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Short Communication

Histogram Modified Local Contrast Enhancement for mammogram images

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ABSTRACT

Early detection of breast cancer in the mammograms is very essential in the field of medicine. Contrast enhancement of mammograms based on Histogram Equalization (HE) is presented. Histogram equalization is an effective and simple technique for contrast enhancement. The standard histogram equalization (HE) usually results in excessive contrast enhancement because of lack of control on the level of enhancement. The Histogram Modified Local Contrast Enhancement (HM-LCE) is introduced in this paper to adjust the level of contrast enhancement, which in turn gives the resultant image a strong contrast and also brings the local details present in the original image for more relevant interpretation. It incorporates a two stage processing both histogram modifications as an optimization technique and a local contrast enhancement technique. This method is tested for Mias mammogram images. The performance of this method is determined using three parameters like Enhancement Measure (EME), Absolute Mean Brightness Error (AMBE) and Discrete Entropy (H) for all 22 numbers of Mias mammogram images with microcalcification. It's enhancement potential is also tested by sobel and otsu methods for the detection of microcalcification in the mammogram image. From the subjective and quantitative measures it is interesting that this proposed technique provides optimum results by giving better contrast enhancement and preserving the local information of the original mammogram images in the Mias data base and the method has increased the detectability of micro calcifications present in the given mammogram image.

1. Introduction

Breast Cancer is the second leading cause of death for women in the United States and is expected to become the leading cause of death in the next several decades. One in eight women in the United States will develop breast cancer during her lifetime [1]. Because the means to prevent breast cancer have not yet been found, early detection is important [2]. Mammography is the primary imaging technique for the detection and diagnosis of breast lesions. However, mammographers miss about 10% of all cancerous lesions [3]. Also, the overall percentage of breast cancer detected per number of breast biopsies performed on the basis of mammographic screening ranges between 10% and 50% [4]. These high miss and high false-positive rates are caused by the low contrast and noisy nature of the images, as well as the overlying and underlying structures in the projection radiograph that obscure features of interest. Several computer-based algorithms have been proposed to enhance the subtle features of interest in the mammogram image. Therefore, detection of cancer, analysis and treatment of cancer have become a big research field.

Modern imaging technology has already had lifesaving effects on the ability to detect cancer early and more accurately diagnose the disease. One big issue that arises when the radiologist screens mammograms is that the contrast of the images obtained with low dose X-ray machine is low. In the low contrast images, the minor difference between the normal tissue and the malignant disease is not discernable and makes the interpretation very difficult. Thus, enhancing the contrast of the images becomes very important when the mammograms are screened.

1.1. Enhancement of Mammogram Images

The fundamental enhancement needed in mammography is an increase in contrast. Contrast between malignant tissue and normal dense tissue may be present on a mammogram, but below the threshold of human perception [5]. Our emphasis at this stage is to provide the radiologist with a superior image. In the past, several image contrast enhancement methods have been proposed. Many image enhancement approaches were proposed [6–10] in the literature. These enhancement methods are not specifically suitable

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for mammogram images. As the mammogram images are texture in nature, it is very difficult to get proper enhancement for these images by these conventional methods. Adaptive unsharp masking [11] technique was also applied for image contrast enhancement. It is also lacking in detecting low contrast edges like microcalcification present in the mammogram image, when it is applied to the mammogram image. The research works have been done on mammograms for its contrast enhancement and for identification of image features like cluster of microcalcification and masses associated with breast cancer [12,13]. These methods introduced enhancement on mammogram features using adaptive neighborhood method which are also not immune to noise and produces more artifacts. Rangayyan et al. worked in mammographic image contrast enhancement in which the contrast has been improved while compromising the naturalness of the original image [14]. They analyzed the effectiveness of their adaptive neighborhood contrast enhancement (ANCE) technique in increasing the sensitivity of breast cancer diagnosis. An alternative way of mammogram contrast enhancement using wavelet based methods resulted in improvement in preserving the details in the image at the cost of noise amplification [15]. They processed the mammogram images with nonlinear filters and wavelets. Kim et al. proposed a method for mammographic image enhancement using first derivative and local statistics [16]. It is only suitable for low degree of gray level discontinuities in the mammogram images and as the mammograms are texture in nature, the method cannot be able to handle this types of images. Contrast enhancement proposed by T.L. Economopoulos et al. [17] using partitioned iterated function systems (PIFS) is also not suitable for mammogram image enhancement in the sense that it gives more irrelevant information as artifacts. The contrast limited adaptive histogram equalization (CLAHE) introduced by Zuiderveld has given very good results in the case of image contrast enhancement [18], but, it is also not so suitable for mammogram images of very fine details. From the literature survey on mammogram image enhancement and detection of microcalcification, still it is a problem in obtaining contrast enhancement without loosing any relevant information in the original mammogram image and if it is tried to reduce any loss of information, then artifacts would be the next challenge or issue in contrast enhancement of mammogram images. The approach taken in this paper is to propose an optimal contrast enhancement for mammogram images to get artifacts free output image while preserving the naturalness of the original image. The proposed method HM-LCE consists of two stages of processing to increase the potentiality of contrast enhancement and to preserve the local details in the images. In the first level, the histogram modification is done for better contrast enhancement and LCE is used for bringing the fine details hidden in the image. Hence there is a chance to give sufficient quality in the mammogram images to allow the radiologist to make his diagnosis with more confidence. The principal objective of enhancement is to process an image so that the result is more suitable than the original image for a specific application. The enhanced mammogram images are tested by sobel and otsu methods for its artifact free optimum performance in getting the meaning full information from the given mammogram image.

