CHAPTER 2

MAMMOGRAMS AND COMPUTER AIDED DETECTION

2.1 INTRODUCTION

This chapter provides an introduction to mammogram and a description of the computer aided detection methods of mammography. This discussion is intended to provide sufficient background information and to demonstrate the need for computer aided screening algorithms in breast cancer detection.

2.2 MAMMOGRAM

A mammogram is an x-ray image of the breast. A digital mammogram image is shown in Figure 2.1. A special type of x-ray machine is used for the breasts, which is different from the x-ray machines used for the other parts of the body. Mammography is performed using low energy x-ray beams which have a comparatively low radiation exposure level as given by Watson et al (1989) and as cited in Radiology Information web site available online (2010). The radiologist who reads the mammogram has a difficult job because the normal appearance of the breasts is different for each woman. The Computer-Aided Detection (CAD) involves the use of computers to highlight suspicious areas on a mammogram to the radiologist’s attention.
Kee (1999) states that benign cysts are seen on the mammogram as well outlined, clear lesions and tend to be bilateral whereas malignant tumors are irregular and poorly defined and tend to be unilateral. Kee (1999) further states that a breast mass cannot be clinically palpable until it is 1 cm in size; so, it may take 5 years or longer to grow and be detectable. Kee (1999) also states that a mammogram can detect a breast lesion approximately 2 years before it is palpable. Breastcancer.org website available online (2010), claims that bilateral means both breasts and unilateral means single breasts.

Breast Cancer, Breast Disorders Merck Manual Home Edition (2008) claims that breast cancer becomes fatal when the disease spreads to the liver, lungs, brain or bones. Hence early diagnosis of breast cancer reduces the fatal rate. No other proven method works better than mammography at spotting a tumor early, while it’s still confined to the breast as cited in Imaginis Breast Health Resource Center website available on line (2010).

Current guidelines from the U.S. Department of Health and Human Services (HHS), the American Cancer Society (ACS), the American Medical Association (AMA) and the American College of Radiology (ACR)
recommend screening mammography every year for women, beginning at age 40. Research has shown that annual mammograms lead to early detection of breast cancers, when they are most curable and breast-conservation therapies are available. The National Cancer Institute (NCI) adds that women who have had breast cancer and those who are at increased risk due to a genetic history of breast cancer should seek expert medical advice about whether they should begin screening before age 40 and about the frequency of screening.

There are two types of mammography: one is film mammography and the other is digital mammography.

In film mammography, the image is created directly on film. Screen-film mammography has some limitations, which include as discussed in Tang et al (2009): limited range of x-ray exposure; alteration of image contrast cannot be possible after the image is obtained; the film acts as the detector, display, and archival medium; film processing is slow and introduces artifacts.

Digital mammography is a technique for recording x-ray images in computer code instead of an x-ray film. National Cancer Institute (2010), states that, the images are displayed on a computer monitor and can be enhanced before they are printed on film. The radiologist can magnify or zoom in on an area. The images can be stored and retrieved electronically, which facilitates easy long-distance consultations with other mammography specialists.

Digital mammography overcome the limitations of film mammography and has the following advantages as given in Tang et al (2009): wider dynamic range and lower noise; improved image contrast; provide a higher signal-to-noise ratio and higher detection efficiency.
There are two types of examinations performed using mammography. They are screening mammography and diagnostic mammography.

Screening mammogram is an x-ray of the breast used to detect breast changes in women who have no signs or symptoms of breast cancer. Each screening examination consisted of 4 mammograms, two projections of each breast of which one is the Cranio Caudal (CC) and the other is the Medio Lateral Oblique (MLO) view as per Sameti (2009).

A diagnostic mammogram is an x-ray of the breast that is used to diagnose unusual breast changes, such as a lump, pain, thickening, nipple discharge or a change in breast size or shape. A diagnostic mammogram is also used to evaluate changes detected on a screening mammogram. A cancerous mammogram image and normal image are shown in Figure 2.2.

![Cancerous (left) versus Normal (right) mammography image](image)

It has been cited by Tang et al (2009) that women who are under high risk factor have to start their treatment before 40 years.
2.3 COMPUTER AIDED DETECTION SYSTEM

CAD is a tool for early detection of breast cancer. The most known risk factors of breast cancer are age, family history, genetic predispositions, hormonal and reproductive history or breast density. This renders primary prevention difficult. Early detection allows more efficient and less heavy treatments (surgery, chemotherapy, radiation therapy), thus reducing the financial as well as psychological costs as discussed by Castella (2009). Tang et al (2009) states that compared with double reading, CAD can reduce the workload of radiologists.

2.3.1 Commercial CAD

The three commercial CAD systems discussed in detail are R2 Image Checker CAD, Second Look CAD and Kodak's Mammography CAD System.

2.3.1.1 R2 Image Checker CAD

One of the CAD systems on the market today is called the Image Checker system developed by R2 Technology. Image Checker CAD was the first U.S. Food and Drug Administration (FDA) approved mammography CAD system and has maintained a market leading position as cited in Hologic web site available online (2010). This device scans the mammogram with a laser beam and converts it into a digital signal that is processed by a computer. The image is then displayed on a video monitor, with suspicious areas highlighted for the radiologist to review. The radiologist can compare the digital image with the conventional mammogram to see if any of the highlighted areas were missed on the initial review and require further evaluation as cited in the National Cancer Institute website available online (2010).
The advantage of using R2 Image Checker CAD is, the Image Checker algorithm looks for characteristics commonly associated with cancer. The algorithm ranks its findings by prominence of features, places marks on those regions above the operating point and then sends the results to the review workstation. D’Orsi (2001) claims that the limitation of this system is that the system does not perform well for masses. The true-positive rate is 85.7%.

