Towards the Detection of Architecture Distortion in Mammograms: A Review

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ABSTRACT
Breast cancer is most frequently occurring disease among women. Early detection is a reliable method which can prevent breast cancer spreading to distant organs. Mammography is considered as the most reliable method for early detection. The purpose of this paper is to succinctly review recent progress and current state of art knowledge related to detection of architectural distortion in mammograms. Though it is a subtle finding owing to its random nature, it is actually the third most common way that breast cancer appears

General Terms
Bio-Medical Image Processing.

Keywords
Breast cancer, CAD (Computer Aided Diagnosis), Architectural distortion, mammography

1. INTRODUCTION
According to data available through Surveillance Epidemiology and End Results (SEER) it is estimated that 226,870 women will be diagnosed with and 39,510 women will die of cancer of the breast in 2012**.** Coming to the Indian Scenario facts from the National cancer registry programme states that, the frequency of occurrence of breast cancer was much lower in India as compared to western countries but since 2008, [2] there has been steadily raising incidence of breast cancer mainly, due to smoking, drinking, unbalanced diet etc. Worldwide 1.38 million women were diagnosis with this disease. At present, there are no effective ways to prevent breast cancers as its causes remain uncertain. The only viable solution is early diagnosis, which [3] increases both survival rate and the treatment options.

But every coin has two sides. Detection of suspicious deformity is a repetitive and weariness causing task. In the midst of number of cases being examined by a radiologist, only 8-10% is cancerous and thus a deformity may be overlooked [3]. According to a pathologist architectural distortion per se is not a mass. It is often due to a desmoplastic reaction in which there is focal disruption of the normal breast tissue pattern.

The aim of this paper is to give a deep perception of CAD system and related methods associated with architecture distortion. The stress is to give an idea of research done specially on architectural distortion alias subtle signs of cancer. Breast lesions are described and reported according to the Breast Imaging Reporting and Data System (BI-RADS™). According to BI-RADS™ an Architectural distortion is defined as the area where normal architecture is distorted with no definite mass visible [5]. An architectural distortion is basically a disruption of the normal random pattern of curvilinear and fine linear radio-opaque structures normally seen on a breast X-ray. [6] Distortion often appears as a stellate shape or with radiating speculations as shown in Fig1.

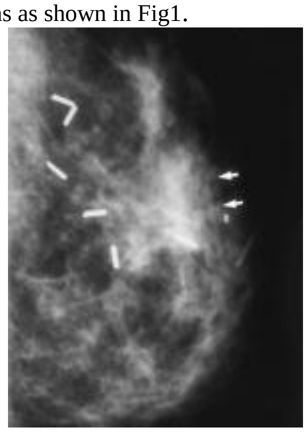

Fig1. Arrows pointing area of architectural distortion. [7]

Generally architectural distortion is considered as an associated finding which express that it can be used in conjunction with a finding to symbolize that the normal tissue structure is distorted or retracted surrounding the finding [6].
This paper is divided into IV parts. In section II, we have given an overview of Computer aided mammography. In section III Stress is laid to techniques used in CAD system for detection of architectural distortion. Section IV concludes the paper with possible future outcomes.

2. COMPUTER AIDED DIAGNOSIS
The visual assessment of a mammogram often results in identification of radio opaque artifacts in form of identification labels. The human visual system can easily ignore such artifacts during the interpretation. CAD has become a part of the day to day work for the detection of breast cancer in mammograms [10], [14], [15] and could offer a cost effective alternative to double reading as a means of reducing errors. The objective of CAD is to improve radiologist's accomplishment by pointing the sites of potential abnormalities, to lessen the number of missed lesions and by providing quantitative analysis of unique regions in an image that lead to better diagnosis. The working of a CAD system is as follows:

a) Radiologist traces out any suspicious area, which is followed by pre-processing.
b) CAD system scans the mammogram to detect suspicious features.
c) The radiologist then analyzes the prompts given by CAD system to verify again that any other suspicious are is left unchecked.

