Developing algorithms and tools to aid the development of Computer Aided Diagnosis (CAD) for the early detection of breast cancer is of great advantages for the Radiologist for making their decisions more accurate and precise. Radiologists can use such systems as a tool to obtain a second opinion for their decision making process. A brief introduction to digital image processing as well as the state of art technology of the mammogram image analysis is presented in this chapter. The tremendous changes in the field of medical imaging technology by the evolution of different medical imaging modalities are also highlighted. Finally the chapter concludes with the statement of motivation and objectives behind the research.
The aim of this research is the development of reliable algorithms for interpreting and analyzing the abnormalities present in the medical images. In this thesis we mainly focus on the different aspects related to the detection and classification of breast abnormalities using digital mammography. The ultimate aim of this work is to identify and classify breast cancer in mammogram images at an early stage. Image processing, data mining and machine learning techniques are the major topics used for devising algorithms for easy interpretation of the wide range of abnormalities in the mammographic images during screening programs. Such algorithms can be fully integrated to the development of an automated Computer aided diagnosis (CAD) system, which assist the Radiologists for making their decisions more accurate and fast [Brijesh Verma and John Zakos, 2001]. Different image processing techniques along with machine learning techniques are applied on the digital mammogram images for this purpose. Developing such tools will provide a second opinion for the radiologist for making their conclusions very effective [Bozek et.al, 2009].

1.1 Digital Image Processing (DIP)

An image is defined mathematically as a two dimensional function, \( f(x, y) \), where \( x \) and \( y \) are spatial coordinates, and the amplitude of \( f \) at any pair of coordinates \((x, y)\) is called the intensity or gray level of the image at that point. When \((x, y)\) and the amplitude values of \( f \) are all finite, discrete quantities, then we call the image as a digital image. The term digital image processing (DIP) refers to processing digital images by means of a digital computer. DIP performs some operations on the image to enhance or extract some useful information from the image for further study. It is a type of signal dispensation in which the input is image, like video frame or
photograph and the output may be image or characteristics associated with that image. Usually Image Processing system treats images as a two dimensional signals and then applies certain set of signal processing methods onto them [Gonzalez and Woods, 2008]. The value or amplitude of \( f \) at spatial coordinates \((x, y)\) is a positive scalar quantity whose physical meaning is determined by the source of the image. When an image is generated from a physical process, its values are proportional to energy radiated by the physical source. As a consequence, \( f(x, y) \) must be nonzero and finite; that is,

\[
0 < f(x, y) < \infty
\]  

(1.1)

The function \( f(x, y) \) may be characterized by two components: (1) the amount of illumination being incident on the scene, and (2) the amount of illumination reflected by the objects in the scene. These two terms are normally called the illumination and reflectance components and they are denoted as \( i(x, y) \) and \( r(x, y) \) respectively. These two functions are combined to as a product of the form \( f(x, y) \):

\[
f(x, y) = i(x, y) \ast r(x, y)
\]  

(1.2)

where \( 0 < I(x, y) < \infty \) and \( 0 < r(x, y) < 1 \).

### 1.2 Steps in Digital Image Processing

In any image processing system, image acquisition is the initial step. There are varieties of electromagnetic and ultrasonic sensing devices available for acquiring the images in different perceptional views. While acquiring images using any modality, certain pre-processing steps are also to be introduced for the effective acquisition and digitization [Gonzalez and Woods, 2008]. The pre-processing steps eliminate the artefacts introduced during acquisition or increase the contrast of the image or enhance the quality
of image. The main pre-processing step in digital image processing is image enhancement. The principal objective of the image enhancement is to bring the images in such a way that the resultant image is more suitable than the original image for a specific application. Basically, the idea behind enhancement techniques is to bring out fine details that are obscured, or simply to highlight certain features of interest in an image or eliminate the unnecessary noise accompanied during the acquisition process. The word ‘specific’ is important in the sense that the method for enhancing one modality of image may not be suitable for the other [Gonzalez and Woods, 2008].

