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DEGRADATION MODEL OF BREAST IMAGING BY DISPERSED RADIATION

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This paper presents a model of interaction of radiation on breast, based on Bosso's filter. This model is used to improve mammographic images for early cancer diagnosis, to be more accurate and to detect cluster of microcalcifications. The model is based on degradation of breast image produced by dispersed radiation using the Bosso`s filter, developed earlier.

Key words: Mammogram, Microcalcification, Computer Vision, Cancer analysis.

1. INTRODUCTION

One of the public health problems associated with females, is breast cancer. This disease is a major cause of death in women between 15 and 54. Breast cancer is the most common cancer among women worldwide, accounting for 16% of all female cancers. It is estimated that this disease killed more than 500,000 women last year, although this cancer is considered a disease of the developed world, the majority (69%) of deaths occur in developing countries [1]. In Chile, breast cancer ranked third in female cancer, rising from 11.7 in 100,000 to 13.3 in 100,000 in ten years [2].

A timely clinical diagnosis and appropriate treatment could prevent and reduce this high mortality. The most widely used method of diagnosis is mammography, which implies a breast radiography under controlled conditions. Condition for a breast mammography is the transversal plane to X-ray beams so that they fall on the film parallel to the breast. The radiography is examined by the specialist who seeks clusters of microcalcifications. Presence of calcium clusters in breast is an important sign of the possible formation of cancer. Microcalcifications have a size close to the limit of resolution of the system, so it is important to improve image quality. The diagnosis interpretation is complicated due to effects of degradation and limits of resolution.

Several authors have proposed different approaches to this problem: One of them is a method for automatic detection of microcalcifications in digitized images. The method compares the texture of mammographic images to achieve better contrast of microcalcifications. This is done by lowering the level of gray of a matrix which should be adjusted according to the associated histogram. This procedure provides a good result, but it reduces levels of gray (from 256 to 64), which means that in our opinion, the image loses part of the information, but gains in computational time. These authors claim that results in a classification rate of 95.6%, achieve a reduction in computational complexity. [3]

A group of works present a survey, a review of image processing algorithms to detect early cancer, and an algorithm based on bilateral asymmetry. The algorithm requires a comparison of both breasts to detect the differences in present areas, which implies an additional dose of radiation. The best result obtained is 89.2% with 4.9 false positives. This methodology requires a proper alignment of the breast in a mirror to be compared, which technically introduces a complexity in the comparison algorithm [4–6].

A method for automatic detection of breast cancer through the enhancement of medical images is based on the concept of fractals applied to an image with an area of autosimilar properties. They have identified areas of possible cancer, as well as microcalcifications. They point out that it is necessary to improve the system to become an automatic process. This method was tested, requiring further work and results [7].

A method of microcalcifications detection in mammograms based on wavelets and adaptive thresholds has been proposed. Breast areas are segmented and divided into overlapped squares, then the wavelet transform is applied on each square image and threshold of each mammogram are calculated to identify the region of interest. Then, these regions are analyzed to reduce false positives. This method provides nearly 89.39% correct classification [8].

Another approach proposes automatic detection of clusters of microcalcifications in mammograms using multiclassifiers, to obtain the suspicious clusters, leaving to the expert the diagnosis responsibility. The system is able to detect 90% of the clusters of microcalcifications, but it needs to classify as positive or negative the whole mammography [9].

A method for breast tumor detection in mammograms based on Jacobi Moments is proposed. It is capable of detecting suspicious areas in mammograms independent of their size, orientation and position. The method is successful in detecting the microcalcification in the mammogram. It has to be tested on much larger sets of data. Furthermore, a clinically useful system for breast cancer detection must be able to detect the breast cancers, not just microcalcifications. This work has to extend the Jacobi Moments features for other types of mammogram [10].

Another work develops a spatial point process modeling approach for detection of clustered microcalcifications in mammogram images. In this approach a marked point process is employed to characterize the spatial distribution of clusters in a mammogram image, wherein prior distributions are defined to describe both the amplitude of the microcalcifications signals and their spatial interactive patterns. The microcalcifications are then simultaneously detected through maximum a posteriori estimation of the model parameters associated with the marked point process. The parameters associated with the prior distributions are determined from a set of training mammogram images. The approach is evaluated with 141 mammograms images. The method has computational complexity and it needs to be reduced [11].

A method to classify mammograms images in five classes to help radiologist detect cancer-affected breasts. is proposed. This method has two steps, one is preprocessing where the boundary errors will be removed successfully using new morphological operations. The second is evaluating the statistical parameters to classify and to find abnormality in breast images. The results obtained out of the existing techniques have been found to have better performances. Further research is needed [14].

