Application of Fractals to Detect Breast Cancer

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ABSTRACT
Breast cancer is one of the major causes of death among women. Small clusters of micro calcifications appearing as collection of white spots on mammograms show an early warning of breast cancer. Image segmentation is an important element of Digital Image processing that subdivides the image into discrete regions/objects, each identified by the property of homogeneity of pixels. X-ray mammography is used as diagnostic tool for diagnosis of breast cancer. Edge detection of micro calcification clusters in mammogram images is the main issue of early detection of breast cancer. Fractals are of rough or fragmented geometric shape that can be subdivided in parts, each of which is a reduced similar of the whole. Fractal dimension and Hurst exponent are used to locate the micro calcifications in the mammogram. The concept of fractal is associated with geometrical objects satisfying criteria such as self-similarity and fractal dimensionality. Present method of edge detection is superior compared to conventional Sobel method, in which detection of edges of the regions or objects in an image takes place by the Fudge factor. The paper presents the application of fractals for early detection of breast cancer.

Key words: Mammogram, edge detection, fractal dimension, Hurst exponent

1. Introduction

Breast cancers are commonly associated with a high incidence and a high mortality rate in the female population worldwide. Mammography associated with clinical and self examination of breast is the only viable and efficient method at present for mass screening to detect breast cancer. Breast cancer is the main cause of death among women [1]. However, at a microscopic and molecular level, breast cancer is not a homogeneous disease. Accordingly, an early detection of breast cancer is an important research component for improving its prognosis. Screening mammography is the best tool available as on today to detect cancerous before appearance of any sorts of clinical symptoms appear. In this context, radiologist can judge the likelihood of presence of malignancy on the basis of shape and arrangement of micro-calcifications. Malignant calcifications are typically of different varieties, such as (1) clustered, (2) small and (3) dot-like or elongated. All the varieties are variable in size, shape and density. Literature study reveals that benign group of calcifications are generally larger, more rounded, smaller in number, more diffusely distributed and more homogeneous in size and shape [1]. Tests and procedures used to diagnose breast cancer include (a) breast exam, (b) mammogram, (c) breast ultrasound, (d) removal of a sample of breast cells for biopsy test and (e) breast magnetic resonance imaging. Basically, a mammogram is an X-ray of the breast which helps doctor to detect and diagnose breast cancer up to two years before the occurrence of tumor. Probability of long term survival of a
patient suffered from breast cancer can be improved by early detection of the disease and early detection is in turn enhanced by an accurate diagnosis. Even though risk factors like ageing, genetic disorder, family history, menstrual periods, not having children, obesity, alcohol, overweight, etc, are known by scientists, but appropriate reasoning of breast cancer is unknown in medical science and accordingly, prognostic methods for early detection is a challenging task. Symptoms of cancer include a lump in the breast or underarm that persists after menstrual cycle, swelling in the armpit, pain or tenderness in the breast, any change in the size, contour, texture, or temperature of the breast, a marble-like area under the skin. Some of the characteristics of malignant tumors are: clustered calcification, isolated ducts, poorly defined mass, etc. Several methods have been proposed for the characterization of ROI such as classical image filtering and local thresholding to contour region of interest. Researchers have attempted several computerized techniques such as method of fuzzy c–means, support vector regression, artificial neural network, naïve Bayes to detect the presence of microcalcification [2]. Nevertheless, the most work reported in the literature employs neural networks for cluster characterization. Each of such techniques has pros and cons. Therefore, an appropriate decision before diagnosis is an important issue. With the advent of artificial intelligence and machine learning technology, a large number of classification (benign or malignant) methods of breast cancer diagnosis are also envisaged. It can be easily said that characteristics of symptoms of breast cancer are of an irregular geometrical objects. Determination of dimension of these irregular objects by contouring or edge detection is the main motivation for developing an innovative method for early detection of breast cancer. In this context, we have developed a fractal technique as a tool for early detection of breast cancer. The paper presents the mathematical structure of fractals, physics of fractals and their application for early detection of breast cancer. Irregular geometry of breast cancer symptoms is due to high frequency component of image spectrum and the fractal dimension of this geometrical shape is evaluated by box counting method. Fractals being self similar object are allowed to grow to contour or detect the edge of the malignant tumor and fractal dimension quantifies the dimension of the target tumor. The remaining part of the paper is organized into four more sections. Section 2 describes mammography. In section 3, we have presented physics of fractals with their mathematical structure. Section 4 presents methodology of early detection of breast cancer using fractal technique and results of case study. Section 5 presents conclusion of the paper.

