Image Quality Enhancing by Efficient Histogram Equalization

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Abstract

A two Level Image Quality enhancement is proposed in this paper. In the first level, Dualistic Sub-Image Histogram Equalization DSIHE method decomposes the original image into two sub-images based on median of original images. The second level deals with spikes shaped noise that may appear in the image after processing. We presents three methods of image enhancement GHE, LHE and proposed DSIHE that improve the visual quality of images. A comparative calculations is being carried out on above mentioned techniques to examine objective and subjective image quality parameters e.g. Peak Signal-to-Noise Ratio PSNR values, entropy H and mean squared error MSE to measure the quality of gray scale enhanced images.
For handling gray-level images, convenient Histogram Equalization methods e.g. GHE and LHE tend to change the mean brightness of an image to middle level of the gray-level range limiting their appropriateness for contrast enhancement in consumer electronics such as TV monitors. The DSIHE methods seem to overcome this disadvantage as they tend to preserve both, the brightness and contrast enhancement. Experimental results show that the proposed technique gives better results in terms of Discrete Entropy, Signal to Noise ratio and Mean Squared Error values than the Global and Local histogram-based equalization methods.

Keywords: - Histogram equalization, image Contrast enhancement, PSNR, MSE

تعزيز جودة الصورة بطريقة كفوؤة لتسوية المدرج الإحصائي

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الخلاصة:

لتعزيز جودة الصورة يقوم هذا البحث باستخدام طريقة مكونة من مرحلتين , في الأولى يتم تجزئة الصورة الأصلية إلى قسمين على أساس مقدار قيمة المتوسط في الصورة الأصلية وحسب طريقة DSIHE. في المرحلة الثانية و مع ارتفاع نسبة الضوضاء التي قد تظهر على شكل نبضات في الصورة الناتجة من معالجة المرحلة الأولى حيث يتم التعامل مع الضوضاء ومعالجته . تم عرض ثلاث طرق التعزيز الصورة وهي GHE، DSIHE,LHE ثم الطريقة المقترحة التي من شأنها تحسين جودة الصورة بكفاءة عالية. تم أجراء تنفيذ العمليات

الحسابية على التقنيات المذكورة أعلاه لدراسة الجوانب الموضوعية لهذه الطرق وكذلك الجوانب الذاتية لها والتي منها مثلا PSNR نسبة الإشارة إلى الضوضاء ، والأنتروبيا H ومعدل مربع الخطأ MSE لقياس جودة الصور الرمادية .

أن التقنيات المعروفة مثل LHE وكذلك GHE تميل إلى تغيير متوسط سطوع صورة إلى مستوى منتصف النطاق الرمادي فيشوه بالتالي حدود الصورة ومن ثم يحد من مدى ملاءمتها لتعزيز التباين في الأجهزة الإلكترونية المستخدمة مثل شاشات التلفزيون. واحدة من طرق تجاوز هذه المشكلة هو استخدام معزز الصورة من نوع DSIHE لأنها تميل للحفاظ على حدود الصورة وبنفس الوقت فهي تعزز السطوع والتباين فيها . وقد اظهرت النتائج أن الأسلوب المقترح يعطي نتائج أفضل من حيث الانتروبيا المتقطعة و نسبة الإشارة إلى الضوضاء ومتوسط الخطأ التربيعي نسبة الى التقنيات الأخرى مثل GHE وتقنية LHE.

Introduction

Image enhancement is one of the keywords in digital image processing. The main purpose of image Enhancement is to increase the contrast in a low contrast image [1]. It produces an output image that subjectively looks better than the original image by changing the pixel's intensity of the input image. It is used as a preprocessing step in useful applications include medical image processing, radar image processing, speech recognition and texture synthesis and many other image processing applications. Histogram Equalization (HE) is one of the most commonly used algorithms to perform contrast enhancement due to its simplicity in implementation and effectiveness it's computationally fast [2]. Histogram can be defined as the probalistic distribution of gray levels and its density in a given digital image in the other hand Histogram Equalization HE is used to get a uniform histogram for the output image by brings out details that are hidden in an image e.g. the average luminance of an image, image contrast, and so on. HE is achieved by normalizing the intensity distribution using its cumulative distribution function so that the resultant image may have a uniform distribution of intensities in the dynamic range.

