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A New Methodology for Improvement of Contrast to Show Fractures in X-ray Images

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Abstract-Imaging is one of the most important application areas of digital image processing. Processing of various medical images is very much helpful to visualize and extract more details from the image. Many techniques are available for enhancing the quality of medical image. For enhancement of medical images, contrast enhancement is one of the most acceptable methods. Different contrast enhancement techniques i.e. Linear Stretch, Histogram Equalization, Convolution mask enhancement, Region based enhancement, Adaptive enhancement are already available. Choice of Method depends on characteristics of image. This research work deals with contrast enhancement of X-Ray images and presents here a new approach for adjustment of contrast so that minor fracture in bones will be visible.

General Terms- Image Processing, Contrast Enhancement, Histogram Equalization, Contrast Stretching.
Keywords-X ray images, bone contrast enhancement, linear stretching, peak signal to noise ratio.

1. INTRODUCTION

There are different techniques for image enhancement such as Gray Scale Manipulation, Filtering, Histogram Equalization (Spatial domain methods) and Smoothening, Sharpening (Frequency domain methods). Different algorithms have been used in medical imaging to enhance MRI, Ultrasound, CT, and X-Ray images. Histogram Equalization has surpassed the other techniques.

Adaptive Histogram Equalization (AHE) was proposed by C. W. Kurak Jr. et al. in 1997 [1]. It is a good contrast enhancement method for medical images. In medical imaging, its automatic operation and effective presentation of all contrast available in the data make it a competitor to the standard contrast enhancement method, interactive intensity windowing. For certain class of images, intensity windowing has no significant advantages in local contrast presentation in any contrast range. The advantage of AHE is being automatic and reproducible. In this method, histogram equalization is applied to each pixel where mapping is based on the region surrounding that pixel. It means each pixel is mapped to intensity proportional to its rank in the pixels surrounding it, but the basic method is slow.

K. Zuiderveld [2] proposed that Contrast Limited AHE (CLAHE) that differs from ordinary adaptive histogram equalization in its contrast limiting. This feature can also be applied to global histogram equalization, giving rise to contrast limited histogram equalization (CLHE), which is rarely used in practice. In the case of CLAHE, the contrast limiting procedure has to be applied for each neighborhood from which a transformation function is derived. CLAHE was developed to prevent the over amplification of noise that adaptive histogram equalization can give rise to. This is limiting the contrast enhancement of AHE. The contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. This is proportional to the slope of the neighborhood cumulative distribution function (CDF) and therefore to the value of the histogram at that pixel value.

C. Tomasi et al. [3] proposed Bilateral filtering that smooths images while preserving edges, by means of a nonlinear combination of nearby image values. The method is noniterative, local, and simple. It combines gray levels or colors based on both their geometric closeness and their photometric similarity, and prefers near values to distant values in both domain and range. In contrast with filters that operate on the three bands of a color image separately, a bilateral filter can enforce the perceptual metric underlying the CIE-Lab color space, and smooth colors and preserve edges in a way that is tuned to human perception. Also, in contrast with standard filtering, bilateral filtering produces no phantom colors along edges in color images, and reduces phantom colors where they appear in the original image.

N. Kanwal et al. [4] Medical Imaging is one of the most important application areas of digital image processing. Processing of various medical images is very much helpful to visualize and extract more details from the image. Many techniques are available for enhancing the quality of medical image. For enhancement of medical images, Contrast Enhancement is one of the most acceptable methods. Different contrast enhancement techniques i.e. Linear Stretch, Histogram Equalization, Convolution mask enhancement, Region based enhancement, Adaptive enhancement are already available. Choice of Method depends on characteristics of image. This paper deals with contrast enhancement of X-Ray images and presents here a new approach for contrast enhancement based upon Adaptive Neighborhood technique. A hybrid methodology for enhancement has been presented. On comparing this approach with the existing popular approaches of adaptive enhancement and linear stretching, it has been concluded that the proposed technique is giving much better results than the existing ones. Phantom X-Ray image has been used for justifying the visual results. Further, the technique is seed dependent so selection of seed is very important in this algorithm. A seed chosen in darker regions will give better results than the seed chosen in brighter region, because it is assumed that user will require enhancing the darker portions of the image.

2. IMAGE CONTRAST ENHANCEMENT METHODS

2.1 Global Histogram Equalization (GHE)

Histogram equalization is one of the techniques used for image enhancement. In HE an input image is expressed in a predetermined number of gray levels. While calculating the probability density function of the gray levels of the input image, for use in histogram equalization, the number of occurrences of each gray level is constrained not to exceed a predetermined value. Then histogram equalization is performed on the input image based on the calculated probability density (or distribution) function. As a result, the mean brightness of the input image does not change significantly by the histogram equalization. Additionally, noise is prevented from being greatly amplified. They are simple, fast, and with them some acceptable results for some applications can be achieved. In HE, the equalization process is done globally. Let us suppose the $f(x, y)$ is an input image which is having discrete gray levels in the dynamic range of [0, L-1].