2.3.1.2 Second Look CAD

The Second Look CAD was developed by CADx Medical Systems. Potential suspicious areas are located using artificial intelligence algorithms as given by Özekes et al (2005).

The advantage of Second Look CAD is it detects up to 72% of actionable missed cancers an average of 15 months earlier than screening mammography. It integrates with existing systems to improve workflow as cited in iCAD website available online (2009).

2.3.1.3 Kodak's Mammography CAD System

Kodak's Mammography CAD System is a commercial CAD for cancer detection in screening and diagnostic mammograms. Algorithms provide efficient identification of image areas that warrant a second review.

The advantage of this system is that 39.4% of missed cancers or 77.9% of actionable cancers can be detected 14.8 months earlier. The digitized mammograms can automatically be sent to an archive for efficient file storage as cited in Carestream Health, Inc., available online (2010).
2.3.2 Noncommercial CAD System

A noncommercial CAD system called M-vision; was developed for detection of cancer from mammogram by Department of Radiology, University of Michigan, Ann Arbor. The CAD system included programs for detection of masses and of micro calcifications. For the detection of masses, the digitized mammograms were preprocessed with a nonlinear density weighted contrast enhancement filter to accentuate mammographically depicted structures. Edge detection was then used to define the borders of the enhanced structures. The object definition was refined by using the k-means clustering algorithm of feature vectors of the pixels in a background corrected region of interest that enclosed each seed object. Morphologic and textural features were then extracted from the refined objects. Rule-based and linear discriminant classifiers were applied to the feature space to distinguish masses from normal structures. For the detection of micro calcifications, a linear band-pass filter was used to enhance the signals and suppress the low-frequency background on the digitized mammograms. The number of false-positive marks was reduced by using rule based classification, with morphologic features extracted from each potential signal. Finally, regional clustering was used to locate clustered micro calcifications that were suspected of being cancerous. The advantage of this CAD system is it achieved a sensitivity of 91% as described by Helvie et al (2004).

2.4 EVALUATION MEASURES OF CAD SYSTEM FOR MAMMOGRAPHY

2.4.1 Sensitivity and Specificity

Sensitivity and specificity are statistical measures of the performance of a classification test. Sensitivity is also called as recall rate. It measures the proportion of actual positives which are correctly identified. Specificity
measures the proportion of negatives which are correctly identified as per Altman et al (1994). Sensitivity and specificity are terms that show the significance of a test related to the presence or absence of the disease. In particular, sensitivity indicates the number of subjects who have the disease and are accurately identified by the test. Thus, it is a measure of the probability of correctly diagnosing a condition. Specificity indicates the number of subjects who do not have the disease and are accurately identified by the test. Thus, it is a measure of the probability of correctly distinguishing when the condition is not present in a subject as discussed by Khuzi et al (2009).

A sensitivity of 100 % means that the test recognizes all actual positives - for example, all cancer are recognized as cancer. Sensitivity alone does not indicate how well the test predicts the negative cases.

\[
\text{Sensitivity} = \frac{\text{TP}}{\text{TP} + \text{FN}} \tag{2.1}
\]

A specificity of 100 % means that the test recognizes all actual negatives – that is, all normal recognized as normal. Specificity alone does not indicate how well the test recognizes positive cases. It is also needed to know the sensitivity of the test.

\[
\text{Specificity} = \frac{\text{TN}}{\text{FP} + \text{TN}} \tag{2.2}
\]

where as in the above

- TP means true positive that is cancer correctly diagnosed as cancer
  \[\text{TP} = \text{Tumor present} + \text{Positive result}\]
- FP means false positive that is normal incorrectly identified as cancer
FP = Tumor absent + Positive result

- TN means true negative that is normal correctly identified as normal
  \[ TN = \text{Tumor absent} + \text{Negative result} \]

- FN means false negative that is cancer incorrectly identified as normal.
  \[ FN = \text{Tumor present} + \text{Negative result} \]

### 2.4.2 Positive Predictive Value (PPV)

The positive predictive value or precision rate is the proportion of patients with positive test results who are correctly diagnosed. It is one of the most important measures of a diagnostic method as it reflects the probability that a positive test reflects the underlying condition being tested for. Predictive values are often used in medical research to evaluate the usefulness of a diagnostic test. Hence the PPV is used to indicate the probability that in case of a positive test, that the patient really has the specified disease as per Altman et al (1994). It is the ratio of true positives to combined true and false positives.

\[
\text{Positive Predictive Value (PPV)} = \frac{TP}{TP + FP} \quad (2.3)
\]

### 2.4.3 Negative Predictive Value (NPV)

The negative predictive value is the proportion of patients with negative test results who are correctly diagnosed. It is the ratio of true negatives to combined true and false negatives as per Altman et al (1994).

\[
\text{Negative Predictive Value (NPV)} = \frac{TN}{FN + TN} \quad (2.4)
\]
2.4.4 Accuracy (ACC)

Accuracy is the proportion of true results both true positives and true negatives in the population

\[ \text{ACC} = \frac{(TP + TN)}{(P + N)} \]  

(2.5)

where
- P is total positive that is TP + FP
- N is total negative that is TN + FN