2. Materials and Methods

2.1. Histogram Equalization

The histogram of a digital image with gray levels in the range [0, $L-1$] is a discrete function $g(r_k)=n_k$, where r_k is the kth gray level and n_k is the number of pixels in the image having gray level r_k. It is common practice to normalize a histogram by dividing each of its values by the total number of pixels in the image denoted by n. Thus, a normalized histogram is given by

$$p(r_k) = \frac{n_k}{n} \tag{1}$$

for $k=0, 1, 2, \ldots L-1$.

Generally, $p(r_k)$ gives an estimate of the probability of occurrence of gray level r_k.

$T(r_k)$ is the discrete version of the transformation function and is given by

$$T(r_k) = \sum_{j=0}^{k} p_r(r_j) = \sum_{j=0}^{k} \frac{n_j}{n} \tag{2}$$

for $k=0, 1, 2, \ldots L-1$.

The transformation function $T(r_k)$ must satisfy the following two conditions,

$T(r_k)$ is single valued and monotonically increasing in the interval $0 \le r \le 1$;

$0 \le T(r_k) \le 1$ for $0 \le r \le 1$;

The requirement in (a) that $T(r)$ be single valued is needed to guarantee that the inverse transformation will exist, and the monotonicity condition preserves the increasing order from black to white in the output image. A transformation function that is not monotonically increasing could result in at least a section of the intensity range being inverted, thus producing some inverted gray levels in the output image. Finally condition (b) guarantees that the output gray levels will be in the same range as the input levels. The above-normalized values can be scaled between 0 and $L-1$ as follows

$$T' \triangleq \mathrm{Int}\left[\frac{(T-T_{\min})}{1-T_{\min}}(L-1)+0.5\right] \tag{3}$$

where $T_{\min}$ is the smallest value in the cumulative probability density function vector $T(r_k)$, T is the normalized value of each gray level and L is 255 for eight bit gray scale image and T' is the transformed value for each gray level. Histogram equalization is simple and it is more powerful image enhancement technique. But it introduces over enhancement in the resultant image which makes the output mammogram image washed-out and some local information is missed.

2.2. Proposed Technique (HM-LCE)

HE uniformly distributes the output histogram by using cumulated histogram as its mapping function. However it produces over enhancement in the output image which leads to loss of more local information in the original mammogram. One more problem with HE is its large backward difference values of mapping functions and the contrast enhancement potential should be enriched without loosing the fine details in the mammogram image. It is important to note that when the input histogram distribution is already uniform, the mapping obtained from cumulating the distribution is $T(r_k)=r_k$, which identically maps input to output. In order to lessen the level of enhancement that would be obtained by HE, the input histogram g_i can be altered so that the modified histogram $\bar{g}$ is closer to a uniformly distributed histogram.

HM-LCE method incorporates a two stage processing both histogram modification and local contrast enhancement technique. Fig. 1 shows the steps involved in the proposed method. The potentiality of this contrast enhancement method is greatly increased to the expected level and this histogram modified LCE technique provides better image contrast enhancement in terms of both subjective as well as objective quality compared with other mammogram image enhancement methods.

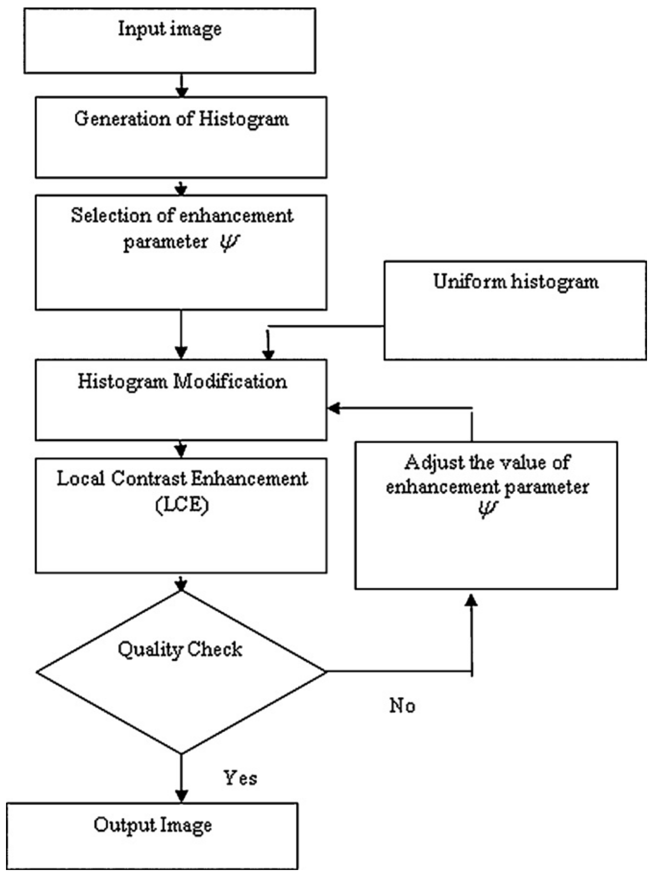

Fig. 1. Flow Chart of the Proposed HM-LCE.

