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Luminosity and Brightness Control Enhancement of Mammograms

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ABSTRACT: The enhancement in the field of medical imaging is a crucial task as it requires the preservation of the information. Most of the existing methods are known for good quality enhancement but also result in degrading the mammograms. The proposed method deals with enhancing the mammograms using a combination of the luminosity enhancement procedure using the modified CLAHE in HSV color format and further, the contrast is controlled using single level SVD-DWT procedure. The performance of the methods are analysed on the basis of PSNR, SSIM and PCC.

KEYWORDS: Image Enhancement, Mammogram Processing, SVD-DWT

I. INTRODUCTION

Breast cancer is one of the major problem that the women suffer from. Mammography is the first screening method to detect the cancer. In mammography, we can also detect the cancer in the early stages so that proper cure can be given on analysing the nature of the tumours that are causing the cancer. The tumour can be of two types, namely, Benign and Malignant. Benign tumour are not cancerous and Benign Mass has a round, smooth and well circumscribed boundary while the other one is malignant tumour which is cancerous and spread to other parts of body too. As mammography helps to detect the breast cancer at the early stages by detecting the calcification part in breast muscle, thereby, image enhancement plays a vital role in removing the noise from the digital images and by combining it with the contrast enhancement, it may help to detect the features (such as boundaries and tumours) in the mammographic images.

In the recent years, Image Enhancement is being evolving a lot in terms of medical images. Image Enhancement is generally a pre-processing step and refers to the digital manipulation of a digital image in terms of improved contrast or brightness. It helps in improving the viewer's perception to visualize a better version of the image. Image enhancement is domain dependent and has two categories-

1. Spatial Domain – In the Spatial Domain methods, the image is assumed to be in the form of pixels only and all the transformations are applied to the pixels directly.
2. Frequency Domain – In the Frequency Domain methods, it is required to convert given image in its frequency domain and for this, it involves in computing the Fourier transform of the image prior to any transformation to be applied on the image. After applying the necessary transform on the images, the inverse Fourier transform is applied to get the output enhanced image.

These transformations can be represented as follows:-

$$E=T(I)$$

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Where

1. E = Output Enhanced Image
2. T = Transformation function
3. I = Input Low Contrast Image

Luminosity control is the essential step to control the brightness of the images and it is calculated in terms of HSV image.

Paper is organized as follows. Section II contains the literature survey of the existing techniques of image enhancement. The proposed work is discussed in section III. Parameter evaluation and results are presented in Section IV and Section V respectively while Section VI concludes the paper work.

II. LITERATURE REVIEW

Lots of work has been done in past on the enhancement of the mammographic images. Makandar and Halalli [1] proposed a method of enhancing the mammogram image. They proposed it in a two-step procedure – first the image is denoised by using average, median, and wavelet filter and second contrast enhancement using histogram based technique as CLAHE. Pisano et al. [2] worked on Contrast Limited Adaptive Histogram Equalization of mammograms. So CLAHE had been used as a major source of enhancement in various methods proposed so far as in [2], [3] and [4]. Huang et al. [5] proposed a method to enhance the color images by converting the colour image into HSV format as “HUE(H), SATURATION(S), VALUE(V)” and enhancement technique is only apply on the V channel. After this, they applied Adaptive Gamma Correction (AGC) and Weighting Distribution (WD) function on V channel for contrast enhancement. Anand and Gayathri [6], in their paper on Adaptive Histogram equalization of mammographic images, proposed a two stage enhancement method as they applied Adaptive Histogram Equalization on the image two times with two different distribution i.e., here on Stage Adaptive Histogram Equalization (AHE) follow another different scale distribution of Adaptive Histogram Equalization. Kaur and Singh [7] proposed a method where they divided the image into histogram up to some recursive level and from that extracted two segmented results as Mean Sub-Histogram Segmentation and Median Sub-Histogram Segmentation then afterwards applied Weighted Function which calculates Weighted Probability. Finally, Gamma Correction with Weighted Distribution Function is applied to the previous result which gave the overall Enhanced Image. Moradmand et al. [8] worked on the micro-calcification in the breast images. So they used a combined approach of enhancement by combining CLAHE and Wavelet Transform. In this, first the noise cancellation was done using Adaptive Median Filter and then contrast enhancement was done by using CLAHE and Wavelet Transform as CLAHE is the improved version of Adaptive Histogram Equalization and the result was broken into five level discrete wavelet decomposition was employed as five sets of Horizontal, Vertical and Diagonal coefficient. In the final step, Inverse Wavelet Transform was employed on these five coefficients to get the enhanced final output image. Petrick et al. [9] worked on Density Weighted Contrast Enhancement (DWCE). DWCE filter was applied on the mammographic image because DCWE Filter uses an adaptive enhancement of local contrast. So, further edge detections and local refinement was done to easily detect the masses in the DWCE enhanced output image. Furthermore, Panetta et al. [10] introduced a non-linear enhancement scheme where basically enhancement was done by NLUM (as non-linear with Unsharp Masking scheme). NLUM involves various fusion #1 and fusion #2 (arithmetic addition and multiplication) techniques and also incorporates a non-linear filtering function the enhancement purpose of Mammography Images.

