CHAPTER 2

LITERATURE REVIEW

2.1 CANCER STATISTICS

One in eight women will develop breast cancer during her lifetime as per the statistical data available [21,22]. Table 2.1 shows the estimated cancer cases in the year 2010. The table reveals very clearly that breast cancer is a very significantly occurring disease in women.

<table>
<thead>
<tr>
<th>Table 2.1 ESTIMATED CANCER CASES – YEAR 2007</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Men - 710,040 Samples</strong></td>
</tr>
<tr>
<td>Prostate</td>
</tr>
<tr>
<td>Lung and bronchus</td>
</tr>
<tr>
<td>Colon and rectum</td>
</tr>
<tr>
<td>Urinary bladder</td>
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<tr>
<td>Melanoma of skin</td>
</tr>
<tr>
<td>Non-Hodgkin lymphoma</td>
</tr>
<tr>
<td>Kidney</td>
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<tr>
<td>Leukemia</td>
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<tr>
<td>Oral Cavity</td>
</tr>
<tr>
<td>Pancreas</td>
</tr>
<tr>
<td>All Other Sites</td>
</tr>
<tr>
<td><strong>Women - 662,870 Samples</strong></td>
</tr>
<tr>
<td>Breast</td>
</tr>
<tr>
<td>Lung and bronchus</td>
</tr>
<tr>
<td>Colon and rectum</td>
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<tr>
<td>Uterine corpus</td>
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<tr>
<td>Non-Hodgkin lymphoma</td>
</tr>
<tr>
<td>Melanoma of skin</td>
</tr>
<tr>
<td>Ovary</td>
</tr>
<tr>
<td>Thyroid</td>
</tr>
<tr>
<td>Urinary bladder</td>
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<tr>
<td>Pancreas</td>
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<tr>
<td>All Other Sites</td>
</tr>
</tbody>
</table>

Prostate cancer is, by far, the most common fatal cancer in men (33%), followed by Lung and bronchus (13%), and Colon and rectum (10%). In case of cancers in women, breast (32%), lung (12%), and colon & rectum (11%) are the leading sites of cancer death.
2.1.1 SCREENING GUIDELINES FOR THE EARLY DETECTION OF BREAST CANCER

- Annual mammograms are suggested starting at the age of 40 and continuing it for as long as she is alive even if a woman is in good health.

- A clinical breast exam must be part of a periodic health check-up, for about every three years for women in their ages of 20s and 30s, and every year for women at the age of 40 and older.

- Women should know how their breasts normally feel and report any abrupt breast changes promptly to their health care providers. Breast self-exam is an alternative for women starting in their ages of 20s.

- Women at increased risk (e.g., family history, genetic propensity, past breast cancer) should talk to their doctors about the benefits and limitations of starting mammography screening earlier and of having more frequent exams.
• Screening should begin roughly three years after a woman begins having vaginal intercourse, but not later than 21 years of age.

• Screening should be done every year with standard Pap tests or every two years using liquid-based tests.

• At or after 30 years, women who have had three normal test results in a row may get screened every 2 to 3 years. However, doctors may suggest a woman get screened more if she has certain risk factors, such as HIV infection or a diluted resistant system.

Table 2.2 Accuracy of Mammography

<table>
<thead>
<tr>
<th>Stage of Disease</th>
<th>% of detection</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mammography</td>
<td>Physical Examination</td>
</tr>
<tr>
<td>Minimal Carcinoma</td>
<td>97</td>
<td>33</td>
</tr>
<tr>
<td>Negative Nodes</td>
<td>92</td>
<td>51</td>
</tr>
<tr>
<td>Positive Nodes</td>
<td>93</td>
<td>77</td>
</tr>
</tbody>
</table>

Table 2.2 tells that the mammographic examination is more accurate than the physical one for various breast diseases.

2.2 NEED FOR IMAGE ENHANCEMENT AND IMAGE SEGMENTATION

• In film screen mammography, the film (mammogram) yields high resolution X-ray images of the breast but of low contrast.

