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Brightness Preserving Contrast Enhancement of Digital Mammogram using Modified-Dualistic Sub-Image Histogram Equalization

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***Abstract*—** Digital Mammogram is widely accepted as a common modality of breast cancer detection. Image enhancement techniques play a significant role in subjectively altering the brightness and contrast of an image. These methods, despite the reported merits, suffer from over-enhancement, which has adverse effect in segmentation as well as feature extraction. This paper presents a new enhancement algorithm that enhances a digital mammogram, based on the iterative partition of its histogram pattern. The proposed Modified-Dualistic Sub-Image Histogram Equalization (M-DSIHE) method primarily partitions the original histogram into two, using the mid-point of the active dynamic intensity range of the input image. Then the partitioned histograms are iteratively divided and the histogram equalization is applied on the each partitioned histogram. This M-DSIHE has the advantage of enhancing the contrast of the original image, with due brightness preservation. The recorded results of the M-DSIHE method is observed to have an edge over the competitive methods, in terms of the quantitative and qualitative metrics.

***Keywords*—** Mammogram enhancement, Histogram, Histogram Equalization, Contrast Enhancement, Mammogram Segmentation, DSIHE

I. INTRODUCTION

Breast cancer is recorded as one of the major causes for women mortality, across the globe. Early detection of breast cancer is reported to reduce the chances of death rate. Digital mammogram is one of the commonly used imaging techniques for breast cancer detection. It is a grayscale breast image that consists of breast components such as fatty tissues, lobules, ducts, pectoral muscles, etc., in the foreground against the predominant dark background [1]. Digital mammogram, by and large is acquired with low contrast and low brightness, due to the limitation of its modality. This drawback of mammograms calls for the development of efficient enhancement algorithms, in order to differentiate the abnormalities from the other breast components and from the background. It is apparent that the existing the mammogram enhancement techniques aim to pronounce the contrast between its background and foreground objects which ultimately pays off in segmentation, feature extraction and analysis of tumors.

A wide spectrum of enhancement techniques for digital mammogram enhancement is being proposed. The global Histogram Equalization (HE) is one of the simplest and effective point processing based enhancement technique [2-3]. The HE based techniques tend to increase the contrast of the image at the cost of undesirable effects on images such as over-enhancement of background and noise amplification. Most of the enhancement methods convert dark background of the image into gray or brighter background. This effect may reduce the contrast between background and foreground of the mammograms images [2-3]. The proposed Modified Dualistic Sub-Image Histogram Equalization (M-DSIHE) method aims to provide solutions for the said drawbacks.

In this research article, section II gives an overview of DSIHE and other standard HE based enhancement methods. The implementation of the proposed method is presented at section III, The results and discussions are deliberated in section IV and conclusion in section V.

II. ANALYSIS OF DSIHE AND OTHER EXISTING METHODS

To overcome the defects of classical HE, Y. T. Kim introduced a Brightness Preserving Bi-Histogram Equalization (BBHE) method [4] for contrast enhancement. The BBHE method partitions the image gray-levels into two parts using mean of the input image as a threshold value. Then HE is computed for both parts independently and then

merged. This method addresses only over-enhancement of images.

Y. Wang, Q. Chen, B. Zhang proposed an extension of BBHE called Dualistic Sub-Image Histogram Equalization (DSIHE) [5]. This method partitions the histogram gray-levels using median threshold value, Instead of mean threshold as in the BBHE. This DSIHE preserves better brightness than BBHE method. Several methods are developed for contrast enhancement, based on the above two methods. Now a days, researchers are trying to devise efficient contrast-enhancement methods which can preserve the mean contrast and brightness of the input image in the enhanced image.