2.3. Histogram Modification

HE does not provide provision for adjusting the level of enhancement. This paper deals with an enhancement technique, which incorporates a provision to have a control over the level of enhancement. The main objective of this method is to find a modified histogram $\bar{g}$ that is closer to uniform histogram and to make the difference between $(\bar{g}-g_i)$ modified and input histogram small, which in turn increases the potentiality of image contrast enhancement and resultant image would be the more relevant to the input image. This is a bi-criteria optimization problem and can be formulated as follows.

$$\min ||\bar{g}-g_i|| + \psi||\bar{g}-u|| \tag{4}$$

Where $\bar{g}$ is the modified histogram, g_i is the input histogram, u is the uniform histogram and ψ is the enhancement parameter and $\bar{g}$, g_i and $u \in R^{256\times 1}$

The enhancement parameter ψ varies in between 0 and α. The solution of above equation traces the optimal trade off curve between the two objectives. HE obtained by $\psi = 0$ corresponds to the standard HE, and as ψ goes to infinity it converges to preserve the original image. Therefore, various levels of contrast enhancement can be achieved by varying ψ. An analytical solution to this above equation can be obtained as follows

$$\bar{g} = \frac{g_i+\psi u}{1+\psi} = \left(\frac{1}{1+\psi}\right) g_i + \left(\frac{\psi}{1+\psi}\right) u \tag{5}$$

The modified histogram $\bar{g}$ is the weighted average of g_i and u. It is very simple to get various levels of contrast enhancement by changing ψ.

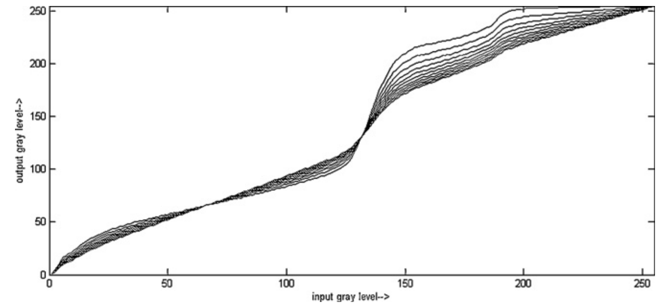

Fig. 2. Mapping for histogram modified mammogram image with ψ = [0 1] for 10 values.

Fig. 2 shows the new mapping function, gray level transformation function, for various values of enhancement parameter ψ which varies from 0 to 1 practically. For very low value of ψ, the mapping function gets saturated earlier to the maximum value (255). Hence this condition leads to over enhancement in the mammogram image. When it is near to 1, the mapping gradually reaches the maximum value, now the naturalness of the image is preserved with increased image quality. Fig. 3 shows the mapping function only for four values of ψ for clarity of this explanation. Here the upper side curve gives the mapping for $\psi = 0$ which is equivalent to the mapping of HE. The second lower curve is for $\psi = 0.1$, the third lower curve is with $\psi = 0.5$ and the bottom most curve is for $\psi = 1$. For $\psi > 1$ the mapping function will closely reach identity mapping which means there is no difference between the original and output image, that is, contrast enhancement is not achieved in this stage.

2.4. Local contrast enhancement

Although the global approach for image contrast enhancement is suitable for some cases, there are situations in which it is necessary to enhance local details in the mammogram image. The number of pixels in this area may have negligible influence on the computation of the global transformation. The solution is to device transformation function based on gray level distribution or other properties in the neighborhood of every pixel in the image. This method of approach is called local contrast enhancement. In this proposed method the histogram modification process is the first step in the given mammogram image and then the local contrast enhancement method is applied to the histogram modified image. The local contrast method is obtained by using some statistical parameters from the histogram. Let r denotes a discrete random variable representing discrete gray levels in the range $[0, L-1]$ and

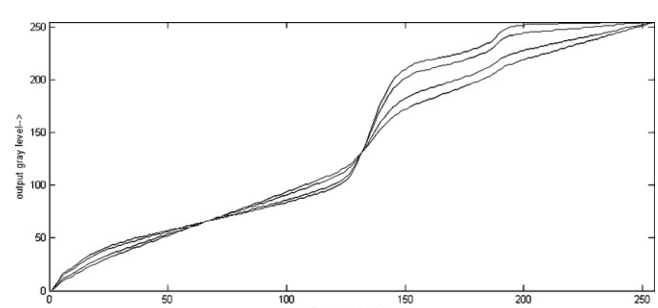

Fig. 3. Mapping for histogram modified mammogram image for four values. With $\psi = 0$ (topfirst), 0.1 (topsecond), 0.5(topthird) and 1(bottom).