HE methods can mainly be categorized into two as global and local. Global HE methods improve the image quality by extending dynamic range of intensity using the histogram of the whole image [2]. HE is an ideal example of this approach that is widely used for contrast enhancement. Local Histogram Equalization LHE methods use the histogram and the statistics obtained from the neighborhood pixels of an image for equalization. They usually divide the original image into several non-overlapped sub-blocks (windows) and perform HE operation on the individual sub-blocks. The resultant image is produced by merging the sub-blocks using the bi-linear interpolation method. One of the disadvantages of these methods is the introduction of discontinuity, called blocking effect which occurs near the boundaries of the sub-blocks [5, 7]. In this work, we introduce a method that can help in image enhancement based on Dualistic Sub-Image Histogram Equalization.

In section 2, some traditional HE techniques are described. Section 3 presents the principle of the proposed technique. In sections 4, the results are discussed according to the metrics of measuring the quality of the enhanced image and the conclusion is given in section 5.

Histogram Equalization Techniques

Some of the existing Histogram Equalization approaches are briefly discussed in this section (e.g. GHE, LHE and DUALISTIC SUB-IMAGE HE)

Global Histogram Equalization

For an input digital image X (i, j) composed of discrete gray levels denoted by $\{ X_0, X_1, \dots \dots X_{L-1} \}$ in the dynamic range of [0, L-1], and if n_k denotes the total number of pixels with gray level intensity$X_k$in the image thenthe Histogram $h(X_k)$ for the digital image with level X_k can be defined with the following discrete function;

$$h(X_k) \quad = n_k \quad .. \ ..... \ (1)$$

For an M × N image the frequency normalized histogram is defined as;

$$p(X_k) \quad = \frac{n_k}{MN} \quad .. \ ..... \ (2)$$

Which gives the approximate Probability Density Function (PDF) $p(X_k)$ of its pixels intensities (an estimation of the probability of occurrence of gray level X_k in an image). Where:$k = 0,1, . \dots L - 1$ and MN is the total number of pixels in the image .The Cumulative Density Function (CDF)$C(X_k)$ can be calculated from the (PDF) as:-

$$C(X_k) \quad = \sum_{j=0}^{k} p(X_j) \quad .. \ ..... \ (3)$$

Global Histogram Equalization *GHE* enhances the input image *X* by using CDF in its transformation function. This transformation function *F* is defined as:-

$$F(X_k) = X_0 + (X_{L-1} - X_0)C(X_k) \dots \dots \dots .. (4)$$

And the digital output image *Y* produced by GHE can be written as;

$$Y = F(X_k)$$

$$Y = F\{X(i,j), \qquad for X(i,j) \in X \} \dots \dots .. (5)$$

It's clear that GHE method can be implemented easily, thus they are suitable for real time image processing applications [14].

Local Histogram Equalization

In order to overcome the insufficiency of Global Histogram Equalization, a Local Histogram Equalization LHE method has been introduced [3,4]. Local Histogram Equalization performs block-overlapped histogram equalization. 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, selection of an optimal block size that enhances all part of an image is not an easy task to perform.

Dualistic Sub-Image Histogram Equalization

There are many approaches that improve the image Histogram by decomposing the image into two or more sub-images and equalizing them separately [3, 9]. The main difference among these methods is the criteria they use to decompose the input image into two or more sub-images. Dualistic Sub-Image Histogram Equalization DSIHE method decomposes the original image into two sub-images based on median of original image's brightness and then equalizes the histograms of sub-images separately. If we have an input image X (i, j) which is segmented by a section with gray level of $X = X_d$and the two sub-images are X_L andX_L, then we have;

