

# Contrast Enhancement for Medical Images Based on Histogram Equalization Followed by Median Filter

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**Abstract**—The goal of image enhancement technique is to improve a characteristics or quality of an image, such that the resulting image is better than the original image. Histogram equalization (HE) is widely used for contrast enhancement. However, it tends to change the brightness of an images, where preserving the original brightness is essential to avoid annoying artifacts. So Bi-histogram equalization (BBHE) has been proposed and analyzed mathematically that it can preserve the original brightness to a certain extends. However, there are still cases that are not handled well by BBHE, as they require higher degree of preservation. The extension of BBHE is Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE). The result of MMBEBHE is bad for the image with a lot details. To overcome these drawbacks, a new method is proposed. In this method, image enhancement is performed by MMBEBHE based on a modified contrast stretching manipulation. While the image is enhanced, the impulse noises present in the images are also enhanced. To avoid this effect, the enhanced image is passed through a median filter. The median filter is an effective method for the removal of impulse based noise on images. This is due to the partial averaging effect of the median filter and its biasing of the input stream, rather than straight mathematical averaging.

**Keywords**—Image Enhancement, Contrast stretching, histogram equalization (HE), MMBEBHE, padding, median filter.

## I. INTRODUCTION

Contrast of an image is determined by its dynamic range, which is defined as the ratio between the brightest and the darkest pixel intensities. Contrast enhancement techniques have various application areas for enhancing visual quality of low contrast images. Histogram equalization (HE) is a very popular technique for enhancing the contrast of an image. Its basic idea lies on mapping the gray levels based on the probability distribution of the input gray levels. It flattens and stretches the dynamics range of the image's histogram, resulting in overall contrast improvement. HE has been applied in various fields such as medical image processing and radar image processing.

In theory, it can be shown that the mean brightness of the histogram-equalized image is always the middle gray level regardless of the input mean. This is not a desirable property in some applications where brightness preservation is necessary. Mean preserving Bi-histogram equalization (BBHE) has been proposed to overcome the aforementioned

problems. BBHE firstly separate the input image's histogram into two based on its mean; one having range from minimum gray level to mean and the other ranges from mean to the maximum gray level. Next, it equalizes the two histograms independently. It has been analyzed both mathematically and experimentally that this technique is capable to preserve the original brightness to a certain extends.

The difference between the MMBEBHE and the BBHE is the threshold. The threshold of the BBHE is the mean of the input image, but the threshold of the MMBEBHE is the minimum mean brightness error between the input image and the output image. MMBEBHE is better than the BBHE, because the brightness error of the MMBEBHE is the least.

In many signal and image processing applications, it is necessary to smooth the noisy signals while at the same time preserving the edge information. The most commonly used smoothing techniques are linear filtering, averaging filtering and median filtering. The linear filters smooth the noisy signals but also the sharp edges. The median of a group, containing an odd number of elements, is defined as the middle element, when the elements of the group are sorted. The median computed at this operation is called the running or the moving median. Since the size of the window is constant, the number of incoming elements is equal to the number of outgoing elements.

In section 2, image enhancement is explained, in section 3 and 4 gives the details about basic histogram equalization and it's type MMBEBHE, in section 5 median filter and it's advantages are explained and section 6 gives the details about the proposed method. Section 7 gives result images and conclusion of this work.

## II. IMAGE ENHANCEMENT

Image enhancement operation improves the qualities of an image. They can be used to improve an image's contrast and brightness characteristics, reduce its noise content or sharpen its details. Image enhancement techniques may be grouped as either subjective enhancement or objective enhancement. Subjective enhancement technique may be repeatedly applied in various forms until the observer feels that the image yields the detail necessary for particular application. Objective image enhancement corrects an image for known degradations. Here distortions are known and enhancement is not applied

arbitrarily. This enhancement is not repeatedly applied but applied once based on the measurements taken from the system.