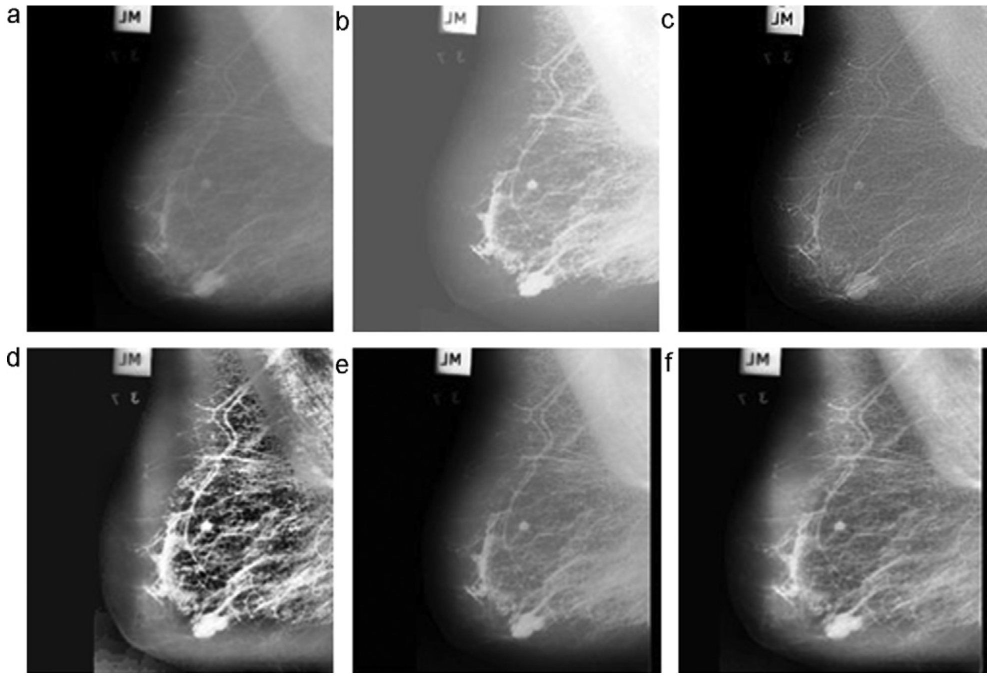

Fig. 4. Enhancement results for fatty mammogram image (mdb005) (a) original mammogram image, (b) Image after histogram equalization, (c) Image after Unsharp masking, (d) Image after CLAHE, (e) Image after Modified Histogram and (f) Image after HM-LCE with $\psi = 0.8$.

let $P(r_i)$ is the normalized histogram component corresponding to the ith value of r. The nth moment of r about its mean is defined as

$$\mu_n(r) = \sum_{i=0}^{L-1} (r_i - m)^n P(r_i) \tag{6}$$

Where m is the mean value of r

$$m = \sum_{i=0}^{L-1} r_i P(r_i) \tag{7}$$

from equation (6) and (7), $\mu_0 = 1$ and $\mu_1 = 0$

The second moment is given by

$$\mu_2(r) = \sum_{i=0}^{L-1} (r_i - m)^2 p(r_i) \tag{8}$$

The equation (8) is the variance of r, which is denoted by $\sigma^2(r)$. The mean is measure of average gray level in an image and the variance or standard deviation is a measure of average contrast. In this work, the local mean and variance are used as the basis for local contrast enhancement.

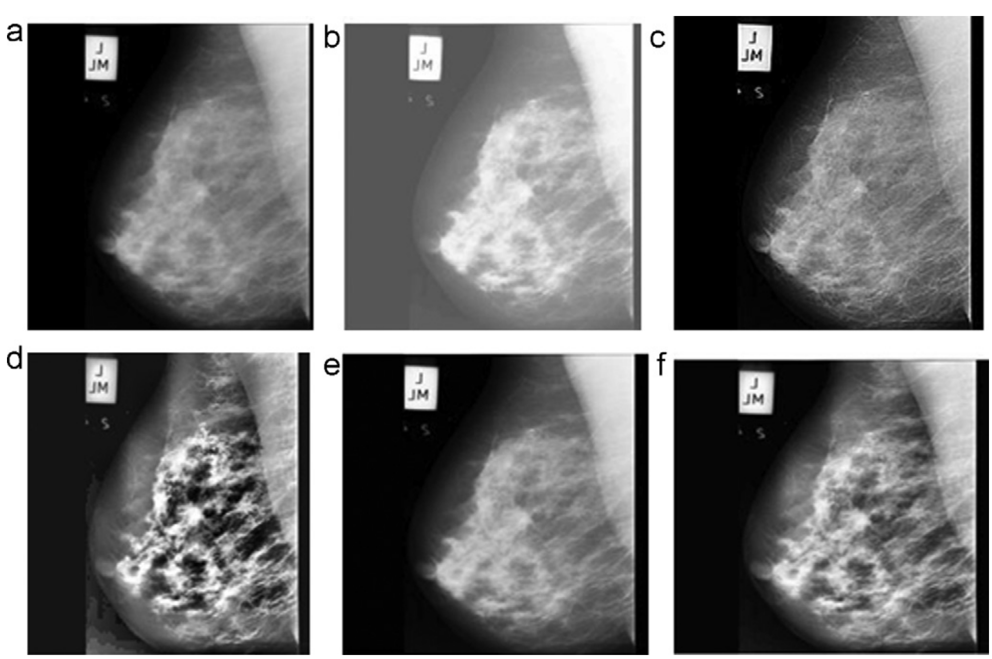

Fig. 5. Enhancement results for fatty glandular mammogram images (mdb219) (a) original mammogram image, (b) Image after Histogram Equalization (c) Image after Unsharp masking, (d) Image after CLAHE, (e) Image after Modified Histogram and (f) Image after HM-LCE with $\psi = 0.8$.

Table 1
Quantitative Measurement results for mdb219, EME denotes Enhancement Measure, AMBE denotes the Absolute Mean Brightness Error and H denotes the Discrete Entropy.

