3 Medical Image Enhancement

3.1 Introduction
During the last three decades of the 20th century, medical imaging, which for nearly 70 years had almost exclusively depended on conventional film/screen X-ray imaging, has experienced major technological growth resulting in the development and commercialization of a plethora of new imaging technologies. X-ray Computed Tomography, Magnetic Resonance Imaging, Angiography, Ultrasound, and various imaging techniques based on nuclear emission (PET, SPECT, etc.) have all been valuable additions to the clinician’s arsenal. Quantitative information, like organ size and shape, can be extracted from these images in order to support activities such as disease diagnosis and monitoring and surgical planning. However, in order to accomplish this, it is first necessary to identify (usually in a segmentation process) the different tissues and anatomical structures being involved.

The University of Washington is currently in a strong position as a leader in medical image computing (Kim), medical image processing and analysis (Haralick, Haynor, Kim, Bassingthwaighte, Lewellen, Yuan), systems (Crum, Martin, Vaezy, Beach, Kim), therapeutic ultrasound (Crum, Martin and Vaezy), and applications (many researchers and clinicians). For example, with new, more powerful processors, we can now tackle the whole ultrasound signal and image processing (about 30 to 50 billion operations per second) in a low-cost programmable fashion. When this is successful, it will change the research and development paradigm of medical ultrasound machines, which will result in
smaller equipment and lower cost. This programmable medical image computing approach can be deployed in other medical imaging modalities, e.g., X-ray CT, MR, fluoroscopy, mammography etc. New image analysis algorithms and innovative clinical applications developed by researchers and clinicians can be easily tested and quickly deployed and commercialized. For example, this kind of high-performance programmable image computing can be easily integrated into therapeutic ultrasound machines to support its unique real-time imaging and computing needs. It can also be applied to future laptop or palmtop ultrasound devices that require more customization and little training for individuals in nursing homes and individual homes for distributed diagnosis and home healthcare[1].

Medical image is window to a human body. It is formed by the imaging modalities that use various forms of radiation and energy to open the body for visualization. As microscope is used to view small things, and the telescope to view things at a distance, medical imaging technology extends our vision into the normally invisible regions of the human body. The general objective of most imaging technique is to visualize the various anatomical structures and any signs of pathology if they are present.

Medical image processing system

Medical image processing system comprises of patient, the imaging system, the system operator, the image itself and the human observer. Generally, the visibility of specific anatomical feature depends on the characteristics of the imaging system and the way in which it is operated. Medical imaging system have a considerable number of variables that must be intellectually selected by the operator. For example intensifying screens in radiography, transducers in sonography or coils in magnetic resonance imaging(MRI). Some variables are adjustable physical quantities associated with imaging process such as kilovoltage in radiography, gain in sonography, and echo time in MRI[2]. The quality of the medical image depends on number of factors like contrast, blur, noise, artifacts, and distortion etc which is explored further.
3.2 Need of Medical Image Enhancement Technique

Medical images usually present undesired properties like low signal-to-noise (SNR) and contrast-to-noise ratios, as well as multiple and discontinuous edges etc.. To be more specific let us consider most burning issues of early detection of breast cancer with the help of imaging technique mammography.

3.2.1 Role of image enhancement technique in early detection of breast cancer

Mammography plays a central role in the process of detecting abnormalities in breast cancer screening. A mammogram is a x-ray projection of the 3D structures of the breast obtained by compressing the breast between two plates. Mammograms have an intrinsic scattered appearance due to the superimposition of densities from differing breast tissues, and the differential x-ray absorption characteristics associated with these various tissues. A high contrast is always required to differentiate very fine structures with slight differences in density, such as microcalcifications. A microcalcification is a tiny granule-like calcium deposit that has accumulated in the breast tissue, appearing as a small bright spot on a mammogram. There is a distinct correlation between the presence of microcalcifications and the incidence of breast cancer which indicates that precise detection of microcalcifications will improve the ability to detect malignant masses. Enhancement is the first stage in the process of microcalcification detection and classification[3].

1. Consequences of an inaccurate reading

Consequences of an inaccurate reading of mammography can lead to

A. False Positive interpretation: leading to unnecessary follow up, tests like biopsies performed on women with benign condition (good tissue).

B. False negative interpretation: causing delay in diagnosis and treatment converting early stage breast cancer to a advanced stage with severe deduction for survival rate and resource utilization[4].

Accuracy of mammogram interpretation can be improved with the help of computer aided diagnosis (CAD) where the computer functions as second reader which improves radiologist’s decision making regarding presence of cancer [3] showing significant improvement in lesion detection, reducing variability in the interpretation using CAD[4],[5]. However due to multifaceted nature of mammogram, the similarity
between masses and normal dense tissues and the great variation of masses in their clinical and computerized feature, the CAD methods usually generates a lot of false positives with the difficult cases missed by radiologists remain undetected, thus degrading computer aided diagnosis of screening mammography. The radiologist indicates the location and outlines the contour of the lesion on both exams (and provided the breast imaging reporting and data system descriptor.)

