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FRACTAL DIMENSION FOR CHARACTERIZATION OF FOCAL BREAST LESIONS

ELINALDO SANTOS DE GOES JUNIOR*, FRANCISCO BRUNO SOUZA OLIVEIRA*, PAULO EDUARDO AMBRÓSIO*

* Graduate Program in Computational Modeling in Science and Technology (PPGMC)
State University of Santa Cruz (UESC)
Campus Soane Nazaré de Andrade, 45662-900 – Ilhéus, BA, Brasil
E-mail: esgjunior@uesc.br

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Abstract. Breast cancer is one of the diseases that cause more deaths around the world. One of the ways to reduce the high rates is the detection of the disease in its early stages. The faster the cancer is diagnosed, the greater the chances of cure without major consequences. Mammography is considered the most effective way to diagnose the lump in the breast. However, due to some factors, it is not always possible to draw conclusive results through the exam. In order to minimize misunderstandings on examinations and to assist the experts, increasingly computational techniques are used during the diagnosis. The similarity between fractals and the nodules suggests that the calculation of fractal dimension can be used as a means of classifying focal breast lesions. Through the results obtained in this work, we conclude that the fractal analysis of the mass outline is an efficient way of classifying mammograms.

1 INTRODUCTION

Computational advances have contributed increasingly to the better understanding in several areas of knowledge. In areas such as health, for example, these advances are allowing decisions to be made ever more quickly and with lower errors rate, which in many cases may be indispensable, since it is people's lives.

The health sector has been constantly the target of concern and of investments by various national and international bodies. The main objective of these investments is, besides preventing diseases, render faster reliable medical diagnosis and allow early detection of the most diverse infirmities, especially those that have a better chance of cure when diagnosed in its initial stage, such as cancer.

1.1 Breast cancer

Cancer is one of the diseases that cause the death of more people around the world, coming to be responsible for 7.6 million deaths during the year of 2008 [1]. Despite advances in medicine, both in diagnosis as in treatment, the amount of cases of the disease has grown each year due to various causes, such as poor eating habits, smoking and alcohol consumption, physical inactivity and greater life expectancy. According to [2] until the year 2030 it is estimated that the number of deaths caused by cancer will increase by approximately 45%.

Among the most lethal cancers stand out of the lung, stomach, liver, colon and breast cancer [1]. In women, the breast cancer is the most responsible for deaths. Only in Brazil, during the year 2010, 12,705 people died as a result of this type of cancer [3]. One of the possible alternatives to reduce these high numbers of deaths is, according to [2,4], the detection of the disease in its early stages. The sooner breast carcinoma is diagnosed the patient, the greater the chances of cure, and lower the risk of mutilation and other complications caused by the disease. Therefore, there is great commotion in debating measures that allow early diagnosis [5], as the application of computational techniques in computer-aided diagnosis (CAD).

1.2 Mammography

Mammography is considered the most efficient method to detect breast cancer [6] and is the responsible for a significant reduction in cases of death. To identify breast cancer, experts separate the mammographic images in normal and abnormal images. The images that show any faults are studied more carefully, seeking to identify the characteristics of the mass found, like: shape, definition of edges,roughness of contour , density and size, to rate it in benign and malignant [7].

However, it is not always possible to have conclusive results through this examination. Due to the characteristics of some types of tits and limitations of mammography devices, viewing of the images can be impaired. Furthermore, in many cases the contrast of the nodule and breast tissue is not much variation between them. These aspects may interfere with the identification of the nodules, and in many cases, it can lead to misinterpretations of the expert examination [5.8].

The benign tumors usually have soft edges and rounded, well defined and of low density, while malignant tumors are often poorly defined edges and irregular contours, often with the presence of spicules, presenting similar to forms found in fractals [7]. However, these rules are not always valid, there are cases in which malignant tumors have well-defined edges, and benign tumors with aspects similar to fractals.