Parameters	Input image	Histogram Equalization	Unsharp masking	CLAHE	**HM-LCE**
EME	170.1030	187.5338	172.2225	181.6499	**177.7860**
AMBE	––	85.0192	0.3007	23.6454	**13.9412**
H	5.2010	3.9974	5.2632	5.6459	**5.5178**

Let S_{xy} denote a sub-image of size w_x, w_y centered at (x, y), the mean value $m_{S_{xy}}$ of the pixels in S_{xy} can be computed as follows

$$m_{S_{xy}} = \sum_{(s,t)\in S_{xy}} r_{s,t} P(r_{s,t}) \tag{9}$$

where $r_{s,t}$ is the gray level at co-ordinates (s,t) in the neighborhood defined by the sub-image and $P(r_{s,t})$ is the neighborhood normalized histogram component to that value of gray level. The gray level variance of the pixels in region S_{xy} is given by

$$\sigma^2 = \sum_{(s,t)\in S_{xy}} [r_{s,t} - m_{s_{xy}}]^2 P(r_{s,t}) \tag{10}$$

The local contrast enhancement for the mammogram image is obtained by applying the following equation (11) after the histogram-modified image is obtained.

$$g(x,y) = \begin{cases} E.f(x,y), & \text{if} \quad m_{S_{xy}} \le K_0 M \\ & \text{and} \quad K_1 D \le \sigma_{S_{xy}} \le K_2 D \\ f(x,y), & \text{Otherwise} \end{cases} \tag{11}$$

where $g(x, y)$ and $f(x, y)$ are final enhanced and histogram modified images respectively and E, K_0, K_1 and K_2 are specified parameters. M is global mean of the input image applied to LCE method and D is its global standard deviation. E, K_0, K_1 and K_2 are positive constants with $K_0 < 1$, $K_1 < K_2$ and K_2 is greater than 1 for enhancing light areas and less than 1 for dark areas.

These two parameters afford a simple, yet powerful local contrast enhancement and by varying the enhancement parameter ψ in the histogram modification process, this method gives a very good promising result in case of mammogram contrast enhancement compared with standard CLAHE technique.

2.5. Adjusting the Level of Enhancement

It is possible to adjust the level of enhancement to achieve the goals in mammogram contrast enhancement so that the subtle microcalcification should be identified by the segmentation process if any applied after the contrast enhancement. The modified histogram is a weighted average of the input histogram g_i and the uniform histogram u. The level of contrast enhancement should be adjusted depending on the input image's contrast. Low contrast images have narrow histograms and with histogram equalization, contouring and noise can be created. It is a good practice to limit the maximum contribution of a histogram, since this will help with the worst-case artifacts created due to histogram equalization.

In Histogram modification part the optimum value of ψ is found by experiment as 0.8 for a given Mias mammogram image. In the later part of this proposed method the successful selection of parameter is also important. In this case the following values are selected by experiment: $E = 3.0$, $K_0 = 0.5$, $K_1 = 0.03$ and $K_2 = 0.5$ for optimum image contrast enhancement. A low value of E is chosen in order to preserve the general visual balance of the image. The choice of these parameters again depends on the enhancement problem that present in the particular situation. The choice of size for the local area is selected as small as possible in order to preserve the detail and keep the computational complexity as low as possible. We have chosen a small 3x3 local region.

3. Results and discussion

For this work, we compare contrast enhancement of HM-LCE with HE, Unsharp masking and CLAHE techniques. From the past researches on contrast enhancement, the CLAHE technique provided comparatively very good results than the others. We used the standard CLAHE technique for comparing the results of this proposed technique. Both subjective and objective measures prove

Table 2
Quantitative Measure for Mias mammogram images with microcalcification.

