Modified Histogram Based Contrast Enhancement using Homomorphic Filtering for Medical Images

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Abstract— **In medical image processing, low contrast image analysis is a challenging problem. Low contrast digital images reduce the ability of observer in analyzing the image. Histogram based techniques are used to enhance contrast of all type of medical images. They are mainly used for all type of medical images such as for Mias-mammogram images, these methods are used to find exact locations of cancerous regions and for low-dose CT images, these methods are used to intensify tiny anatomies like vessels, lungs nodules, airways and pulmonary fissures. The most effective method used for contrast enhancement is Histogram Equalization (HE). Here we propose a new method named "Modified Histogram Based Contrast Enhancement using Homomorphic Filtering" (MH-FIL) for medical images. This method uses two step processing, in first step global contrast of image is enhanced using histogram modification followed by histogram equalization and then in second step homomorphic filtering is used for image sharpening, this filtering if followed by image normalization. To evaluate the effectiveness of our method we choose two widely used metrics Absolute Mean Brightness Error (AMBE) and Entropy. Based on results of these two metrics this algorithm is proved as a flexible and effective way for medical image enhancement and can be used as a pre-processing step for medical image understanding and analysis.**

Keywords—Mammogram, Medical Image Enhancement, Histogram Equalization, Homomorphic Filtering, Contrast Enhancement.

I. INTRODUCTION

In digital image processing contrast enhancement techniques are an important techniques for both human and computer vision. Histogram Equalization (HE) is one of the simplest and effective technique to perform contrast enhancement. In histogram equalization we reduce the number of gray levels by combining two or more less frequent neighboring gray levels (having small probabilities) in one gray level; also we stretch high frequent intensities over high range of gray levels to achieve comparatively more flat histogram. This flattering causes the overall enhancement of contrast of the input image. In histogram equalization we do not have any mechanism to control the enhancement level, due to this sometime output image have over enhanced regions. Also HE could not effectively work, when the input image contains regions that are significantly darker or brighter than other parts of the image.

To overcome above mentioned limitations of the traditional HE method and make it more flexible, a number of HE based methods proposed by various groups of researchers. One of the most significant contributions in this line was Adaptive Histogram Equalization proposed by Hummel [1], Ketcham [2], and Pizer [3]. In this method, authors proposed that each pixel should be mapped to intensity proportional to its rank in the pixels surrounding it. AHE has produced excellent results in enhancing the signal component of an image but in many cases it enhances noise too. Noise enhancement introduces the artifacts in the output image and theses artifact reduces the ability of observer to detect information contained in the image. K. Zuiderveld [4] introduces a new and effective tool named Contrast Limited Adaptive Histogram Equalization (**CLAHE**), designed to deal with these artifacts in the output image. Later various researcher proposed variants of CLAHE, few of them were discussed in [5], [6], [7], [8]. Another interesting technique proposed by Polesel et al., [9], Adaptive Unsharp Masking (US) technique. This technique is effective but in certain cases for example in medical images it is unable to detect low contrast edges present in images. All the above mentioned methods improve image contrast but they have a common drawback that they are not able to preserve image brightness.

Here we propose a new method named "Modified Histogram Based Contrast Enhancement using Homomorphic Filtering" (MH-FIL) for medical images. In proposed method, we initially modify the histogram of input image using a histogram modification function and then we apply HE method for contrast enhancement on this modified histogram. After that we use homomorphic filtering for image sharpening and then to minimize the difference between input and processed image mean brightness, we normalize it.

The rest of this paper is organized as follows. Section II briefly covers the histogram equalization method. Section III describes in detail the proposed method MH-FIL. Some experimental results are shown in Section IV and a short concluding remark is given in Section V.

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II. Histogram Equalization Method

The histogram of an image is the graphical representation of the relative frequencies of the different gray levels in the image. It provides a total description of the appearance of an image. There are several contrast enhancement techniques based on histogram are available in order to improve the visible quality of an image. The most common approach is the histogram equalization.

Histogram equalization is a preprocessing technique to enhance contrast in all type of images. Equalization implies mapping from given intensity distribution (the given histogram) to uniform intensity distribution (a wider and more flat distribution of intensity values) so the intensity values are spread over the whole range. Through this adjustment, we can achieve close to equally distributed intensities in an output image.

In histogram equalization we consider an image as a 2 dimensional array of gray levels. Let the (i, j) element of this array is $X(i; j)$ be the intensity of (i, j) pixel of the image, where $X(i; j)$ is from the L discrete gray levels denoted by $\{X_0, X_1, \ldots, X_{L-1}\}$. The probability mass function (PMF) of of gray level X_k; is denoted by $P[X_k]$ and defined as:

$$P[X_k] = \frac{n_k}{n}, \qquad k = 0,1,\ldots,L-1, \tag{1}$$

where n_k be the number of pixel having intensity k and n be the total number of pixels in image.

