Estimation of Architectural Distortion in Mammograms using Fractal Features

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***Abstract*–Moving towards accurate breast cancer detection, X-ray mammography is the gold standard in medical imaging for its efficiency and reliability. Abnormalities often encountered in mammograms are in the form of benign or malignant masses, calcifications, asymmetry and architectural distortion. Other than masses and calcifications, architectural distortion should not be overlooked, since it is often the major cause of non-palpable cancer. However, due to the appearance variability and subtle differences of the abnormalities from the tissues, the radiologists face ambiguity to detect and differentiate the malignant one from the benign one. Due to the existence of irregular and ill-defined structure in architecturally distorted areas, fractal features namely fractal dimension and lacunarity are considered in our work to differentiate the malignant architectural distortion from the benign architectural distortion. Our study can provide a second opinion to the radiologists in decision making. The performance of the proposed system has been evaluated with a dataset of total 19 mammograms with architectural distortions from the mini-MIAS database. The Mann Whitney Wilcoxon nonparametric test shows the statistical significance of fractal features in differentiating the abnormal mammograms from the benign ones. Based on the experimental results, we found that the combination of fractal dimension and lacunarity feature gives a prediction accuracy of 90%.**

I. Introduction

Breast cancer is one of the major causes of cancer related deaths in women [1]. Survival rates are low in less developed countries due to lack of accurate detection [2]. X-Ray Mammography is considered as the gold standard screening modality for breast cancer. Abnormalities present in mammogram mainly constitute of circumscribed and spiculated masses, architectural distortion, asymmetry and calcifications [3]. Masses and calcifications are the most common form of abnormalities which are considered as pre-cancerous or cancerous conditions [4]. However, architectural distortion should not also be overlooked, since it is the most common sign of non-palpable breast cancer. Analyzing the architectural distorted sites can lead to detection of abnormality at an early stage. As defined by BI-RADS [3] the normal area is distorted in architectural distortion with no mass visible. Architectural distortion is normally categorized as malignant or benign, where the malignant distortions represent the cancer and benign distortion includes scar and soft-tissue damage due to trauma [5]. Based on the characteristics of the distorted area having asymmetric, localized distorted patterns, poorly circumscribed opacities with ill-defined and irregular contours, the fractal features are found to be effective in differentiating these differences. Fractal features has found its wide applications in various imaging modalities such as in detection of breast abnormalities in mammograms or thermograms and in brain tumor detection from Magnetic Resonance Images [6, 7, 8, 9]. Fractal Dimension quantifies the space filling capacity of a fractal pattern and lacunarity quantifies the way in which the space is occupied by the shape with respect to their gaps [10]. Here in this work, the space filling capacity of the distorted area is determined by using fractal dimension and the Lacunarity is used to extract the information about how the space is filled by the distorted area. Based on the way of space filling, benign and malignant cases can be distinguished.

Over the last few decades, various authors have worked on classification of various abnormalities in breast mammograms especially benign and malignant masses, but to the best of my knowledge, no work has been focused on determining the malignancy and benign nature of architectural distortion. Mudigonda and Rangayyan [11] had used texture flow field analysis for the detection of malignant tumors in mammograms. The masses were classified in benign and malignant cases based on five texture features. Chen et al. [12] applied fractal analysis for differentiating benign and malignant breast lesions based on the difference of gray values of the neighboring pixels. Guo et al. [10] had applied the concept of fractal analysis to characterize and distinguish both lesions and normal breast parenchyma in mammograms. Our study investigates feasibility of fractal features in differentiating benign architectural distortions from malignant architectural distortions in mammograms.

II. Methodology

Fractals are self-similar repetitive patterns that are more detailed in nature as the scale of observing window increases. For estimating the features for architectural distorted sites, the region of interest chosen in our work is based on the centre coordinates and radius, provided in the mini-MIAS database for each image [13]. It is followed by the computation of fractal dimension and lacunarity measures of these regions by

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using box-counting and gliding box methods, respectively. To determine the dimension, the region of interest is laid on an equally spaced grid, and the number of boxes required to cover the whole set is counted each time by changing the size of the boxes. Let F be any non-empty bounded subset of R^n and let $N^{\delta}(F)$ be the minimum number of sets of diameter at most δ which can cover F. Then the fractal dimension is given by Equation (1). The fractal dimension is measured by observing how the number of boxes deviates as the grid becomes finer by applying a box-counting algorithm [14] on the region of interest (ROI). As shown in Fig. 1, the region of interest is divided into boxes and at each iteration the no. of boxes covered by the ROI is calculated. Finally, the graph is plotted for each iteration and the slope of the line gives us the fractal dimension. The plot for the box counts for malignant and benign architectural distortion has been shown in Fig. 2.

