the full interval $[g_{min}, g_{max}] = [0, 255]$ for the output image. This stretches the contrast to the boundaries of the grayscale.

A linear transformation of the input gray level interval $[f_{min}, f_{max}]$ onto the output interval $[g_{min}, g_{max}]$ has the form of Equation (2) above, where the slope *a* is defined as usual. Thus

$$a = (g_{max} - g_{min})/(f_{max} - f_{min}) \quad (3)$$

$$g(m,n) = af(m,n) + b$$

$$= [(g_{max} - g_{min})/(f_{max} - f_{min})]\, f(m, n) + b \quad (4)$$

at each location (m,n). When $f = f_{min}$ we desire that $g = g_{min}$, so we can substitute into Equation (4) the point (f_{min}, g_{min}) to solve for b via

$$b = g - [(g_{max} - g_{min})/(f_{max} - f_{min})]f_{min} = g_{min} - af_{min} \quad (5)$$

Upon substituting for b in Equation (4) and collecting terms, we obtain

$$g(m,n) = [(g_{max} - g_{min})/(f_{max} - f_{min})](f(m,n) - f_{min}) + g_{min}$$

5.2.2 Non Linear Transformation

An example of the nonlinear transformation is logarithmic transformation which stretching the darker, lighter and middle gray levels.

A nonlinear transformation is usually done after a linear transformation has set the contrast and range of gray levels to that desired. It maps small equal intervals into non-equal intervals.

Assume that most of the pixels have values at the lower end of the gray scale and it is to spread them out to see the detail there. So a small input interval at the low end is mapped to a larger interval at the low end for the output image. It is also required to map 0 to map to 0 and 255 to map to 255. The function

$$g(m,n) = (c)\log_2(f(m,n) + 1) \quad (6)$$

spreads out the lower gray levels.

It must map 0 to 0, and $(c)\log_2(1) = 0$.
It also must map 255 to 255, so that
$255 = (c)\log_2 (255 + 1) = (c)\log_2 (256) = 8c$.
Thus $c = 255/8 = 31.875$,
so we have

$$g(m,n) = (31.875)\log_2 (f(m,n) + 1) \quad (7)$$

For an example, a number 128 maps to
$31.875\log_2 (128 + 1) (31.875)(7.001) = 223.157$,
which is truncated to the integer 223.

Thus the gray levels from 0 to 128 are dilated (more strongly at the lower end).

The following formula can also be used for mapping of an pixel.

$$g(m,n) = (c)\log_2 (af(m,n) + 1) \quad (8)$$

where $a > 0$ is a constant and $b > 1$ is a logarithm base.

The X-ray images are known to satisfy the intensity function
$f(m,n) = f_0 \exp[-r(m,n)]$,
where $r(m,n)$ is the attenuation of the x-ray signal at (m,n) due to the density and thickness of the material. Therefore, logarithmic transformations (to the base e) can be used to enhance the detail on x-ray images.

5.3 Balanced Histogram Algorithm

In this section of the work, an efficient algorithm is proposed for achieving better outcome by computing the histogram of an image. The algorithm is described in a high level programming language using MATLAB 16a.

Computation of Histogram

```
for k = 0 to 255 do                        //Initialize all counts
        c[k] = 0;                          //c[k] = count of pixels at gray level k
for m = 0 to M-1 do                        //For each row & column in the image
        for n = 0 to N-1 do
                c[f[m,n]] = c[f[m,n]] + 1; //increment count at gray level f(m,n)
for k = 0 to 255 do                        //Proportionalize each gray level count
        h[k] = c[k]/(M*N);
```

A histogram denoted by h_k for an image, may have its non-zero proportions predominately in the lower, middle and upper part of the grayscale. Normally, the image grays should cover the range [0, L-1] and not have too many or too few counts in any gray levels. A transformation that spreads out the gray levels used and also changes the proportions to be more uniform is called histogram equalization.

6. Experimental Analysis

6.1 MATLAB for Image Processing

The proposed algorithm is implemented using MATLAB software. MATLAB (MATrix LABoratory) is an mathematical software that offers Integrated Development Environment (IDE) with a programming language (language M). Among its high potential, basic functions worthy of mention are matrix manipulation, data and functions representation, creation of user interfaces (GUI), implementation of algorithms and communication with other programming languages and other hardware devices [23].

6.2 Implementation of Balanced Histogram Algorithm

The Histogram Equalization algorithm basically enhances the contrast of images by transforming the values in an intensity image so that the histogram of the output image is approximately flat.