Some works apply fuzzy logic to develop new image processing algorithms. A comparative study of fuzzy image enhancement techniques applied on digital mammogram images has been done. Compared to other non-linear techniques, fuzzy filters are able to represent knowledge in a comprehensible way [16].

Multimedia represents powerful tool for dissemination of data and interpretation of research results. One work presents an animation on breast cancer easy to use patterns for patient, students and researchers [17].

Optimizing the quality of the images goes against the degradation caused by the interaction of radiation, but also produces dispersed radiation which in turn affects the image plate. This dispersed radiation is added to the main beam radiation resulting in a degraded image of the object contours, with less quality.

This paper presents a model of interaction of radiation on breast, based on the Bosso's Filter. This model is used to improve mammographic images, for the diagnosis of cancer to be more accurate, showing the microcalcifications. The idea is to require only a single dose of radiation. The model used is based on a degradation model by dispersed radiation and using the Bosso's Filter, developed earlier [12, 13].

2. BOSSO'S FILTER

The Bosso's Filter is defined by the equation (1), where a and λ are the parameters, and $A(N, \lambda, a)$ is a normalized constant depending on λ and a. N is the dimension of the matrix in pixels.

$$B\left(N,\lambda,a\right)=A\left(\lambda,a\right)\frac{\mathrm{e}^{-\lambda\sqrt{r^2+a^2}}}{r^2+a^2}. \tag{1}$$

The Euclidean distance is $r^2 = (i^2 + j^2)$, where i, j are the positions of the matrix cell. The free parameters are: N, λ, a. In the discrete domain, the equation of the filter is given for:

$$B(N,a,\lambda,r_0) = A(N,\lambda,a,r_0)\sum_{i}^{N}\frac{e^{-\lambda\sqrt{(r_i-r_0)^2+a^2}}}{(r_i-r_0)^2+a^2}, \tag{2}$$

where r_0 is the position of central pixel in the kernel.

The application of the filter considers the convolution operation for square images with $M\times M$ dimensions.

In the analysis of Bosso's Filter behavior the IDL software (NASA original program) and the Fourier Transform FT are used. The algorithm allows observing the changes that take place when varying the three parameters of the filter on digital images. The software permits to use the Fourier Transform for determining the Bosso's Filter frequencies spectrum, and evaluates the behavior shown during the experiment. The results are compared with classic filters.

The Bosso's Filter behavior is done at different values of its a, λ and N parameters. It is found that there are regions where the filter seems to act similar to classical filters, such as lowpass, bandpass and highpass. In some regions, the filter has a bad performance and does not act. This versatility permits to change the performance of the filter with small variations of one of the parameters. There are ranges of parameter values where the filter does not work. This λ range is [–25, 0]. The great versatility of the Bosso's Filter permits to be applied to images in real time, varying the parameters automatically.

The Bosso's Filter can be used in two-dimensional images, inferring the effect and possible applications in on-line vision applied to the industry or medical applications. These applications are carried out in images with a great variety of gray levels. It is observed that the borders can be stood out, placing certain values to the parameters, so that the high frequencies are completely notorious [15].

3. DISPERSED RADIATION

X radiation interacts with matter in three ways, according to the Rayleigh effect, photoelectric effect and Compton effect. That is, it can deposit some or all of the energy in it according to these effects, which generally depends on the photon energy, the density of the material, as well as the type of atoms composing the material [12]. It can be approximated by the linear attenuation coefficient of the photoelectric effect using eq. (3)

$$\mu = aN\frac{Z^5}{E^{7/2}}, \tag{3}$$

where α is a constant, N the number of electrons per unit volume, Z the atomic number and E the photon energy. When Z is increased, attenuation and E (energy) are greater and the damping factor of the photoelectric effect μ is lower. The Compton effect predominates for energies between 50 kev and 500 kev, depending linearly on the atomic number Z of the material. These two effects predominate in radiography image. In the case of mammograms, the photoelectric effect predominates when the photon energy is 20–30 kev. However, the material of the breast is less dense compared with other tissues (bone, internal organs) and there exist absorption energies close to kev. In the case of photoelectric effect, an electron is ejected from the inner layers of the atom because these are already occupied, producing an emission of the energy characteristic of the atom electronic transition.

