

Effectiveness of Existing CAD-Based Research Work towards Screening Breast Cancer

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Abstract—Accurate detection as well as classification of the breast cancer is still an unsolved question in the medical image processing techniques. We reviewed the existing Computer Aided Diagnosis (CAD)-based techniques to find that there has been enough work carried out towards both detection as well as classification of the breast cancer; however, all the existing techniques were implemented in highly controlled research environment. The prime contribution of this paper is it reviews some of the significant journals published during 2005–2016 and discusses its effectiveness thoroughly. The paper finally discusses about the open research issues that require a serious attention from the research community in order to address the existing issues. At the end, the paper makes some suggestion for carrying out future work direction in order to bridge the research gap explored from the existing system.

Keywords—Breast cancer detection; computer aided diagnosis; cancer; classification

I. INTRODUCTION

Breast cancer is one of the prominent reasons of mortality among the women in many countries. One of the most challenging and unfortunate part of this disease is that maximum women understand that they have breast cancer in latter stage and not in early stage. For this reason, preliminary prevention mechanism becomes one of the most challenging aspects [1]. The diagnosis of the cancer is carried out with respect to presence of micro-calcification and masses that are explored after the mammography is carried out. The x-ray based mammograms are considered as the prime screen test for evaluating as well as diagnosing the disease in its early stage, whereas its processing followed by analysis is considered to be best prognosis factor [2]. In a mammogram, the benign glandular tissues as well as the masses normally exist in very minimal contrast and are found to be quite blurred in nature. This strikes a significant challenge to the radiologist to understand the significance of the disease. Therefore, various professionals and researchers have been evolving up with a scheme that can assist in proper interpretation and diagnosis. Till date, there is no such mechanism for resisting the breast cancer to occur. Hence, the preliminary detection is the first significant step towards the diagnosis and treatment of the breast cancer. In this regards, Computer Aided Diagnosis (CAD) based techniques assist in providing us various mechanism for both prognosis as well as diagnosis [3], [4]. From this viewpoint, mammography is one of the most practiced methods for early screen of breast cancer. It has also

the added advantage of cost effectiveness and higher availability. Irrespective of its advantages, mammography suffers from the issues of low reliability when it comes to detection of dense breast tissues. This causes higher sensitivity to the dense tissue but better detection performance over the micro calcification [5], [6]. There are different forms of abnormal conditions found in mammograms e.g. architectural distortion, microcalcification, asymmetry, masses, etc. Because of this reason, maximum quantity of the mammograms will be required to be cross checked by the radiologists who are less in numbers in comparison to mammograms. This causes significant misdiagnosis as one radiologist has to interpret many numbers of mammograms by their naked eyes. This process eventually causes stress to eyes leading to error in interpretation. Adoption of digital image processing as well as pattern recognition in CAD techniques is quite frequent in order to perform an effective detection followed by classification of the breast cancer. Unfortunately, the most frequently used screening programs of breast cancer cannot forecast the prognosis for the situation of the patient is really suffering from breast cancer. In such condition, the cells spread very fast and take the shape of malignancy stage which is less likely to be controlled by common drugs. Apart from this problem, another bigger set of problem is medical image itself is a quite challenging signal which is very different from natural images. This is also the prime reason why normal object-based detection or classification approaches are not directly applicable on medical images. Normally, medical images are bigger in size and they are usually grey scale, which makes the diagnosis more difficult. Poor illumination condition, artifacts, external factors while taking the images are also equally responsible for increasing challenges in diagnosis of medical images.

Apart from the discussion presented in [7]-[9], there are no review work till date to evaluate the effectiveness of existing techniques of breast cancer. Hence, this paper presents an updated review of effectiveness in CAD-based method for screening breast cancer with respect to detection mechanism and classification techniques. Section II discusses about the essential fundamental information about the CAD-based screening of breast cancer. Section III discusses about the existing research contribution towards detection and classification followed by briefing of open research issues in Section IV. Finally, Section V concludes the paper.