2. **Study of breast tissue density**

Risk of breast cancer development is determined by mammographic parenchymal pattern[8]. To be more specific, the relative amount of fibro-glandular and adjacent tissue appears to be a major marker of the breast cancer risk. It is being observed that there is strong correlation between breast density and cancer threat.

1. Applying segmentation on mammogram

   The segmentation were taken on both cancerous and normal mammograms at screening detected and missed stages respectively [9].

3. **Complexities of micro calcification enhancement**

Many factors contribute to difficulties in detecting microcalcifications.

1. Microcalcifications are small and exhibit a broad range of variability with respect to their morphology, size, and distribution pattern as shown in figure 3.1 [3].

2. Microcalcifications are often situated in a non-homogeneous background

3. Having low contrast with the background

4. Their intensity may be similar to noise or other structures like film artifacts, radiopaque markers.

5. If the background region is composed of fatty tissue the process of identifying microcalcifications is easier than if they are embedded in dense fibro-glandular tissue.

Enhancement of microcalcifications is a delicate process which involves improving contrast while preserving visual acuity. Too little enhancement may prevent the detection of minor microcalcification peaks where as too much enhancement may significantly increase the amplitude of background noise leading to a large number of false detections.
Figure 3.1 Microcalcification (left-to-right): (a) vascular. (b) round. (c) Popcorn. (d) rim. (e) rod. (f) spherical. (g) punctuate. (h) dystrophic.

**Image Enhancement** takes an important role here for the segmentation and analysis process. Although improving imaging techniques, e.g., contrast agents, biological markers improves the image quality which is not always enough to give a good result. However, there is a need for developing more effective image enhancement technique.

### 3.3 Objective of chapter

Objective of this chapter is

1. To review different medical imaging techniques and study factors that affect quality of original image like contrast, blur, noise etc.

2. To present a new image enhancement technique (for medical images) using heterogeneous approach which is based on the well-established standard image enhancement technique.

3. Evaluation of performance measures of image quality visually or statistically based on problem

Our work is intended for reducing shortcomings found in the process of early detection of breast cancer in screening mammogram by proposed image enhancement technique which is a fundamental and preprocessing step in computerized analysis and detection of cancers missed by radiologists. Ultrasound images and Bone scan images are also processed using the same technique.

Medical images are processed using standard image enhancement techniques that is by using monotonous approach and using a newly developed heterogeneous approach through this research work. A proposed a new approach of image enhancement techniques which improved image quality of the medical images for example.
mammogram image, ultrasound image etc. consist of a specific sequences of classical image enhancement techniques like point operators, spatial operator, transform technique along with morphological operator as a pre and / or post processing operator which can play an important role further in the segmentation and analysis process. Finally, some results are presented along with table, graphs in order to show the computational performance of couple of enhancement technique developed through this research work as compared to traditional approach.

Although improving imaging techniques improves the image quality but at the same time increasing the cost of imaging technique remarkably. Applying appropriate image enhancement technique reduces complexities in further computational task at comparatively low cost.

3.4. Review of medical imaging technology

1. Computed Tomography (CT):
Computed Tomography is X-ray based technique developed in 1970 is in a wide spread medical use. The basic idea is to take many X-rays of the same slice of a body, from different angle. It is then possible to reconstruct these X-rays to give a comprehensive image of the slice; which is a complex and computer based task. This procedure is then repeated on several slices, to produce a 3-D image.

2. Magnetic Resonance (MR):
MR uses strong magnetic fields to distinguish the different forms of tissue in particular their water content. The images that an MR scanner generates can give interior detail to a great extent.

3. Ultrasound:
Ultrasound is a noninvasive, harmless widely used sound based technique. It measures the difference in echo properties of different organs, and can thus generates images simply by projecting sound into the body, and measuring how and what bounces back. Ultrasound (US) is the second most widely used diagnostic imaging modality (next to X-ray). Both as the primary modality and as an adjunct to other diagnostic procedures, it has a wide array of clinical applications, including fetus imaging, cardiac imaging, vessels imaging, prostate imaging, breast imaging, and image-guided surgery, etc.[10].

4. Mammography:
At present, mammography is the only proven method that can detect minimal breast cancers. However, despite advances in mammography, human interpretation still remains very difficult. 10-30% of the breast cancers that are visible on mammograms in retrospective studies are not detected due to various technical or human factors and about 40% of the missed tumors appear as masses[11].

The mammograms for a patient are digitized by a high-resolution film scanner. The digitized mammograms are then processed by automated detection programs to identify the regions containing suspicious microcalcifications or masses. In each region of interest (ROI), the identified lesion is analyzed by the appropriate classifier to estimate its likelihood of malignancy. The digitized mammograms will be displayed on the CAD workstation. The locations of the detected lesions and their likelihood of malignancy is superimposed on the displayed mammograms. A digitized mammogram is processed with a different-imaging technique that enhances the microcalcifications and suppresses the structured background and random noise. A locally adaptive gray level thresholding technique is used to segment the potential signals.