Fig. 1 shows the incident X-ray beam into breast tissue and the produced dispersed radiation, where d is the mamma thickness, ρ is the plane distance from point O to point (x, y). The principal beam going through the material, produces emissions in all directions, that is to say, it produces spherical point sources in the way of the main beam.

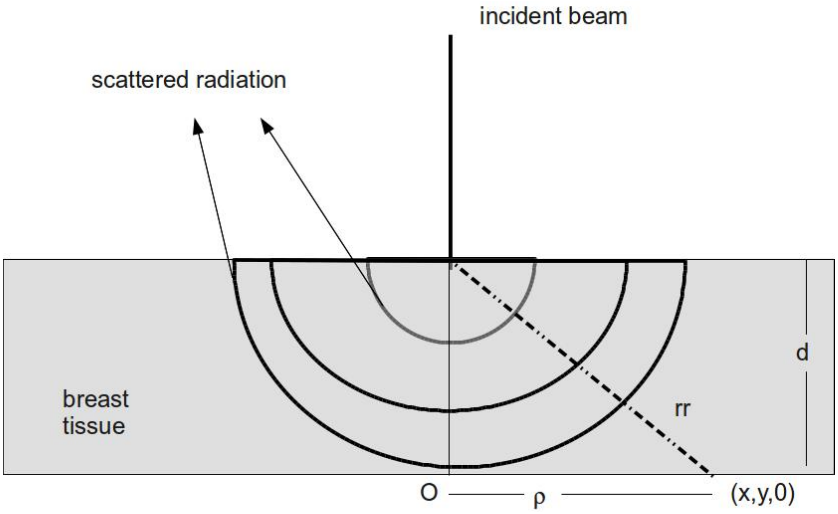

Fig. 1 – Incident and dispersed radiation inside the breast tissue.

By the law of attenuation, the intensity of incident beam is attenuated according to equation 4.

$$I = I_0 \mathrm{e}^{-\mu d}. \tag{4}$$

The atom emissions within the material can be thought of as point sources, in a medium that attenuates the radiation, producing intensity in the plate given by (5)

$$I = I'_s \frac{\mathrm{e}^{-\mu r}}{r^2}, \tag{5}$$

Where $r = \sqrt{\rho^2 + d^2}$ and $\rho = \sqrt{x^2 + y^2}$ are distances r and ρ, as shown in Fig. 1. The quadratic term r^2 is due to the intensity of a spherical wave and I decreases with the square of the distance. Equation (5) is the Bosso's Filter [12, 13].

Assuming these conditions, the intensity at point 0 can be written as (6).

$$I = I_0 \mathrm{e}^{-\mu d} \delta(\rho) + I'_s \frac{\mathrm{e}^{-\mu r}}{r^2}. \tag{6}$$

The breast tissue is not homogeneous, therefore linear attenuation coefficient μ depends on the position (x, y). As an approximation, it can be assumed that the attenuation coefficient can be calculated with eq. (7).

$$\mu(x, y) = \frac{-1}{d} \ln\left(\frac{I(x, y)}{I_0}\right). \tag{7}$$

In this case, the value of d corresponds to the thickness of the breast in terms of image acquisition. This parameter is not fixed, but it gives a good reference value.

To calculate the intensity I_s, it assumes the following hypothesis: "The total intensity deposited in the plate is I'_0. This implies that integral $I(x, y)$ on the surface (eq. 4) must be equal to I_0. In this way, an expression for the calculation of I_s is presented in eq. (8)

$$I'_s = I_0 \left(\frac{1 - \mathrm{e}^{-\mu\sqrt{\rho^2 + d^2}}}{z(d)}\right), \tag{8}$$

with

$$z(d) = \int_0^\infty \frac{\mathrm{e}^{-\mu\sqrt{\rho^2 + d^2}}}{\rho^2 + d^2} \rho \, \mathrm{d}\rho. \tag{9}$$

In a previous work [12], the infinite is replaced by a value of 100d, because the function $z(d)$ converges rapidly in the range of value μ. This new image is the contribution of dispersed radiation in the central pixel. Subtracting $I_s(x, y)$ to the image $I(x, y)$, an image without the contribution of the dispersion, $\Delta I = I(x, y) - I_s(x, y)$, is obtained, where the difference depends on the value of d.

4. BOSSO'S FILTER APPLIED TO BREAST MAMMOGRAM

The Bosso's Filter is programmed using IDL software. The IDL program routines describe the equations presented. The integration is achieved using Simpson Integral.