$$X_L = \{X(i,j) < X_d for X(i,j) \in X\} \dots\dots\dots (6)$$

Which means that sub-image $X_L$contains gray level; $\{ X_0, X_1, \dots\dots\dots\dots X_{d-1}\}$

$$X_U = \{X(i,j) \geq\ X_d for X(i,j) \in X\} \dots\dots\dots (7)$$

Which means that sub-image $X_U$contains gray level; $\{ X_d, X_{d+1}, \dots\dots\dots X_{L-1}\}$

$$X = X_L \cup X_U$$

The Cumulative Density Function (CDF) based on the images PDF will be:

$$C_L(X_k) \quad = \frac{1}{p}\sum_{j=0}^{k} p(X_j) \dots\dots.. \quad 0 \leq k < d .. \quad ..... \; (8)$$

$$C_U(X_k) \quad = \frac{1}{p-1}\sum_{j=d}^{L-1} p(X_j) \dots\dots.. \quad d \leq k < L ..... \; (9)$$

Where $p(X_j)$represents Image's gray level distribution probability, which is the probability that brightness level chosen from certain image region is less than or equal to a given brightness value and increase from 0 to one [12]. The Histogram equalization may be expressed as;

$$F_L(X_k) = X_0 + (X_{d-1} - X_0)C_L(X_k) \dots\dots \; 0 \leq k < d \dots.. (10)$$

$$F_U(X_k) = X_d + (X_{L-1} - X_d)C_U(X_k) \dots\dots d \leq k < L \dots.. (11)$$

And the final result enhanced image will be composed these two sub-images into one image; $Y = F_L(X_k) \cup F_U(X_k)$ or;

$$Y = \{X_0 + (X_{d-1} - X_0)C_L(X_k)\} \cup \{X_d + (X_{L-1} - X_d)C_U(X_k)\} \ldots\ldots..(12)$$

Histogram Equalization with De-noising

For the processed image of eq. 12 denoted by Y , some noise may be present in this enhanced output image, however problem of de-noising or removing additive noise from a corrupted image can be resolved effectively and simply using wavelet thres holding which is a simple non-linear technique operates on one wavelet coefficient at a time. Wavelet thres holding involves threes steps [16], a linear forward wavelet transform, nonlinear thres holding and then linear inverse wavelet transform , for example if we consider our image is two dimensional matrix $M \times M$ denoted by x_{ij} : $i, j = 1,2, \ldots\ldots. M$, where M is an integer of power 2 , and the noise corrupted signal is y_{ij} : $i, j = 1,2, \ldots\ldots. M$and can be expressed as :

$$y_{ij} = x_{ij} + z_{ij} \qquad \ldots\ldots\ldots..(13)$$

Given that z_{ij} is zeromean, white Gaussian Noise with standard deviation σ, if we use Minimum Mean Squared error (MSE) to estimate the required signal $\overline{x_{ij}}$ from noisy signal y_{ij} , then:

$$|X - \bar{X}|^2 = \frac{1}{2}\sum_{i=0}^{N-1} \left|x_{ij} - \overline{x_{ij}}\right|^2 \ldots\ldots\ldots\ldots\ldots(14)$$

The wavelet thres holding based Denoising scheme can be expressed as:

$$x = W^{-1}(T(Wy) \ldots\ldots\ldots.(15)$$

Where T (.) is the wavelet thres holding function that used and W , W^{-1}, are the Wavelet transform and it's inverse respectively, Wavelet transform of noisy signal should be taken first and then thresholding function is applied on it. Finally inverse wavelet transformation for the output must be applied to obtain the estimate x .There are four thresholds frequently used [15], hard threshold, soft threshold, semi-soft threshold, and semi-hard threshold. The hard-thres holding function chooses all wavelet coefficients that are greater than the given threshold λ and sets the others to zero. The threshold λ is chosen according to the signal energy and the noise variance. If a wavelet coefficient is greater than λ, we assume that as significant and attribute it to the original signal. Otherwise, we consider it to be due to the additive noise and discard the value. The hard thres holding function keeps the input if it is larger than the threshold; otherwise, it is set to zero. It can be expressed with following function:

$$f(x) = \quad x \ for \ \geq \ \lambda \text{ and zero other wise } \ldots\ldots\ldots.(16) \ .$$

Flow chart of various algorithm's steps of the proposed HE technique is depicted in figure 1.