3.5. Characteristics of medical image

The internal structure and functions of the human body are not generally visible to the human eyes. However by various imaging technology, images can be created through which the medical professional can look into the body to diagnose abnormal conditions and guide therapeutic procedures. Different medical imaging methods reveal different characteristics of human body. With each method image quality and structure visibility can be considerable, depending on characteristics of the imaging equipment, skill of operator, and compromises with factors such as patient radiation exposure and imaging time.

1. Image contrast

Generally, visibility of an object is determined with respect to its immediate background. An imaging system translates a specific tissue characteristic into image shades of gray or color which can be referenced as contrast. Contrast is the fundamental feature of an image. An object within the body will be visible in an image only if it has sufficient physical contrast relative to surrounding tissue, that is, it must represent a difference in
one or more tissue characteristics. For example, in radiography an object can be imaged if there is adequate difference in either density or thickness of tissue.

The fundamental characteristics of an imaging system that establishes relationship between image contrast and object contrast is its contrast sensitivity. When the imaging system has a relatively low contrast sensitivity, only object with a high object contrast is visible in the image. If the imaging system has a high contrast sensitivity, the lower contrast object will also be visible[2].

2. Bluring

Structures and objects in the body vary not only in physical contrast but also in size. Objects range from large organs and bones to small structural features such as trabecula patterns and small calcifications. It is the small anatomical features that add detail to a medical image. Each imaging method has a limit as to the smallest object that can be imaged and thus on visibility of detail. Visibility of detail is limited because all imaging methods introduce blurring into the process. The primary effect of image blur is to reduce the contrast and visibility of small objects or detail.

The original image and its blurred version, obtained through a low pass filter, are combined so that the high frequency components of the image are amplified and as a result the perception of the image around edge areas improves. All high frequency components of the image are amplified and the noise in the image will also be inadvertently amplified [11].

3. Artifacts and distortion

Most of the imaging methods can create image features that do not represent a body structure or object. These are image artifacts. In many situations an artifact does not significantly affect object visibility and diagnostic accuracy. But artifacts can obscure a part of an image or may be interpreted as an anatomical feature. A medical image should give an accurate impression of body objects in terms of their size, shape, and relative positions, however, it may introduce distortion of these factors.

4. Image noise

It is generally desirable that image brightness is to be uniform except where it changes to form an image. There is a variation in the brightness of a displayed image even when no image detail is present. This variation is usually random and has no particular pattern
reducing image quality specifically when the images are small and have relatively low contrast. This random variation in image brightness is nothing but a noise. All medical images contain some visual noise. The presence of noise gives an image a grainy, textured, or snowy appearance. No imaging method is free of noise, but noise is much more prevalent in certain types of imaging procedures than in others [2].

5. Shot noise (black and/or white spots) removal
Dropout pixels (common in some types of microscopy such as interference microscopes, or from dust on a scanned negative, and also produced by dead or locked transistors in digital cameras) are typically filled in with a median filter. It can also be used to remove scratches, cracks, etc. narrow than the radius of the neighborhood[12].

3.6 Enhancement using morphological approach
The low pass filter used in image enhancement is mainly intended to generate a blurred image. Weighted difference of the blurred image and the original image results in an amplification of high frequency components and overall enhancement of the image[11]. Mathematical morphology is a technique used for extracting image component that are useful in the representation and description of region shape, such as boundaries, skeletons etc [13]. The erosion operation is useful for removing small objects, having a disadvantage that it shrinks object size. This drawback can be overcome by dilating the image after erosion with same structuring elements. This combination operation is called an opening operation [14]. The principle of morphological contrast enhancement was introduced by Soille [3],[15]. Morphological contrast enhancement is based on the notion of morphological top-hats which were first proposed by Meyer [3],[16]. A top-hat is a residual filter which preserves those features in an image that can fit inside the structuring element (SE) and removes those that cannot.

Step by step representation of image enhancement technique using morphological approach is given in section 3.7.4, 3.7.5, 3.7.6, 3.7.7,3.7.9 along with other developed enhancement technique. Details about this image enhancement technique using morphological approach is given in annexure B

A. Structuring Elements
A structuring element is a small set used to probe an image. Morphological analysis has
traditionally been performed using flat structuring elements, which have two dimensions in the case of two-dimensional images. Conversely non-flat structuring elements are 3D structuring elements, used to probe the intensity “shape” of features in the image, in addition to simply shape. Sternberg [17] introduced the concept of such non-flat SE, however there is very little application of such SE in the literature. Di Ruberto et al. [18] use a hemisphere shaped SE to enhance the roundness and compactness of red blood cells in images of stained blood slides. A non-flat SE has more of a 3D appearance. It has 0’s and 1’s to define extent of structuring element in x-and y-plane and add height values to define third dimension.

