Chapter

8. Conclusion and Future Scope

This chapter concludes and summarizes the research contributions made. The achievements and objectives of the research with respect to the experimental results obtained are highlighted along with the key findings. This chapter also discusses the impact of the developed system to radiologists for mammogram interpretation.

8.1 Benefits of the Developed System

Early detection of breast cancer is very crucial as localized cancer is curable. Mammography is a widely used standard imaging tool for the early detection of breast cancer. However, the sensitivity of mammography is affected by image quality and the radiologist’s level of expertise. Computer-aided methods have the potential to increase the diagnostic accuracy by reducing the FPs, while increasing the positive predictive values (PPVs) of mammographic abnormalities. CAD systems have been developed to improve the results of mammographic screening programs by assisting radiologists. This research work has focused on automatic detection of breast cancer through different phases such as preprocessing, single view detection and ipsilateral view detection using FFDM images. The benefits obtained of using the developed algorithms to be used in CAD for breast cancer are as follows:

1. This system will aid the radiologists in the mammogram interpretation by acting as a second pair of eyes.
2. This system will reduce the false positives (FPs), which will help in eliminating unnecessary biopsies and reduce cost being incurred.
3. This system will reduce patient examination time by inspecting mammograms and reporting the findings within a few seconds.

8.2 Contribution and Significance of Research

Thus, the primary contributions of this research as outlined in chapter 3 are:

- Preprocessing of the FFDM images to reduce the processing time and efforts
- Identification of the most suspicious likelihoods of abnormal lesions
- Characterization of the suspicious lesions to classify them as either benign mass or malignant tumor
- Fusion of single view and two views features for breast cancer diagnosis

### 8.3 Achievement of Research Objectives

As presented in Section 3.6, the specific goals of this research is to increase the diagnostic accuracy of image processing and machine learning algorithms for optimum classification between malignant tumors and benign masses. This classification accuracy in turn is useful in improving mammographic interpretation. In order to accomplish these goals, the research objectives outlined in Section 3.6 have been achieved and the same are discussed as follows:

1. The transformation and windowing technique has improved the visibility of the FFDM images. The modified fuzzy c-means algorithm has successfully separated the breast profile on the mammograms. The separated profile help in reducing the image width and hence computations for further processing. The scale space method has been applied to detect the breast border accurately. The morphological operations and modified RANSAC algorithms have shown encouraging results on pectoral muscle extraction. Thus, the algorithms designed and developed in chapter 4 are useful in effective preprocessing of FFDM images and are helpful in reducing the computational overhead on actual image analysis steps. Thus the algorithms for preprocessing have complied with the first research objective.

2. The chapter 5 has presented a proposed hybrid mechanism for segmenting candidate abnormal lesions on FFDM images. A novel algorithm for neighboring pixel selection reduces the computational complexity of fuzzy region growing algorithm to a great extent. Consequently, mammogram segmentation results have demonstrated that the segmentation efficiency is improved substantially by the proposed algorithm without debasing the quality of segmentation. The abnormality detection of the proposed algorithm is tested on different types of mammographic breast densities with sensitivity of 91.67% but at the cost of less specificity of 58.33%. Of course, there are some false
positives. The subjective evaluation of the detection by the radiologists involved in the study showed that the segmentation results are satisfactory. The IOU indices of all the lesions show that the results of the proposed segmentation algorithms are more closely resembling with the GT given by the radiologists. The empirical rules applied are proved helpful in reducing false positives to some extent. In this way, the algorithms developed in chapter 5 comply with the second research objective.

3. The reduction in false positives and improvement in the specificity is possible in the classification stage as discussed in chapter 6. A computer-aided mass detection scheme is expected to mimic the radiologists by selecting the small number of strong features performing robustly in the classification task to reduce the false positives. This selection should lead to higher possible accuracy with least false positives per image among a set of images to avoid unnecessary biopsies. However, the CAD systems are found to indicate many false positives beneficial to mass detection with some unnecessary biopsies. In this regard, our selection of features shows that the specificity of the overall diagnosis after classification is improved to a great extent as shown in Table 6.5 of chapter 6. This is because of the reduction in false positives with the help of classifiers using combination of geometric and textural features. Comparing the figures in Table 5.2 of chapter 5 with their counterparts in Table 6.5 of chapter 6, one can easily notice two changes. First, the overall performance of the proposed scheme is improved to a great extent. Second, there is proper balance of sensitivity and specificity. The classification performance of proposed method is comparable with other algorithms reported in the literature. The idea of combining the geometric features with textural features into the k-NN and SVM classifiers has yielded encouraging results with reduction in FPs. Thus, the classification algorithms implemented in this research are capable of reducing the number of misclassified cancers (FPs), which complies with the third objective of the research.