• Breast tumors, microcalcifications and architectural distortions are visualized poorly in the mammogram owing to differential X-ray attenuation between these structures and normal breast tissue.

• In original mammographic images, most of the information is hidden to the human observer and display only about 3% of the information detected.
Existing mammographic film screen systems are not quantum-limited and particularly for fine structures, noise in the imaging system is dominated by fluctuation associated with the imaging system.

Detection of small malignancies and lesions is difficult, especially in young women who have denser breast tissue owing to tradeoff between spatial resolution and detector X-ray interaction (detection) efficiency.

Microcalcifications are very small areas of calcium deposit within the breast tissue which appear as small white spots on the mammogram and may occur single or in clusters/groups which have to be enhanced.

The above examples clearly illustrate that the mammographic film needs image enhancement and image segmentation for conveying significance. With these techniques, the features present in the image can be turned on and off instantly to allow the radiologist to view the images under different enhancement conditions. This facilitates the decision as to whether or not suspicious structures are real or artifacts.

The main benefit of image enhancement is derived from relatively simple operations that improve contrast in dense regions and sharpen subtle structures.

2.2.1 Image Enhancement

One algorithm each from the categories of adaptive unsharp masking, contrast-limited adaptive histogram equalization [7,23], adaptive neighborhood contrast improvement [11,24], and wavelet-based enhancement [13,25] were selected for analysis. (Because the fuzzy modeling [26,27] mammographic enhancement algorithm is still preliminary, it was not considered for this study.) These kind of algorithms were implemented in the “C” programming language and run on an Iris Indigo TM XZ workstation (Silicon Graphics, Mountain View, CA). The 40 images in our data set (20 with microcalcifications and 20 with masses) were processed with each of the four algorithms to obtain four improved images per case. For all
algorithms except the adaptive neighborhood contrast improvement, certain parameters had to be fixed prior to running the algorithm.

*Adaptive unsharp masking.*—Unsharp masking is the process of subtracting a blurred image from the original and is often used as an image enhancement tool in photography. For a digital image $I$, an unsharp masked image, $I_{UNS}$, can be obtained by first creating low-pass filtered and high-pass filtered versions of $I$, namely, $I_L$ and $I_H$. Then $I_{UNS}$ is given by:

$$I_{UNS} = I_L + G I_H$$

where $G$ is an appropriate gain factor. In the case of standard unsharp masking, $G$ is a single number. In the case of adaptive unsharp masking, $G$ varies for each pixel and depends on the local neighborhood of each pixel in $I$. The adaptive unsharp masking algorithm proposed by Ji et al. [17,28] is preferred for our analysis.

This gain ($G$) [29] is based not only on the local characteristics of the image but also on two important properties of the human visual system. The primary property is the fact that the threshold contrast in a region is a function of the spatial frequency in that region. The second is the improved sensitivity of the human eye to noise in “busy” or detailed areas in which the spatial activity is higher than in smoother regions.

The algorithm consists of first creating three images from $I$: $I_L$, a low-pass filtered image obtained using a moving average filter; $I_H$, a high-pass filtered image obtained by subtracting $I_L$ from $I$; and $I_G$, a gradient image obtained using two orthogonal Prewitt standard gradient operators. $I$ is also divided into contiguous regions that are blocks with 50% overlap. $I_H$ is used to obtain the local contrast in every region. $I_G$ is used to classify the regions in $I$ into smooth and detail regions, and to acquire the spatial frequency and thus the threshold contrast over every detail region. For a soft region, $G$ is equal to 1. For a detailed region, $G$ is greater than 1 only if the local
contrast is less than the threshold contrast. The $G$ value for each region is applied to the central pixel in the region. $G$ at any other pixel is created by bilinear interpolation of the contrast gains of the pixel's four adjacent blocks. The final image is then given by equation 2.1.