The cumulative distribution function (CDF) of X_k, is denoted by $C[X_k]$ and defined as

$$C[X_k] = P[X \le x] = \sum_{j=0}^{k} \frac{n_k}{n}, \qquad k = 0,1,\ldots,L-1, \tag{2}$$

it is obvious that $C[X_{L-1}] = 1$. Now we define a transform function $f(.)$ for histogram equalization, which maps an input gray level X_k into an output gray level $f(k)$, given as

$$f(X_k) = X_0 + (X_{L-1} - X_0)C[X_k], \quad k = 0,1,\ldots,L-1. \tag{3}$$

III. Modified Histogram Based Contrast Enhancement Using Homomorphic Filtering

In this section we will completely describe proposed method Modified Histogram Based Contrast Enhancement using Homomorphic Filtering (MH-FIL). Our method has two step processing, in first step global contrast of image is enhanced using histogram modification followed by histogram equalization and then in second step homomorphic filtering is used for image sharpening, this sharpening is followed by image normalization. Figure 1 shows block diagram of proposed method.

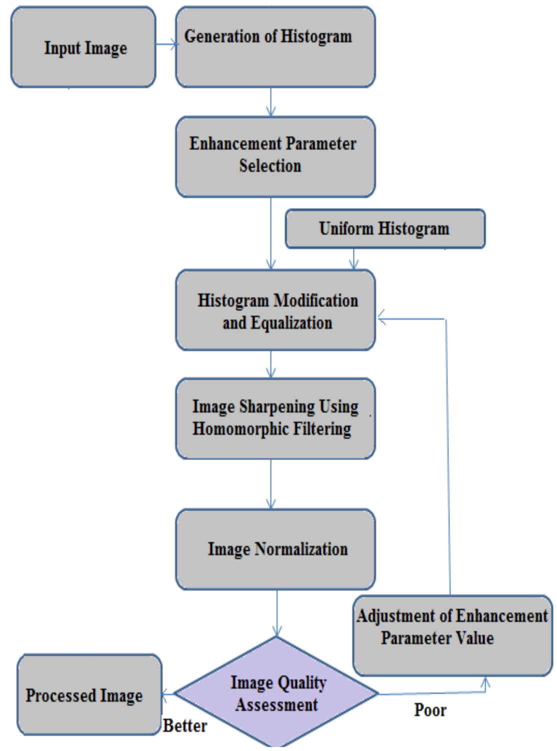

Figure 1: shows functional block diagram of proposed method MH-FIL

Step 1. Histogram Modification: The main drawback of histogram equalization is that it does not provide any mechanism by which we can adjust the level of enhancement. Here we are going to propose a technique by which we have a control over level of contrast enhancement in the output image. HE uses a level transformation function to enhance the image contrast, this transformation function also redistributes the input image histogram such that the resultant histogram is closed to uniform distribution.

Here we proposed another new method of histogram modification for contrast enhancement. The proposed method has the ability to control the level of contrast enhancement in the output image.

Let H be the histogram of the input image and let H_u be the uniform histogram. The main idea is to obtain a modified histogram H' from the input histogram H such that the difference between H' and H_u is sufficiently small, keeping the H' closer to H. Now it is an optimization problem and can be formalized as:

$$H' = \alpha H + (1-\alpha)H_u, \tag{4}$$

where $0 \le \alpha \le 1$.

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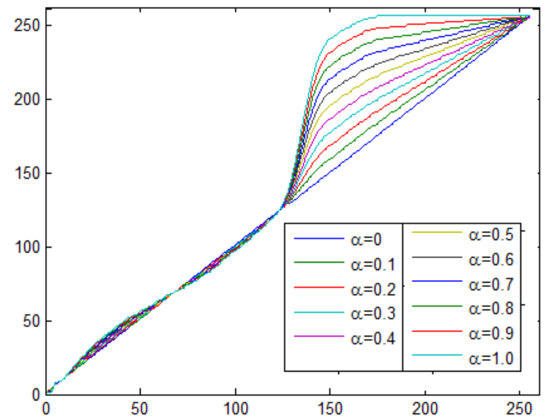

Figure 2: shows importance of power law function

In the above figure we are showing mapping function for different values of α which varies from 0 to 1. for $\alpha = 1$ this function gets saturated earlier to maximum value. Hence this condition leads to over enhancement in the mammogram image, when this value is near to 0 then the mapping gradually reaches the maximum value. Now after applying above mentioned histogram modification, we apply HE to this modified histogram. In our method we have chosen value of $\alpha = 0.55$. Our method produces images with better contrast enhancement in terms of both subjective and objective as compared to other medical image enhancement methods.