3.7 Various image enhancement technique developed throughout research work

Various image enhancement technique developed throughout research work are listed below and are applied on Medical images and Biometric Image. Mammogram image mm4.jpg is from book “Digital image processing using Matlab” by R.C.Gonzalez, Wood,Eddins available on internet site (http://www.digitalimageprocessingplace.com) Mammogram image mm3.jpg is from mammography system GE SENOGRAPHY where operator has to select only film density. Here CNT mode is used for soft,fatty breast ,STD is standard mode used for average (50% fatty,50% glandular). Ultrasound images are from Logic 400 Pro series color doppler with frequency 4 MHz to 11 MHz. Results of biometric technique are explored in chapter 4

3.7.1. ET1[19].

1. Input Medical/Biometric original image and display
2. Filter input image with Laplacian mask [-1 -1 -1;-1 8 -1;-1 -1 -1]
3. Image filtered with Laplacian mask is added to original input image showing sharpness significantly.
4. Object edges are detected with Sobel mask
5. Image obtained in step 4 is smoothed by averaging filter.
6. Multiplying step3 with step 5 forming mask image.
7. An input image is again made sharp by adding to it step 6
8. Final result is obtained by processing result is step 7 by intensity transformation function .
9. Display enhanced image/result.

3.7.2. ET2[23].

1. Input Medical/Biometric original image and display.
2. Intensity values are rescaled between 0.0 and 1.0
3. Apply threshold value >=0.4 to rescaled image
4. Thresholded image is smoothed with Gaussian filter of size 3×3 and σ=0.5
5. Laplacian mask [0 1 0;1 -8 1;0 1 0] is applied on image generated in step 4.
6. Subtracting Laplacian filtered image from Gaussian filtered image isolates objects
7. Apply special filter ‘log’ of size 5×5, σ=0.5
8. Image obtained in step 7 is subtracted from thresholded image in step 3.
9. Display enhanced image/result.

3.7.3. ET3[23].
1. Input Medical/Biometric original image and display.
2. Intensity values are rescaled between 0.0 and 1.0
3. Apply threshold value >=0.4 to rescaled image
4. Applying edge detection operator ‘log’ with threshold T=0.02, σ=2
5. Applying edge detection operator ‘zerocross’ with h=fspeial(‘log’,[5 5],0.5) to the image generated in step 4, showing isolated object
6. Image generated in step 4 is smoothed with Gaussian filter showing double edges

3.7.4. ET4: Morphological approach using Flat Structuring Element [3], [19].
1. Input Medical/Biometric original image and display.
2. Morphological opening operation is performed using flat structuring element ‘disk’ with radius R, processing speed factor N=4 suppress bright detail smaller than structuring element
3. Opened image is subtracted from original input image, thus performing tophat transformation.
4. Morphological closing operation is performed on input image which suppress dark detail smaller than structuring element.
5. Input/original image is subtracted from closed image, thus performing bottom hat transformation.
6. Tophat by opening by opening produce an image that contain all residual features removed from opening. Adding these residual result features to the original image has effect of accentuating high intensity value structure. The dual residual obtained by using the tophat by closing, is then subtracted from the resulting image to accentuate
low intensity (dark structure)

7. Display enhanced image/result.

3.7.5. ET5: Morphological approach using Non Flat Structuring Element ‘ball’ [3], [19].
1. Input Medical/Biometric image.
2. Morphological opening operation is performed using non flat structuring element ‘ball’ with parameter radius R, height H which suppress bright detail smaller than structuring element.
3. Opened image is subtracted from original/input image, thus performing tophat transformation.
4. Morphological closing operation is performed on input image which suppress dark detail smaller than structuring element.
5. Input/original image is subtracted from closed image, thus performing bottom hat transformation.
6. Tophat by opening by opening produce an image that contain all residual features removed from opening. Adding these residual result features to the original image has effect of accentuating high intensity value structure. The dual residual obtained by using the tophat by closing, is then subtracted from the resulting image to accentuate low intensity (dark structure).
7. Display enhanced image/result.

3.7.6. ET6: Morphological approach using Non Flat Structuring Element ‘Arbitrary’ [3], [19].
1. Input Medical/Biometric original image and display.
2. Morphological opening operation is performed using non flat structuring element ‘Arbitrary’ represented for example as se = strel([0 1 1;1 0 0;1 0 1],[1 1 0;1 1 1;1 0 1]); with parameter radius R, height H which suppress bright detail smaller than structuring element.
3. Opened image is subtracted from original/input image, thus performing tophat transformation.
4. Morphological closing operation is performed on input image which suppress dark detail smaller than structuring element.
5. Input/original image is subtracted from closed image, thus performing bottom hat transformation.
transformation.

6. Tophat by opening by opening produce an image that contain all residual features removed from opening. Adding these residual result features to the original image has effect of accentuating high intensity value structure. The dual residual obtained by using the tophat by closing, is then subtracted from the resulting image to accentuate low intensity (dark structure)

7. Display enhanced image/result.

3.7.7 ET7 [24].

1. Input Medical/Biometric original image and display.
2. Apply contrast enhancement technique
3. Apply linear spatial filter; ‘Gaussian’ filter with size [3 3] and \( \sigma = 0.5 \) to the image generated in step 2.
4. Apply tophat transform to filtered image which enhance details in the presence of ridge structure in case of fingerprint image
5. Finally enhanced image is obtained.
6. Display enhanced image/result.