2.2 Adaptive Histogram Equalization (CLAHE)

In medical imaging its automatic operation and effective presentation of all contrast available in the data make it a competitor to the standard contrast enhancement method, interactive intensity windowing. AHE has advantages of being automatic and reproducible, and requiring the observer to examine only a single image. In AHE, histogram equalization is applied on each pixel on the basis of the pixels in a region surrounding that pixel (its contextual region). That is, each pixel is mapped to intensity proportional to its rank in the pixels surrounding it. But the basic method is slow, and under certain conditions the enhanced image has undesirable features.

It is an excellent contrast enhancement method for both natural images and medical and other initial non visual images.

2.3 Linear Contrast Stretching Enhancement (LCS)

Linear contrast enhancement, also referred to as a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. By expanding the original input values of the image, the total range of sensitivity of the display device can be utilized. Linear contrast enhancement also makes subtle variations within the data more obvious. These types of enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms, meaning, all the brightness values fall within a narrow range of the histogram and only one mode is apparent. There are three methods of linear contrast enhancement:

- Minimum-Maximam Linear Contrast Stretch
- Percentage Linear Contrast Stretch
- Piecewise Linear Contrast Stretch

In the minimum-maximum linear contrast stretch, the original minimum and maximum values of the data are assigned to a newly specified set of values that utilize the full range of available brightness values. Consider an image with a minimum brightness value of 45 and a maximum value of 205. When such an image is viewed without enhancements, the values of 0 to 44 and 206 to 255 are not displayed. Important spectral differences can be detected by stretching the minimum value of 45 to 0 and the maximum value of 120 to 255.

2.4 Region Based Adaptive Contrast Enhancement (RACE)

The whole algorithm is split into four major steps.

1) A seed point is selected on the image to be enhanced.

2) Based upon the selected seed point, whole image get split into foreground and background region.

3) Foreground region is then enhanced by equalizing histogram adaptively and then background region is added to the enhanced foreground.

4) Finally the enhanced image is obtained by adding gradient of original image to the image obtained in step 3.

The execution of algorithm will depend heavily upon the seed point. For splitting the image in different parts all the pixels of the image will be checked against some threshold defined in accordance to seed point gray value.

2.5 Hybrid Approach for Image Contrast Enhancement

In the proposed technique, hybrid of Contrast Limited Adaptive Histogram Equalization and Bilateral Filter is used. Contrast Limited AHE (CLAHE) differs from ordinary adaptive histogram equalization in its contrast limiting feature. In this technique for each neighborhood from which transformation function can be derived, the procedure of contrast limiting has to be applied. In adaptive histogram equalization problem of over amplification in largely homogeneous regions was there to tackle this problem CLAHE was developed. For achieving this contrast enhancement in AHE is to be in limit. Slope of the transformation function gives the contrast amplification in the vicinity of a given pixel value. It is proportional to the slope of the neighborhood cumulative distribution function (CDF) and value of the histogram at that pixel value.

A bilateral filter is an edge-preserving and noise reducing smoothing filter. When filtering noise using a Gaussian filter there is a problem of edge blurring between areas of different colors. A bilateral filter is a combination of two filters, working both on the area and range of the function (image).

The intensity value at each pixel in an image is replaced by a weighted average of intensity values from nearby pixels. This weight is based on a Gaussian distribution, but also on differences in the range, e.g. color intensity. This preserves sharp edges by systematically looping through each pixel and adjusting weights to the adjacent pixels accordingly.

3. PARAMETERS USED FOR EVALUATION

3.1 Mean Square Error (MSE)

$$\text{MSE} = \frac{1}{MN}\sum_{j=1}^{M}\sum_{k=1}^{N}\left(x_{j,k} - x'_{j,k}\right)^2 \qquad (1)$$

where, M and N are rows and columns, respectively of the image. $x_{j,k}$ is the original image and $x'_{j,k}$ is the corresponding output image. The MSE should be less, which means that the pixel intensity of the input and output image should be as close as possible.

3.2 Peak Signal to Noise Ratio (PSNR)

$$\text{PSNR} = 10 \log_{10} \frac{255^2}{MSE} \qquad (2)$$

Peak Signal to Noise Ratio should be as large as possible which means that the content of signal in the output is large and the noise is less. Since it is peak signal to noise ratio that's why the value of the signal is considered as maximum which is 255 (for gray scale images the gray scale ranges from 0 – 255).

3.3 Entropy

$$\text{ENTROPY} = -\sum_{s=1}^{256} h(s) \times \log_2 h(s) \qquad (3)$$

where, *h(s)* is the normalized histogram of the output image. Entropy has been used to measure the content of the image, with higher values indicating images that are richer in details.