II. PREAMBLE: BREAST CANCER SCREENING

Computer Aided Diagnosis (CAD) is the most frequently used practices for screening the breast cancer. The primary target of using CAD schemes is mainly to segregate the region containing masses that is suspected with carcinoma from parenchyma in the background [10]. Usage of CAD schemes allows the radiological images of breast cancer in the form of numerous regions that doesn't intersect with each other followed by extracting the segment within an image bearing strong clinical significance (see Fig. 1).

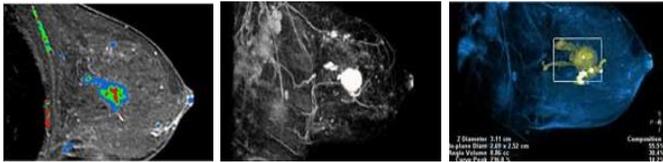


Fig. 1. CAD-generated images of breast cancer.

The CAD mechanism has been used in the medical sector in order to enhance the level of efficiency as well as accuracy from the radiological images so that physician can take decision of treatment based on the criticality of the disease from the CAD generated images. All the radiological images are interpreted by the CAD system which is again divided into two types, i.e. 1) CADE; and 2) CADx [11]. CADE is basically used for detection of the region of the breast inflicted with cancer while CADx is used for making essential classification. Hence, both the techniques are quite important for making decisions. At present, there are various other techniques based on image processing e.g. discrete wavelet transform [12], fractal analysis [13], Markov random field [14], etc. Although detection becomes very important when it comes in early stages, however, owing to the complex nature of the disease, it is quite difficult to perform positive detection. The frequently exercised clinical belief of positive detection of breast cancer is the presence of masses or micro-calcified part. This is the prime reason of maximum work towards cancer detection is based on microcalcification and detection of masses [15]-[17].

A. Tools for Diagnosis

Basically, the mechanism of screening breast cancer is by using mammogram, magnetic resonance imaging (MRI), as well as clinical breast examination. The clinical breast examination is carried out by visually examination while mammogram is carried out using x-ray to reconstruct breast image. Breast MRI uses magnetic fields and is highly invasive as compared to mammography (see, Fig. 2).

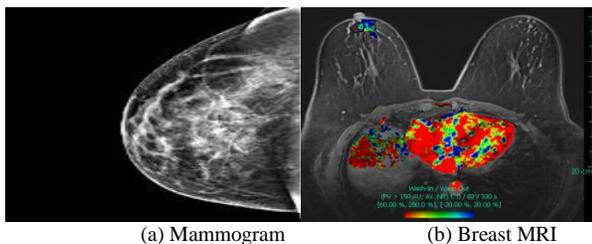


Fig. 2. Screening mechanism of breast cancer.

B. Problems in Existing CAD System

The common imaging tools to extract images are ultrasound, mammography, positron emission mammography, molecular breast imaging, etc. These techniques are frequently used for identification of cancer from dense tissue within a breast. Although CAD based system to generate radiological image of breast give better visual field for assessing the presence of cancer, but yet physician believe that they can be wrong too. For an example, mammogram is one of the effective mechanism to find cancer but only in early stage however, accuracy of mammogram is still questionable as it is still less invasive. Basically, a mammogram can never provide that the abnormally identified area is infected with cancer. It is only based on the skill of radiologist or the physician that the true inference could come. This is the reason certain physician suggest going for high end screen test for breast cancer. Another bigger limitation of mammogram is that it fails its diagnostic capability for dense tissue within a breast. At the same time, when people believe that breast MRI is highly accurate and suitable for cancer detection, radiologist believes it in otherwise. It is because breast MRI uses a contrast agent causing reaction [18] and occurrences of false positives are more in breast MRI as compared to mammogram. There are certain types of biopsies that are carried out on the basis of breast MRI. It is only possible in breast MRI and not in mammogram, but it has dependency of highly skilled professional to do so making it one of the expensive diagnostic processes compared to mammograms. Frequent occurrences of the higher false positives also provoke the doctor to suggest for extra biopsies causing anxiety and stress to the patients. Ultrasound is another frequently used practice to differentiate between solid masses and cyst. Although, sometime it could be also employed to differentiate between malignant and benign stage, but still usage of ultrasound is not much recommended as compared to mammogram in breast cancer.