3.7.8. ET8[25].

1. Input Medical/Biometric original image and display.
2. Map input image using intensity mapping.
3. Fast Fourier Transform (FFT) of intensity mapping image
4. Multiply (convolve) transformed with highpass filter transfer function
5. Inverse of FFT (IFFT)
6. Convolve inverse FFT image with quick mask edge detector
7. Average filtering using convolution for smoothing the ridges in case of fingerprint
8. Finally enhance image is obtained.
9. Display enhanced image/result.

3.7.9. ET9: Algorithm for enhancing mammogram image using heterogeneous approach[ 26]

1. Input Medical/Biometric original image and display.
2. Extract the background of an image having distributed intensities using morphological operation opening and display
3. Display background of an image with suitable structuring element
4. Subtracting background image from original image and display
5. Apply contrast enhancement technique using function imadjust and display
6. Generate binary image by thresholding the adjusted image and display.
7. Calculate mean, standard deviation, entropy and signal to noise ratio

3.7.10 ET10: Adaptive contrast limited enhancement technique [19]

1. Input Medical/Biometric original image and display.
3. Display enhanced image/result.

3.8. Experimental result

Results of applying various image enhancement technique on various medical images is shown with the help of tables, graph as follows

3.8.1 Medical Image Database

Medical Image Database used throughout Experimental Work [19],[20],[21] is shown in table 3.1

Table 3.1: Medical Image Database used throughout Experimental Work
<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Application of image enhancement</th>
<th>Original image OI</th>
<th>Image Source</th>
<th>Statistical measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>MEAN (MO)</td>
</tr>
<tr>
<td>1</td>
<td>Mamography</td>
<td>DSCI0038.jpg (cropedgraymamo.jpg)/mm3.jpg</td>
<td>Mangal Medi Center (Open MRI, Mammography, USG, 2-D Echo, X-Ray), Aurangabad</td>
<td>99.021</td>
</tr>
<tr>
<td>2</td>
<td>Mamography</td>
<td>Fig3.04(a).jpg/mm4.jpg</td>
<td><a href="http://www.digitalimageprocessingplace.com">http://www.digitalimageprocessingplace.com</a></td>
<td>66.718</td>
</tr>
<tr>
<td>3</td>
<td>X-ray image</td>
<td>Fig9.18(a).jpg/mm5.jpg</td>
<td><a href="http://www.digitalimageprocessingplace.com">http://www.digitalimageprocessingplace.com</a></td>
<td>92.561</td>
</tr>
<tr>
<td>4</td>
<td>WBN Saunders</td>
<td>Fig3.46(a).jpg/mm6.jpg</td>
<td><a href="http://www.digitalimageprocessingplace.com">http://www.digitalimageprocessingplace.com</a></td>
<td>17.244</td>
</tr>
<tr>
<td>5</td>
<td>Ultrasound image</td>
<td>Appendix_1.jpg/mm7.jpg</td>
<td>Dept. of Radiology and Imaging, MGM Hospital, Aurangabad</td>
<td>75.945</td>
</tr>
<tr>
<td>6</td>
<td>Ultrasound image</td>
<td>Appendix-3-B.jpg/mm8.jpg</td>
<td>Dept. of Radiology and Imaging, MGM Hospital, Aurangabad</td>
<td>77.379</td>
</tr>
<tr>
<td>7</td>
<td>Ultrasound image</td>
<td>Mass with collection-2.jpg/ SN2.jpg</td>
<td>Dept. of Radiology and Imaging, MGM Hospital, Aurangabad</td>
<td>69.98</td>
</tr>
</tbody>
</table>
3.8.2. Evaluating performance measures of different enhancement technique in tabular format for mammogram image mm4.jpg

Evaluating performance measures of different enhancement technique on Image: mm4.jpg is shown below and its details are in annexure A.

SNRO is signal to noise ratio of original image and SNRE is signal to noise ratio of enhanced image[22] used throughout performance evaluation process.