For the unsharp masking procedure, even though the original algorithm includes a global improvement procedure, before the actual calculation of the unsharp mask image, it was found that this step was not essential. Two parameters were required to be precise: $p_T$, a threshold to separate smooth and detail regions, was selected as 0.1, and $JND_0$, the Just Noticeable Difference at low spatial frequencies, was set to 50.

**Contrast-limited adaptive histogram equalization.**—Histogram equalization [30] is a standard technique used for the enhancement of images and is performed by replacing every pixel in a given image by the integral of the histogram of the given image up to the value of the pixel. With adaptive histogram equalization, a local histogram is considered and used to acquire the final value. With standard and adaptive histogram equalization, there is a threat of over enhancing the image because of the noise enhancement. High peaks in the histogram, caused by almost uniform regions, leading to large values in the final image because of incorporation. This problem can be corrected by limiting the amount of contrast improvement at every pixel, which is obtained by clipping the original histogram to a limit. This is the essential idea behind the contrast-limited adaptive histogram equalization algorithm proposed by Pizer et al. [7,31]. Because histogram clipping requires reorganization of those pixels that are above the contrast limit, an iterative binary search procedure is used to perform this reorganization. Thus, the procedure consists of obtaining a local histogram at every pixel, clipping this histogram to the particular clipping limit, modifying the histogram by redistributing pixels using the binary search procedure, and integrating the histogram up to the value of the pixel to get the final value. For our investigation, the contrast limit is selected as 0.5. Even though
the algorithm does not require binning of the histogram, this step was found to be needed. A bin of size 100 is preferred. At each pixel, a neighborhood size of $20 \times 20$ pixels was selected. According to the algorithm in the study by Pizer et al., the inventive image can be divided into blocks, with the histogram modification procedure being performed only for the central pixel in each block, so that bilinear interpolation can be used to obtain the remaining pixel values. This method was found to provide poor results. Therefore, the histogram modification procedure was applied to each pixel, which was computationally costly.

**Adaptive neighborhood contrast enhancement.**—In the algorithms already discussed, the local neighborhood at each pixel is a rectangular region, which may not adequately represent the local characteristics of a pixel. Thus, at every pixel, it is important to define a contextual region, appropriate to that particular pixel which defines the local neighborhood of that pixel. This is done with adaptive-neighborhood or region-based image processing.

The adaptive-neighborhood contrast improvement algorithm described by Morrow et al. [32] is used for our analysis. The algorithm consists of the following: Every pixel in the image is a seed pixel for a region aggregation procedure. Starting at the seed pixel, the local region around the pixel is formed by adding neighboring pixels to the region if they are within a specified gray-level deviation, $k$, from the seed pixel. Once the local region (called the foreground) is formed, a background (having approximately the same number of pixels as the foreground) is grown around the foreground. If $f$ and $b$ are the mean gray-level values of the foreground and background, then the contrast, $C$, of the region is given by:

$$C = \frac{f-b}{f+b} \quad (2.2)$$
This equation is similar to Weber's ratio, $W$, which defines the proportion of luminance difference between a just noticeable object and its background, to its background luminance [33]. $W$ is approximately 0.02 for simple objects viewed under standard lighting circumstances, which implies that regions that are fewer than 2\% in luminance difference from their background will be indistinguishable from their background. The minimum contrast, $C_{\text{min}}$, that a region has with respect to its background is related to the gray-level deviation $k$ by $C_{\text{min}} \approx k / 2$ [11]. Hence, for the region or feature to be just distinguishable from its background, $k$ has to be at most 0.04. On one occasion the foreground and background are grown for a given kernel pixel, $C$, and is calculated using equation 2. An empirically defined look-up table has been described [11,34], by a pixel whose region has a contrast $C$ from its background and is given a new value to enlarge the contrast. The look-up table has been constructed so that regions with high contrast are not affected, and only regions with low to moderate contrast are improved. Equation 2 can be rearranged to get the new gray level at the kernel pixel. Every pixel in a foreground region having the similar value as the seed pixel (called redundant pixels) are also updated to the similar new value, thereby saving computational time.

