Chapter 15

Summary

The fight against cancer was started 5000 years ago when ayurvedic doctors treated patients with symptoms of abnormal growth or tumours. From then medical practitioners are relentlessly fighting the battle against cancer for cure. Definitely it can be said that although the sure-shot perfect cure is not achieved yet, still with the support of modern medicine, surgery and awareness, medical practitioners are saving thousands of lives from cancer. Every day medical science is developing rapidly towards desired objective. In this struggle, computer science is also contributing in large to assist the medical practitioners. Now-a-days, computer aided detection and computer aided diagnosis are one of the most important field of research due to its proven competence and accuracy.

Significant development of mammogram based computer aided detection using image processing techniques has been reported by different research articles. Huge opportunity still persists to develop fully automatic system to detect abnormalities and predict future risk factors. Digital histopathology to analyse breast biopsy slide image is also evolving sustainably, though it is in budding stage. So, substantial scope is left for research in the field for biopsy slide image analysis and develop diagnostic tool for breast cancer.
The research described in the thesis deals with the development of a comprehensive real
time fully automatic CAD system for breast cancer diagnosis. The thesis is of two distinct
parts. The first part of the thesis concerns about mammographic analysis to identify
abnormalities and future risk prediction whereas the latter one deals with
histopathological biopsy slide image examination for diagnosis of breast cancer. The first
part is basically detection phase where different algorithms are developed to isolate the
abnormalities using mammogram image. Moreover it also extracts the features associated
with future risk prediction which has equal importance with detection of abnormalities due
to its potential to reduce mortality by taking early preventive measures and building
awareness. The concluding part is diagnostic phase which is an elementary effort for
registration and enhancement of digitised histopathological biopsy slide image to retrieve
the relevant observations towards taking definite decision by medical experts.

15.1 Contributions
The name of the thesis suggests the objective of this research work conducted by me. It
also provides the focus area of working on digital mammogram and digitised
histopathological slide images of human breast for the development of a low cost, fully
automated, real time and comprehensive CAD system for breast cancer diagnostics.

A fully automated system functions without any human intervention. The basic objective
of such systems is that the CAD system will perform in a standalone basis where it will
provide processed output in the form of reports, images when input data is fed to it. The
proposed algorithms in this CAD system has been designed in such manner that they will
perform sequentially without any human intervention and produce the desired results.
A real time system can be defined as a high performance system. The objective of this thesis is to develop algorithms that will show high performance. The time complexity of algorithms is crucial for the development of such algorithms. High emphasis has been given so that the time complexity of algorithms are minimum, so that, the processing time can be significantly reduced without compromising the outcome. The development of real time algorithms are with the objective to develop embedded system incorporated with the hardware/firmware of the mammographic devices.

To develop a comprehensive system related to medical science it is extremely important to gather knowledge about the disease, and its signs and symptoms and then incorporate that knowledge into the CAD system for better analysis. To make the CAD system comprehensive a number of algorithms have been developed that directly or indirectly fulfills the objective. The purpose of identification of mass and to calculate the future risk factors, preparation and pre-processing are equally important component to derive accurate results.

The preparation phase consisting of three distinct processes namely artefact removal, homogeneous orientation of mammogram image and de-noising. Three separate algorithms have been proposed to accomplish the objective. Next step is the pre-processing phase where five new algorithms are proposed namely Divide and Conquer Homogeneity Enhancement Algorithm (DCHEA) for mammogram image registration, novel Edge Detection Algorithm (EDA) to extract the edge from mammogram image, modified Seeded Region Growing (SRG) algorithm for pectoral muscle isolation and suppression, alternatively Pectoral Muscle Boundary Detection Algorithm (PMBDA) which is a pectoral muscle supressing technique based on pixel traversing technique, Breast Boundary
Detection Algorithm (BBDA) along with Breast Boundary Smoothing Algorithm (BBSA) to determine the accurate breast contour and anatomical segmentation of breast ROI (ASB).