Table 3.2 Evaluating performance measures of different enhancement technique on Image: mm4.jpg

<table>
<thead>
<tr>
<th>Enhancement Technique</th>
<th>Measures of Enhanced image</th>
<th>ME</th>
<th>SDE</th>
<th>EE</th>
<th>SNRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET1</td>
<td></td>
<td>50.005</td>
<td>64.532</td>
<td>5.0963</td>
<td>2.2526e-0</td>
</tr>
<tr>
<td>ET2</td>
<td></td>
<td>211.56</td>
<td>95.27</td>
<td>0.85736</td>
<td>0</td>
</tr>
<tr>
<td>ET3</td>
<td></td>
<td>0.016459</td>
<td>0.12723</td>
<td>0.12107</td>
<td>0</td>
</tr>
<tr>
<td>ET4</td>
<td></td>
<td>66.718</td>
<td>50.368</td>
<td>5.7947</td>
<td>0.058823</td>
</tr>
<tr>
<td>ET5</td>
<td></td>
<td>65.48</td>
<td>50.052</td>
<td>5.8534</td>
<td>0.059987</td>
</tr>
<tr>
<td>ET6</td>
<td></td>
<td>66.855</td>
<td>47.067</td>
<td>5.5471</td>
<td>7.4839e-005</td>
</tr>
<tr>
<td>ET7</td>
<td></td>
<td>2.4471</td>
<td>4.9186</td>
<td>2.7333</td>
<td>0.00065</td>
</tr>
<tr>
<td>ET8</td>
<td></td>
<td>11.368</td>
<td>60.545</td>
<td>3.287</td>
<td>-0.65434</td>
</tr>
<tr>
<td>ET9</td>
<td></td>
<td>38.801</td>
<td>51.545</td>
<td>4.0569</td>
<td>0.0056308</td>
</tr>
<tr>
<td>ET10</td>
<td></td>
<td>79.104</td>
<td>53.255</td>
<td>6.6987</td>
<td>0.033733</td>
</tr>
</tbody>
</table>

3.8.3 Code and result of enhancement technique ET1 for image mm4.jpg

clear all, close all;

%I = imread('c:\matlab7\work\Fig3.04.JPG');
I = imread('mm4.jpg');
I = rgb2gray(I);
mo1 = mean2(I);
so1 = std2(I);
% I = imread('c:\matlab7\Appendix\Appendix-1.jpg');
% I = imread('c:\matlab7\work\Fig3.46(a).jpg');
% w4 = fspecial('laplacian', 0);
% w8 = [1 1 1; 1 -8 1; 1 1 1];
w8 = [-1 -1 -1; -1 8 -1; -1 -1 -1];
I = im2double(I);
% g4 = I - imfilter(I, w4, 'replicate');
g8 = I - imfilter(I, w8, 'replicate');
imshow(I), title('Original image a')
figure, imshow(g4)
figure, imshow(g8), title('laplacian b');
c = imadd(I, g8);
figure, imshow(c), title('sharp using a + b = c');
h = fspecial('sobel');
gs4 = imfilter(I, h, 'replicate');
figure, imshow(gs4), title('sobel of a');
I1 = imread('sobex7.jpg);
I1 = im2double(I1);
h1 = fspecial('average', [3, 3]);
ga4 = imfilter(I1, h1, 'replicate');
figure, imshow(ga4), title('sobel image smoothed with average mask 5*5 e');
f = immultiply(c, ga4);
figure, imshow(f), title('product c, e f');
g = imadd(I, f);
figure, imshow(g), title('sum a, g');
I2 = imread('summamo1.jpg');
% I2 = im2double(I2);
I2 = rgb2gray(I2);
J = imadjust(I2, stretchlim(I2), [0 1]);
% J = imadjust(I2, [ ] [ ]); 
figure, imshow(I2), title('enma');
figure, imshow(J), title('adjusted');
% h2 = fspecial('unsharp');
% I2 = imfilter(I, h2);
% imshow(I), title('Original Image')
% figure, imshow(I2), title('Filtered Image')
c = im2uint8(c);
g = im2uint8(g);
J = im2uint8(J);
mo = mean2(I);
mc = mean2(c);
mg = mean2(g);
mj = mean2(J);
% me = mean2(gs4);
% me = mean2(gs4);
so = std2(I);
sc = std2(c);
sg = std2(g);
Sj = std2(J);
e0 = entropy(I);
ec = entropy(c);
eg = entropy(g);
ej = entropy(J);
qo = qualityindex(I);
qc = qualityindex(c);
qg = qualityindex(g);
qj = qualityindex(J);
Results of enhancement technique ET1 applied to image mm4.jpg

(a) Original Mammogram Image. (b) Laplacian Filtered Image of (a). (c) Original Image sharpened by adding (a) with (b). (d) Gradient of Image (Sobel operator) (a). (e) Smoothing Image in (d) with averaging mask. (f) Multiplying (e) with (a). (g) Adding (f) to (a) producing more sharpness. (h) Intensity adjusted image of (g)

3.8.4 Code and result of enhancement technique ET3

%ET3mm4.m
clear all, close all;
I = imread('mm4.jpg');
I = rgb2gray(I);