Moreover, risks of false positives are more in CAD-based techniques. Certain area can be interpreted as abnormal in mammogram but in originality, it may be quite normal, hence, it gives rise to false positives. There is another type of cancer called as ductal carcinoma in situ which is not at all a type of invasive cancer. It may be rather called as benign and never malignant as it just stay within the breast duct and never spreads out. This is the condition when there is a need of an effective classification process of detecting it as benign or malignant type of cancer. Hence, an effective algorithm is required to solve such issues.

Normally, a CAD-based algorithm [19], [20] needs its input in the form of digitized image. Hence, if the image is generated by any other analog means than it has to be altered to digital signal for applying CAD based algorithms before applying the detection or classification approaches. At present, majority of the methods of validating the CAD system is basically based on laboratory-based experiments and no such computational modeling is yet prototyped for this cause. However, sensitivity and specificity is the only mechanism to check the legitimacy of the claims of absence or presence of cancer for a given image. The next section will brief about the existing research work towards the detection and classification of the breast cancer.

III. EXISTING RESEARCH WORK

This section discusses about the existing research work being carried out towards measuring effectiveness of imaging technologies evolved for detection and classification techniques of breast cancer.

A. Detection Techniques

Majority of the detection techniques adopts CAD techniques for assessing the criticality of the radiological image of breast. The prime purpose is to ensure that the image provides more information that could assist in detection of the critical regions infected with carcinoma. One of the recent studies shows that human factor significant affects in the cancer detection process. The study on such direction was carried out by Singh et al. [21] by introducing descriptor-based technique called as polar complex exponential transform followed by feature extraction of region suspected with cancer. The study outcome was testified with ROC curve to find more than 97% of accuracy. Usage of imaging from Ultra-Wide Band microwave was considered in the study of Li et al. [22] who have implemented a detection technique on the basis of empirical mode decomposition. The author have used experimental approach using oscilloscope, switching matrix, amplifiers, differentiator, and pulse pattern generator for performing detection of cancerous part of breast. Adoption of microwave system as well as similar experimental approach was also found in the work carried out by Santorelli et al. [23]. A circuit board of multiple layers is designed in order to monitor breast cancer. Thermo Acoustic Imaging is another novel form of medical imaging techniques that was also reported to be used for breast cancer detection. A study conducted by Wang et al. [24] has used contrast while performing Thermo Acoustic Imaging. An experimental as well as simulation-based approach was used considering real-time breast phantoms. Yin et al. [25] have adopted ultra-wide band imaging mechanism to perform detection of breast cancer. The authors have focused on tumor detection problem due to certain complex tissues and uses correlation-based pairwise weighting as a solution. The study outcome was found to be resilient against artifacts and exhibits enhanced detectability skills. Song et al. [26] has adopted experimental approach to solve the problem of breast cancer detection. The authors have used circuit design using Gaussian monocycle pulse with antenna array of ultra-wide band. The technique allows the generated signal to be transmitted on specific frequency to transmitter using switching matrix. A prototype is designed for identification of breast cancer with 1-cm accuracy limit. Kwon et al. [27] have adopted time domain for enhancing the radiological image generated by microwave imaging system in order to perform detection of cancer. The technique has used Gaussian band pass filtering using simulation-based approach. The study outcome was evaluated with respect to signal-to-mean ratio. Adoption of medical images from ultra-wide band was also seen in the work carried out by Jalilvand et al. [28] where the authors have used a three-dimensional identification system for breast cancer using bowtie antenna. Basically, authors have implemented near-field imaging mechanism. Kirshin et al. [29] have presented a study where medical image of breast cancer was obtained from both microwave radar and thermo acoustic imaging for