The feature extraction and mass detection is the decision making phase to identify the abnormalities in mammogram image by using a statistical decision making system. The most important future risk prediction part where three features are calculated that are related to future risk of breast cancer. Bilateral asymmetry analysis is performed both morphologically and based on the internal anatomical structures. Volume calculation and density estimation and classification are developed using newly proposed algorithms. The proposed complex geometric structure called Elliptical Paraboloid Model to calculate breast volume and density estimation using Progressive Elimination Method (PEM). The mass detection and future risk prediction is the main objective of the CAD system requires the preparation and pre-processing phases as perquisite.

The final part of this thesis discussed the digital histopathological biopsy slide image analysis. It is a confirmatory phase of the breast cancer diagnosis. A two-step pre-processing algorithm is proposed to analyse the histopathological biopsy slide image. The first algorithm converted the image to grey-scale for image registration and next one is image enhancement algorithm using colour polarisation. This phase is an introductory initiative for further prospective future research.

Analysis of experimental results for the proposed algorithms is done quantitatively, qualitatively and comparatively with other comparable algorithms of other authors to measure the accuracy of the result. The quantitative accuracy measures obtained by the proposed algorithms are summarised below which shows more than 95% accuracy level that is generally considered as acceptable [307].
Table: 15.1. Summary of Algorithmic Accuracy

<table>
<thead>
<tr>
<th>Algorithm Proposed</th>
<th>Purpose</th>
<th>Achieved Quantitative Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Artefact Removal Algorithm</td>
<td>Preparation</td>
<td>Accuracy of 96.9%</td>
</tr>
<tr>
<td>Image Orientation Algorithm</td>
<td>Preparation</td>
<td>Nearly accuracy of 100%</td>
</tr>
<tr>
<td>Homogeneity Enhancement and Registration using newly proposed Divide and Conquer Homogeneity Enhancement Algorithm (DCHEA)</td>
<td>Pre-Processing</td>
<td>Mode LSD Value 0.6524</td>
</tr>
<tr>
<td>Edge Detection using newly proposed Edge Detection Algorithm (EDA)</td>
<td>Pre-Processing</td>
<td>Simple and Fast</td>
</tr>
<tr>
<td>Pectoral Muscle Suppression using newly proposed methods Modified Seeded Region Growing Algorithm (MSRGA)</td>
<td>Pre-Processing</td>
<td>Accuracy of 95.7%</td>
</tr>
<tr>
<td>Pectoral Muscle Boundary Detection Algorithm (PMBDA)</td>
<td>Pre-Processing</td>
<td>Accuracy of 99.8%</td>
</tr>
<tr>
<td>Breast Contour Detection using newly proposed Breast Boundary Detection Algorithm (BBDA)</td>
<td>Pre-Processing</td>
<td>Accuracy of 99.4%</td>
</tr>
<tr>
<td>Anatomical Segmentation using newly proposed Anatomical Region Segmentation Algorithm (ARSA)</td>
<td>Detection</td>
<td>Mass Identification Accuracy of 96% Mass boundary detection Accuracy of 99%</td>
</tr>
<tr>
<td>Abnormality detection using newly proposed Mass Detection Algorithm (MDA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bilateral Breast Asymmetry Detection Algorithms using newly proposed Landmark based Registration and Intensity Histogram</td>
<td>Future Risk Prediction</td>
<td>Accuracy of 98.1%</td>
</tr>
<tr>
<td>Breast Volume Calculation Algorithm using the newly proposed Elliptical Paraboloid Model</td>
<td>Future Risk Prediction</td>
<td>Average Volume 751.3 cc</td>
</tr>
<tr>
<td>Density Estimation and Classification using newly proposed Progressive Elimination Algorithm</td>
<td>Future Risk Prediction</td>
<td>MIAS % of Agreement 73.91 and Kappa (κ) 0.673 whereas DDSM % of Agreement 72.79 and Kappa (κ) 0.698</td>
</tr>
</tbody>
</table>

15.2 Application

As discussed earlier, breast cancer is a significant health hazard in India. Like other developing countries, poverty and inadequate health services in terms of infrastructure and human resource are the common problems in India. Several government and non-
government efforts are being made throughout the country to solve the problem. Initially the mass awareness campaign may be one of the most significant steps towards combating the disease. The mass screening program which is very successful in developing countries like US, Australia and Europe may be applied in India also. However, vastly populated countries like India, mass screening programmes may face several key impediments. The first one may be economic problem; secondly, India is living in far flung villages where primary health facilities are inadequate, and finally shortage of medical practitioners and technicians.