1.3 Fractal dimension

Fractals are forms that have fractional dimension, not obeying the traditional Euclidean geometry where the objects have entire dimensions [11.12]. The term is derived from the Latin *fractus*, and was first used by the French mathematician Benoit Mandelbrot, around the years 70.

Due to its complexity of form, fractional dimension, and endless details fractals cannot be represented completely [12].

Nevertheless, the concept of fractal can be applied to certain groups of natural structures to which the Euclidean geometry don't apply very well, as irregular structures of malignant tumors.

A fractal can be classified according to their degree of irregularity [11]. This measurement of irregularity can be obtained by calculating fractal dimension, which can also be used as a quantitative measure to differentiate benign nodules from malignant nodules, owing to differences in complexity in the form. This similarity between fractals and nodules suggests that the calculation of fractal dimension can be used as a means of classification of mammograms [9,10].

Among the ways to calculate fractal dimension, we can highlight various techniques, among them the Hausdorff-Besicovitch and Box-Counting technique. The first, and is used to calculate the fractal dimension,but also allows to calculate the size of said objects "perfect" [9]. The technique Hausdorff-Besicovitch can be expressed by the formula

$$FD = \frac{\log N}{\log \frac{L}{U}} \qquad (1)$$

Where FD is the fractal dimension, N is the number of parts in each iteration, L is the initial length of the object U and the length of each segment.

Calculation of the fractal dimension by box-counting method makes use of a measure in which the object is quantified on a plan with grid. The process is represented by the formula of [12]

$$FD = \lim_{n\to\infty} \frac{(\log(N_{n+1}(U)) - \log(N_n(U)))}{\log(\frac{1}{U_{n+1}}) - \log(\frac{1}{U_n})} \qquad (2)$$

2 MATERIALS AND METHODS

The mammograms used in this work are part of the mini-MIAS database of mammograms, obtained in [13]. These images are in PGM format, grayscale, with size of 1024 x 1024 pixels. Each image in the database has a coordinate (x, y) and RADIUS, to facilitate the identification of the area where the lesion is.

Mammograms with benign abnormalities, containing 11 images, and mammograms with malignant abnormalities, containing 15 images: Altogether 26 mammograms were divided into two groups were used. All the images have undergone a process of equalization, with balancing the grayscale and contrast adjustment, facilitating the visualization of regions of interest.

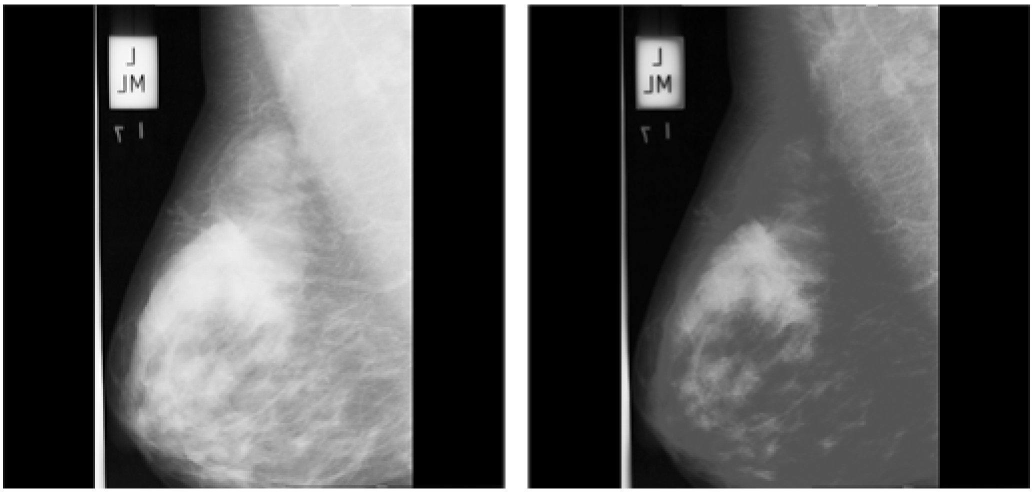

Figure 1: Mammography
(a) Original Image (b) Equalized Image

After the Equalization process, shown in Fig. 1, the region of interest is identified through the parameters provided by [13]. Then, the image was using a segmented improved thresholding variable for each image, due to their different features.