Image restoration is an area that also deals with improving the appearance of an image. Restoration attempts to reconstruct or recover an image that has been degraded, by using a priori knowledge of the degradation phenomenon. The main differences between these two are; image restoration is an objective process in which images are reconstructed or recovered based on the mathematical or probabilistic models whereas enhancement is purely based on human subjective preferences [Gonzalez and Woods, 2008].

After the pre-processing phase, next step in the image processing is the Image segmentation, which involves partitioning an image into a set of homogenous and meaningful regions, such that the pixels in each partitioned region possess an identical set of properties or attributes. These set of properties of the image may include gray levels, contrast, spectral values, or textural properties. The result of segmentation is a number of homogenous regions, each having unique label. An image is thus defined by a set of regions that are connected and overlapping, so that each pixel in the image acquires a unique region label that indicates the region it belongs to. The set of objects of interest in an image, which are segmented, undergoes
subsequent processing such as object classification and scene description [Acharya and Ray, 2005].

Once the image is segmented, then the next task is to recognize the segmented objects or regions in the scene. The main objective of pattern recognition is to recognize objects in the scene from a set of measurements of the objects. Each object is a pattern and the measured values are the features of the pattern [Acharya and Ray, 2005]. Subsequently, these measured features of the object that may constitute raw pixels of data or the boundary of the region, or group of pixels separating different regions or all the points in the region that can be made as an input to the representation and object description stage of the DIP for identifying and labelling the object. Description is also called feature selection which deals with extracting attributes that result in some quantitative information of interest for differentiating one class of objects from another class [Gonzalez and Woods, 2008].

1.3 Medical Image Processing

Medical imaging is an area which deals with the human body anatomy and function of organs and tissues, which are readily affected by physical interventions into their working environment. These interventions may result in alterations of the anatomic and functional status of the human body. The twentieth century had witnessed a tremendous change in the field of medical imaging technology. This revolutionary change has been led to the development of more sophisticated and powerful instruments and techniques to study the anatomic structure of internal organs with unprecedented precision to recognize the gross pathology of organs with disease, non-invasively. The transmission of radiant energy through the body produces
images without subjective sensations and does not directly affect the function of body tissues at the dose levels required to produce useful images. A beam of radiation passing through the body is absorbed and scattered by structures in the beam path to varying degree, depending upon the composition of these structures and on the energy level of the beam. The images produced from radiant energy passing through parts of the body provide a direct recording of internal, unseen structures [Acharya and Ray, 2005].

The discovery of X-rays by Wilhelm Rontgen in 1895 heralded a new era in the practice of medicine. The X-rays are used for the visualization of internal structure of the human body without painful and often dangerous surgery. The X-ray imaging is the fastest and easiest way for a physician to view and assess broken bones, a cracked skull or in back bone by imaging on photographic films. Diagnostic X-ray images can be created by passing small highly controlled amounts of radiation through the body, capturing the resulting shadows and reflections on a photographic plate. The X-ray images are caused by various levels of absorption by calcified structures, soft tissues and fatty substances. The conventional X-ray imaging techniques have several important limitations. Small characteristics differences (1% to 2%) of X-ray attenuation by various body tissues are not detectable in recording on X-ray film or fluoroscopic screens. A large percentage of the radiation detected is scattered from the body reduces the true signal-to-noise ratio of the recorded information [Acharya and Ray, 2005] [Robb, 2000].

In 1960 Cormack and Godfrey Hounsfield contributed to the invention of X-ray Computed Axial Tomography, popularly known as CT-scan or CAT scan. The CT-scan advanced rapidly sparking a literal revolution in medical imaging. In this modality different X-ray views were taken at different angles to produce sufficient information that uniquely determines the internal
structure of the body. Thus diagnostically useful images could be reconstructed from these determinations. This led to a mathematically accurate way of quantitatively reconstructing cross-sectional images from X-ray projections [Acharya and Ray, 2005].

In 1980, both the disadvantages of X-ray CT (use of ionizing radiation) and its promise (high resolution 3-D imaging) gave birth to 3D computed tomography using other imaging form such as Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET). The decade of the 1990 heralded the era of multimodality imaging in which multiple types of images formed by different energy sources interacting with the same object(tissues) could be coherently combined to provide a powerful synergistic picture of the body structures and functions that never available before [Acharya and Ray, 2005].