Image enhancement fall into two broad categories as below:

1. Spatial domain technique
2. Frequency domain technique

Spatial domain refers to the image plane itself, and approaches in this category are based on direct manipulation of pixels in an image. Frequency domain processing techniques are based on modifying the Fourier transform of an image. Spatial domain refers to the aggregate of pixels composing an image. They operate directly on these pixels. Spatial domain processes will be denoted by the expression.

$$g(x, y) = T(f(x, y))$$

where

$f(x, y)$  is the input image

$g(x, y)$  is the processed image

$T$  is an operator on  $f$

### III. HISTOGRAM EQUALIZATION

For a given image  $\mathbf{X}$ , the probability density function  $p(X_k)$  is defined as

$$p(X_k) = \frac{n_k}{n} \quad (1)$$

for  $k = 0, 1, \dots, L - 1$ , where  $n_k$  represents the number of times that the level  $X_k$  appears in the input image  $\mathbf{X}$  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 which have a specific intensity  $X_k$ . In fact, a plot of  $n_k$  vs.  $X_k$  is known histogram of  $\mathbf{X}$ . Based on the probability density function; the cumulative density function is defined as

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

where  $X_k = x$ , for  $k = 0, 1, \dots, L - 1$ . 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

$$f(x) = X_0 + (X_{L-1} - X_0)c(x). \quad (3)$$

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

$$\mathbf{Y} = f(\mathbf{X}) \quad (4)$$

$$= \{f(X(i, j)) | \forall X(i, j) \in X\} \quad (5)$$

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. Based on information theory, entropy of message source will get the maximum value when the message has uniform distribution property.

### IV. MINIMUM MEAN BRIGHTNESS ERROR BI-HISTOGRAM EQUALIZATION (MMBEBHE)

The process of MMBEBHE is:

1. Calculate the mean brightness  $E_k(Y)$  for each of the threshold gray level  $X_k$ . Let's denote  $E_m(Y)$  as the output mean of BBHE with threshold level set as  $X_m$ . So  $X$  can be assumed to have symmetry distribution around  $X_m$ . But it cannot be assumed to have symmetry distribution around  $X_k$  for the MMBEBHE.

Then it follows that:

$$E_k(Y) = \left( \frac{X_0 + X_k}{2} \right) \left( \sum_{i=0}^k p(X_i) \right) + \left( \frac{X_{k+1} + X_{L-1}}{2} \right) \times \left( \sum_{i=k+1}^{L-1} p(X_i) \right) \quad (6)$$

2. Calculate the Absolute Mean Brightness Error (AMBE) for each of the threshold level. It is defined as the absolute difference between the input and the output mean.  $AMBE_k$  is brightness error when the threshold is  $X_k$ .

$$AMBE_k = |E(X) - E_k(Y)| \quad k=0,1,\dots,L-1 \quad (7)$$

3. Find the minimum value of the  $AMBE_T$ ,  $AMBE_T$  is assumed the minimum value  $\{AMBE_k\}$  when the threshold gray level is  $X_T$

4. Separate the input histogram into two based on the  $X_T$  found in step (3) and equalized them independently as in BBHE. At last it combines the two histograms.

### V. MEDIAN FILTERING

A median filter finds the median of a number of elements at its input. The median of a group, containing an odd number of elements, is defined as the middle element, when the elements of the group are sorted. In the standard median filtering applications, a window of size  $W$ , where  $W$  is odd, is moved along the sampled values of the signal or the image. For each position of the window, the median of the elements within the windows is computed and then written at the output pixel located at the same position as the central element of the window. The median computed at this operation is called the running or the moving median. Since the size of the window is constant, the number of incoming elements is equal to the number of outgoing elements. The dimensions of the filter mask must be odd. Mask sizes are 3x3, 5x5 or 7x7. Minimum mask size is preferred in many cases. In this paper, the mask size is 3x3.

The averaging filters have some undesirable features like outlier points that distort the filtered signal, and edge information loss. The median filters have proved to be good because they have some very interesting properties: 1) they can smooth the transient changes in signal intensity (e.g., noise); 2) they are very effective for removing the impulsive noises from the signals; 3) they can preserve the edge information in the filtered signal; and 4) they can be

implemented by using very simple digital nonlinear operations. Because of these properties of the median filters, they are frequently used in various signal and image processing applications.

#### A. Padding

When the center of the mask moves closer to the border, one or more rows or columns of the mask will be located outside the image plane. There are several ways to handle this situation. One such approach is padding. Padding is the process of adding rows and columns of '0's. Padding is stripped off at the end of the process so that the size of the filtered image is same as the original image.

#### B. Advantages of median filter

- They provide excellent noise reduction capabilities, with considerably less blurring than linear smoothing filters of similar size.
- Median filters are particularly effective in the presence of both bipolar and unipolar impulse noise.
- Median value must be one of the pixel values present in the Neighborhood. So median does not create new unrealistic pixel value.

In this paper, histogram equalization followed by the median filter is designed using VHDL language

### VI. PROPOSED METHOD

Proposed method consists of three steps.