Wavelet-based enhancement.—A multi resolution or wavelet decomposition of an image approximately divides the image into several subbands containing features at different scales. The advantage of a multi resolution decomposition of mammograms is that small features like micro calcifications will be prominent in one subband, while larger features like masses will be dominant in a different subband. The dyadic wavelet improvement algorithm [13, 35,36] is used for our analyses. The given image $I$ is first decomposed into a set of subband images using appropriate analysis filters $F$. The image can be reconstructed or synthesized from its subband images using synthesis filters $G$. An $L$-level $M$-orientation disintegration and reconstruction of $I$ is given by:
\[ I = W^{-1} W \left[ I_0^0 \right] + \sum_{i=1}^{L} \sum_{j=1}^{M} W^{-1} W \left[ I_j^i \right] \]  

(2.3)

where \( W \) denotes filtering \( I \) by \( F \) into subband images \( I_j^i \), whereas \( W^{-1} \) denotes filtering \( I_j^i \) by \( G \). Once the subband images \( I_j^i \) are obtained, they can be separately improved using any standard improvement procedure before the reconstruction process. A two-dimensional dyadic wavelet transform partitions orientations into two bands so that \( M = 2 \) in equation 2.3.

After dyadic wavelet decomposition, the multi-scale adaptive gain procedure [37] is used to improve each subband image. This process consists of suppressing pixel values of very low amplitude and increasing those that are higher than a certain threshold contained by each level. A graylevel \( y \) in the original subband image is converted to \( f(y) \) by:

\[ f(y) = a[\text{sigm}(c(y - b)) - \text{sigm}(-c(y + b))] \]  

(2.4)

Where \( a = \frac{1}{\text{sigm}(c(1 - b)) - \text{sigm}(-c(1 + b))} \)  

(2.5)

with \( 0 < b < 1 \) where \( \text{sigm}(y) \) is defined by:

\[ \text{sigm}(y) = \frac{1}{1 + e^{-y}} \]  

(2.6)

In this step, \( b \) and \( c \) control the threshold and rate of improvement respectively, and must be specified. Three levels were chosen for the decomposition, with \( b = 0.2 \) and \( c = 20 \). Even though, according to the procedure described by Laine et al. [38] all subband images are improved, it was noted that results were much superior when only the first level was improved.

A multi-resolution unsharp masking (USM) technique is developed for image feature improvement in digital mammogram images. This technique includes four processing phases:
(1) determination of parameters of multi-resolution analysis (MRA) based on the properties of images;

(2) multi-resolution decomposition of original images into sub-band images via wavelet transformation with perfect reconstruction filters;

(3) modification of sub-band images with adaptive unsharp masking technique; and

(4) reconstruction of image from modified sub-band images via inverse wavelet transformation.

An adaptive unsharp masking technique is applied to the sub-band images in order to modify the pixel values based on the edge components at various occurrence scales. Smoothing and gain factor parameters, employed in the unsharp masking, are obtained according to the resolution, frequency, and energy contented of the sub-band images. Experimental consequences show that this technique is able to improve the contrast of region of interest (micro calcification clusters) in mammogram image.

2.3 THE PRINCIPLES BEHIND IMAGE ENHANCEMENT

Image enhancement process is a collection of techniques that seeks to improve the visual appearance of an image or to convert the image to a form that is better suited for analysis by man or machine. Classification of mammographic image enhancement algorithms based on the type of image processing used reveals three broad categories:

- Unsharp masking [39,40]
- Histogram equalization [41,42]
- Wavelet-based image enhancement [1,4,8,43]
2.3.1 UNSHARP MASKING

Unsharp masking is the process of subtracting a blurred image from an original. For a digital image I, an unsharp masked image, \( I_{\text{UNS}} \), can be obtained by first creating low-pass filtered and high-pass filtered versions of I, namely, \( I_L \) and \( I_H \). Then \( I_{\text{UNS}} \) is given by equation (2.7)

\[
I_{\text{UNS}} = I_L + GI_H
\]  

Where \( G \) is an appropriate gain factor. In case of standard unsharp masking [50], \( G \) is a single number. In case of adaptive unsharp masking, \( G \) varies for each pixel and depends on the local neighbourhood of each pixel in I.