enhanced detectability. The study uses time-domain approach of finite difference. The study outcome was studied with respect to Peak-To-Side Lobe Ratio (PSLR) and false alarms. Shahzad et al. [30] have presented an enhanced beam forming-based technique in order to mitigate the phase effects as well as dispersion using a novel pre-filtering approach. Hossain et al. [31] have presented a technique using enhancement for microwave imaging that could leverage the detection system significantly. Using MRI image phantoms, the technique applies beamspace transformation in order to mitigate the skin-based artifacts and enhance the imaging performance. Bassi et al. [32] have presented an experimental approach where CMOS is used along with antenna patch for obtained microwave images of breast cancer. The unique radio transceiver has been designed for this purpose in order to identify tumor on breast phantom. Peter et al. [33] have developed a unique imaging mechanism using single frequency in order to enhance the performance of breast cancer detection. The study outcome was testified using ROC curve. Ruvio et al. [34] have presented a discussion to show that multi-frequency-based technique with numerous classifications of signals provides an effective detection performance. Guardiola et al. [35] have presented a imaging technique by integrating tomography with three dimensional microwave for the similar purpose of breast cancer detection. However, the focus is more on algorithm efficiency than on imaging. Using three dimensional phantoms, the microwave signals are found to provide better detection capabilities. Similar category of the work is also carried out by Grzegorzczak et al. [36]. Usage of thermoacoustic imaging along with microwaves has been used for generating reconstructed image for breast cancer detection by Wang et al. [37]. Aguilini et al. [38] have discussed about a Matlab-based approach for converting MRI image in the form of contrast maps in order to assists in detection of breast cancer.

B. Classification Techniques

This technique is more towards understanding the type of the disease or the specification of the criticality. Majority of the research technique evolved in due course of time are related to categorizing the cancer stages and disease criticality based on the successful detection techniques. Hence, the successful classification techniques can only happen if the detection technique is successful. Work in this direction has been recently carried out by Bekker et al. [39] where a classifier has been designed using logistic-based technique as well as stochastic approach. The prime idea was to classify benign and malignant stage of cancer. The study outcome evaluated with respect to performance parameters e.g. accuracy, sensitivity, specificity, etc. A problem of classifying micro-calcification was also investigated by Chen et al. [40] where multi-scale morphology is used for analyzing the topology of the micro-calcification. The system also generates graph of micro-calcification depending on the spatial connectivity. Gangeh et al. [41] have presented a technique of computer-aided theragnosis of non-invasive nature. The technique has adopted an attribute based on the kernel using learning depending on arbitrary under sampling. Spanhol et al. [42] introduces a technique where the comprehensive dataset was developed in order to perform analysis / classification of breast cancer. The outcome was found with 85% of accuracy. Vu et al. [43] have presented a technique of involuntary feature extraction using

dictionary learning technique. It was found that the dictionary significantly assists in classification process. Uniyal et al. [44] have implemented a technique that uses time-series analysis to perform classification of the malignancy in breast cancer. The technique generates a map of malignancy using machine learning approach. Soares et al. [45] have developed a modeling technique that performs classification of significant features using multifractal scaling exponent. Krawczyk et al. [46] have presented a technique of classification based on thermogram image of breast. The technique extracts thermogram images for analyzing bilateral symmetries and applies ensemble classification technique. The technique develops classifier based on neural network and evolutionary algorithm. Liu et al. [47] have developed a new feature extraction technique using supervised learning technique over mammogram. An extensive statistical procedure was adopted to testify the effectiveness of the proposed study. Amaral et al. [48] have presented a technique that performs involuntary classification and ranking of the significant portions in microarrays. Ashraf et al. [49] have introduced a technique of classification of breast cancer using Markov Random Fields. The technique is based on single channel Markov Random Fields. Filipczuk et al. [50] have presented a technique of diagnosing breast cancer using cytological images. The study

outcome was found to possess 98% of effectiveness to furnish potential information. Tripoliti et al. [51] have presented a classification technique using random forest. The technique also utilizes fitting method in order to obtain better accuracy. Dundar et al. [52] have introduced ROI-based classification technique along with training-based approach for categorizing intraductal lesion in breast. The author uses a prototyping along with feature extraction and training of classifier in order to achieve a better classification outcome. The study outcome was evaluated with respect to sensitivity and specificity. ROI-based technique was also adopted by Frascini et al. [53] where a wavelet as well as neural network was used for incorporating the classification process of breast cancer. Usage of metrological characteristics was seen in the work carried out by Mencattini et al. [54] in order to perform validation of the extracted features as well as its selection process. The technique also uses Monte Carlo curve in order to carry out simulation. Using ROI-based approach, the main classification algorithm of the presented technique will perform extraction of section with clinical interest that consists of segmentation, feature extraction, feature selection, and classification of tumoral mass. Classification technique was also applied on the medical images captured using ultra-wide band signals. One of such study was carried out by Teo et al. [55].