The proposed method overcomes the limits of contrast enhancement of the mammograms as none of the previous paper did not work luminosity of the mammographic images, as previous all method apply spatial domain operation directly on images [2],[3],[4],[5],[6] or some apply contrast filter directly on images[10] and some work on frequency domain but in our proposed method we first focus on brightness control of images by converting image into HSV format and after individually band is got enhancement differently by more focus on V band as it help to control the brightness of image then after all this luminosity control we apply our enhancement technique, in our enhancement part we apply DWT to detect the lower frequency band then apply the SVD on that band to get the enhance image to detect the calcification part of the muscle.

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III. RELATED WORK

This section proposes a method of enhancing the mammographic image using Luminosity control and then applying Gamma correction to it. After this, we break down the image in sub components and reconstruct the image after applying a correction adjustment factor to the image.

3.1 Luminosity Control Procedure – Luminosity is directly related to the brightness of the image or the intensity of pixels in that image. So luminosity can be adjusted by changing the scale of the greyscale or RGB image to HSV image where H stands for Hue, S for Saturation and V for Value. The value component is analysed and it is enhanced by using certain transformations.

The detailed steps for the luminosity control are given below:-

1. The original image I of size $M \times N$ is analyzed for the number of levels it contains. If the number of levels is 1, it is a greyscale image and the value component is directly calculated for uint8 image using the equation below:-

$$V(i,j) = I(i,j)/255$$

Where

- V = Value component of the image
- I = Input low Resolution image
- i = range of values from 1 to M
- j = range of values from 1 to N

If the number of levels of the image is found to be 3, then the image is broken up in the HSV image and then its value component V is taken into consideration.

2. The value component is processed through Adaptive Histogram Correction and Gamma Correction by using a threshold value T calculated on the basis of the image being analysed to obtain new value V' . This threshold value T is calculated by obtaining the bin containing the maximum points of similar intensity and all the values are scaled accordingly with respect to it in 3 regions :-
 - Less than 1 for all the intensities of pixels which have their values below the threshold value.
 - Equal to one for all the points in the image where the intensity of pixels is equal to the threshold value.
 - Greater than 1 for all the intensities of pixels which have their values above the threshold value.
3. The Hue and Saturation values are also enhanced using Adaptive Histogram Equalization to obtain H' and S' respectively.
4. The obtained values of H' , S' and V' are merged back to form an enhanced HSV image.
5. Convert the enhanced HSV image back to greyscale/RGB image to obtain the luminosity controlled image I' .

3.2 Discrete Wavelet Transform and Singular Value Decomposition Procedure – Discrete Wavelet Transform, popularly known as DWT, is used for partitioning the image in 4 sub bands i.e. Low Low (LL) Sub band, Low High (LH) Sub band, High Low (HL) Sub band and High High (HH) Sub band respectively. The technique of DWT can be traced back to the year 1976 when it was devised for the Signal Processing. DWT technique is used here for improving the pixel resolution of the image.