For contrast enhancement of mammogram, *M. Sundaram, K. Ramar, N. Arumugam, G. Prabin*, developed a method based on Contrast Limited Adaptive Histogram Equalization (CLAHE), which is called Histogram Modified–CLAHE (HM-CLAHE) method [6]. The HM-CLAHE method adjusts the level of contrast enhancement to avoid excessive enhancement. However this method does not reduce the brightness error between input and resultant image. Several studies, reviews and surveys reveal that lack of enhancement of mammograms might affect segmentation, feature extraction and tumor analysis [7-9]. B. C. Patel and G. R. Sinha introduced Gray-Level Clustering and Contrast Enhancement (GLC-CE) method for mammogram images enhancement [10]. The GLC-CE method groups the gray-levels and forms a cluster. The researchers applied a mean based histogram equalization methods which did not ensure the over-enhancement of background of mammogram images. *K. Akila, L. S. Jayashree* and *A. Vasuki* proposed indirect contrast enhancement techniques for mammogram images and analysis using Effective Measure of Enhancement (EME) and Peak Signal to Noise Ratio (PSNR) [11]. For enhancement of mammogram, *M. Kumar, V. M. Thakkar, H. S. Bhadauria, I Kumar* introduced a spatial and frequency domain de-noising for mammograms using adaptive histogram equalization, median filter, butter-worth filter, frost filter and wavelet de-noising filter [12], the results show that median filter and wavelet de-noising yielded better PSNR. *B Gupta* and *M Tiwari* developed a tool for contrast enhancement of mammogram images, this method does not perform up to the mark among the background and foreground objects in mammogram. *N. Kharel, A. Alsadoon, P. W. C. Prasad*, proposed a combined CLAHE and Morphology method for early breast cancer diagnosis which produces better results than several existing methods. But it is not compared with recently reported methods [14] and sufficient samples were not used for quality measures. The observations across the review of literature motivated the development of the proposed M-DSIHE.

III. MODIFIED-DUALISTIC SUB-IMAGE HISTOGRAM EQUALIZATION (M-DSIHE)

The M-DSIHE method is proposed to overcome the drawbacks of those mentioned methods. It addresses the problem of over-enhancement of background, noise amplification and loss of foreground gray-levels components. The M-DSIHE method restrains the over-transformation of background in digital mammogram images. The computational mechanism of M-DSIHE is depicted in Fig. 1 and the methodology is presented in section 2.1.1.

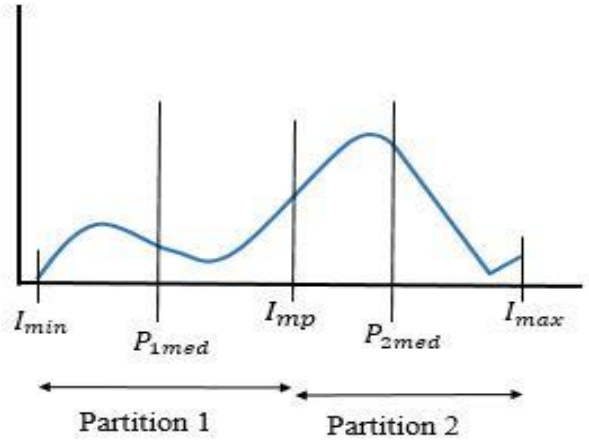

Figure 1:Histogram Partitioning of M-DSIHE, **(a)** *Imin*, *Imax* and *Imp*: Minimum, Maximum and Mid-Point of the intensity scale of input image. **(b)** *P1med*: Median of [*Imin* - *Imp-1*], **(c)** *P2med*: Median of [*Imp* – *Imax*]

Fig.1 depicts the partitioning mechanism of M-DSIHE on the histogram of input mammogram image. The first division on the histogram is performed using the mid point (Imp) of the histogram. It is computed as shown in Eqn.(1).

$$I_{mp} = round\left(\frac{I_{max} - I_{min}}{2}\right) \quad (1)$$

Based on the mid-point of the histogram, the intensity scale of the input image is divided into two, as Partition1 (P1) and Partition2 (P2). The median intensity of P1 representing [$I_{min} - I_{mp}$-1] and P2 representing [$I_{mp} - I_{max}$] are computed as $P1_{Med}$ and $P2_{Med}$ respectively.

2.1.1 Algorithm for Modified-Dualistic Sub-Image Histogram Equalization (M-DSIHE)

Input: Digital Mammogram Image

Output: Enhanced Digital Mammogram Image

Step 1: Find Minimum (*Imin*) and Maximum (*Imax)* intensity of the Input Image I

Step 2: Calculate mid-point of gray-level of the histogram by using Equ.1

Step 3: Partition the input image Histogram P1 and P2 regions by using *Imp* value.