TABLE I. SUMMARY OF EXISTING RESEARCH IN BREAST CANCER DETECTION

Author	Problem	Technique Applied	Remarks
Singh et al. [21]	Minimizing human-factor involvement in detection	Polar Complex Exponential Transform, Wavelets, Neural Network	Pros:97% accuracy better than 7 existing techniques Cons: Accuracy depends on training.
Li et al. [22]	Tumor detection from reconstructed image	Experimental, 3D printing	Pros: Less accuracy for detecting position of cancer Cons: Not Scalable, will not support faster response
Santorelli et al. [23]	Imaging system for Tumor detection from reconstructed image	Experimental, microwave circuits,	Pros: Less accuracy for detecting position of cancer Cons: Not Scalable, will not support faster response
Wang et al. [24], Wang et al. [37].	Thermo Acoustic Imaging	Experimental, Simulation	Pros: Could use thermo-acoustic imaging Cons: Doesn't support faster response, no comparative analysis
Yin et al. [25]	Tumor detection from reconstructed image	Correlation-based pairwise weighting	Pros: Resistive of artifacts. Cons: No discussion of accuracy
Song et al. [26]	Imaging system for Cancer detection	Experimental, CMOS circuits, microwave imaging	Pros: Good Detection performance Cons: No comparative analysis
Kwon et al. [27]	Enhancing image for cancer detection	Simulation, Gaussian band pass filtering	Pros: -NIL- Cons: Doesn't show better outcomes, needs more tuning.
Jalilvand et al. [28]	Imaging system for Detection of Tumor	Experimental, three-dimensional imaging, bowtie antenna	Pros: Good demonstration of detection on breast phantoms Cons: No comparative analysis
Kirshin et al. [29]	Imaging system for Cancer detection	Microwave radar and thermo acoustic image	Pros: Good PSLR performance Cons: No comparative analysis
Shahzad et al. [30]	Imaging system for Cancer detection in early state	Beamforming, prefiltering	Pros: Good accuracy Cons: No comparative analysis
Hossain et al. [31]	Imaging system for Cancer detection	Time-Reversal, Beamspace transformation	Pros: Good SNR performance Cons: Leads to Computational Complexity for big dataset
Bassi et al. [32]	Imaging system for Cancer detection	Prototyping transceiver using CMOS, microwave image,	Pros: good performance Cons: No comparative analysis
Peter et al. [33]	Imaging system for Cancer detection	Terahertz frequency,	Pros: 70% lesser discrimination value Cons: No comparative analysis
Ruvio et al. [34]	Comparative analysis of imaging system	Multifrequency Multiple Signal Classification	Pros: good detection capability Cons: No comparative analysis
Guardiola et al. [35], Grzegorzczuk et al. [36]	Imaging system for Cancer detection	Tomography, microwaves,	Pros: Supports complex images of breast cancer Cons: No comparative analysis