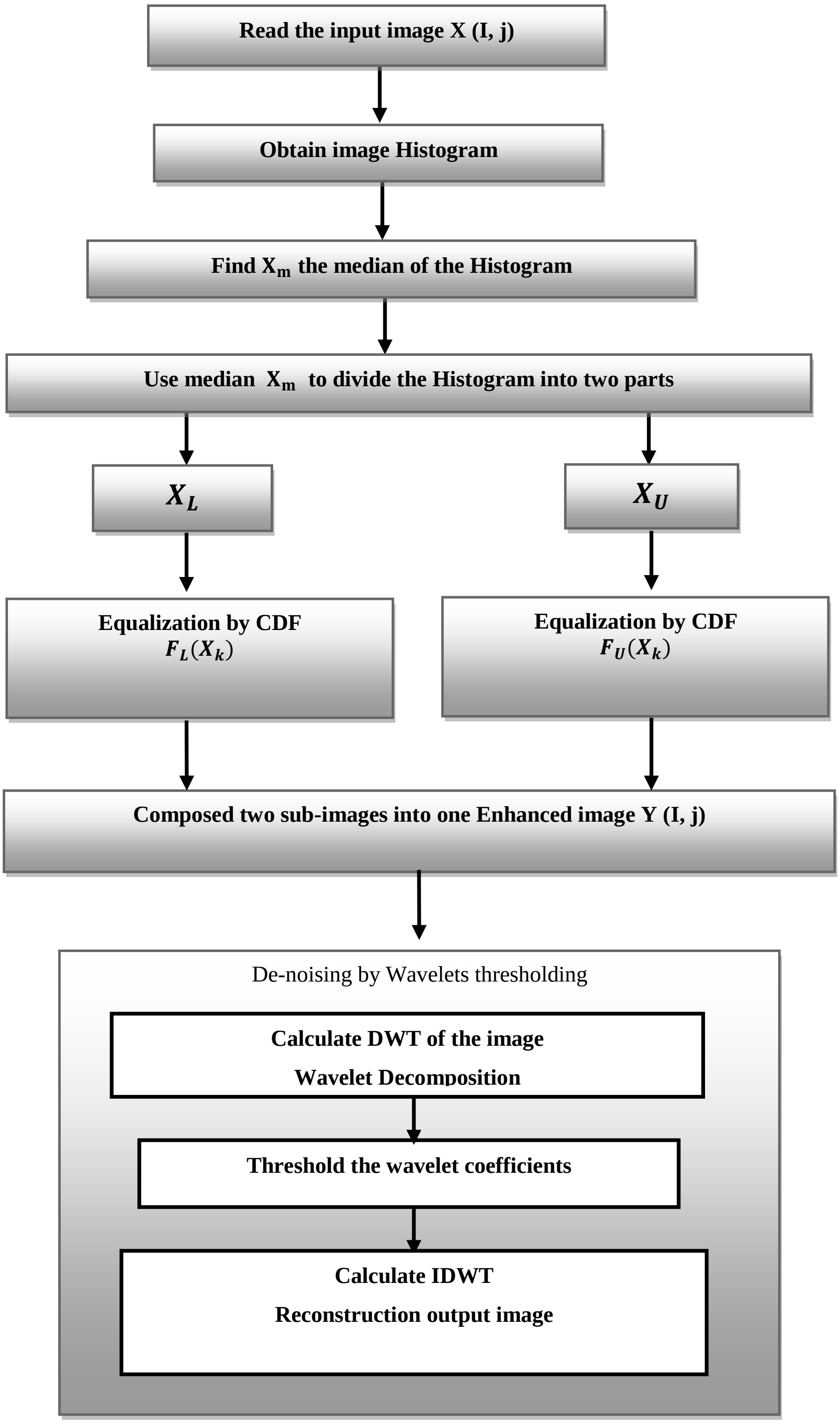

Figure (1) Flow chart of the proposed image enhancement technique.