% I = imread('ap1.jpg');
imshow(I);
mo = mean2(I);
so = std2(I);
eo = entropy(I);
qo = qualityindex(I);
J = imadjust(I, stretchlim(I), [0 1]);
figure, imshow(J), title('intensity adjusted image');
me = mean2(J);
se = std2(J);
ee = entropy(J);
qe = qualityindex(J);
I1 = imread('3adjofmm4.jpg');
level = graythresh(I1);
bw = im2bw(I1, 0.4);
figure, imshow(bw), title('thresholded image, level=0.4');
bw = im2uint8(bw);
mt = mean2(bw);
st = std2(bw);
% g = edge(I,'log', 0.02, 2);
BW2 = edge(bw, 'log', [], 2);
figure, imshow(BW2), title('edge detected with log');
BW2 = im2uint8(BW2);
md = mean2(BW2);
sd = std2(BW2);
% g = imfill(BW2, 'holes');
% figure, imshow(g), title('fil');
% h = fspecial('log', [5 5], 0.5);
%h = fspecial('sobel')
h = fspecial('laplacian',.2)
BW3 = edge(bw,'zerocross',[],h);
figure,imshow(BW3),title('zeross');
% BW3=im2uint8(BW3);
% mz=mean2(BW3);
% sz=std2(BW3);
% w=fspecial('gaussian',5,2)
% g3=imfilter(BW3,w,'replicate');
% g4=imfilter(bw,w,'replicate');
% figure,imshow(g3),title('gaussian filter image');
% g3=im2uint8(g3);
% % I2=imread('apg1.jpg');
% I2=imread('3gaofmm3.jpg');
% J1 = imadjust(I2,stretchlim(I2),[0 1]);
% figure,imshow(J1),title('intensity adjusted image');
% mg=mean2(g3);
% ww=[0 1 0;1 -8 1;0 1 0];
% g4=imfilter(BW3,ww,'replicate');
% g4=imfilter(bw,ww,'replicate');
% g4=im2uint8(g4);
% figure,imshow(g4,[],title('lap of g'));
% ml=mean2(g4);
% sl=std2(g4);
% ql=qualityindex(I);
et=entropy(bw);
qt=qualityindex(bw);
ed=entropy(BW2);
qd=qualityindex(BW2);
mz=mean2(BW3);
sz=std2(BW3);
ez=entropy(BW3);
qz=qualityindex(BW3);
eg=entropy(g3);
% ed=entropy(BW2);
% f1=im2double(f1);
% BW = edge(I,'log',thresh,sigma)
% figure,imshow(BW);

Results of enhancement technique ET3 applied to image mm4.jpg

Figure 3.3 Results of applying ET3 technique on image mm4.jpg (a) Original Mammogram Image. (b) Intensity adjusted image (a). (c) Thresholded image with level =0.4. (d) Edge detected with “log” edge detector. (e) Edge detected with “zero cross” edge detector.

3.8.5 Results of enhancement technique ET1 to ET10 applied to image mm4.jpg with respect to original image
Figure 3.4 Results of applying enhancement technique ET1 to ET10 on mammogram image mm4.jpg
3.8.6 Graphical representation of evaluating performance measures of different Enhancement Technique for image mm4.jpg

![Graphical representation of evaluating performance measures of different Enhancement Technique](image_mm4.jpg)

Figure 3.5 Evaluating performance measures of different Enhancement Technique on image mm4.jpg
Figure 3.6 Evaluating performance measures of standard deviation of different Enhancement Technique of image mm4.jpg

Figure 3.7 Evaluating performance measures of entropy of different Enhancement Technique of image mm4.jpg
Figure 3.8 Evaluating performance measures of signal to noise ratio of different Enhancement Technique of image mm3.jpg
3.8.7 Evaluating performance measures of different enhancement technique on ultrasound image: Image: mm7.jpg

Table 3.3: Evaluating performance measures of different enhancement technique on ultrasound image: mm7.jpg

<table>
<thead>
<tr>
<th>Enhancement Technique</th>
<th>ME</th>
<th>SDE</th>
<th>EE</th>
<th>SNRE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ET1</td>
<td>123.12</td>
<td>64.729</td>
<td>7.8154</td>
<td>0.016469</td>
</tr>
<tr>
<td>ET2</td>
<td>237.69</td>
<td>46.082</td>
<td>2.2206</td>
<td>0.50008</td>
</tr>
<tr>
<td>ET3</td>
<td>0.10913</td>
<td>0.3118</td>
<td>0.49729</td>
<td>0</td>
</tr>
<tr>
<td>ET4</td>
<td>106.44</td>
<td>37.901</td>
<td>6.7373</td>
<td>0.01099</td>
</tr>
<tr>
<td>ET5</td>
<td>73.425</td>
<td>56.044</td>
<td>7.2874</td>
<td>0</td>
</tr>
<tr>
<td>ET6</td>
<td>40.353</td>
<td>76.12</td>
<td>7.1732</td>
<td>0</td>
</tr>
<tr>
<td>ET7</td>
<td>11.035</td>
<td>29.28</td>
<td>4.5239</td>
<td>0.030954</td>
</tr>
<tr>
<td>ET8</td>
<td>28.548</td>
<td>149.97</td>
<td>4.382</td>
<td>-0.00275</td>
</tr>
<tr>
<td>ET9</td>
<td>38.089</td>
<td>35.254</td>
<td>6.0646</td>
<td>0</td>
</tr>
<tr>
<td>ET10</td>
<td>110.31</td>
<td>56.532</td>
<td>7.7544</td>
<td>0.071205</td>
</tr>
</tbody>
</table>
Figure 3.9 Results of applying enhancement technique ET1 to ET10 on Ultrasound image of appendix mm7.jpg
Figure 3.10 Evaluating performance measures of different Enhancement Technique on image mm7.jpg
3.9. Analysis of experimental result