Lacunarity is a measure that can describe the fractals with same fractal dimension but different appearance. It shows the probability of occurrence of gaps at each box size and finally computes the mean $m_1(r)$ and the variation from the mean $m_2(r)$ [10]. It is a measure of variance of the number of pixels present in a box normalized by the square of the mean for obtaining a single value as in Equation (2)

$$\dim_B(F) = \lim_{\delta \to 0} \frac{\log N^{\delta}(F)}{-\log(\delta)} \quad (1)$$

$$\Lambda(r) = \frac{m_2(r)}{(m_1(r))^2} \quad (2)$$

III. Experimental Results And Discussions

For experimental purpose, a mammogram database namely mini-MIAS [13] has been used. Currently the mini-MIAS database consist of 322 images of normal and various breast abnormalities: calcification, circumscribed masses, speculated masses, ill-defined masses, architectural distortion and asymmetry. However, out of these 322 images, a set of only

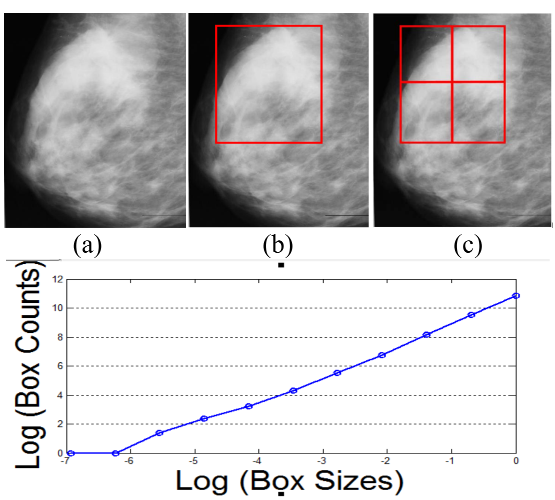

Fig. 1. (a) Malignant architectural distortion mammogram. (b-c) Process of Box Counting on the region of interest, (d) Plot of Box count versus Box size.

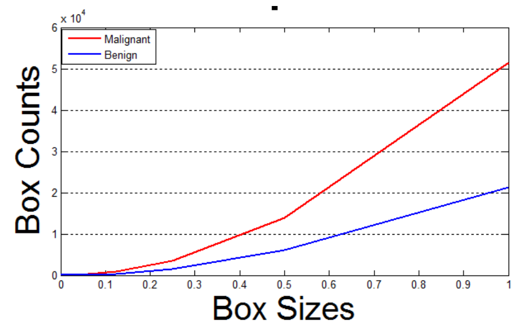

Fig. 2. Box Counting plot for malignant and benign architectural distortion.

19 images with architectural distortions has been found, which is considered here for the experimental purpose.

Due to the irregularity and heterogeneity present in the mammograms with malignant architectural distortion, the fractal dimension and lacunarity values of the region of interest in almost all abnormal cases were found to be higher than the benign cases. The nonparametric Mann-Whitney-Wilcoxon (MWW) test [15] with significance value of $p<0.01$ also proves the statistical significance of the fractal features in detection of malignant architectural distortion from mammograms as shown in Table I. The null hypothesis Ho: states that the median of the fractal features of malignant cases is equal to the median value obtained from the benign cases. It is observed that with $p<0.01$, MWW rejects the null hypothesis of equal medians at the default $p<0.01$ significance level for both features.

The analysis of the fractal features is followed by the classification of breast mammograms containing architectural distortion. To evaluate the performance of the proposed breast abnormality detection system, SVM classifier has been used for classification of the mammograms with benign and malignant architectural distortions. The feature vector consists of two fractal features: fractal dimension and lacunarity. Based on the classification results, it was observed that with combination of fractal dimension and lacunarity, an accuracy of 90% has been obtained.

As referred in the literary works, authors have found fractal features to be effective in distinguishing malignant and benign masses. In [11], Mudigonda and Rangayyan reported an overall accuracy of 74% in differentiating malignant masses from benign one by using texture features, while the system developed by Chen et al. [12] showed a better accuracy of 88.80% when using fractal features. Moreover, Guo et al. [10] had showed that among their five methods, the Fractional Brownian motion provided the highest area under ROC curve of 0.839 and 0.903 in two datasets respectively. Our experimental result also validates the efficiency of fractal

TABLE I P-Value of Fractal Features of Malignant and Benign Architectural Distortion.

Type of Mammograms	Fractal Features	
	Fractal Dimension	Lacunarity
Malignant Architectural Distortion	1.677662	1.059033
Benign Architectural Distortion	1.458781	1.005761
P-Value	0.00004	0.00003

dimension and lacunarity in differentiating malignant and benign distortions with an accuracy rate of 90%.

IV. Conclusion

This paper presents the performance analysis of fractal features in predicting malignant and benign architectural distortions from breast mammograms. Two fractal features, fractal dimension and lacunarity have been combined to classify the architecturally distorted mammograms into benign and malignant classes. The accuracy obtained approves that the fractal features are efficient in discriminating malignant architectural distortion cases from the benign cases.

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