Results and discussion

With aid of MATLAB 2011a programming tool ,we conducted experiments using the method described in section 3 on standard low contrast image 'pout.tif' with image size of 291x240 . The original image and its histogram are showing in Figure 2. To compare the performance of the proposed method, the same image is enhanced with the other enhancement techniques, global enhancement GHE and local enhancement LHE, the results of the enhanced images and corresponding histograms are showing in figures 3-4-5 respectively. For all these three methods, the performance is qualitatively measured in terms of human visual perception and by quantitatively using Peak Signal-to-Noise Ratio (PSNR) values as shown in Table1. It is evident from the visual comparison that proposed enhancement exhibits better performance than GHE due to its noise filtering enhancement .Moreover, for this image it is apparent from Figure 4, that LHE introduce sun wanted artifacts in the enhanced image. GHE exhibits better results. However, it is noted that proposed HE Figure 5, shows better results in terms of visual perception when compared to those of GHE and LHE. Figure 5 also shows the variations in the histograms, it’s clearly indicated the degree of enhancement in the image pixels.

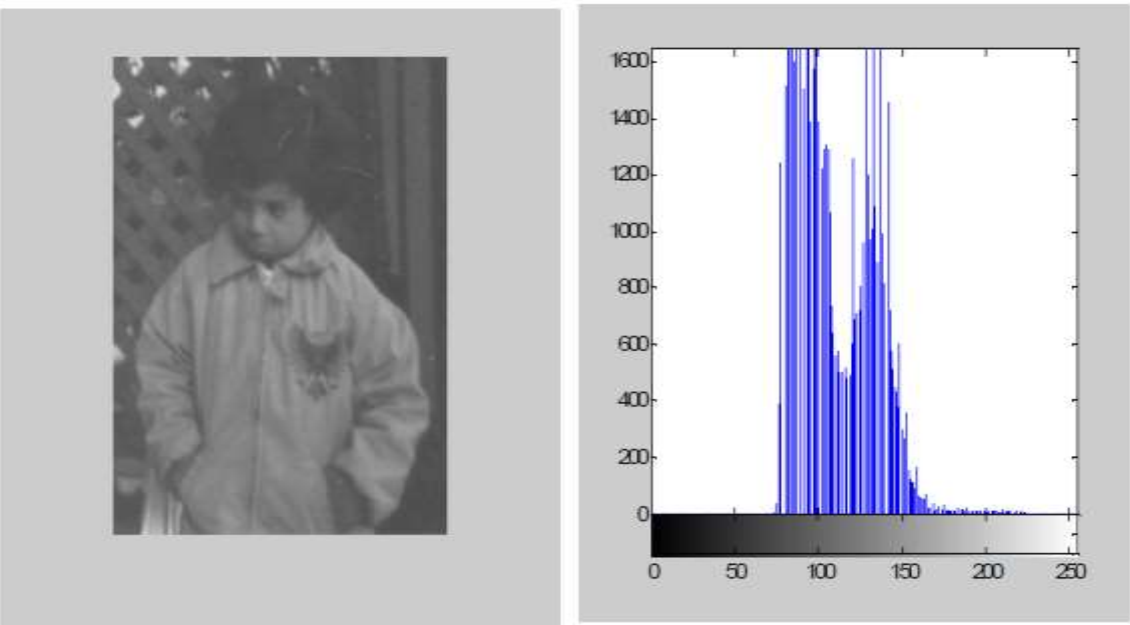

Figure 2 . The original 'pout.tif' image and the corresponding Histogram .