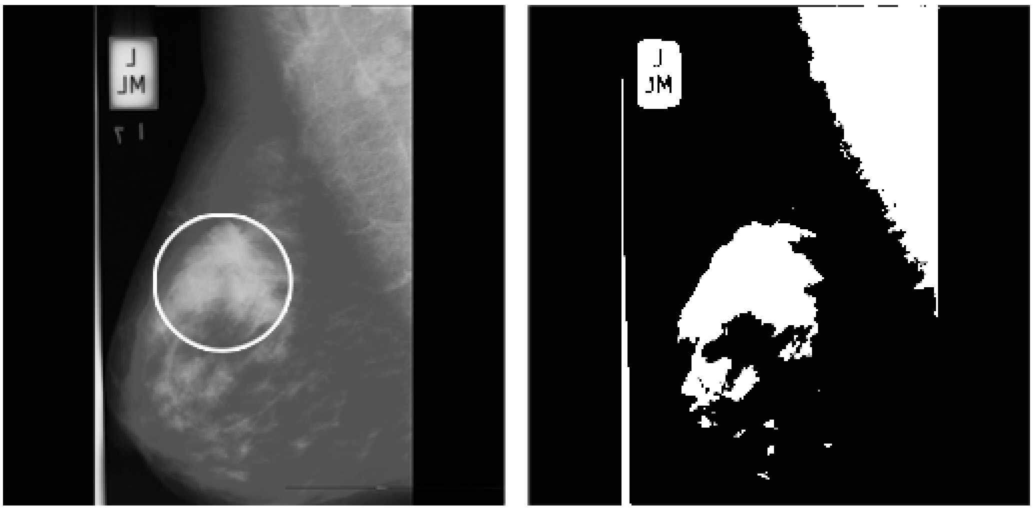

Figura 2: (a) Area of Interest (b) Segmented Image

As can be seen in Fig. 2 (b), the segmentation of the image, in addition to identifying the tumor, also identified regions that are not part of the area that interests us, as the identification of the patient and the pectoral muscle. To perform the calculation of the fractal dimension of these areas were dropped, leaving only the region where the lesion is present.

In this study we used the technique of box-counting for the quantification of the nodules.

Were analyzed only the edges and contours of the region of interest in the binary image, without concern for the mass density or texture.

3 RESULTS AND DISCUSSIONS

The algorithm of calculating fractal dimension by the box-counting method used in this work was implemented in MATLAB tool R2012b, 8.0.0.783 version.

According to the literature [5,7] There are cases in which benign tumors may be confused with malignant tumors, due to its structure and the fibers present in the breast. The opposite can also occur, depending on the patient's breast density. For this study were selected with diagnosis mammograms given, no room for ambiguity. As [10], we can see that benign nodules usually have less fractal dimension than malignant nodules, as shown in Table 1.

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Table 1: Fractal dimension of benign and malignant nodules

Benign nodules		Malignant nodules	
ID	FD	ID	FD
mdb002	1.27413	mdb178	1.98069
mdb005	1.51553	mdb186	1.95125
mdb010	1.39715	mdb202	1.97205
mdb012	1.49815	mdb209	1.96023
mdb015	1.62464	mdb213	1.97675
mdb019	1.55709	mdb231	1.98501
mdb021	1.56164	mdb241	1.97501
mdb025	1.69565	mdb249	1.98117
mdb059	1.51145	mdb256	1.96425
mdb083	1.30403	mdb264	1.91694
mdb097	1.27792	mdb265	1.92731
		mdb267	1.95731
		mdb270	1.99247
		mdb271	1.94784
		mdb274	1.95365

Observing the Table 1 it is possible to notice that all the mammograms diagnosed as benign nodules have values smaller than 1.69. On the other hand, the malignant nodules were quantified with value greater than 1.92. Through this study, we didn't get any case of false positive or negative, taking into account that the values for the two groups are quite distant.