Mammogram images with H and EME		EME				AMBE				H			
		HE	US	CLAHE	HM-LCE	HE	US	CLAHE	HM-LCE	HE	US	CLAHE	HM-LCE
mdb 209 (5.0612	164.9838)	188. 3995	169.7211	179.8266	178.4712	102.8823	0.33977	21.1928	16.0765	3.8360	5.0329	5.5248	5.4367
mdb 211 (4.4373	136.5595)	187.4394	108.6747	165.5994	161.3535	112.5214	0.1932	6.9868	4.8113	3.1384	4.4103	5.2005	408757
mdb 212 (4.3520	124.2032)	187.0114	92.1608	161.9072	157.8641	114.2394	0.4680	8.0112	6.3422	3.2513	4.3325	5.2043	4.8764
mdb 213 (3.7960	92.8884)	187.6922	94.4474	160.5134	147.9458	135.7015	0.0935	12.4243	8.1635	2.7501	3.7888	4.0068	4.0122
mdb 214 (3.7233	90.2601)	187.7983	91.7762	160.5869	148.0689	139.8378	0.3933	15.2348	9.8576	2.6555	3.7340	3.9794	3.9795
mdb 218 (5.2147	169.0520)	180.1451	88.8584	179.4326	178.9988	88.8584	0.0935	13.1638	13.0478	4.0848	5.2267	5.8069	5.8575
mdb 219 (5.4772	126.0019)	188.4512	178.2105	181.9858	180.7541	80.1303	0.2507	10.6251	8.5092	9.9787	5.4568	5.7067	5.5983
mdb 222 (4.5732	126.7017)	186.5035	95.2117	162.1290	157.6567	111.8763	0.4241	12.7044	9.4508	9.4790	4.5744	5.5029	5.1979
mdb 223 (3.7149	93.3817)	187.6712	94.6790	159.8789	147.2193	140.3397	0.2362	17.0754	9.7753	2.7442	3.7326	4.0026	4.0162
mdb 226 (4.1678	116.2812)	187.0861	91.6060	158.9346	156.8565	126.3143	0.3452	15.9910	15.0707	3.1186	4.1384	5.2105	4.9085
mdb 227 (3.6985	129.7510)	188.3711	99.4127	164.4389	157.9762	134.4454	0.1540	8.2390	5.4565	2.5561	3.6586	4.2248	3.9943
mdb 231 (5.3590	169.7896)	187.4341	172.6984	180.8920	178.7180	86.4891	0.4571	23.1508	19.0099	2.2679	5.4034	5.9003	5.7608
mdb 236 (5.1845	168.0287)	187.1169	172.5222	177.2637	177.7531	83.0678	0.3524	5.6595	9.2460	4.0315	5.2436	5.7969	5.8396
mdb 238 (4.3925	141.2994)	186.1772	91.2993	160.6800	158.1980	116.7904	0.4255	14.2349	12.9445	3.3599	4.4775	5.4360	5.1176
mdb 239 (5.3879	172.4759)	187.3479	176.1591	181.0420	179.6806	70.5104	0.3757	1.9937	4.3055	4.1543	5.4055	5.9061	5.8931
mdb 240 (5.3825	169.5625)	187.0488	172.8473	180.7963	178.7715	69.7316	0.1329	3.2839	3.8604	4.0974	5.3715	5.9252	5.9117
mdb 241 (3.6541	99.7044)	187.7760	105.0532	160.9342	148.9943	129.7576	0.2221	9.1734	5.8139	2.7780	3.6786	4.0427	4.0123
mdb 248 (5.1235	166.3485)	188.1937	169.8399	180.0086	179.3582	93.8297	0.2947	16.9140	16.6534	3.3794	5.0854	5.7437	5.7884
mdb 249 (4.5789	135.7116)	186.8656	112.7843	165.3396	161.6140	106.4655	0.1754	7.8589	7.0488	3.3669	4.6034	5.5394	5.1496
mdb 252 (4.3608	139.3436)	186.8269	95.8650	162.3591	161.2591	113.6854	0.4751	13.0721	12.3740	4.1493	4.4112	5.4917	5.8679
mdb 253 (5.2534	170.2483)	186.8968	174.3041	179.7610	178.3919	75.4637	0.3936	6.2716	8.7194	4.0581	5.3268	5.8701	5.5913
mdb 256 (5.0037	168.1237)	188.5296	172.4117	180.4031	179.1093	83.3375	0.2199	12.4297	12.6794	4.0581	5.0369	5.6732	5.5913