Step 2. Homomorphic Filtering: In general, enhancement in contrast also leads to enhancement of noise in some visually important areas, hence we are applying homomorphic filtering to reduce the content of noise in histogram equalized image. Homomorphic filtering is a popular method used to enhance or restore the degraded images having uneven illumination. This technique uses illumination-reflectance model in its operation. This model consider that, the image is been characterized by two primary components. The first component is the amount of source illumination incident on the scene being viewed $i(x, y)$. The second component is the reflectance component of the object on the scene $r(x, y)$. The image $f(x, y)$ is then defined as:

$$f(x, y) = r(x, y)i(x, y). \tag{5}$$

In this model, the intensity of $i(x, y)$ changes slower than $r(x, y)$. Therefore, $i(x, y)$ is considered to have more low frequency components than $r(x, y)$. Using this fact, homomorphic filtering technique aims to reduce the significance of $i(x, y)$ by reducing the low frequency components of the image. This can be achieved by executing the filtering process in frequency domain. In order to process an image in frequency domain, the image need first to be transformed from spatial domain to frequency domain. This can be done by using transformation functions, such as Fourier transform. However, before the transformation is taking place, logarithm function has been used to change the multiplication operation of r(x,y) with i(x,y) in equation (5) into addition operation [10].

Following figure 3 shows flow chart of homomorphic filtering.

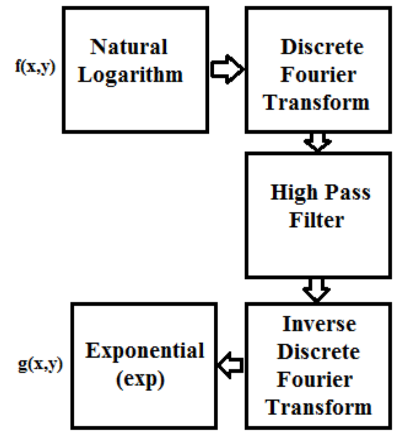

Figure 3: shows flow chart of homomorphic filtering

After applying homomorphic filtering, we apply image normalization using the following formula:

$$g(x, y) = (X_{MI}/X_{MO})f(x, y), \tag{6}$$

where X_{MI} and X_{MO} are mean brightness of input image and image produced after homomorphic filtering respectively.

IV. Experimental Results

In this section, we demonstrate the performance of the proposed method MH-FIL in comparison with some existing HE based contrast enhancement methods, like HE, US (Unsharp Masking) and CLAHE.

In the following figure 4, we have shown contrast enhancement by different methods on chest-xray-vandy image.

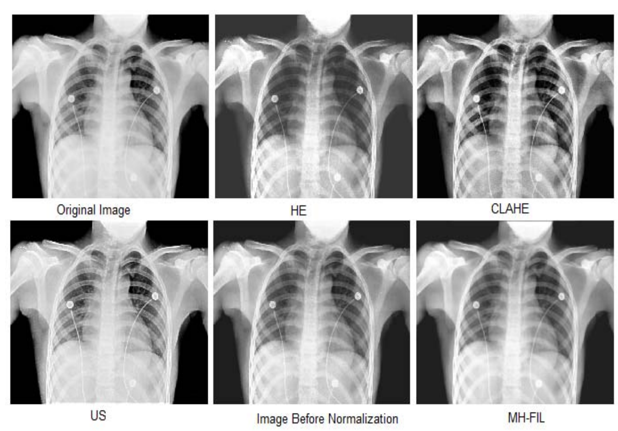

Figure 4: shows results produced by various methods on chest-xray-vandy image

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From the results of figure 4, it is clear that other HE based methods does not work well when the image contains regions that are significantly brighter or darker than other parts of the image, these regions can not be well enhanced by some HE based methods including HE and CLAHE. If we check results of our method MH-FIL from others then we come to a conclusion that MH-FIL produces visually better results than other methods.

In the following figure 5, we are showing effectiveness of our method in detection of cancerous region in an mammogram image patch.