4. The significantly vital concurrent analysis for estimating likelihood of cancer of the abnormal lesions on the ipsilateral views of the mammogram is described in chapter 7. The proposed approach is more realistic as it closely
mimics the radiologist’s clinical practice of two views based analysis of breast anomalies. The preliminary results after fusion of single view features with two views information have demonstrated a slight improvement in the case based diagnostic accuracy and FPsI close to the film based scheme. The findings of proposed two view scheme are significantly useful compared to the traditional single view CAD systems. The proposed algorithms are helpful to improve the outcomes and efficiency of two views CAD system for assisting the radiologists during their diagnostic decisions in clinical practice. However, the results obtained can be further optimized in terms of case-based sensitivity and specificity. The perfection and accuracy in automatic nipple detection can be improved further and we are attempting to do the same to enhance the performance of our proposed approach. The overall performance improvements in our proposed algorithms are encouraging to increase the potential usage of our two views CAD system as a “second reader” in breast cancer diagnosis. Thus, the fusion of single view features with two views score using ipsilateral views of mammograms with improved case based lesion detection at a comparable FP rate complies our fourth objective of the research.

8.4 Impact and Significance to Radiologists

The framework developed for the computerized breast cancer detection system in Figure 1.1 has potential to be a part of CAD system. The radiologists are satisfied with the performance of the algorithms but are expecting further improvements in detection mechanism. They are happy with the classification results of malignant and benign abnormalities.

8.5 Conclusion

This preliminary clinical study reveals the potential of proposed hybrid mechanism for segmenting candidate lesions and characterizing them as benign masses or malignant tumors on FFDM images. A novel algorithm for neighboring pixel selection reduces the computational complexity of fuzzy region growing algorithm to a great extent. The novel scheme for segmentation of suspicious lesions yield good results but need to be improved in order to provide higher sensitivities with fewer
false positives. Experiment on a wide variety of suspicious lesions shows that classifiers have achieved better performance by maintaining tradeoff between sensitivity and specificity. The classification algorithms are trained and tested on actual cases from real clinical practice and on publicly available dataset as well. The accuracy of the classification depends on the features used and the type of the classifier. The accuracy of the classifiers was found very interesting. A combination of specific geometric and textural features of suspicious lesions with classifiers lead to the significant reduction in FPsI and subsequently the improvement in specificity up to 91.67% with 85.56% sensitivity. The overall performance of the proposed scheme is promising with a proper balance of sensitivity and specificity. Thus the proposed scheme has potential to be a part of CAD system to assist radiologists in clinical decisions regarding breast cancer diagnosis.

8.6 Future Scope

The results of the algorithms for detection and diagnosis of breast cancer, though encouraging, are not yet sufficiently conclusive to directly incorporate into a CAD for actual clinical practice. In order to make the algorithms ready to use in CAD system for clinical practice, we are looking for the future work as follows.

- Using soft computing techniques for the improvement in the breast border detection algorithms, nipple detection algorithms and pectoral muscle extraction algorithms to handle difficult cases.
- Incorporating the particle swarm optimization with adaptive fuzzy region growing method for improving abnormal lesion detection even in case of difficult images with higher segmentation accuracy and least possible FP rate.
- Making use of Genetic algorithms for improving learning techniques and in turn the performance of k-NN and SVM classifier.
- Carrying out the experiment on large dataset of FFDM images belonging to at least 500 patients to verify the robustness of the proposed system and modify the algorithm to yield higher sensitivity with least FPsI.

Due to the tremendous advancement in image acquisition devices, the data is quite large that makes it challenging and interesting for image analysis. This rapid
growth in medical images and modalities requires extensive and tedious efforts by medical expert that is subjective, prone to human error and may have large variations across different experts. Deep learning is a type of machine learning that can analyze data, recognize patterns, and has the potential to make more accurate predictions. Deep learning will not only help to select and extract features but also construct new ones. Furthermore, it does not only diagnose the disease but also measure predictive target to provide actionable prediction models to help physician efficiently. The recent advent of deep learning has replaced many other machine learning methods, because it avoids the creation of hand-engineering features, thus removing a critical source of error from the process. Hence, as our major future work, we intend to apply deep learning techniques to large volume of mammographic images to enable earlier and more accurate disease detection.