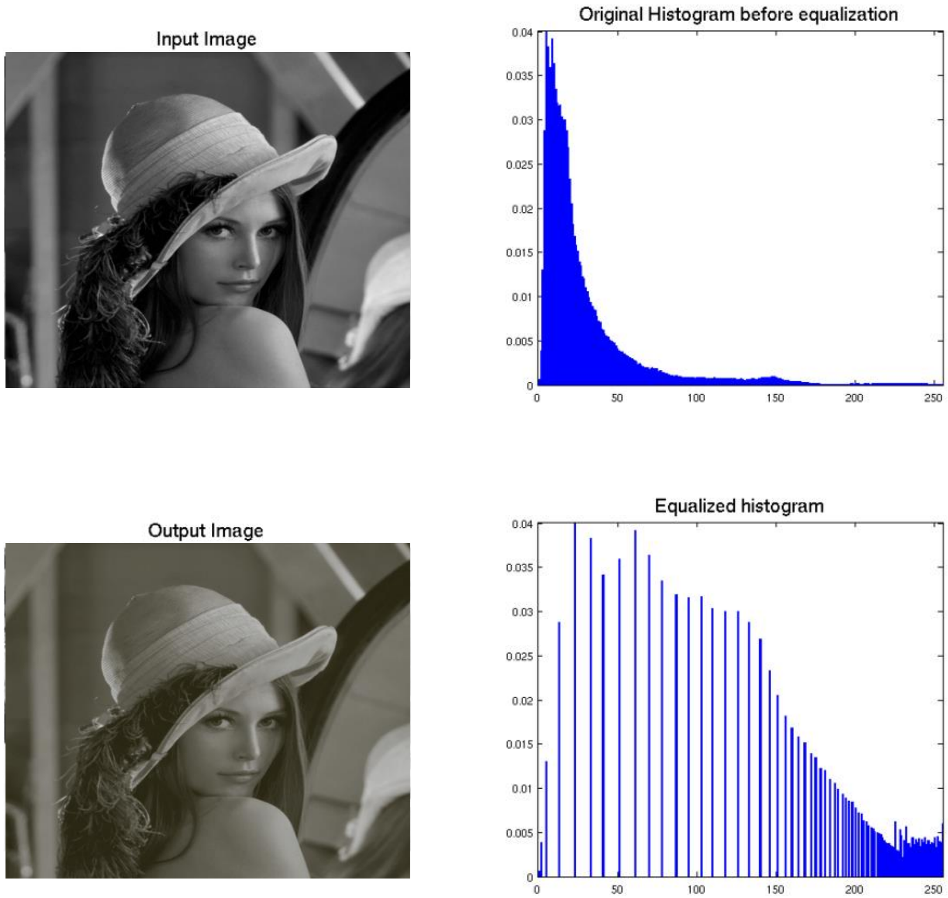

Figure 1 : Equalization of Lenna Image

As we can notice in the above figures, if we balance the peak of colour intensity, the contrast of the image has clearly been enhanced by performing equalization algorithm. The success of the procedure is proven by the histogram associated to the image. It is showing that the range has been stretched to occupy the whole spectrum of levels.

With respect to the qualitative judgment on the image, it is clearly found that the contrast is better because we are able to watch that is the background and that the picture is really showing in the crowd. It is not in the previous one.

7. Result and Discussion

The Histogram equalization usually increases the contrast of images, particularly when the usable data of the image is represented by nearby contrast values. A new approach named the Balanced Histogram Equalization (BHE) with brightness and detailed information preservation is presented in this research study. The presented approach recursively separates the input histogram based on the entropy value of histogram.

The proposed method provides a better distribution of intensity levels which results in an effectively incensement of contrast value. The information well preserved by utilizing a novel approach to adjust the probability density function of the gray level.

The proposed algorithm in this research work is compared with some other Histogram equalization based algorithms, and a number of images from standard image database are used to test the performance of the proposed method. The experimental results have shown that the proposed balanced histogram equalization method given better performance as compared other implemented methods.

Table 2 : Comparison of various histogram equalization methods with its advantages and disadvantages

S.No.	Methods	Advantage	Disadvantage
1	Histogram Expansion	Simple and enhanced contrast of an image	If they are grey values that are physically far apart from each other in the image
2	LAHE	Offers an excellent enhancement of image contrast	Computationally very slow, requires a high number of operations per pixel
3	PAR Sectioning	Easy to implement	Better suited to hardware implementation
4	Balanced Histogram Equalization	Easy to implement	Better result as compared to other convention methods of image processing and do not require any special hardware support.

Following table shows the comparison of proposed and already implemented histogram processing techniques.

Table 3 : Comparison of Histogram Processing Techniques

Technique	Fully enhance image	Complex	Histogram shape affected	Characteristics affected
Histogram Sliding	No	No	According to user input	Brightness
Histogram Stretching	Yes	No	According to user input	Contrast
Transforming Histogram Equalization	No	Yes	Yes	Brightness
Balanced Histogram Equalization	Yes	Yes	Yes	Contrast and Brightness

Balanced Histogram equalization is best method for image enhancement. It provides better quality of images without loss of any image information. The practical results of the proposed techniques explained the popular images in image processing which are divided by greyscale.

8.0 Conclusion

The histogram equalization is a process of non-linear type. The equalization method involves intensity values of an image, not only the color components. For an RGB color image, the histogram equalization cannot be applied directly on the channels.

An efficient algorithm is proposed for achieving better outcome by computing the histogram of an image. The algorithm is described in a high level programming language using MATLAB 16a. The experimental results shows that the proposed balanced histogram equalization method shows better performance in terms of balancing the peak of colour intensity.

If the histogram is already distributed over almost the whole range of intensities, equalization do not give effective result because the stretch is not going to be as strong so it's not going to change a lot the intensity distribution.

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