Now-a-days, concept of mobile medical unit and telemedicine are becoming popular in developing countries due to its socio-economic acceptability. These mobile unites can visit the remote rural areas with medical experts and serve the medical need of the region. Due to enormous development of communication system, experts present in remote cities can be consulted for complicated health problems through telecommunication.

The stated breast cancer diagnosis system can be converted to a comprehensive CAD tool and using them on mobile unit can be easily deployed with portable mammographic machines. This portable machine will be connected with computers and real time image analysis can be done using the said CAD tool. For complicated cases images may be transmitted via internet to nearest base station for further analysis, confirmation and appropriate action. These units can perform mass screening programme in our country with minimal workforce and with reasonable cost.

15.3 Future Scope
In the concluding part of this thesis, an introductory pre-processing part of histopathological biopsy slide image analysis of cancer diagnosis has been performed. Although the research described in this dissertation has presented comprehensive models
for real time fully automatic CAD system, it has not exhausted the possibilities of further future works. Some recommended extensions of the work are mentioned herewith.

The research has been done mostly using MLO view of mammogram. Except for the volume calculation, most of newly proposed algorithms are based on two dimensional mammogram images. In future 3D image analysis can be considered using both MLO and CC view of mammogram. The 3D localisation of abnormalities is further convenient to medical experts especially to the surgeons. In future algorithms may be developed to extract the features from magnetic resonance imaging (MRI), ultrasonography (USG) and Computer tomography (CT) for the same purpose or for other field of studies like brain tumour, nodules of lungs etc. There are immense scopes left for further research in the field of future risk prediction. The proposed algorithms may be further enhanced to derive more accurate results. The 3D modelling of gland disc may be further supportive to classify according to density and assess the asymmetry of bilateral pair of breast.

The most significant area of future research is the histopathological biopsy slide image analysis. Vast work remains undone. This thesis discussed only the preliminary portion of the same. It is also surveyed that some work has been done by different research groups but mostly they are theoretical in nature. The comprehensive and robust CAD almost absent for histopathological biopsy slide image analysis in public domain. There are plenty of opportunities left in the field of segmentation, feature extraction, feature classification and decision making steps of biopsy slide image analysis for breast cancer.

15.4 Conclusion
The primary objective of the research is to develop a comprehensive real time fully automatic computer aided diagnostic system for breast cancer using digital mammogram and digitised histopathological biopsy slide image. To fulfil the desired objective
comprehensive and critical review of present approaches was first undertaken to establish the development of knowledge in that field and the existing state of the art methods. After reviewing the exiting works, a series of new algorithms are proposed to detect breast abnormalities using mammogram and to analyse histopathological biopsy slide image to draw a definite inference. In detection and future risk prediction part, all the possible areas are covered intensively but the diagnosis part of research is introductory and huge work is left for future research. Although the initial objective of the proposed method is met, at the same time results are encouraging for further development. The results obtained by implementing the proposed algorithms in Microsoft C# on standard available dataset, are verified using standard statistical methods to establish the correctness of algorithms. In the algorithm development phase, the complexity of algorithm in terms of time was taken into account for efficient execution. The results were comparable with different research in the related field. The research papers are nationally and internationally appreciated and cited by different researchers. Different experts in the field of medical science are consulted about the research outcomes and they endorsed and appreciated. The dream with the proposed dissertation is to design and implement a CAD system for mass screening programmes for breast cancer which will be applicable for rural areas using mobile medical unit with least workforce and low cost.