Various constituents organs in human body contains considerable amount of water molecules and fat, and thus there is an abundance of Hydrogen in our body tissues. The MRI signals emanate from the hydrogen nuclei when they are excited by magnetic stimuli and these signals are used for imaging. Noted physicists Bloch and Purcell have first conceived the concept of MRI. The basic principle behind MRI is to stimulate the matter magnetically and the imaging signal is obtained by the changes in the fundamental properties of matter in response to the magnetic stimuli [Acharya and Ray, 2005] [Robb, 2000].

In nuclear medicine, radioactive materials are usually given through intravenous (IV), or swallowed or inhaled to obtain images of human organs. The passage of the movement of radioactive substance is tracked by a detector. Radio nuclides get tagged with certain substances within the body.
It emits gamma radiation which is captured by a sensor in a gamma camera. These images are poor in resolution, yet they visualize the physiological functions such as metabolism in a clear way [Acharya and Ray, 2005] [Feng, 2008].

In ultrasound images, an ultrasonic pulse propagates from a transducer placed on the skin of the patient. The back scattered echo signal is recorded from which an image is constructed. Ultrasound gets transmitted through water. The cysts which are variety fluid structure do not send any echo to the recorder. On the other hand, bones, calcification and fats absorb and reflect the ultrasound beam to a small extent and create acoustic shadowing. These cysts can be detected in any organ using ultrasound images [Acharya and Ray, 2005] [Feng, 2008].

The detection and classification of various types of tumours in digital mammograms using mammogram image analysis system has found paramount importance in recent times. Breast masses, both non-cancerous and cancerous lesions, appear as white regions in mammogram films. The fatty tissues appear as black regions, while other components of the breast, such as glands, connective tissue, tumours, calcium deposits etc. appear as shades of gray, more towards the brighter intensity on a mammogram [Acharya and Ray, 2005] [Robb, 2000].

Imaging science and biomedical visualization have benefitted by the significant advances in the microelectronics industry during the last few decades. High end computing facility in miniature size desktop with minimum cost is the by-product of the development in microelectronics industry. These powerful computational capabilities with modest cost have given the freedom to programmers and software developers to be more
creative in developing and testing algorithms without spending significant periods of time and effort to achieve acceptable performance. Concomitantly, the improvements in the quality of images produced by medical and biological imaging systems have also increased dramatically in the last decade, providing faithful high resolution images. The combination of high quality images and high performance, low cost computing and the advancements in molecular and cell biology have provided an ideal opportunity for the development of powerful, yet practical tools for automatic analysis and synthesis of biomedical images [Robb, 2000].

1.4 Breast Cancer (BC)

Breast cancer is the most frequent neoplasm in women across the globe [Engan et. al, 2007]. It stands second in position for the cause of deaths in women, especially in the developing and under developing countries [Thangavel et.al, 2007]. Breast cancer is common among men also. It accounts 1% of total breast cancer found in the world [Sakka et.al, 2005] [Cheng and Wang, 2003]. In India itself, breast cancer accounts 23% of all female cancers followed by cervical cancer which is only 17.5% [Shetty et. al, 2009].

Latest statistical report from RCC (Regional Cancer Centre Trivandrum, 2012) reported a 280 % increase in the number of cancer cases in the past decade in Kerala state. The data released by RCC shows that breast and thyroid cancers have become the predominant cancers in women in the State, unlike 30 years ago, when cancer of the uterine cervix affected the most. However during the last 30 years, cancer of the uterine cervix declined significantly but the breast cancer incidence rose steeply especially
among young women. As of 2011, breast cancer is the leading cancer among women, accounting for 28.1 per cent of all cancers among women reported.

Environmental and lifestyle changes have great influence on the increase in the number of breast cancer cases. The only way to decrease the mortality rate of the breast cancer is the early detection [Rashed et. al, 2007]. The commonly used diagnostic methods for breast cancer include biopsy, mammography, thermograph and ultrasound image [Arode et.al, 2006]. The mammography, which is a non-invasive method, is considered as the best approach among all the above approaches [Jelen et. al, 2008] [Kim et. al, 1997] [Li et. al, 1997]. In the light of the above, development of sophisticated algorithms for processing digital mammogram leading to design of better CAD system for breast cancer is needed.