Singular Value Decomposition is a popular image enhancement technique. SVD works on the process of breaking down a square or rectangular matrix block A into 3 sub matrices (i) A left singular value matrix U , also called orthogonal matrix, (ii) A singular value matrix S where all the values are concentrated as diagonal elements and (iii) A right singular value matrix V , which is the transpose of the matrix U . The matrix A can be represented as the product of these three matrices as shown in the equation below:-

$$A = U * S * V^T$$

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The detailed steps for DWT SVD based enhancement are given below:-

1. The image extracted as output of the luminosity control phase becomes the input of this phase.
2. Separate out the different bands from the image I' i.e. if the image is a color image, its Red band, Green band and Blue band are separated out from each other.
3. For all the three color bands, do perform the steps 4-10 in parallel.
4. Apply the Adaptive Histogram Equalization on each of the sub bands and then apply a First level DWT transform to obtain equalized sub bands LL_{eq} , LH_{eq} , HL_{eq} and HH_{eq} separately for each color band.
5. Apply a First level DWT transform to partition the image in LL, LH, HL and HH sub bands separately for each color band.
6. Decompose the LL band further to obtain its 3 sub matrices U, S and V and similarly decompose the LL_{eq} band to obtain its 3 sub matrices U_{eq} , S_{eq} and V_{eq} by using SVD.
7. Calculate the multiplication correction adjustment coefficient Σ for each sub band by using the equation below:-

$$\Sigma = \max(S_{eq})/(\max(S))$$

8. Apply the correction on the diagonal matrix, S. This can be calculated using the equation below:-

$$S' = S * \Sigma$$

9. Calculate the enhanced LL sub band by combining the matrix U, the obtained diagonal matrix S' and the matrix V by using the equation below:-

$$LL'_{eq} = U * S' * V^T$$

10. Perform the Inverse DWT of the four sub bands LL'_{eq} , LH, HL, HH to get the output enhanced color band.
11. Concatenate all the three color bands R, G and B to obtain the contrast enhanced final image I'' as output.

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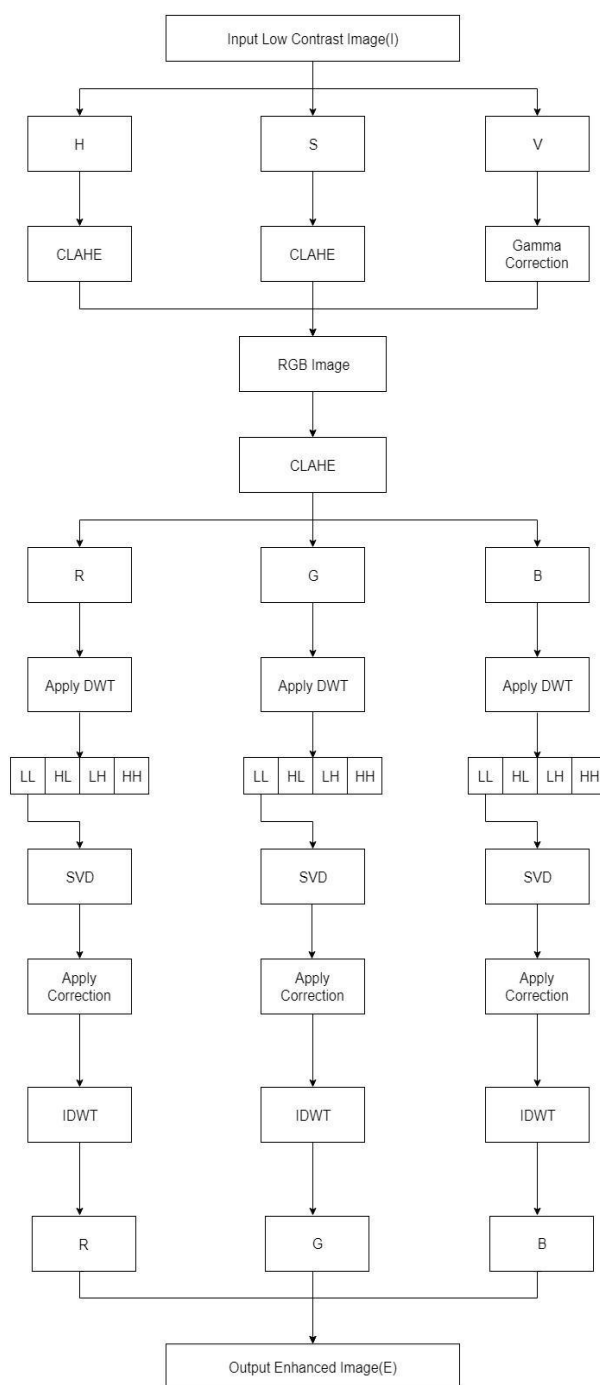