1. Contrast Stretching of original image
2. MMBEBHE of stretched image
3. Median filtering

#### A. Contrast Stretching

Our proposed enhancement method performs histogram equalization based on a local modified contrast-stretching manipulation and replaces each original intensity value. The new intensity is assigned to each pixel according to an adaptive transfer function that is designed on the basis of the statistics of the input images. The details of this algorithm are given below.

First assumed that the input image is  $I$ , the output image is  $X$  and the size is as same as the size of input image and define the intensity range of the input image as  $range$ , which can be calculated as (8).

$$Range = |I_{max} - I_{min}| \quad (8)$$

where  $I_{max}$  and  $I_{min}$  are the maximum and minimum intensity values of the input image. The new intensity is assigned to each pixel according to equation (9)

$$X_k = \begin{cases} I_k - \sigma_k & , \text{ if } I_k = I_{max} \\ I_k + \sigma_k & , \text{ if } I_k = I_{min} \\ f_k & , \text{ else} \end{cases} \quad (9)$$

$$\text{where, } f_k = I_{min} + \frac{r_k |I_k - I_{min}|}{|I_{max} - I_{min}|} \quad (10)$$

$$\text{and } r_k = w - \sqrt{(range - w)^2} \quad (11)$$

$w$  lies between 0.01 to 0.02.

Using the above formulas each pixel value is replaced. The result of contrast stretching is given as the input to the MMBEBHE. The image is enhanced in a better way by contrast stretching followed by MMBEBHE. While the image is enhanced, the impulse noises present in the images are also enhanced. To avoid this effect, the enhanced image is passed through a median filter.

### VII. RESULTS AND CONCLUSION



Fig. 1a. CT Chest image with Gaussian noise



Fig. 1b. Result of Contrast stretching

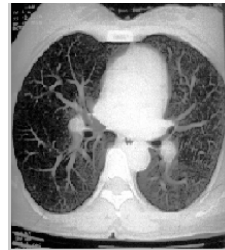


Fig. 1c. Result of MMBEBHE

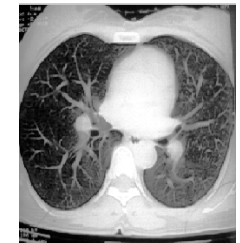


Fig. 1d. Result of proposed method

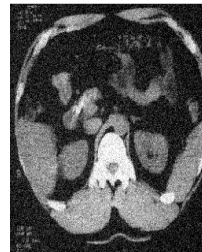


Fig. 2a. CT Abdomen image with Gaussian noise



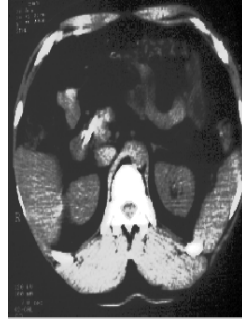
Fig. 2b. Result of Contrast stretching

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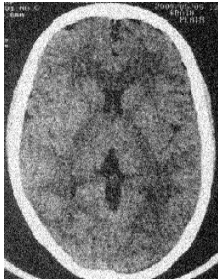
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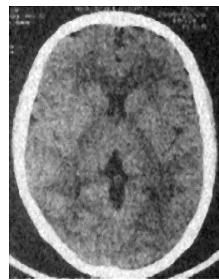
**Fig. 2c. Result of MMBEHHE**



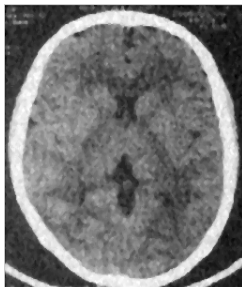
**Fig. 2d. Result of proposed method**



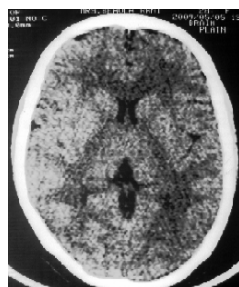
**Fig. 3a. CT brain Image with Gaussian noise**



**Fig. 3b. Result of Contrast stretching**



**Fig. 3c. Result of MMBEHHE**



**Fig. 3d. Result of proposed method**

The conventional histogram-based contrast enhancement technique is limited in real time application due to large computational and storage requirements. In addition to the hardware complexity, conventional techniques also exhibit quality degradation caused by possible loss of infrequently distributed pixel intensities, which may result in disastrous loss of important information. In this paper, we proposed a contrast enhancement system for image sequences which can enhance contrast with suppressing undesired noise amplification based on median filtering processing. From the results (Figure. 1d, 2d and 3d) it is clear that the proposed method is best in contrast enhancement compared to other methods.

This can be extended to 3-D medical images and it is possible to apply the algorithm for color images also.