This gain \( G \) is based on the local characteristics of the image and also on two important properties of the human visual system. The primary property is the fact that the threshold contrast in a region is a function of the spatial frequency in that region. The second property is the increased sensitivity of the human eye to noise in "busy" or detailed areas in which the spatial activity is higher than that of smoother regions. The algorithm consists of first creating three images from I:

- \( I_L \), a low-pass filtered image obtained using a moving average filter.
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- \( I_G \), a gradient image obtained using two orthogonal Prewitt standard gradient operators. I is also divided into adjacent regions that are blocks with 50% overlap.
- \( I_H \) is used to obtain the local contrast in every region. \( I_G \) is used to classify the regions in I into smooth and detail regions, and to obtain the spatial frequency there by the threshold contrast over every detail region.
- For a smooth region, \( G \) is equal to 1.
- For a detail region, G is greater than 1 only if the local contrast is less than the threshold contrast.
- The G value for each region is applied to the central pixel in the region. G at any other pixel is obtained by bilinear interpolation of the contrast gains of the pixel’s four neighbouring blocks. The final image is then given by equation (2.1).

An adaptive unsharp masking, a CLAHE, an adaptive-neighborhood contrast enhancement and a wavelet approach were applied on 40 cases containing malignant or benign, micro calcification clusters and masses. The adaptive neighborhood contrast enhancement algorithm was the most preferred in 49% of the microcalcification interpretations by the radiologists. Wavelet-based approach follows with the preference in 28% and the unenhanced images in 13% of the microcalcification clusters. Hemminger et al. [44] reported an increased detection performance of histogram-based intensity windowing technique compared to CLAHE and unprocessed mammogram in the detection of simulated pathologies. Wavelet contrast enhancement methods reported by Sakellaropoulos et al. [45,46], lead to a significant improvement of local contrast and noise amplification. Direct comparison with the results about the efficiency of the enhancement method is not possible, since the CAD systems used are different and none of the researchers tunes parameters of the system.

### 2.3.2 HISTOGRAM EQUALIZATION

Histogram equalization [47,48] is a standard technique used for enhancement of images and is performed by replacing every pixel in a given image by the integral of the histogram of the given image up to the value of the pixel. With adaptive histogram equalization, a local histogram is designed and used to obtain the final value. With standard and adaptive histogram equalization, there is a danger of excessive enhancement because of the enhancement of noise. High peaks in the
histogram (caused by nearly uniform regions) lead to large values in the final image because of incorporation. This difficulty can be corrected by limiting the amount of contrast enhancement at every pixel, achieved by clipping the original histogram to a limit. This is the essential initiative behind the contrast-limited adaptive histogram equalization algorithm proposed by Pizer et al. [49]. Histogram clipping requires redistribution of those pixels that are above the contrast limit. Therefore an iterative binary search procedure is used to perform this redistribution. Accordingly, the process consists of obtaining a local histogram at every pixel, clipping this histogram to the particular clipping limit, changing the histogram by redistributing pixels using the binary search procedure and integrating the histogram up to the value of the pixel to obtain the final value.

2.4 WAVELET-BASED IMAGE ENHANCEMENT

Wavelets [13,50] are functions defined over a finite interval, having an average value of zero. The fundamental idea of the wavelet transform is to represent any arbitrary function \( f(t) \) as a superposition of a set of such wavelets or basis functions. Those source functions or baby wavelets are obtained from a single prototype wavelet called the mother wavelet by dilations or contractions (scaling) and translations (shifts). The Discrete Wavelet Transform [10,51] of a finite length signal \( x(n) \) having \( N \) components, for instance, is expressed by an \( N \times N \) matrix.