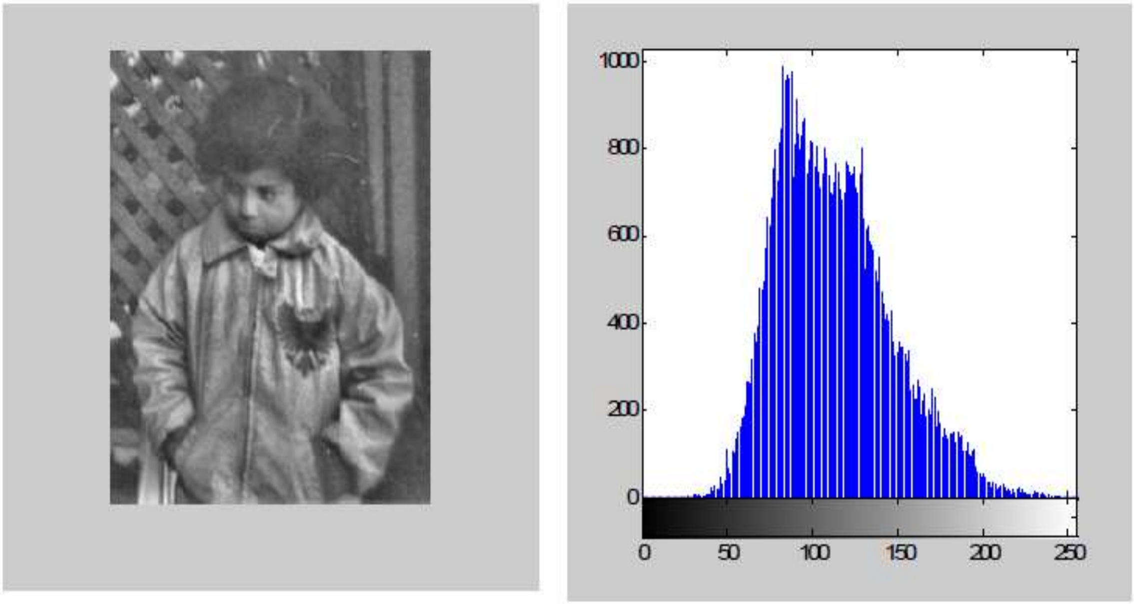

Figure 3 . The GHE image and the corresponding Histogram .

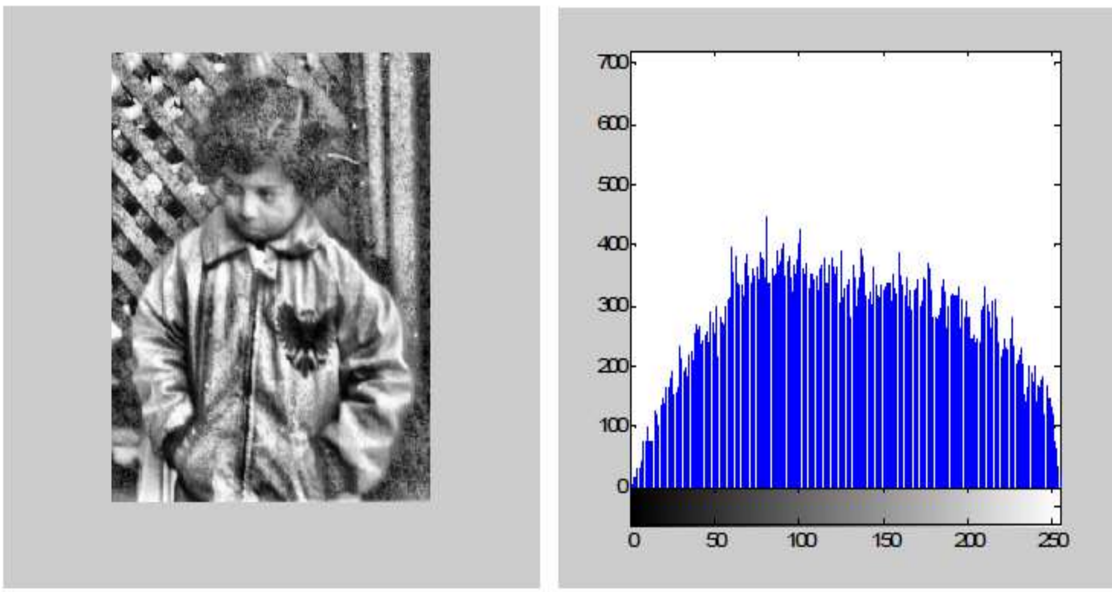

Figure 4 . The LHE image and the corresponding Histogram .