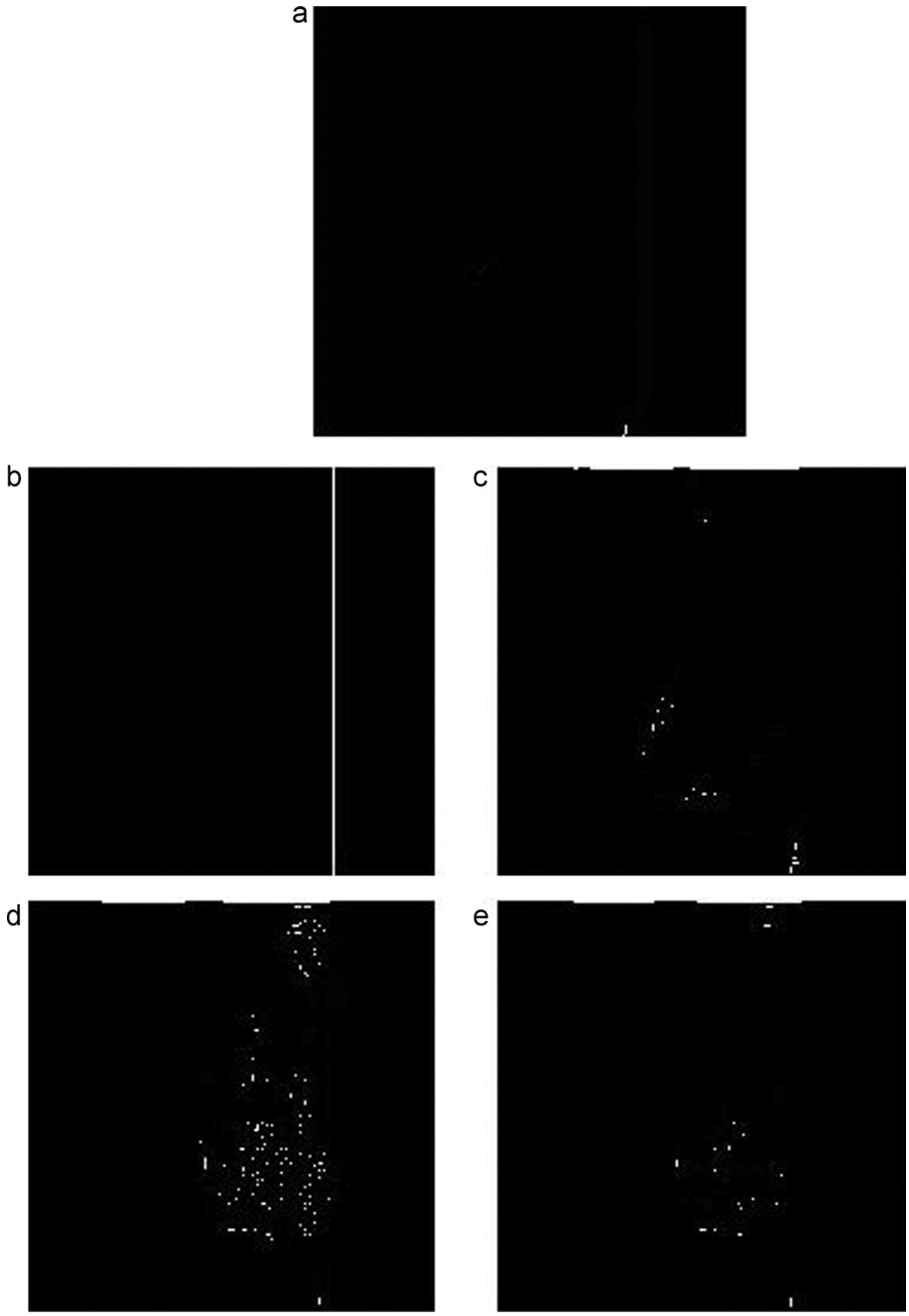

Fig. 6. Response of Sobel operator (threshold = 0.12) on the enhanced images (a) for original image (b) for histogram equalized image (c) for unsharp masking (d) for CLAHE (e) for the proposed HM-LCE.

that the HM-LCE technique provides better performance than CLAHE technique in providing stronger contrast enhancement with preserving more local information of the original image.

Any contrast enhancement technique is expected to have both strong contrast enhancement and preservation of all local information of the original image, in the sense of optimum contrast enhancement. In this aspect the new HM-LCE method provides the promising enhancement results. Figs. 4 and 5 show the enhancement results for Mias fatty mammogram image and fatty glandular mammogram images respectively. The requirement for mammogram image enhancement is highly fulfilled by the HM-LCE technique compared with CLAHE method. As we see from the figure. Even though the CLAHE technique provided strong contrast enhancement, it is not so successful to preserve some local information in the input mammogram image. The results have been improved to higher level in the proposed method for both above mentioned mammogram images with the value of $\psi = 0.8$.

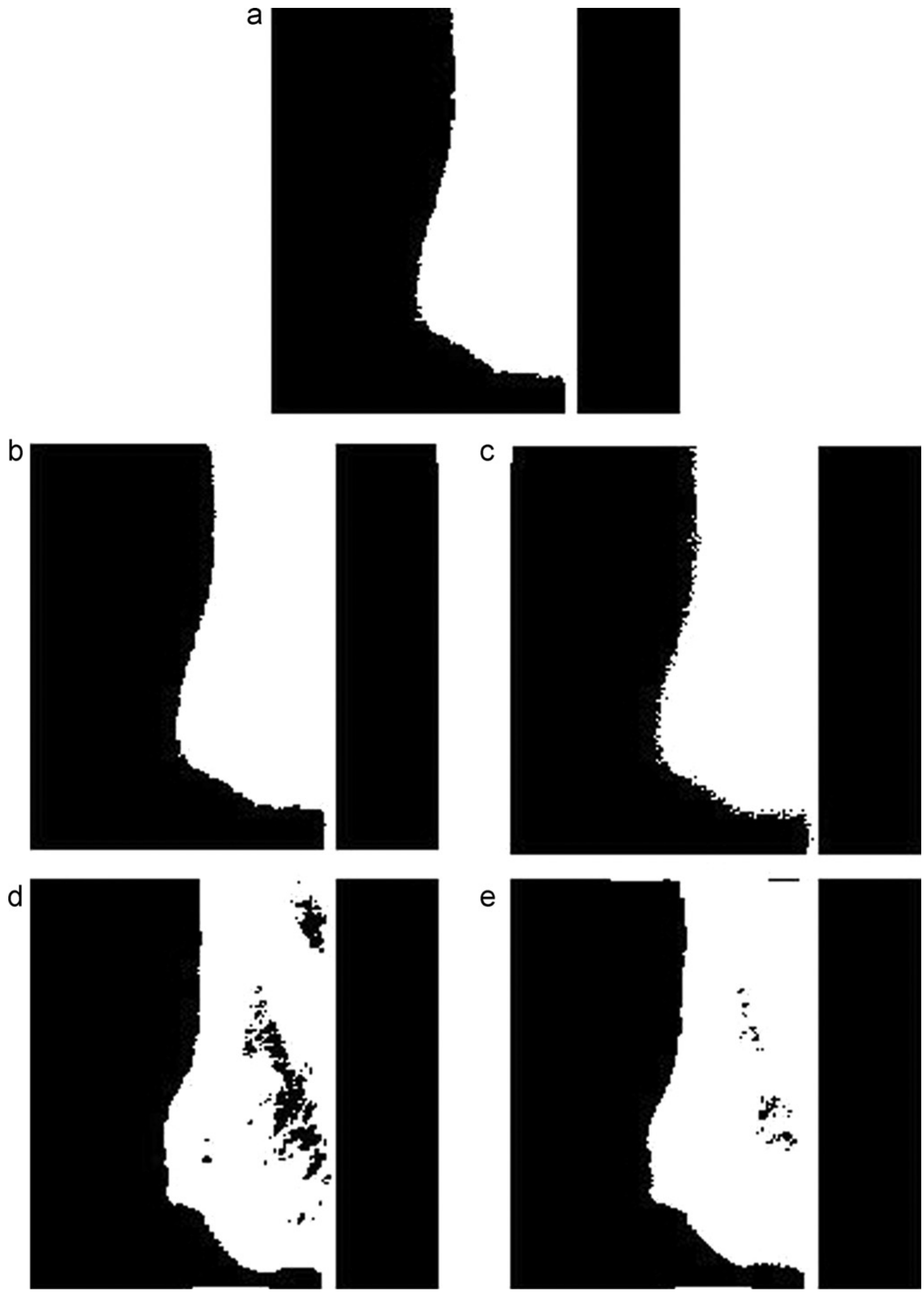

Fig. 7. Responses of otsu method on the enhanced images (a) for original image (b) for histogram equalized image (c) for unsharp masking (d) for CLAHE (e) for HM-LCE.