2.4.1 ADVANTAGE OF WAVELET-BASED IMAGE ENHANCEMENT

Despite all the advantages of using conventional image processing techniques such as unsharp masking and Contrast Limited Adaptive Histogram Equalization (CLAHE) on visualizing masses alone, these methods also leave shortcomings. Large variation in feature size and shape reduces the effectiveness of classical fixed neighbourhood such as unsharp masking [10,52]. Fixed neighbourhood or global techniques may adapt to local features within a neighborhood, but do not adapt the size of the neighbourhood to local properties. Alternatively, they change the image
depending on global properties (such as the image spectrum) which may not be representative of a small region of interest in the image. Many images (including mammograms) have isolated regions which are the primary feature of interest. These features can differ extensively in size and shape and often cannot be enhanced by fixed neighbourhood or global techniques. In the case of adaptive histogram equalization, there is a danger of excessive enhancement of the image because of the high occurrence of noise. High peaks in the histogram, caused by nearly uniform regions lead to large values in the final image because of integration.

Wavelet-based image analysis techniques could occupy a leading position in digital mammography [53]. The advantage of using wavelet is to discriminate different frequencies and to preserve signal details at different resolutions. In fact, this approach exploits the orientation and frequency selectivity of the wavelet transform to make microcalcifications more visible. This method is robust in the sense that it does not require the use “of heuristics” or “prior” knowledge of the size and the resolution of the mammogram. This is due to the “zoom in” and “zoom out” capability of the wavelet filters which can translate themselves properly to preserve the resolution of that portion of the signal.

When a multiresolution analysis is generated using multiple scaling functions and wavelet functions, it gives rise to the notion of Multiwavelets. A multiwavelet with ‘r’ scaling functions and ‘r’ wavelet functions is said to have multiplicity ‘r’. When r = 1, with one scaling function and one wavelet function, the multi wavelet system reduces to the scalar wavelet system. Unlike scalar wavelets, multi wavelets can be designed to possess the orthogonality and symmetry properties simultaneously which are desirable features for many signal processing applications.
2.5 WAVELETS USING MULTI-RESOLUTION ANALYSIS:

2.5.1 SURVEY ON WAVELET USING MULTI-RESOLUTION ANALYSIS

In the past, number of digital image processing techniques such as unsharp masking [50,54], contrast limited adaptive histogram equalization [55,56,57,58] on the image enhancement field and fuzzy C-means clustering, Otsu thresholding [59] on the segmentation field have been developed for the mammogram image analysis. The performance of these techniques do not improve the accuracy and call-back rates of the unenhanced image thus resulting in poor visibility of the observed phenomenon to the radiologist. Recently, wavelet transform has emerged as a cutting edge technology of the image enhancement and making a way for image segmentation using active contour model [41,60]. This combination provides substantial improvement in accuracy and call-back rates, thus bringing out the hidden information to the human observer (radiologist) and thereby improving the quality of the picture [1,3,61]. Over the earlier few years, a variety of powerful and sophisticated wavelet based schemes for image enhancement and segmentation have been developed and implemented.

Recent discoveries show that a multi-resolution approach exists in human vision system, thus leading to an idea of using wavelet based multi-resolution analysis for mammographic image processing. Wavelet approach has been used by Strickland and Hahn [62] for detection of microcalcifications, while Qian et al.[9] used wavelets and tree-structured nonlinear filtering for micro calcification segmentation. Laine, Fan, and Yang [63] used wavelets for contrast enhancement in digital mammography. Micro calcifications usually come in clusters having very sharp edges and usually irregular shape with very small size. Hence it requires a new technique of image enhancement using wavelets because they appear as white (or high intensity) spots on mammograms due to their high attenuation properties.

Multi-resolution image processing used in computer vision, subband coding developed for speech and image compression and wavelet series expansions
developed in applied mathematics have been recently recognized as different views of signal theory. The classical approach for the analysis of non-stationary signal is the Short – Time Fourier Transform (STFT) or Gabor Transform. With the advent of Wavelet Transform (WT), short windows at high frequencies and long windows at low frequencies can be used to provide better signal resolution than the STFT [21,64]. There are several types of wavelet transforms that can be chosen depending on application.