However through literature, it is known that erroneous classifications are quite common, especially when it is taken into consideration only the outline of the lump for the calculation of its size, as is the case of this study. In addition, it was observed that in other studies, as in [14] values are generally lower than those who are presented in Table 1. This factor indicates that possibly the box-counting algorithm used still need some adjusting.

4 CONCLUSION

Breast cancer is a deadly disease and in many cases difficult to be diagnosed. Given the importance of being identified in early stages is essential to the use of methods that allow greater reliability in the interpretation of breast examinations. The objective of this work was to use fractal analysis to quantify, and consequently classify benign and malignant nodules, based just on the edge of the nodules.

This work is a small contribution to the analysis of mammograms, and their classification by calculating fractal dimension. Through this study, it was possible to verify that the set of images chosen, it was possible to differentiate patients with malignant tumors of patients with breast cancer. But improvements need to be made in making the application of this study as automatic as possible, especially in the process of image segmentation and the detection of the region of interest.

The box-counting method proved quite effective for this study, but experimenting with other calculation methods is still necessary for us to obtain parameters that allow us to compare how best to assist the diagnosis.

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REFERENCES

[1] WHO – “Câncer”. http://www.who.int/mediacentre/factsheets/fs297/en/index.html, 2013

[2] WHO – “Are the number of cancer cases increasing or decreasing in the world?”. http://www.who.int/features/qa/15/en/index.html, 2008

[3] INCA - Instituo Nacional do Câncer. Ministério da Saúde. “Câncer – Tipo - Mama”. http://www2.inca.gov.br/wps/wcm/connect/tiposdecancer/site/home/mama, 2013

[4] INCA – Instituo Nacional do Câncer. Ministério da Saúde. “O que é o cáncer?” http://www.inca.gov.br/conteudo_view.asp?id=322, 2013

[5] Sclowitz, M.L.; Menezes, A.M.B.; Gigante,D.P.; Tessaro, S. (2005). “Condutas na prevenção secundária do câncer de mama e fatores associados”, Rev Saúde Pública 2005; 39(3):340-9, FSP.

[6] FDA Safety Communication: Breast Cancer Screening - Thermography is Not an Alternative to Mammography. U. S. Food and Drug Administration. Disponível em <http://www.fda.gov/MedicalDevices/Safety/AlertsandNotices/ucm257259.htm> Acesso em: 10/07/2013

[7] Grazia Raguso et al. “*Application of Fractal Analysis to Mammography*”, 32nd Annual International Conference of the IEEE EMBS. Buenos Aires, Argentina, August 31 - September 4, 2010

[8] Nunes, F.L.S.; Schiabel, H. (2000). “Detecção de agrupamentos de microcalcificações mamárias através de processamento de imagens mamográficas com detecção semi-automática de regiões de interesse”, Revista Brasileira de Engenharia Biomédica, vol.16, n.3, p. 139-151. ISSN 1517-3151.

[9] Sedivy, R.M.D. (1999). “Fractal Analysis: An Objective Method for Identifying Atypical Nuclei”, Gynecologic Oncology 75, 78-83

[10] 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.

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

[12] Silva, M.M.; Souza, W.A. (2010), "*Dimensão Fractal",* REMat - Revista Eletrônica de Matemática, nº2 - 2010.
[13] J Suckling *et al* (1994): "*MIAS - The Mammographic Image Analysis Society Digital Mammogram Database"* Exerpta Medica. International Congress Series 1069 pp375-378. (http://peipa.essex.ac.uk/info/mias.html)
[14] Radu Dobrescu, Loretta Ichim, Daniela Crisan. "*Diagnosis of breast cancer from mammograms by using fractal measures*", Iternational Journal of Medicina Imaging, 2013; 1(2): 32-38. Published online October 30, 2013 (http://www.sicencepublishinggroup.com/j/ijmi)