Step 4: Find median for both P1 and P2 regions are *P1med* and *P2med* respectively

Step 5: Divide the P1 into *P1L* and *P1U* and P2 into *P2L* and *P2U* using, *P1med* and *P2med*

Step 6: Apply Histogram Equalization on *P1L, P1U, P2L* and *P2U* independently.

Step 7: Merge equalized the regions

Step 8: Map the input intensities to the equalized intensities

Step 9: Output of histogram equalized digital mammogram

The DSIHE partitions the input image using its median only once. In most of the mammogram images median is found to be zero, due to its pre-dominant background intensity. So the median threshold based single partitioning mechanism does not produce the expected outcome. The proposed M-DSIHE performs the first level partitioning based on the image I_{mp} (Mid-Point) and the second level partitioning using median. Then each partition is subjected to classical histogram equalization. The HEed intensities at the four levels are merged. The input intensities are suitably mapped with the HEed intensities.

IV. RESULTS AND DISCUSSION

The M-DSIHE was implemented using MATLAB 2017b. To validate the performance of M-DSIHE, five input mammograms were chosen from mini-MIAS database, out of which two mammograms are fatty type (mdb005 and mdb028), one is fatty-glandular type (mdb148) and last two is dense type (mdb001 and mdb002). The performance is quantified in terms of Absolute Mean Brightness Error) and Human Visual Perception (HVP) is accounted for quantitative assessment. Lower the AMBE values lesser the error rate. The M-DSIHE is confirmed to give better AMBE than its counterparts and contemporary methods. Entropy, Structural Similarity Index (SSIM) and Peak Signal to Noise Ratio (PSNR). Entropy is a measure of information gain; higher values of entropy indicate higher information gain. The higher value of PSNR denote higher quantum of signal. SSIM measures the degree of similarity between the enhanced image and the input image. It is measured in the range of 0 -1, which denotes the least and most similarity respectively.