2.5.2 BALANCED MULTIWAVELETS

2.5.2.1 BALANCED MULTIWAVELET THEORY

A multi wavelet with r scaling functions and r wavelet functions is said to have multiplicity r. When r = 1, one scaling function and one wavelet function, the multi wavelet system reduces to the scalar wavelet system. Multi waves with r = 2 are considered. The perfect reconstruction multi wavelet filter bank employs 2×2 matrix filters that provide extra degrees of freedom in the design. Unlike scalar wavelets, multiwavelets can be designed to possess the orthogonality and symmetry properties simultaneously. This is a desirable feature for many signal processing applications, including image enhancement. The 2- Dimensional wavelet transform is implemented as two separable 1-Dimensional transforms. The 2×2 matrix filters in the multi wavelet filter bank require vector inputs. Thus, a 1-Dimensional input signal must be transformed into two 1- Dimensional signals. This transformation is called pre-processing. For some multi wavelets, the pre-processing must be accompanied by an appropriate pre-filtering operation that depends on the spectral characteristics of the multiwavelet filters [48,65]. However, some multiwavelets obviate the pre filtering (and the pre-processing) operation due to certain desirable properties of their basis functions; these multiwavelets are called balanced multiwavelets [51,66].
In multiwavelets [67], more than one scaling function and mother wavelet are used to represent a given signal. Unlike scalar wavelets in which Mallat’s pyramid algorithms [52,68,69] can be engaged directly, the application of multiwavelets requires that the input signal be first vectorized, which is a difficulty known as multiwavelets initialization or pre-filtering. To address this problem, Xia et al. [70] have proposed new algorithms to compute the initial multiwavelets transform coefficients by using appropriate pre and post-filtering techniques. Later, Strela et al. [71] investigated the construction of “constrained” multiwavelets for filtering two-dimensional images, and applied them to image denoising. The concept of balanced multiwavelet was investigated by Q. Jiang [36,72], P. Rieder, J.Gotze, J.S.Nossek, and C.S. Burrus [73] and I.W. Selesnick [74]. One of the goals of the balanced multiwavelet concept is to avoid intricate steps of pre/post filtering [75] that are required with systems based on multiwavelets that do not satisfy the interpolation/approximation properties of balancing. The construction of orthogonal compactly supported multiwavelets with symmetries is possible by increasing the order of balancing.

2.6 MAMMOGRAPHY

It is the process of using low-energy-X-rays (usually around 30 kVp) to examine the human breast and is used as a diagnostic and a screening tool. The goal of mammography is the early recognition of breast cancer, typically during detection of characteristic masses and/or micro calcifications. The majority of doctors believe that mammography reduces deaths from breast cancer, although a minority does not.

In many countries routine mammography of older women is encouraged as a screening method to diagnose early breast cancer. In 2009, the U.S. Preventive Services Task Force (USPSTF) recommended that women with no risk factors have screening mammographies every 2 years between age 50 and 74. They found that the information was inadequate to recommend for or against screening between age...
40 and 49 or above age 74. Overall clinical trials have found a relative reduction in breast cancer mortality of 20%.

Like all x-rays, mammograms use doses of ionizing radiation to create images. Radiologists then analyze the image for any abnormal findings. It is usual to use lower energy X-rays (typically Mo-K) than those used for radiography of skeleton.

At this time, mammography along with physical breast examination is the modality of choice for screening for early breast cancer. Ultrasound, ductography, positron emission mammography (PEM), and magnetic resonance imaging are adjuncts to mammography. Ultrasound is usually used for further evaluation of masses found on mammography or palpable masses not seen on mammograms. Ductograms are still used in several institutions for evaluation of bloody nipple discharge when the mammogram is non-diagnostic. MRI can be helpful for further evaluation of questionable findings as well as for screening pre-surgical evaluation in patients with known breast cancer to detect any additional lesions that might change the surgical approach, for example from breast-conserving lumpectomy to mastectomy. New procedures, not yet accepted for use in the public, including breast tomosynthesis may offer benefits in years to come.