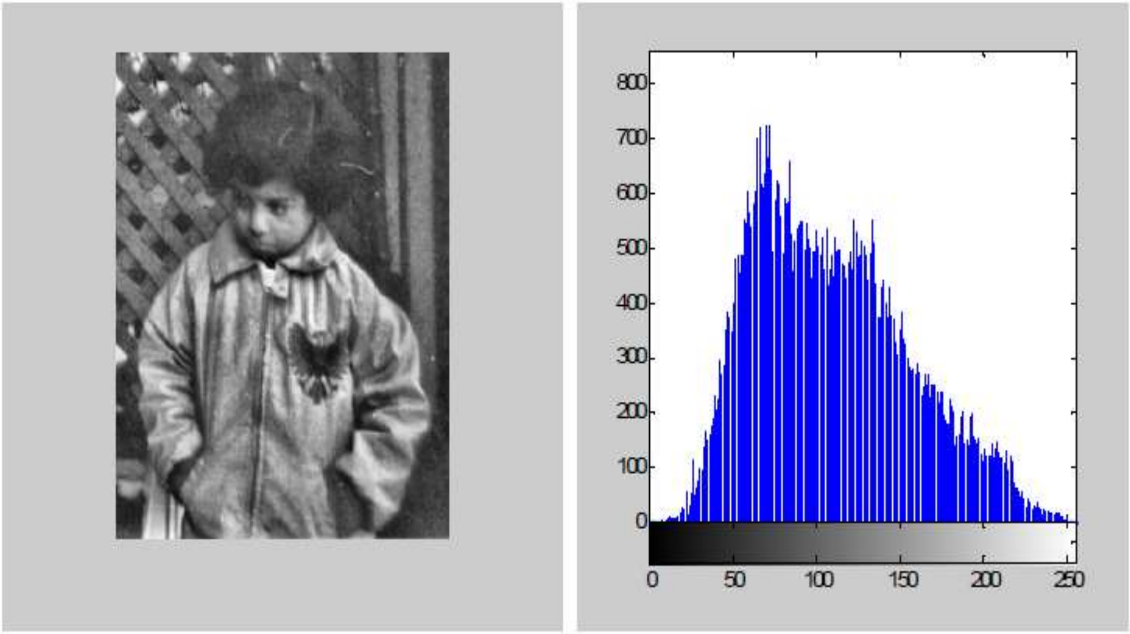

Figure 5 . The proposed HE image and the corresponding Histogram .

In order to make fair comparison with other existed method , enhancement performed on another images which used commonly in such tests: 'moon.tif'and'forest.tif',where the results of different methods are shown in figures 6 and 7 , again , the proposed method have a good outcome with average of performance outperforms GHE and LHE.

(a) (b) (c) (d)

Figure 6 . (a) Image to be enhanced . (b) GHE . (c) LHE.

(d)The proposed HE image.