2. Background of Mammography

Mammography is known as the most efficient method to detect breast cancer. Experts separate the mammographic images in normal and abnormal images for detecting breast cancer. In order to seek to identify the characteristics of the affected tumor like: shape, definition of edges, roughness of contour, density and size for rating it as benign or malignant tumor, the corresponding images are studied more carefully. However, it is not appropriate to have conclusive results by this examination. In addition, limitations of mammography devices, viewing images can be impaired. Furthermore, there is not much variation between the contrast of the nodule and breast tissue in many cases. These aspects may interfere with the identification of the nodules, and in many cases, it can lead to misinterpretations of the expert examination. The benign tumors are well defined and usually rounded, have soft edges, of low density, while malignant tumors are often poorly defined edges and irregular contours. Malignant tumors often examined as self similar pattern with the
presence of specula, thus allowing users to apply fractals for the detection [3]. Fractal dimension and Hurst exponent may be the quantification scheme of the detection.

3. Physics of Fractals

A fractal is a mathematical object that is both self-similar and chaotic. Self-similarity of fractal signifies that if we magnify, we can see the object over and over again in its parts. In other words, fractals are of rough or fragmented geometric shape subdivided in parts. They are creased objects and are most often characterized by their fractal dimension. A fractal dataset is known by its characteristic of being self-similar. The dataset has roughly the same properties for a wide variation in scale or size i.e., parts of any size of the fractal are almost similar to the whole fractal. Fractals are forms that have fractional dimension, not obeying the traditional Euclidean geometry where the objects have entire dimensions.

3.1 Edge detection

Edge detection is one of the main tasks for contouring of the affected tumor. Edge detection technique uses the abrupt intensity changes among the pixels of an image. Edge is a set of connected pixels that lie on the boundary between two regions. The magnitude of the first derivative is used to detect an edge. The sign of the second derivative can determine whether an edge pixel is on the dark or light side of an edge. The first order derivatives in an image are computed using the gradient operator. The second-order derivatives are obtained using the Laplacian operator.

3.2 Fractal dimension

The fractal dimension contains information about the geometrical shape of fractals and therefore it is an important characteristic of fractal. The dimension of the object never changes whatever the object undergoes any transformation. This type of dimension is known as topological dimension, symbolized by d, introduced by Mandelbrot. The fractal dimension is a statistical quantity which measures the degree of fractal boundary fragmentation or irregularity over multiple scales. It also differentiates fractal from Euclidean objects (point, line, plane, circle etc.). A fractal can be classified according to their degree of irregularity. Fractal dimension is an effective measure for complex objects. It is widely applied in the fields of image segmentation and shape recognition.

3.3 Mathematical Definition

Mathematically, fractal dimension is defined by equation (1).

$$FD = \frac{\log N}{\log \left(\frac{L}{U}\right)} \quad (1)$$

where, FD represents the fractal dimension, N, the number of parts for each iteration, L signifies the initial length of the object , and U is the length of each segment. Now, in order to calculate FD, we have adopted Box-Counting technique in which the object is quantified on a plan with grid. Fractal dimension by Box-Counting technique is formulated mathematically by equation (2).
The fractal dimension can be any non-negative real number and can be estimated in several ways.