Within an interval, the value of ΔI is calculated as a function of d parameter for two radiographies obtaining the results shown in Figs. 2 and 3. Figure 2 shows the unprocessed breast mammogram. The image is processed by using Bosso's Filter, presented in B, which enhances the region with microcalcifications.

Figure 3 shows C, unprocessed image of a phantom (device used for calibration of imaging equipment that contains within it, elements similar to the body) with defects. The image D is processed by using Bosso's Filter, has phantom with more defects that in the original image where calcifications are appreciated.

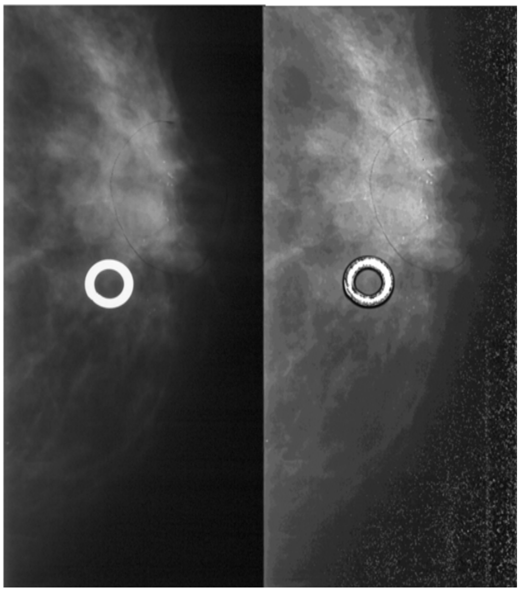

Fig. 2 – Breast unprocessed (A) and processed (B) image.

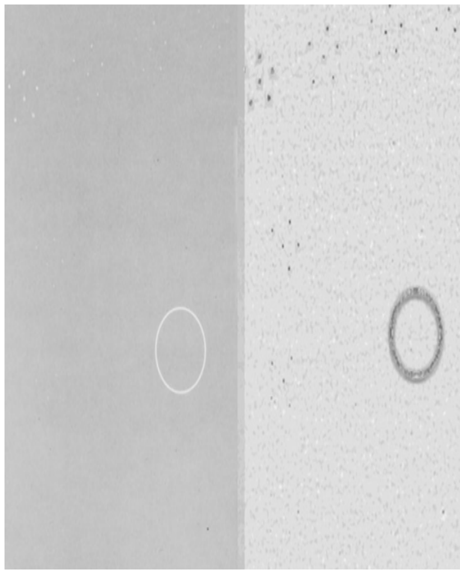

Fig. 3 – Phantom (C) unprocessed and (D) processed image.

Several evaluations have been done, calculating ΔI for different values of d, to choose the best d value. The idea is to obtain the better resolution.

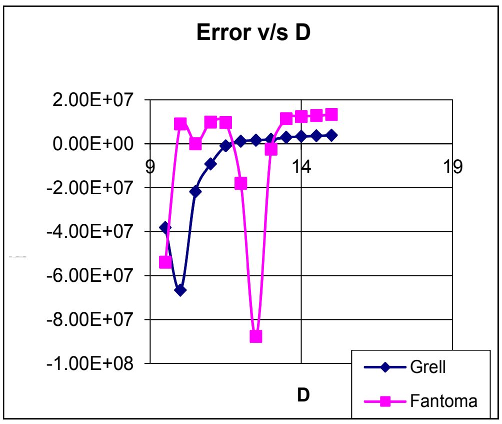

Fig. 4 – Parameter d versus error.

5. CONCLUSIONS

This paper presents a model of interaction of radiation on breast, based on Bosso's filter. This model is used to improve mammographic images for early cancer diagnosis, to be more accurate and to detect cluster of microcalcifications. The model is based on degradation of breast image produced by dispersed radiation using the Bosso's filter, developed earlier.

The Bosso's Filter estimates the *d* parameter for improving mammograms images, which allow a better diagnosis of breast cancer enhancing microcalcifications. Bosso's Filter requires a parameter *d* to good behavior and its calculation can take a long time. The degradation phenomena of X-rays in matter are estimated values of the free variables of the model and define an error function of the parameter *d*, obtaining a minimum error. The filter is applied to a mammographic image and a phantom, giving new images with new details, such as microcalcifications. In turn, the phantom highlights the microcalcifications.

The results are evaluated by several medical expertises, saying that the processed images (after applying Bosso's Filter procedure) have better contrast in the mammographic image, enhancing microcalcifications and permitting better possibilities in the detection of breast cancer. This opinion is also valid with phantom breast images.

Further studies are required to check the validity of the results and refine the parameters of the filter.

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