Existing standard image enhancement technique along with various enhancement techniques developed through out research work as depicted in detail in section 3.7 are applied on medical image database as shown table 3.1. First, enhancement technique are applied on mammogram images, then to ultrasound images. Further, they are applied to finger print image whose experimental details are given section 4.3 of chapter 4. Results of applying each technique with some statistical measures and other like signal to noise ratio for mammogram image mm4.jpg is shown in table 3.2. Result can be visualized in figure 3.4 and analyzed with human perception system as well as some statistical measure like standard deviation (SD) which is a measure of...
contrast improvement, entropy(E) which is measure of texture improvement[13] and other measures like quality index represented as SNR which is capable of measuring contrast, luminance distortion, structural distortion[22] is also used.

Mammogram image mm4.jpg shows highest contrast value (SDE in table 3.2) and clear cyst and some microcalcification for enhancement technique ET2 as compared to original image and existing standard contrast enhancement technique ET10. ET2 is an object isolation method.

Structural detail are found improved with enhancement technique ET4, ET5.

Improvement in texture of image is with enhancement technique ET4, ET5, ET6, with ET5 being highest with respect to original image.

Observation based on *human perceptual system* shows better result for ET1 technique which consist of sharpening, smoothing operation along with arithmetic operator. It shows cyst along with infected mass and few microcalcification appearing as tiny dots, as compared to original image as well as image obtained by applying ET10 technique. This is helpful to the doctor for early detection of breast cancer.

ET3 is zero crossing edge detector using \( h = \text{fspecial('log', [5 5], 0.5)} \) to the image generated by applying Laplacian of Gaussian edge detector, showing clear objects like cyst, microcalcification, area of infected mass.

Enhancement technique ET6 uses non linear image enhancement approach that is a morphological approach using non flat structuring element ‘arbitrary’. Selecting Enhancement technique ET6

Enhancement technique ET7 is applies tophat transform to Gaussian filtered image thus showing some what smooth image detail like cyst (may be cancer cyst /maligent tissue), vein pattern etc.

ET8 gives improvement in contrast (SDE).

Enhancement technique ET4, ET5, ET6 uses non linear image enhancement approach that is a morphological approach. Selecting appropriate structuring element with appropriate argument is a crucial job. Appendix B shows detail of these techniques on a mammogram image.

Enhancement technique ET9(1) is contrast enhancement of tophat transformed image where as ET9(2) gives binary image by thresholding the intensity adjusted image generated with ET9(1) technique. Visual quality is better for ET9(1) technique. It shows detail which are uncovered in original image and clarity in infected masses, microcalcification and a malign dense tissues in the form of cyst as compared to standard contrast enhancement technique.

Same technique as discussed above are applied on another mammogram image mm3.jpg, details about this are given in annexure A. Then image enhancement techniques are applied on ultrasound appendix mm7.jpg images, which are explored in section 3.8.7, with results shown in figure 3.9 to 3.11.

Contrast was found improved with ET1, ET6, ET8 as compared to ET10 and enhancement technique ET2, ET4, ET5, ET6 shows better contrast as compared to original image.

Structural detail showed improvement with ET2 technique statistically but at the cost of losing image detail as per human perception system.

Enhancement technique ET1 has shown improvement in texture of an image as compared to ET10 and original image.
Same enhancement techniques are also applied on another mammogram image mm3.jpg, X-ray image mm5.jpg and whole body scan image mm6.jpg whose performance evaluation is shown statistically and with graph in detail in annexure A, showing highest contrast with ET2 technique, thus solving commonly faced problem by medical image that is low contrast.

Detail about morphological approach based technique ET4, ET5, ET6, choosing appropriate flat and nonflat structuring element is given in annexure B.
Reference

3. Michael Wirth, Matteo Fraschini, Jennifer Lyon, “Contrast enhancement of microcalcifications in mammograms using morphological enhancement and non-flat structuring elements”, Proceedings of the 17th IEEE Symposium on Computer-Based Medical Systems (CBMS’04) University of Guelph, Guelph Canada, Dipartimento di Scienze Mediche - Università di Cagliari, Italy, mwirth@uoguelph.ca
10. Yifeng Jiang Zhijun Zhang Feng Cen Hung Tat Tsui Tze Kin Lau,"An Enhanced


19.“Digital image processing using Matlab” by R.C.Gonzalez, Wood,Eddins available on internet site

20.Mangal Medi Center (Open MRI, Mammography, USG, 2-D Echo,X- Ray), Aurangabad

21. Dept.of Radiology and Imaging, MGM Hospital , Aurangabad