Fig 1. Flowchart of Algorithm

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IV. PARAMETER EVALUATION

We tested our model on mini-Mias Dataset[12] on MacBook Air with MacOS High Sierra, 8GB RAM, Intel Core i5 Processor. The code was written and executed in MATLAB. Quality metrics are used to measure the quality of improvement in the images after comparing it with the original image. We have used following quality metrics for comparison of our proposed method for other methods:-

1. PSNR - PSNR stands for Peak Signal to Noise ratio and it indicates the ratio of maximum pixel intensity to the power of distortion of the images.

$$\text{PSNR} = 10 \log_{10} R^2 / \text{MSE}$$

where - i) R represents the variation of pixels of the input image. It is 255 for uint8 images.

ii) MSE stands for Mean Squared Error and it is the sum of the difference of squares of all the pixels between the enhanced image and the original image.

2. SSIM – SSIM stands for Structural Similarity Index and its value lies between -1 to 1. Its basic objective is to find the degree of similarity between the images. It deals with various aspects as luminosity, contrast and structure of the pixel intensities.
3. PCC – PCC stands for Pearson Correlation Coefficient and its value lies between -1 to +1. It basically measure the strength of linear association between two images whereas values greater than zero gives positive association and less than zero indicate negative association.

V. EXPERIMENTAL RESULTS

Table 1 shows the comparisons of the state-of-the-art methods in comparison with the proposed method on the basis of PSNR ratio. The results help in distinguishing the proposed method to perform better than the other compared methods as it contains the enhanced image is expected to contain less noise as compared to all the other compared methods.

Images	Histogram Equalization	CLAHE	Contrast Stretching	Proposed Method
mdb001	24.0654	30.2024	24.0654	56.1291
mdb002	24.0659	29.7502	34.1514	47.857
mdb003	24.0666	31.1066	48.1308	49.5214
mdb100	24.0654	31.1815	24.0654	45.1548
mdb200	24.0655	30.6397	25.2082	49.8172
mdb320	24.0977	32.1188	48.1308	49.7749
mdb321	24.0654	31.8318	24.0654	52.6043
mdb322	24.0654	31.5633	24.609	53.2598

Table 1 – Table showing the Peak Signal to noise ratio (PSNR) comparisons between methods - (a) Histogram Equalization (b) CLAHE (c) Contrast Stretching (d) Proposed Method.

Table 2 shows the comparisons of the state-of-the-art methods in comparison with the proposed method on the basis of its SSIM index. Results help in showing that the proposed method is also efficient in the least distortion of the image structure as compared to the existing methods.

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Images	Histogram Equalization	CLAHE	Contrast Stretching	Proposed Method
mdb001	0.221	0.4832	0.3113	0.7213
mdb002	0.2958	0.5239	0.5731	0.6615
mdb003	0.287	0.5195	0.929	0.704
mdb100	0.2821	0.4894	0.366	0.7508
mdb200	0.3063	0.5463	0.4369	0.6925
mdb320	0.4798	0.662	0.9514	0.595
mdb321	0.318	0.5923	0.4524	0.6646
mdb322	0.3	0.5717	0.456	0.6747

Table 2 – Table showing the Structural Similarity Index (SSIM) comparisons between methods - (a) Histogram Equalization (b) CLAHE (c) Contrast Stretching (d) Proposed Method.