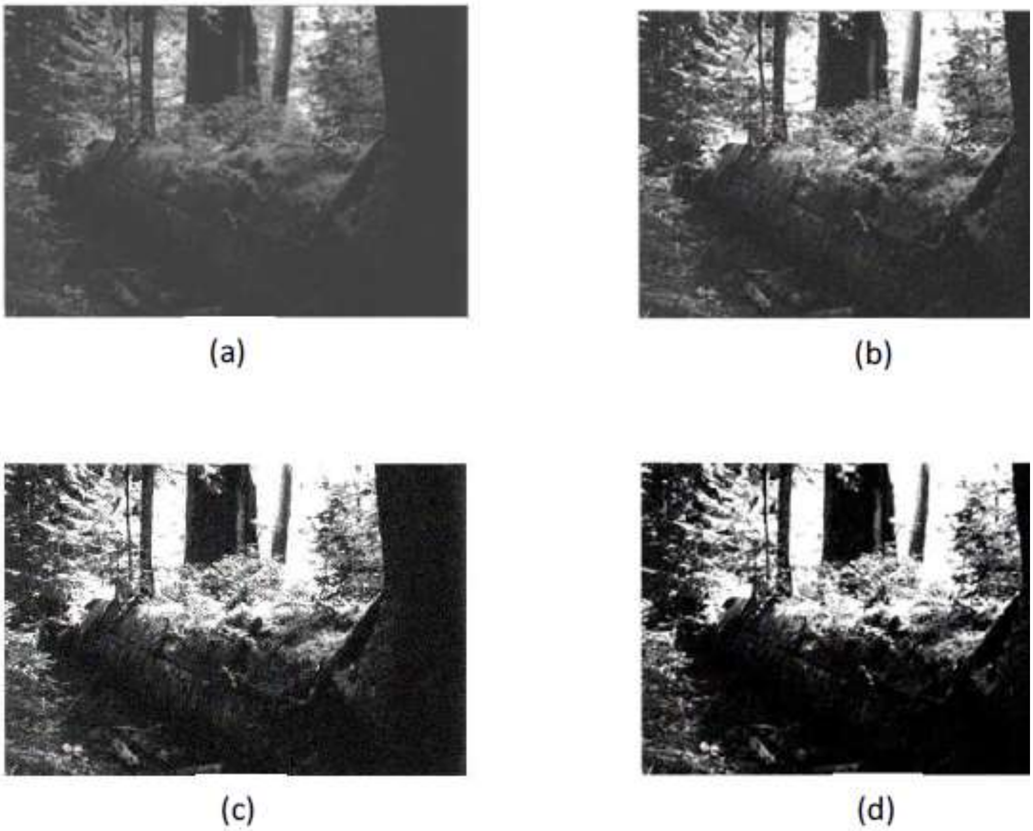

Figure 7 . (a) Image to be enhanced . (b) GHE . (c) LHE.

(d)The proposed HE image.

Let us now discuss image quality evaluation metrics;

Peak Signal-to-Noise Ratio

Peak Signal-to-Noise Ratio is the important standard feature of the reconstructed image quality. The lower values of PSNR means that image is poor quality. PSNR can be defined as;

$$PSNR = 10\, log \frac{(L-1)^2}{MSE} \ldots\ldots\ldots.(17)$$

Given that L is the maximum possible value that can be assigned for the image signal, and since we use 8 bits so L is 256, MSE is the Mean Square Error and for $M \times N$ image MSE can be expressed as;

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}|X(i,j) - Y(i,j)|^2 \ldots\ldots\ldots\ldots\ldots..(18)$$

Where $X(i,j), Y(i,j)$ are the original image and enhanced image respectively.

Discrete Entropy

In general, the entropy is a useful tool to measure the richness of the details in the output image after enhancement. Discrete entropy H can be given as;

$$H(X) = -\sum_{k=0}^{L-1} p(X_k) \, . log_2 \, (p(X_k(k)) \dots \dots \dots \dots (19)$$

Table 1 .image quality evaluation metrics.

HE metrhod	Peak signal to noise ratio	Discrete entropy	Mean square error
Original image	---------	6.45	--------
Global HE	27.7801	5.84	33.25
Local HE	29.8925	5.61	34.12
Proposed HE	27.8455	6.21	12.75

However, if the entropy value *H*of the enhanced image is closer to that of the original input image then the details of the original input image is said to be preserved in the enhanced image and that is clear from table1, Proposed HE image is closer to the Original image.

Conclusions

The proposed contrast enhancement technique is proved to be a good approach for low contrast images. Experimental results on standard image have shown that the degree of enhancement of proposed HE, measured in terms of MSE, H and PSNR is better than convenient GHE and LHE equalization techniques. Moreover, this method is proved to preserve the details of the input images during enhancement. So, this method can find wider applications in the fields including, medical image processing and video processing in consumer electronics.

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