4. Methods

We have used the database of breast imaging-reporting and data system (BI-RADS). BI-RADS is a unitary system designed for helping medical professionals assess, interpret and classify mammography, ichnography and magnetic resonance imaging results in a concise and ambiguous and standardized way, by assigning numbers or numerical codes to different risk categories. For example, (a) BIRADS-I means that the breast is almost entirely fatty, (b) BIRADS-II signifies that there is some fibro-glandular tissue, (c) BIRADS-III means that the breast is heterogeneously dense and (d) BIRADS-IV means that the breast is extremely dense. All these four varieties are as shown in Fig. 1.

\[ FD = \frac{\log(N_{n+1}(U)) - \log(N_n(U))}{\log(U_{n+1}) - \log(U_n)} \]  

(2)

The fractal dimension can be any non-negative real number and can be estimated in several ways.
have used the box-counting technique to quantify the nodules to compute the fractal dimension of the region of lesion. Images were also analyzed for their edges and contours of the region of interest without concerning the mass density or texture.

4.1 Box counting
Box counting is a method of accumulating data or analyzing complex patterns by dividing a dataset, object, image, etc. into smaller and smaller pieces, typically "box"-shaped, and analyzing the pieces at each smaller scale [4].

4.2 Results
An algorithm is developed for detection of microcalcification clusters from a mammogram image. Input of this algorithm is a 2-dimensional mammogram image, I and output is an outlined edges of microcalcification in I. Algorithm written is as follows:

Algorithm:

Step 1: Read a 2-Dimensional input mammogram image I
Step 2: \([M, N] \leftarrow \text{SIZE} [I] \]
Step 3: If \(M > N\) then \(r \leftarrow M\) Else \(r \leftarrow N\)
Step 4: Compute fractal dimension \(D\)
Step 5: Dilate and erode \(I\)
Step 6: Compute Hurst coefficient \(H\)
Step 7: Detect the edges of \(I\) using Sobel operator with \(H\)
Step 8: Dilate the edge detected image
Step 9: Fill the interior gaps in the edge detected image
Step 10: Smoothen the image by erosion
Step 11: Outline the segmented image to detect the clusters
Step 12: Stop.

We have first found the fractal dimension \(D\) for the input mammogram image (I). We have used box counting method to estimate the fractal dimension, \(D\). Thereafter, morphological operations such as dilation and erosion are applied on I and results are shown in Fig. 2.
As the fractal analysis is sensitive to noise, application of morphological operations tend to suppress noise if any, in addition to image enhancement on the input image. In addition to estimation of Hurst coefficient factor the edge detection is done using Sobel operator. Both the results are analyzed. The edges constructed using Hurst coefficient is far accurate and are found to be confined to the microcalcification clusters. Results are shown in Fig. 3.

![Fig. 2](image)

(a) Original  (b) Dilated  (c) Eroded

The result of detection of microcalcification using fractal Hurst coefficient is shown in Fig. 4.

![Fig. 4](image)
5. Conclusion
Fractals have applied as a tool for early detection of breast cancer. Physics of fractals with its mathematical formulation are presented. Fractal dimension is used as the measure for detection of abnormality malignancy. Box counting technique is applied to compute the fractal dimension.

6. REFERENCES

[1] Crisan, D.A., Dobrescu, R. ;Planinsic, P., “Mammographic Lesions Discrimination Based on Fractal Dimension as an Indicator”. Systems, Signals and Image Processing, 2007, pp. 74-77.

[2] RaduDobrescu, Loretta Ichim, Daniela Crisan. “Diagnosis of breast cancer from mammograms by using fractal measures”, International Journal of Medica Imaging, 2013; 1(2): 32-38. Published online October 30, 2013 (http://www.sciencepublishinggroup.com/j/ijmi)

[3] Napolitano, A.; Ungania, S., Cannata, V., “Fractal Dimension Estimation Methods for Biomedical Images”, MATLAB - A fundamental Tool for Scientific Computing and Engineering Applications, vol.3, 2012.

[4] Sedivy, R.M.D., “Fractal Analysis: An Objective Method for Identifying A typical Nuclei”, Gynecologic Oncology 75, 1999, pp. 78-83.