Breast self-examination (BSE) was once promoted as a means of finding cancer at a more curable stage, however, it has been shown to be unproductive, and is no longer routinely recommended by health authorities for general exercise. Awareness of breast health and familiarity with one's own body is typically promoted instead of self-exams.

Mammography has a false-negative (missed cancer) rate of at least 10 percent. This is partially due to dense tissues obscuring the cancer and the fact that the appearance of cancer on mammograms has a large overlap with the appearance of normal tissues.
2.6.1 Procedure:

During the procedure, the breast is compressed using a dedicated mammography unit. Parallel-plate firmness evens out the thickness of breast tissue to increase image quality by reducing the thickness of tissue that x-rays must penetrate, the following amount of scattered radiation (scatter degrades image quality), dropping the required radiation dose, and holding the breast still (preventing motion blur). In screening mammography, both head-to-foot (craniocaudal, CC) view and angled side-view (mediolateral oblique, MLO) images of the breast are in use. Investigative mammography may include these and other views, including geometrically exaggerated and spot-compressed views of the particular area of concern. Deodorant, talcum powder or lotion may show up on the X-ray as calcium spots, and women are disallowed from applying these on the day of their exam.

Until some years ago, mammography was typically performed with screen-film cassettes. Now, mammography is undergoing conversion to digital detectors, known as digital mammography or Full Field Digital Mammography (FFDM). The first FFDM system was approved by the FDA in the U.S. in 2000. This improvement is some years later than in general radiology. This is due to several factors:

1. the higher spatial resolution demands of mammography,
2. significantly increased expense of the equipment,
3. concern by the FDA that digital mammography equipment demonstrate that it is at least as good as screen-film mammography at detecting breast cancers without increasing breast dose or the number of women recalled for further evaluation.

As of March 1, 2010, 62% of facilities in the United States and its territories have at least one FFDM unit. (The FDA includes generated radiography units in this figure.)
In order to encourage the use of mammograms as a screening measure for breast cancer, several number of hospitals, cancer centers and other healthcare groups have started mobile mammography vans to bring reasonable, accessible and suitable mammograms to their communities. Numerous mobile mammography vans prioritize helping uninsured, low-income and/or non-English-speaking women who otherwise could not afford a mammogram or who are unaccustomed to consulting a doctor. Many of them offer free or low-cost mammograms to women who are uninsured and/or cannot afford a mammogram.

2.6.2 Mammogram Preparation

- Fasting is not essential on the day of the test, and no need of examining any particular dietetic rules in the days before a mammogram. In several women, caffeine-containing products (such as coffee, cola, and chocolate) could make the breasts more tender. For this cause, women who are receptive to caffeine should stop caffeine consumption for 2 weeks before the test.

- The phase of the menstrual cycle does not affect the quality of the images; though, it is better to perform a mammogram when a woman's breasts are not painful. Avoid the preovulatory and postovulatory period (half cycle) and premenstrual period. If a woman is still having menstrual cycles, she may get it more relaxed to have a mammogram 1-2 weeks after her period, when her breasts tend to be less tender.

- It is preferable to wear two-piece clothing, such as pants and a top, to simplify undressing for the mammogram.

- In the hours prior to the test, keep away from applying cosmetics, oils, creams, and particularly talc or deodorant.
• Give the radiologist all the previous mammograms for assessment, even if they were performed in other medical centers. One can request that these be sent before having the mammogram.

• Because breast tissue changes during a woman's life, the radiologist may not think about a mammogram useful for certain women. The density of breast tissue in younger women often makes a mammogram very difficult to interpret. In fact, as women age, several changes occur in the structure of the breasts: glandular and fibrous tissues decrease in size, and breast tissues happen to be more full of fat. These changes adapt the clarity of the mammogram, making it much clearer in older women where breast cancers are more easily "seen" by mammograms.