3.4 Normalized Absolute Error (NAE)

Normalized Absolute Error is measured as,

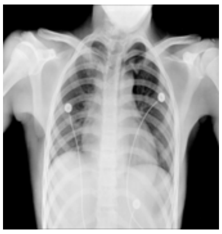
$$\text{NAE} = \frac{\sum_{j=1}^{M}\sum_{k=1}^{N} | x_{j,k} - x'_{j,k} |}{\sum_{j=1}^{M}\sum_{k=1}^{N} | x_{j,k} |}$$

where, $x_{j,k}$ is the original image and is the corresponding output image $x'_{j,k}$. Normalized Absolute Error is the error, so it should be minimum.

NAE gives the difference between input image and output image.

4. Results And Comparison

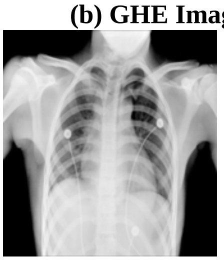
4.1 Results of Chest Image



(a) Original Image

(b) GHE Image

(c) CLAHE Image



(d) LCS Image

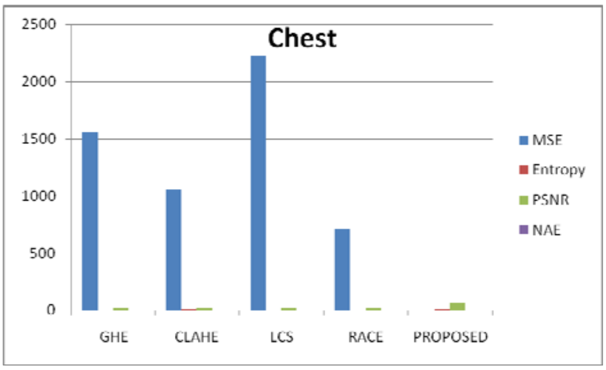
(e) RACE Image

(f) Proposed Enhanced Image

Fig 1. Results of GHE, CLAHE, LCS, RACE, Proposed Techniques on Original Image a.

Table 1. Comparison of various parameters for "CHEST" image

Parameter Technique	MSE	Entropy	PSNR (dB)	NAE
GHE	1551.0	5.1339	16.2247	0.2462
CLAHE	1057.5	7.0415	17.8882	0.1724
LCS	2229.3	3.5331	14.6492	0.2791
RACE	708.19	6.3992	19.62	0.0811
PROPOSED	**0.0158**	**7.2657**	**66.14**	**0.1715**



MSE and NAE are error and it should be minimum, here it can be seen that proposed technique performs better than other technique.

4.2 Results of Knee Image

(a) Original Image

(b) GHE Image

(c) CLAHE Image

(d) LCS Image

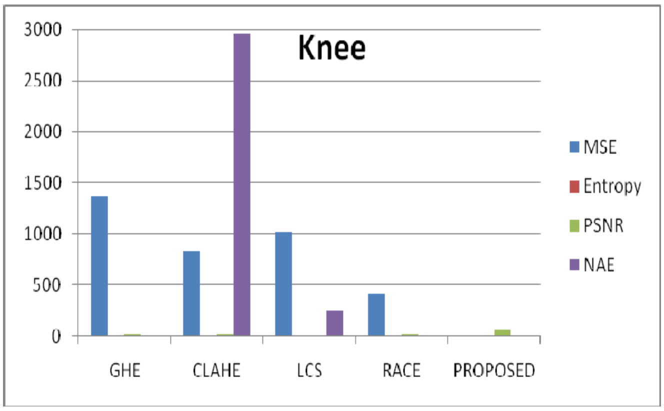
(e) RACE Image

(f) Proposed Enhanced Image

Fig 2. Results of GHE, CLAHE, LCS, RACE, Proposed Techniques on Original Image a.

Table 2. Comparison of various parameters for "KNEE" image

Parameter Technique	MSE	Entropy	PSNR (dB)	NAE
GHE	1366.0	5.3613	16.7763	0.3693
CLAHE	839.22	5.8955	18.8920	02962
LCS	1017.5	5.9538	8.055	254.00
RACE	412.90	5.7524	21.97	0.1148
PROPOSED	**0.0125**	**6.3639**	**67.16**	**0.2992**



From this graph also MSE and NAE of proposed technique is minimum than all other techniques.

CONCLUSION

The result of the tables 1 and 2 show that PSNR values for proposed technique is better than other ones and also MSE is very less in comparison to others. The proposed methodology performs better than other filters to find out the details from the x-Ray bone images.

The future scope is that above technique can be applied to color images also. The proposed methodology can be further improved to find out the details of bones in more refined way.

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