Fractal Analysis of Digital Mammograms

Edis Đedović¹, Azra Gazibegović-Busuladžić¹*, Adnan Beganović¹,²

¹Faculty of Science, Department of Physics, Sarajevo, Bosnia and Herzegovina
²Clinical Center University of Sarajevo, Sarajevo, Bosnia and Herzegovina

Abstract

It has been shown that fractal analysis is useful in image processing, texture analyses and texture image segmentation. It is important to clearly detect edges of breast masses, and precisely locate individual microcalcification in mammograms. We present practical help in that area by fractal analysis, using the concept of fractional Brownian motion. It can be shown that there is a correlation between specific quantitative result of such analysis (Hurst coefficient) and the type of breast mass or tumor.

Keywords: digital mammograms, image segmentation, fractals, fractional Brownian motion, Hurst coefficient.

Introduction

Mammography is one of the main imaging techniques for breast cancer. However, confirmation of malignancy of a tumor mass registered on mammogram often relies on biopsy. It is important to correctly detect the edges of breast masses in order to classify them and successfully treat the cancer.

There are attempts to establish computer analysis of digital mammograms that would help physicians to correctly determine the edges of the breast masses and to classify them, and possibly reduce the need for biopsies. Fractal analysis of digital medical images are widely used for this purposes. Box counting method, ruler method, fractional Brownian motion method are some of them. In this paper we are analyzing digital mammograms applying fractional Brownian motion method to determine fractal dimension of specific regions, and so called Sobel method to segment individual microcalcifications and precisely determine the edges of microcalcification groupations. We are going to conduct this kind of analysis within different specified regions of interest (ROI-s). We intend to explore the correlation of obtained value of Hurst parameter and type of the analyzed tumor.

The base for this kind of medical image processing lies in the self-similar structure of human tissue. Self-similarity is the basic property of fractal object [1]. Fractal dimension of ROI-s is the measure of the roughness of digital image in the specified region and can be helpful in determination of concerning tumor type [2]. It is necessary to recognize ROI that includes suspicious objects that differs from surrounding tissue background in order to reduce time for computer analysis. It is possible to use MATLAB code that includes some predefined subroutines for adequately preparing and image processing in order to acquire proper image segmentation [3].
Methodology

Sobel method for edge detection

Edge detection technique uses the abrupt intensity changes between the pixels of an image. The edge consists of the pixels that lie on the boundary between two regions. The magnitude of the gradient, i.e. first derivative, is used to detect an edge. The first-order derivatives in an image can be computed using the Gradient operator. It is convenient to use Sobel method to calculate $x$ and $y$ gradient component. Pixel at position $(x,y)$ is going to be considered as one at the edge if gradient intensity calculated for that position is greater than some predefined value. We are going to use modified Sobel method that modifies that predefined value according to the roughness of the digital image. The MATLAB code used for the edge detection is given in the appendix.

Fractional Brownian function

Function $I(r)$ is considered as fractional Brownian function with Hurst coefficient $H$ when cumulative distribution function $F(z)$ is defined as:

$$F(x) = Pr\left(\frac{|I(r + \Delta r) - I(r)|}{|\Delta r|^H} < z\right), \quad z \in R. \quad (1)$$

Fractal dimension $D$ for digital images with self-similar structure is obtained as $D=3-H$

One need to calculate intensity difference for several distances $|r|$ to obtain multiscale intensity difference vector MIDV. Hurst coefficient can obtained from linear regression of MIDV on $|r|$ within log-log scale [4].

Morphological operators

Morphological processing of digital image implies changes of dimensions of specific objects on the image to obtain their segmentation and shape description. The basic morphological operations used in the paper are dilation and erosion. In digital morphology, a small pattern or shape, known as structuring element, probes the image. For the dilation operation, the area around a pixel is set as the structuring element and the original object is allowed to grow larger. Erosion is an operation on the image in which the pixels matching the structuring element are deleted.

Digital mammograms we are going to analyze are grey scale images. Intensity level function $I(x,y)$ of the pixel at the position $(x,y)$ carries the information about the tissue structure. Contrast enhancement is performed in the way that original value of intensity level function $I(x,y)$ is replaced with $I_{out}(x,y)$ on the final image histogram, so that it approximately matches some predefined histogram.

Results

On the figures Figure 1, and Figure 2 specific region of interest from digital mammogram II is presented before and after the segmentation. The edges of the microcalcificates are clearly visible after segmentation by modified Sobel method with Hurst coefficient for presented ROI. This coefficient is taken as the measure of roughness of the image.
Figure 3 and Figure 4 presents ROI of digital image I2 that contains grouped microcalcifications before and after image processing of segmentation by modified Sobel method respectively. Calculated value of Hurst coefficient for presented ROI of digital image I1 is 0.2002, and for presented ROI of digital image I2 is 0.2463. Value of Hurst coefficient depends on selected ROI, and especially whether it is calculated for entire rectangular ROI or for the region near the edge of suspicious object. The results of modified Sobel method should depend on the choice of the region for Hurst coefficient calculation, and we wanted to further investigate influence of this choice to the edge detection.

On the Figure 5 segmented microcalcifications for ROI-I3 are obtained with Sobel method modified by Hurst coefficient calculated for entire rectangular ROI, while on the Figure 6 microcalcifications are segmented with Sobel method in which intensity gradient is compared to combination of Hurst coefficients calculated for entire rectangular ROI and for the narrow region around suspicious area.
Conclusions

Modified Sobelov method of segmentation is tested on different digital mammograms. Using the Hurst coefficient for determination of pixel intensity gradient that corresponds to the edge of microcalcifications, image segmentation quality and edge determination precision is increased. Hurst coefficient is considered as the measure of the roughness of the image, and its calculated value depends on the size of rectangular area around suspicious mass. That is why Hurst coefficient calculated for rectangular ROI may not be precise and sufficient parameter to distinguish between benign and malignant masses. There is more information needed for sufficiently reliable conclusion on the type of tumor. The difference between Hurst coefficient for entire rectangular ROI, and for more narrow region around suspicious may provide additional information that can help to estimate if concerned tumor is benign or malignant. In the case of segmented microcalcifications, determination of the corresponding edges depends largely on the parameter used for Sobel method. For precise determination of segmented microcalcifications edges, suitable parameter should be carefully chosen. Underestimation or overestimation of that parameter leads to different image segmentation.

Declaration of interest

The authors declare no conflict of interest for this study.

Appendix

se = strel('disk',5);
se1 = strel('disk',3);
Jd = imdilate(I,se); figure, imshow(Jd);
Je = imerode(Jd,se1); figure, imshow(Je);
[j,t] = edge(imadjust(I),'sobel');
T = H(1,1)*t;
BW = edge(Je,'sobel',T);
BW1 = edge(Je,'sobel',t*0.5);
se2 = strel('line',1,90);
se3 = strel('line',1,0);
se4 = strel('disk',3);
BW = imdilate(BW,[se3,se2]);
BW1 = imdilate(BW1,[se3,se2]);
BWdfill = imfill(BW,'holes');
BWdfill1 = imfill(BW1,'holes');
BWoutlineH = bwperim(BWdfill);
BWoutlineS = bwperim(BWdfill1);
Segout1 = I;
Segout2 = I;
Segout1(BWoutlineH) = 255;
Segout2(BWoutlineS) = 255;
figure, imshow(Segout1, 'InitialMagnification', 200),
title('outlined original imageH');

References