TABLE II. SUMMARY OF EXISTING RESEARCH IN BREAST CANCER CLASSIFICATION

Author	Problem	Technique Applied	Remarks
Bekker et al. [39]	Classification of micro-calcification	Logistic regression, stochastic	Pros: Simple empirical model Cons: Lesser Accuracy
Chen et al. [40]	Classification of micro-calcification	Multi-scale morphology, topology	Pros:96% of accuracy Cons: Doesn't emphasize on computational complexity.
Gangeh et al. [41]	Early cancer detection	Machine learning, multi-parametric approach	Pros: 90% accuracy Cons: No comparative analysis
Spanhol et al. [42]	Classification of breast cancer	Introduced a new dataset	Pros: Simpler Technique Cons: Accuracy controlled by training
Vu et al. [43]	Classification problems	Dictionary-based learning	Pros: 97% of classification accuracy Cons: Doesn't emphasize on computational complexity
Uniyal et al. [44]	Classification of malignancy	Random forest, time-series, machine learning	Pros: Simple ROI based classification Cons: No Effective comparative analysis
Soares et al. [45]	Diagnosis of breast cancer	Multifractal image analysis	Pros: Good Classification Cons: No Effective comparative analysis
Krawczyk et al. [46]	Classification from thermogram image	Bilateral symmetry analysis, neural network evolutionary algorithm	Pros: Good Accuracy Cons: Not computationally efficient technique
Liu et al. [47]	Feature selection for classification	Supervised learning techniques	Pros: Simple approach. Cons: Only comparable with learning-based techniques
Amaral et al. [48]	Classification based on microarray	Bag of visual words	Pros: Good Accuracy Cons: No Effective comparative analysis
Ashraf et al. [49]	Classification problems	Markov Random Fields, supervised training	Pros: Higher true positive cases Cons: Only comparable with learning-based techniques
Filipcuk et al. [50]	Diagnosis from cytological images	Hough transform, support vector machine	Pros:98% effectiveness Cons: Applicable to only one type of image database,
Tripoliti et al. [51]	Classification	Random forest	Pros: Good Accuracy Cons: No Comparative Analysis
Dundar et al. [52]	Classification	Feature extraction, training	Pros:84% of accuracy Cons: Computationally expensive process
Fraschini et al. [53]	Classification	Wavelet, neural network	Pros: Good Accuracy Cons: No Comparative Analysis
Mencattini et al. [54]	Classification	ROI, Feature extraction, Segmentation, Selection	Pros: Good technique to differentiate. Cons: No Comparative Analysis
Teo et al. [55]	Classification from UWB signal	Correlation	Pros: Can identify multiple morphology of lesion. Cons: No Comparative Analysis

IV. OPEN RESEARCH ISSUES

From the previous section, it was found that the existing research techniques have presented some of the deliberate attempts towards detection as well as classification of the breast cancer. The scopes as well as the advantages of the

existing techniques are summarized in Tables 1 and 2. This section will explicitly discuss about the open research issues after reviewing the existing techniques of detection and classification methods:

- *More Emphasis on Signal Generation Process:* It is widely seen that majority of the detection scheme have

emphasized on its microwave technologies and its generated medical images. The positive point in this is all such work has been carried out using hardware-based approach to prove its efficiencies of detection using breast phantoms. However, the major limitation will be the lesser extent of benchmarking and less effective comparative analysis. Another open research issues is that even using such sophisticated devices, the rate of false positives are not diminished to a significant extent. Because of this phenomenon, usage of ultra-wide band microwave images are more as compared frequently used MRI images in existing detection techniques.

- *Less Emphasis on Feature Extraction Process:* Although many of the existing techniques have extracted features but it has not been emphasized from mathematical viewpoint. It's the simple low-level feature that has been extracted. It is widely known that transform-based techniques are good for feature extraction but its usage was found quite limited in case of both detection and classification of breast cancer for existing system. Moreover existing feature selection process are less optimized and more iterative causing low impact on increasing accuracy of the detection process.
- *Less Optimized Frameworks:* Usage of computational framework is quite less when it comes to classification process of breast cancer. Some of the simplified works on micro-calcification gives a good shape of modeling but they cannot be re-used under different circumstances e.g. change of dataset, or inclusion of new algorithms, etc. Moreover, the ROC curve, accuracy, specificity, sensitivity, etc. are not found to achieve a significant change in their patterns.
- *Lesser Extent of Benchmarking:* At present, there is only little work that has actually being benchmarked. Moreover, more number of the research work is found without comparative assessment this causes unreliability factor for implying the presented system in real-time environment or changing to some other environment or complexity.

V. CONCLUSION

This paper has discussed about the significance of techniques used for screening breast cancer. There are two part of this where one part is related to real-time practices of radiologist in hospitals and another is where researchers practices with breast phantoms. After more than a decade of investigation towards CAD based techniques, it was found that majority of the existing techniques are shrouded by pitfalls which requires serious attention. Moreover, in existing system more emphasis is laid on to the process of capturing the disease and less on improving the accuracy. Moreover studies towards classification are quite less to find as none of the studies till date are found to be benchmark. Hence, our future direction of study will be to introduce a modeling of CAD tool for diagnosing breast cancer effectively with higher accuracy. As there are lesser journals towards considering MRI image, our

future experiments will be on the basis of MRI breast image to perform more critical detailing of tumors or lumps for reliable diagnosis.

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