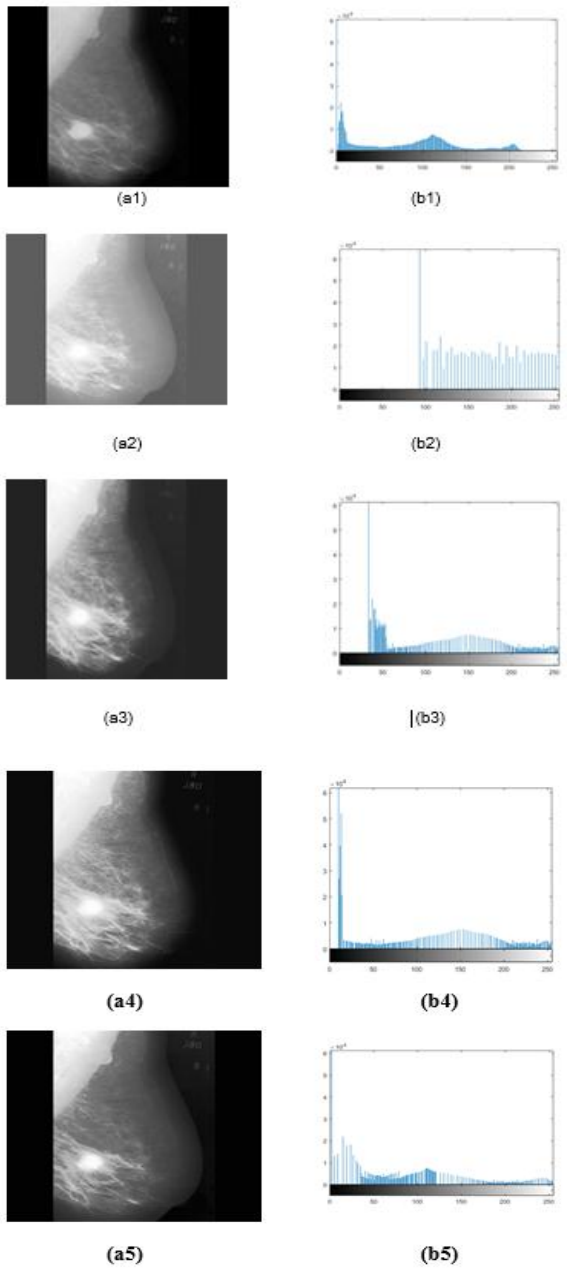

Figure 2: Comparison of M-DSIHE method with existing enhancement methods. (a1) Original mammogram **(b1)** Histogram of (a1) Equalized Image of **(a1)** using **(a2)** HEed **(a3)** BBHE **(a4)** DSIHE **(a5)** M-DSIHE (proposed), **(b1) – (b6)**: Histogram of **(a1)** – **(a5)**

It is evident that the proposed M-DSIHE has stretched and equalized the histogram of the input mammogram, than other methods. The AMBE, Entropy, SSIM and PSNR were computed and recorded for HE, BBHE, DSIHE and M-DSIHE (proposed) are respectively and are reported in table (1) – (4). Table 1 presents the comparison of proposed method (M-DSIHE) with state of the art methods such as HE, BBHE, DSIHE. Five mammogram samples are randomly selected from database for illustration purpose.

Lesser the AMBE is better, here in table 1 except for one sample M-DSIHE for proposed method is lowest. Higher the entropy is better, here in Table 2, proposed method either produce almost equal entropy or higher. Higher the SSIM Index is better, here in table 3, either the proposed method produces almost equal SSIM values or higher. Similarly, higher the PSNR value indicates good quality of results, here in Table 4, proposed method yields highest PSNR values then state of the art methods. Results from the above experiment describe the potential of proposed method M-DSIHE in mammogram image enhancement that works as pre-processing technique in cancer detection.

Table 1 Comparison of AMBE

IMAGE	HE	BBHE	DSIHE	M-DSIHE (Proposed)
mdb005	85.0713	34.0461	**13.9386**	14.241
mdb028	91.2991	32.6208	19.1676	**8.0392**
mdb148	55.1786	28.0086	26.8965	**9.9987**
mdb001	135.6014	24.5374	18.052	**6.7242**
mdb002	109.2837	25.7301	12.8858	**5.982**

Table 2 Entropy

IMAGE	Original	HE	BBHE	DSIHE	M-DSIHE (Proposed)
mdb005	5.1761	3.9665	4.8107	4.8249	**4.9405**
mdb028	5.5805	4.2201	5.264	5.2772	**5.4109**
mdb148	6.7607	5.3039	6.4683	6.4774	**6.523**
mdb001	4.0196	2.8252	3.7805	**3.9489**	3.6901
mdb002	4.7658	3.512	4.4682	**4.5116**	4.4101

Table 3 SSIM

IMAGE	HE	BBHE	DSIHE	M-DSIHE (Proposed)
mdb005	0.4067	0.4151	0.4492	**0.7301**
mdb028	0.3913	0.4871	0.5877	**0.7745**
mdb148	0.5836	0.705	0.7152	**0.8032**
mdb001	0.2199	0.3263	**0.7824**	0.7098
mdb002	0.2947	0.3946	**0.8396**	0.7564

Table 4 PSNR

IMAGE	HE	BBHE	DSIHE	M-DSIHE (Proposed)
mdb005	9.2209	15.7999	19.5033	**20.5708**
mdb028	8.8377	16.9117	19.2379	**25.0115**
mdb148	12.6714	18.1158	18.3827	**23.9224**
mdb001	5.2535	19.7307	19.191	**26.6584**
mdb002	7.0031	18.7554	22.6836	**28.4656**

V. CONCLUSION

The enhancement of digital mammogram is helpful to easy segmentation of tumors and their analysis. The proposed M-DSIHE method is confirmed to enhance the digital mammogram, without altering the originality of breast components. It ideally enables the segmentation techniques to achieve better segmentation of breast tumors. This proposed enhancement method is also effective on the other image modalities too. M-DSIHE performs excellently well on fatty type of mammogram images, whereas it stumbles on the other types of mammogram images.

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