Computer-Aided diagnosis (CAD) has become a major research subject in diagnostic radiology. Image Checker, a CAD system developed in 1998 is used to detect breast lesions in mammograms, received FDA approval for clinical use. Since then, CAD technology has made great progress.

Research on various types of CAD system has great significance. Birdwell et al. [8] investigate the performance of a commercial CAD system in spotting cancers overlooked by radiologists. Another group of researchers Kita et al. [8] estimated the 3D locations of lesions in mammograms. The result showed the clinical promise of CAD system. Evans et al. [9]was pioneer in evaluating the ability of a computer-aided detection system to mark appearance of invasive lobular carcinoma in a large series of screening-detected consecutive breast cancers and system. They succeeded in identifying 17 of 20 cases of architectural distortion. Ciatto et al. [10] did the comparison between conventional mammogram reading and CAD reading on national proficiency test of screening mammogram and concluded that the performance of single reading with CAD is similar to that of double reading. Baker et al. [11] discussed the issue of sensitivity of commercial CAD system for detecting architectural distortion. Bornefalk [12] showed that there is additional matter of determining the CAD operating point by which a particular CAD system performs better than another on unseen data in a clinical setting. While R2 image checker [13] places an asterisk at site and CAD mark was considered as true if asterisk was anywhere within boundaries. But while evaluating CAD second look, the technique was to place a variable sizes oval to encompass location of possible mass. The sensitivity of former was 33% and that of the latter was 49. Brandon and Brown [16] considered the parameter of human variability in case of CAD systems and compared the detection performance of readers with and without CAD. The comparison was done with ROC characteristics, summarized by the reader averaged area under the ROC curve.

These outcomes indicate the need for further research in this field as the development of algorithms designed depends on certain performance metrics. The metrics provide meaningful and computable measure used for quantitative evaluation. It involves use of ground truth. The ground truth contains information on position, size and morphology of a feature. The various performance of a CAD algorithm can further analyzed through specificity, robustness, sensitivity, accuracy, reliability, adaptability and efficiency. The performance evaluation is needed in CAD system as it provides a quantitative method of evaluation an algorithm. But certain difficulties needed to be overcome like use of different database during testing. Beside this the mammogram may not be representative of clinical testing.

3. LITERATURE SURVEY

Literature survey reveals that different algorithms for computer aided diagnosis system have been suggested and developed. For the sake of comparison, it is very difficult to get a result as of which system is better one as it depends upon many factors like number of cases to be examined, type of abnormalities and database being used.

Considering that mammograms are images with low contrast and strong noise, pre-processing is especially important to improve image quality, thus, making the later feature extraction more reliable and classification more effective. A typical mammogram has two kinds of noises viz: black background and medical labels. To minimize these kinds of noise, a cropping operation is performed. Another problem with mammogram images is with respect to low contrast. Over brightness and darkness diminish the image features. In addition, the illumination conditions are generally different for mammograms acquired at different time. Thus, it is generally recommended to normalize the histograms before comparing two or more images on a specific image feature, such as texture. The Contrast enhancement techniques can improve the ability of a radiologist to retrieve subtle features. Beside this the radiation dose can be reduced by extent of 50% if contrast is improved to a considerable level. [17]. Yang et al have proposed two-stage process consisting of gradient enhancement and median filter based smoothing. The first level enhances gradient values of pixels with high intensities which are assumed to be potential mass pixels. While, the second stage uses a median filter to eliminate the noise in the [18]. High frequency noises had been removed by anisotropic diffusion filter [19]. The various types of mammogram enhancement techniques are histogram, equalization [20], CLAHE, Area Morphology, Multi scale processing [21] and Ground Truth Mask. Among almost all the enhancement techniques, the metrics have been used to measure the performance namely Contrast (ratio between image foreground, image background difference and sum), CII (Contrast Improvement Index), PSNR (Peak Signal-to-Noise Ratio) and SNR (Average Signal-to-Noise Ratio).The architectural distortion due to its subtle characteristics also needs improvement in its enhancement.