Table 3 is used to compare the existing and the proposed method on the basis of the degree of correlation help between the enhanced and the original image(PCC). The proposed method outperforms in PCC as it always has it value near about 1.

Images	Histogram Equalization	CLAHE	Contrast Stretching	Proposed Method
mdb001	0.9594	0.9657	0.9984	0.9987
mdb002	0.9735	0.9613	0.9956	0.9978
mdb003	0.9349	0.9817	0.9758	0.9898
mdb100	0.9854	0.9814	0.9965	0.9996
mdb200	0.9829	0.9688	0.9789	0.9894
mdb320	0.9781	0.9907	0.9973	0.9977
mdb321	0.9589	0.9739	0.9835	0.9998
mdb322	0.9456	0.9639	0.9788	0.9888

Table 3 – Table showing the Pearson Correlation Coefficient (PCC) comparisons between methods - (a) Histogram Equalization (b) CLAHE (c) Contrast Stretching (d) Proposed Method.

Table 4 shows a summary of all the methods and documents the state-of-the-art methods and the proposed method details on the basis of parameters like PCC, PSNR and SSIM. As it can be seen, the proposed method outperforms in every aspect above all the existing techniques, whether the chosen parameter is PSNR or SSIM or PCC.

S.No.	Technique	PSNR	SSIM	PCC
1	Histogram Equalization	24.0697	0.3113	0.9648
2	CLAHE	31.0493	0.5485	0.9734
3	Contrast Stretching	31.5533	0.5595	0.9881
4	Proposed Method	50.5148	0.6831	0.9952

Table 4 – Table showing the summary of all the state-of-the-art methods tested on 20 images.

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Figure 2 demonstrates the visual comparison of all the state-of-the-art methods and the proposed method along with their histogram to know the region of concentration of the intensities in the images. The proposed method condenses all the intensities towards the darker side without much affecting the brighter intensities in the images resulting in a cleaner and visually separable image.

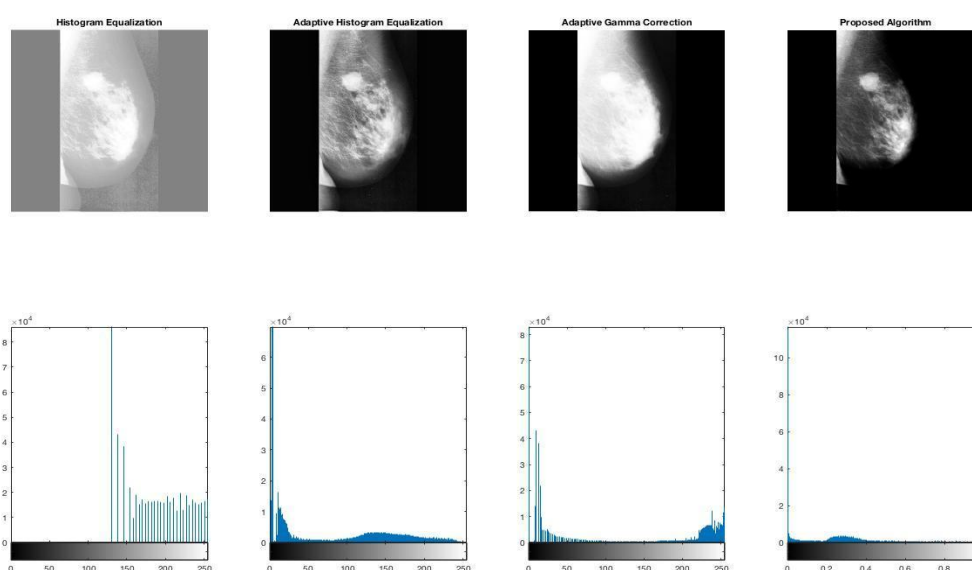


Fig 2. Output of Enhanced images and its histogram using (a) Histogram Equalization (b) Adaptive Histogram Equalization (c) Adaptive Gamma Correction (d) Proposed Algorithm

Figure 3 shows the results of implementing the proposed method on the Mini-MIAS dataset. The first image on the left depicts an original image from the dataset, the middle image being the one in which the luminosity of the image is being controlled as per the proposed method. To get the final output in the right most image results, a single level SVD-DWT scheme has also been applied on the luminosity controlled image of the mammogram. Since it is a 2 step procedure, the results of enhancement after both the steps are depicted in Figure 3. The results were evaluated on 20 mammograms from the dataset and the enhancement results can be accessed both visually as well as on the basis of parametric evaluation too.