3.1. Performance Measure

The improvement in images after enhancement is difficult to measure. A processed image is said to be enhanced over the original image if it allows the observer to better perceive the desirable information in the imaging. In images the improved perception is difficult to quantify. There is no universal measure, which can specify both the objective and subjective validity of the enhancement method. In practice many definitions of the contrast measure are used. Here we use three techniques to measure the enhancement level of the image. They are, Enhancement Measure (EME), Absolute Mean Brightness Error (AMBE), and Discrete Entropy (H) [19–21]. The quantitative performance measure of these three parameters are a tabulated in Table 1 for mammogram image mdb211 in the MIAS dada base and Table 2 shows the quantitative performance measure for all 22 numbers of abnormal MIAS mammogram images in terms of micro calcification. When the value of EME is too high, it indicates over enhancement in the output image and it shows a loss of local information due to washed-out output image or leads to insufficient medical details during diagnosis and sometimes it situation introduces artifacts in the resultant image. On the other hand, a very low value of EME indicates hidden information is not significantly enhanced. Then it is necessary to have an optimum value of EME in order to have both contrast enhancement and preserving more local details of the mammogram images. From the experimental results, it is clear that HM-LCE gives optimum level of enhancement (EME = 177.7860) without compromising the fine detail information of original mammogram image where HE provides the highest value of EME for the given mammogram image (EME = 187.5338). The EME value for CLAHE method is also on the higher end which shows it's over enhancement (EME = 181.6499). Unsharp masking (EME = 172.2225) also provides more close EME value to that of input mammogram image (EME = 170.1030) which means less contrast enhancement. We also came to understand that mere histogram modification without LCE again gives very close performance like Unsharp masking which is far away form that of HM-LCE. The performance measures based on the EME value shows that the proposed method strongly outperforms the other existing state of the art methods.

Another way of measuring the enhancement level is the AMBE technique. AMBE is defined as the absolute difference between the input and output mean. The expression for AMBE may be given as

$$\text{AMBE} = |\text{E}(\text{X}) - \text{E}(\text{Y})| \quad (12)$$

Where E (X) is the mean of the input image, E (Y) is the mean of the output image. A median value of AMBE implies better brightness preservation. Either a very low value or the highest value of AMBE also indicates poor performance in case of contrast enhancement, which is experienced in the unsharp masking technique (AMBE = 0.3007) and histogram equalization (AMBE = 85.0192) respectively. In case of CLAHE method, it is AMBE = 23.6454. But the HM-LCE method gives a very optimum value of AMBE (13.9412) which shows that the proposed method preserves the naturalness of the original mammogram image. Comparisons of discrete entropy (H) again show the performance of the proposed method (H = 5.5178), which is slightly higher than that of the input image (H = 5.2010). It proves the increase in average information and closeness to the original image. The highest value of H for CLAHE (H = 5.6459) shows its deviations from the original image. On the whole comparisons, it is clear that the proposed HM-LCE method outperforms all other methods presented here principally it outperform the CLAHE method for the mammogram images. This proposed method is implemented using MATLAB software. Table 2 observations also conform the above justification which is obtained for all 22 Mias images having microcalcification. In the first column of Table 1, the label of the mammogram image tested and its entropy and EME values are given. The above discussion is also conformed, when the enhanced images are tested by sobel edge detection and otsu thresholding methods. This results are given in Figs. 6 and 7 for sobel and otsu methods respectively. The sobel operator threshold is fixed at 0.12 for better results. The sobel operator gives very poor response to the input image due to very low contrast of the input mammogram image, but it is seemed washed out for HE due to over enhancement. On the other hand, response for the Unsharp masking is slightly increased, but it's response for CLAHE is somehow related to artifacts in the information. At the same time, the proposed method gives the optimum response that is, the information obtained is neither washed out nor artifacts. Again the optimum performance of this HM-LCE method is also well proved by otsu method as given in Fig. 7. Otsu method gives the optimum meaningful response for the proposed method. The artifacts produced by the Clahe method is also evident from the response of the otsu method. As micro calcifications are cluster in nature rather than point discontinuities, the otsu method responses to HM-LCE in a meaningful way. Hence this method can contribute more for the radiologist in better during the diagnosis of breast cancer and it is evident that the proposed method has increased the detectability of microcalcification present in the given mammogram images.

4. Conclusion

A novel contrast enhancement for mammogram images is presented. The proposed work provides a better contrast enhancement and information preservation of input mammogram image. The experimental results are also more effective without compromising contrast as well as original information. As it uses the input histogram, which does not change significantly, the proposed work does not introduce artifacts in the output. The proposed method is more suitable for all types of mammogram images of fatty, fatty-glandular and dense-glandular mammogram images and its performance is evaluated for all 22 numbers of Mias mammogram images with microcalcification. The subjective and objective measures are also encouraging. This work may be extended to test its performance for mammogram images in presence of noise and this method can support for detecting of microcalcification in mammograms. It is evident that the proposed method has increased the detectability of microcalcifications present in the mammogram images.

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