Many researchers have proposed various techniques for CAD of Breast neoplasm, but problem of detecting architectural distortion or subtle abnormalities still remains a hot area of research due to its varying and complex nature. Birdwell et al. [7] have shown empirically that subtle signs are more predominant in medial, subareolar and retro glandular regions of breast. The authors also clarified that missed lesions tend to occur in dense breast and are frequently found in the retro glandular region.

Karssemeijer and Brake [22] described a method that is based on the statistical analysis of a map of pixel orientations. If increase of pixels pointing to a region is found then region is marked suspicious. The authors showed that stellate lesions in mammograms have a much more complex appearance than artificial images. The classifier was built using a data set of features vectors taken from mammogram. The authors clarified that the Bayesian technique is based on the estimation of class conditional probability density functions of features for background and tumors points. A decision tree, subdivides regions in feature space into two subspaces, each time using a threshold in one dimension that separates two classes as much as possible.

Matsurba et al. [23] developed the notion for identification of architectural distortion existing around skin line and within mammary glandular tissues. To detect the suspected areas, top hat processing was performed. The technique was tested on 17 cases with focal retraction and was quite effective to detect architectural distortion.

Kelcz et al. [24] showed that mammographic management of architectural distortion can be challenging and frustrating as this finding is generally subtle and is sometimes seen on only a single projection. The authors conclude that cancer was diagnosed in 25% of cases sent to MRI after inconsistent mammographic characterization of architectural distortion. Incorporating breast MRI into the imaging algorithm can significantly alleviate the frustration associated with the mammographic workup.

Sampat et al. [25] has used the statistics of the physical characteristics of the speculated masses and architectural distortion to determine the parameters of the detection algorithm. The authors have proposed new types of filters called radial Spiculation filters. The main purpose is to enhance the spicule that can be approximated as linear structures. The spicules are modeled as lines of certain width or thickness. The authors computed radon transform of image and then perform filtering the radon domain to enhance linear structures. Due to its potential for detection of early cancer at prior mass formation stage, researchers have been directed towards the methods and techniques for detection of architectural distortion for better accuracy and lower complexity.

Ichikawa et al. [26] developed an automatic method for detecting areas of architectural distortion with Spiculation. The distorted areas are detected by concentration indexes of line-structures extracted by using mean curvature. After that, discrimination analysis of nine features is employed for the classifications of true and false positives. The employed features are the size, the mean pixel value, the mean concentration index, the mean isotropic index, the contrast, and four other features based on the power spectrum. The accuracy of the classification was 76% and the sensitivity was 80% with 0.9 false positives per image in our database in regard to Spiculation. Although method was effective in detecting the area of architectural distortion yet, some architectural distortions were not detected accurately because of the size, the density, or the different appearance of the distorted areas.

Wang et al. [27] discussed the case study of woman with multifocal Lobular carcinoma in situ (LCIS) involving an area of mammographic-ally detected architectural distortion. Feng et al. [28] work was related to ultrasound imagery. They described that Traditional two-dimensional ultrasound cannot easily find spiculations because spiculations normally appear parallel to the surface of the skin. Three-dimensional (3-D) ultrasound has been gradually used in clinical applications and it has been proven to be useful in determining the architectural distortion or Spiculation that surrounds a breast tumor. The author's aims to identify Spiculation from 3-D ultrasonic volume data of a tumor found by a physician. In the proposed method, each coronal slice of volume data is successively extracted and then analyzed as a 2-D ultrasound image by the proposed Spiculation detection method. First, in each horizontal slice, the modified rotating structuring element (ROSE) operation is used to find the central region in which Spiculation lines converge. Second, the stick algorithm is used to estimate the direction of the edge of each pixel around the central region. A pixel whose edge points toward the central region is marked as a potential Spiculation. Finally, the marked pixels are collected around the central region and their distribution is analyzed to determine whether Spiculation is present.