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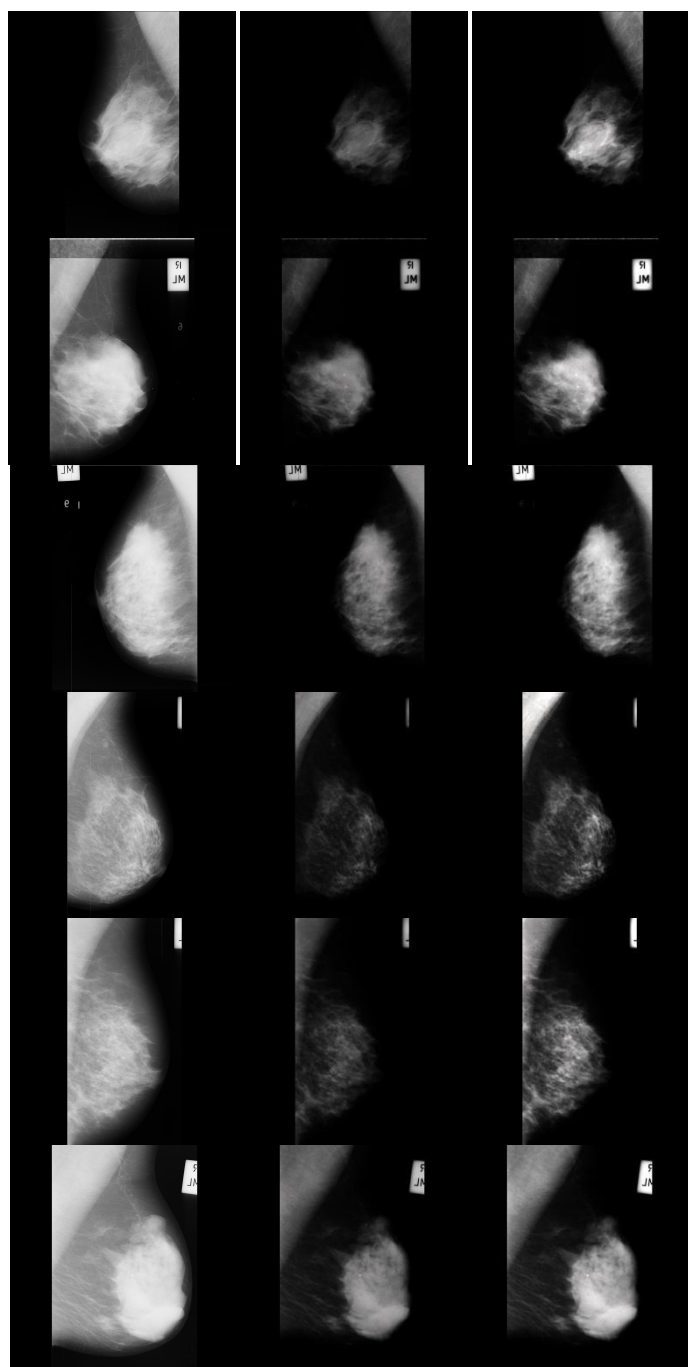


Fig 3. Results of enhancement by proposed method – (a) Original Mammographic Image (b) Luminosity Controlled image (c) Output Enhanced Image

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VI. CONCLUSION

The various algorithms and proposed method was tested on a number of images in the dataset. Out of the certain methods studied and compared, the proposed algorithm has a much greater PSNR values as compared to the other state-of-the-art methods. Similarly, the proposed method also helps in maintaining the physical structure of the enhanced images with a high degree of correlation. Hence, the proposed method has a high impact over the other compared techniques.

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