1.5 Motivation

Identifying the development of tumours in human body is one of the challenging tasks of any experienced Radiologists. They identify the symptom at an early stage by their expertise and skills acquired through experience. But the scarcities of experienced radiologists make the problem more crucial. Professionally unskilled radiologists make unnecessary biopsy and often misinterpret positive diagnosis cases. So CAD systems for identifying tumours at an earlier stage emerged as an application of digital image processing. The radiologist can consider the decision of such CAD systems as a second opinion for their diagnosis. Many research works leading to the design of such CAD system have been reported. Such CAD systems though performs satisfactorily, it posses many drawbacks. A detailed study of the methodologies adopted in the existing CAD system is required to identify the limitations of such systems.
Mammography is widely recognized as the best imaging modality for the early detection of breast cancer. Mammography examination reduced the breast cancer mortality in spite of growing number of detected cancers during the last 10 years. Even though it is the most reliable method for early detection, it has many limitations. One important aspect is that the accuracy rate tends to decrease when physicians’ read high volume of mammograms. Second important factor is that digital mammograms are difficult to analyze due to their low contrast and differences in the types of tissues. Important visual clues of breast cancer include preliminary signs of masses and calcification of clusters. Unfortunately, at the early stages of breast cancer, theses signs are very subtle and varied in appearance. This makes the diagnosis process difficult even for specialists. Third important problem is the management of storage and retrieval of mammogram images, as the images are required during pre and post treatment period for analysis and comparison.

1.6 Objectives

The objectives of this research work are:

- To study enhancement of mammogram images and to propose novel approaches for enhancement.

- To develop a novel fully automated method for extracting the Region of Interest (ROIs) from mammogram images.

- To study prominent feature extraction methods and to propose new approaches to extract features from ROIs and its selection.

- Selection and implementation of classification algorithms both supervised and unsupervised methods for classifying mammogram images.
1. Compare and suggest feature extraction and classification methods for identifying types of abnormalities in mammogram images.

1.7 Organization of the thesis

Chapter 2 deals with the anatomy of the breast and its function followed by the breast tumour and its symptoms. This chapter also discusses the different imaging modalities with a special attention to digital mammography. Finally the computer-aided diagnosis for the early detection of breast cancer and the different performance evaluation parameters used for computer-aided diagnosis systems are discussed.

Chapter 3 is dedicated to the methods and materials used for developing a fully automated classification system for identifying and classifying breast tumour at an early stage. As part of the materials we included the details about different set of digital mammogram images that are used for classification. To classify the digital mammogram images, two different feature extraction methods as well as the formation of feature vector are discussed in this chapter. Finally, different classification algorithms used for the detection and classification of breast cancer are also included in this chapter.

Chapter 4 begins with a discussion of different mammogram enhancement approaches using soft and semi thresholding techniques. A new enhancement techniques named as Wavelet Semi-Thresholding Algorithm (WSTA) using morphological Top hat filtering and Hit-or-miss transformations is proposed and described in detail. The comparative performance of the conventional thresholding approaches and WSTA are also evaluated.

Chapter 5 explains a fully automated segmentation technique for extracting region of interest (ROI) of the mammogram image. The segmentation
algorithm proposed in this chapter initially identifies the seed point location and then extracts ROIs of mammogram images around the seed point using modified region growing algorithm.

Chapter 6 discusses the implementation of different classification algorithms for detection of abnormalities in mammogram images. Detailed description of experiments carried out with the two chosen feature sets and the different classifiers employed is presented. A thorough analysis of the results obtained and outcome of the comparative analysis of performance are dealt in detail.

Chapter 7 focus on the unsupervised learning method for classifying mammogram images using clustering techniques viz. K-means clustering and Fuzzy C-means algorithms. The wavelet and GLCM features are used as feature vectors. This chapter also discusses the classification of a real dataset obtained from local hospitals.

Finally, chapter 8 concludes with summary of the all the works discussed in the thesis. A brief description about the major contributions as well as the future scope of this works is also presented.