Li et al. [29] developed a new CAD technique for improving breast cancer in screening mammogram by focusing on the cancer missed by radiologists. They concluded that mammographic density at missed stage is closely correlated to that at detected stage while cancer on high dense mammogram was harder to detect by CAD.

Recent survey on subtle signs has shown that oriented features present in mammographic images are related to various normal structures in the breast such as vessels, ducts and fibro glandular tissue and to abnormal elements that may be associated with the presence of breast cancer based on definition of architectural distortion the organization of oriented features may be used to detect this subtle abnormality.

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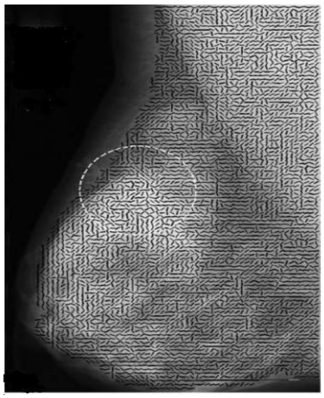

Fig 2 Orientation field [30]

Ayres and Rangayyan [30] used Gabor filters and phase portraits maps to determined oriented texture in mammograms to detect architectural distortion. The sensitivity was found to be 89% at 4.5 false positive per images. The main limitation of this method was complexity of the algorithm and lot of computation time it takes to perform its operation. The orientation field retrieved is as shown in Fig 2 and typical steps in proposed system are depicted in Fig 3. Matsurba et al. [31] developed an automated detection algorithm for the suspicious area based on the concentration of mammary glands to assist physicians with diagnosis. The authors observed that directionality of a normal mammary gland is towards the nipple while that in abnormal gland is towards the distorted area. Matsurba et al. [31] developed an automated detection algorithm for the suspicious area based on the concentration of mammary glands to assist physicians with diagnosis.

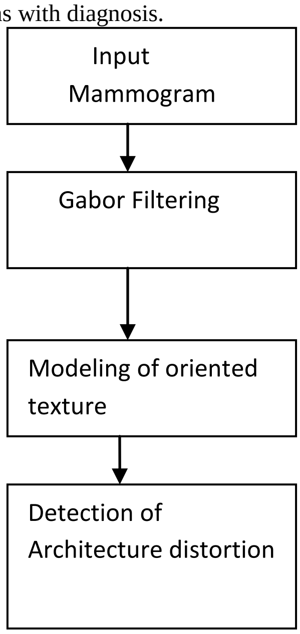

Fig.3 Typical steps of system based on oriented texture [30]

The authors observed that directionality of a normal mammary gland is towards the nipple while that in abnormal gland is towards the distorted area.

Bovik et al. [32] developed a method for the detection of spiculated masses in digitized mammograms. The techniques consist of two stages, enhancement of spiculations followed by the detection of the location where they converge. It was tested on digitized mammograms obtained from the digital database for screening mammography (DDSM).While the algorithm was not tried for the detection of architectural distortions but can be modified to do so.

Guo et al. [33] find out the behavior of architectural distortion using Hausdorff dimension. The authors used SVM based classifier to distinguish between distorted and non distorted areas. Sampat et al. [34] proposed a new class of linear filters called Spiculation filter. The authors showed that unmodulated versions of these filters can be used to detect the central mass region of spiculated masses and were precisely called toroidal Gaussian filters. Rangayyan et al. [35].studied the characterization of architectural distortion in mammographic ROIs using phase portraits. A sensitivity of 76.5% and specificity of 76.4 % were obtained. Ayres and Rangayyan [36] moved one step further when they included a shape constrained on the phase portrait model. This resulted in achieving sensitivity of 84%.Tourassi et al. [37] investigated the fractal dimension (FD) of mammographic regions of interest (ROIs) using the circular average power spectrum technique. Initially, the variability of the FD estimates depending on ROI location, mammographic view and breast side was studied on normal mammograms. The effect of several factors such as ROI size, image sub sampling and breast density was studied in detail. Overall, the average FD of the normal ROIs was statistically significantly higher than that of the ROIs with AD.