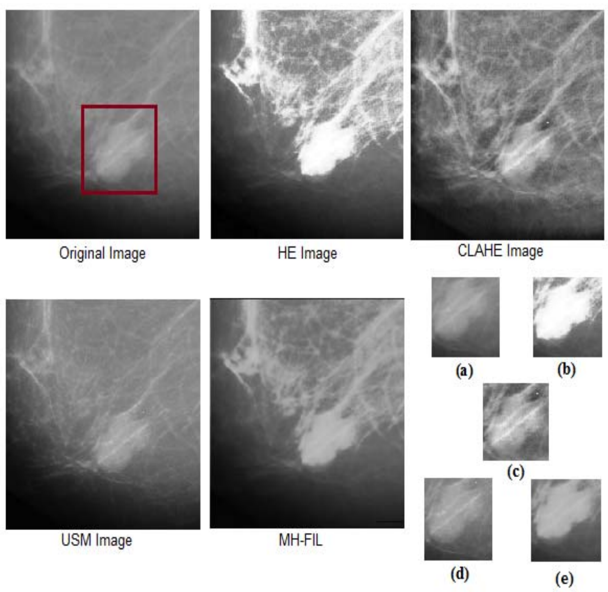

Figure 5: shows results produced by various methods on a mammogram image patch.

From the results of figure 5, we observe that here, original image patch does not provide clear information about cancerous region (a). Using HE (b) we can enhance the contrast in a given mammogram image. The limitation of HE is that the mean gray level of output image changes drastically and we do not have any control over it. CLAHE produces better results but the drawback of CLAHE (c) is that this method enhances the background and foreground at equal level, this leads the enhancement of noise in the background area and hence some artifacts appears in background of enhanced image, similar problem occurs with US (d). MH-FIL (e) produces much better results as compared to results of other given methods; as this method neither over enhances the contrast nor it enhances background and foreground at equal grey level.

A. Image Quality Assesment

We are showing results for 10 medical images, these images include mias mammogram images and images of [12] provided online at [11].

The following, Table I shows results of Absolute Mean Brightness Error (AMBE). AMBE is used to calculate difference in mean brightness between two images. Mathematical expression to calculate AMBE between two images is given as:

$$AMBE = | X_M - Y_M |, \quad (7)$$

where X_M and Y_M are mean brightness of input and processed image respectively.

Table I Absolute Mean Brightness Error (AMBE)

Image Name	HE	CLAHE	US	HM-FIL
mdb143	5.20	7.07	6.40	7.13
mdb144	5.46	7.23	6.74	7.26
mdb145	4.44	5.96	5.92	5.52
mdb146	4.34	5.94	5.92	5.48
mdb147	5.40	7.21	6.59	7.21
mdb148	5.30	7.20	6.82	7.12
headCT-Vandy	2.96	4.11	3.77	3.87
chest-xray-vandy	5.13	7.04	6.57	6.81
MRI-of-knee-Univ-Mich	5.15	7.19	6.11	6.96
MRI-spine1-Vandy	4.45	6.57	5.57	5.81
Average	**4.78**	**6.55**	**6.04**	**6.32**

Based on results of Table I, we observe that MH-FIL has least values in all 10 images as compare to other methods. Further if we look at last row of Table I, which shows average results of AMBE then we find then MH-FIL has least average AMBE values among other methods.

Table II shows results of entropy values on given images by different methods. In general, the higher the entropy is, the richer details and information the image holds. Mathematical expression to calculate entropy of an image is given as:

$$Ent[P] = -\sum_{k=0}^{L-1} P(k) log_2 P(k), \quad (8)$$

where $P(k)$ is probability mass function (PMF) of image histogram.

Table II Entropy

Image Name	HE	CLAHE	US	HM-FIL
mdb143	54.695	6.959	1.354	0.005
mdb144	46.798	8.376	1.093	0.000
mdb145	77.711	4.654	1.152	0.013
mdb146	80.608	4.607	1.008	0.049
mdb147	50.405	6.873	1.365	0.008
mdb148	68.119	8.512	1.142	0.000
headCT-Vandy	85.757	0.660	2.875	0.042
chest-xray-vandy	8.521	20.059	2.388	0.077
MRI-of-knee-Univ-Mich	12.759	14.318	5.976	0.040
MRI-spine1-Vandy	61.084	7.817	1.940	0.048
Average	**54.646**	**8.283**	**2.029**	**0.028**

Based on results of Table II, a careful examination of the entropy values reveals that our method produces comparatively better average entropy values from that of HE and US.

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V. Conclusion

The MH-FIL method provides optimum contrast enhancement while preserving the brightness of given medical image and suitable for all types of medical images. We used Mias-mammogram images and low-dose CT images for comparing our method with the existing other methods. Experimental results show that AMBE of the proposed method is less in comparison of other methods. Also entropy of the proposed method is better from HE, US and is comparative with the CLAHE. On the basis of analysis of these two metrics shows that MH-FIL preserves the input image brightness more accurately and gives processed image with better contrast enhancement.

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