Eltonsy et al. [38] described a method for tracing out the architectural distortion based on the identification of points surrounded by concentric layers of image activity. The sensitivity was found to be 91.3% with 9.1 false positive per image.Rashed et al. [39] proposed an effective supervised classifier using the discrete wavelet transform. They have discussed that in some cases there were no suitable difference in shape between benign and malignant lesion and it could be identified only through biopsy. Since the texture of mammogram is an irregular texture therefore features like entropy, energy, contrast and homogenous nature could be improved when texture is combined with multi resolution transform. Spiculated lesions were classified better than circumscribed lesion, microcalcifications, and normal tissues. But there was no fixed range that could be detected for ill defined lesion. The authors also missed out the effect of testing with other wavelets other than Daubechies.

Banik et al. [40] introduced the concept of prior mammograms where the screening mammogram was obtained in the visit prior to that when breast cancer was detected. The author used estimated Fractal dimension of each ROI. The FROC (Free receiver operating characteristics) analysis done with a set of four features including fractal dimension, entropy, sum entropy and inverse difference moment provided a sensitivity of 79% with 8.9 false positive per image. Banik et al. [41] traced out the detection of architectural distortion, in mammograms of interval-cancer cases taken prior to the diagnosis of breast cancer, using Gabor filters, phase portrait analysis, fractal dimension, and texture analysis. For each ROI, the fractal dimension and Haralick texture features were computed. Analysis of the performance of the methods with free-response receiver operating characteristics indicated a sensitivity of 0.80 at 10.5 false positives per image. Biswas and Mukherjee [42] designed an intelligent set of distinctive textures for identifying architectural distortion in digital mammograms. Their model assumes that every mammogram can be characterized by a bag of primitive texture patterns and the set of textural primitives is represented by a mixture of Gaussians.The results obtained on two publicly available datasets, namely MIAS and DDSM; demonstrate the efficacy of the proposed approach.

4. ROC AND FROC

Receiver Operating Characteristic (ROC) and Free-response Receiver Operating Characteristic are the two graphical methods to analyze factors like sensitivity and specificity. ROC graph is a plot between sensitivity and specificity. ROC graph is used for diagnosis and classification purpose. While the FROC graph is used to where the radiologist has to detect and localize multiple lesions on the same image. It is a curve between sensitivity and false positive index.

5. CONCLUSISON

Since the scope of this review paper is focused on detection of subtle signs, only CAD techniques used for detection of architectural distortion is discussed. A number of CAD algorithms have been developed. However, it is extremely difficult to make a fair comparison as they are often evaluated with varying databases. Having more public datasets for evaluating the detection technique could help better understand the current status of the field. CAD offers a suitable alternative in reducing errors in mammographic screening to a level comparable to that achieved with double reading. From the above literature survey the findings did not show the sensitivity of CAD to be significant for lesion location, lesion mammographic size, breast density, o r age of the patient. However, findings did show that CAD was more sensitive in identifying calcifications than masses. But smaller numbers of methods for the detection of architectural distortion have been proposed.

The vast amount of research related to analysis of mammography, as well as widespread interest from the medical community stimulates the development of for new CAD systems. There is further need to develop more effective CAD systems that may lead to reduction in complexity, Robustness again quantum noise, while maintaining the system accuracy to improve the detection of subtle signs of breast cancer. Besides mammography, other imaging modalities such as MRI and 3-D ultrasonography can be further investigated in the literature. The information obtained from these modalities could be useful for validating the ground truth used for current and new methods.

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