Proposal to Construct a 3D Image Viewer Based on a Commercial Ultrasonic 2D Imaging System

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***Abstract* — This paper describes an approach to develop a procedure to reconstruct 3D volumes of breast cancer by using 2D ultrasonic (US) images in order to provide the shape and the dimensions of the cancer. We obtained 91.66% of accuracy in the 3D reconstruction process. Breast and breast cancer phantoms where made in order to mimic acoustic properties (speed propagation). The US images of the phantoms were taken with a commercial US equipment (Prosound 6, Aloka) by using a convex transducer probe (3-6 MHz and 82° scanning angle) which was moved with a mechanical positioner with a resolution of 0.1 mm. Then, US images were segmented with mathematical algorithms; we obtained an accuracy of 96.63± 3.93 %, [1], in the process. These algorithms consist, first, in the images enhance in contrast with an adaptive histogram. Second, the removal or the enhancements of the images from the speckle by using the Gabor tune in function. Third, we made the segmentation of the region of interest by using the Watershed transform. And finally, a 3D volume was created with all the images processed with an interpolation technique.**

Keywords — breast cancer, ultrasonic (US), phantom, acoustic properties, segmentation, Gabor function, Watershed transform, 3D array and interpolation.

INTRODUCTION

In the whole world, every day, thousands of women are diagnosed with breast cancer, which is the second most common cancer amongst females, and is also the leading cause of cancer-related mortality [2].

“Approximately, 232,340 new cases of invasive breast cancer and 39,620 breast cancer deaths were expected to occur among US women in 2013” [3].

The occurrence of breast cancer is growing up in the industrialized world caused by the increase of life expectancy, rise urbanization and the adoption of western lifestyles. Even though, some risk reduction might be achieved with prevention; these strategies cannot eradicate the majority of breast cancers that are developed in low- and middle-income countries where breast cancer is detected in very late stages. Therefore, early detection in order to improve breast cancer outcome and survival remains the cornerstone of breast cancer control [4].

In this way, this paper shows a procedure to reconstruct 3D volumes of breast cancers by using 2D-US images, taken from phantoms which mimic the mechanical properties of breast and breast cancer, in order to facilitate the physician diagnoses.

I. Phantom elaboration

Phantoms are materials with specific geometrics and material compositions and are frequently used in the development and the characterization of imaging systems or mathematic algorithms in medical imaging. A phantom emulates important properties of biological tissue in order to provide a more clinical realistic imaging environment [5].

In this paper, we emulate breast and breast cancer acoustical properties with US phantoms.

1.1 Phantom materials

The materials used to elaborate phantoms were:

- **Bi-Distilled water**: it is the solvent in the solution which does not contain minerals and salts. The used bi-distilled water has a specific conductivity at 25 ℃ of $1\,\frac{micromhos}{cm}$, 6.5 of pH and 1 pmm.
- **Agarose:** it gives consistency to the mixture. The utilized agarose in the

phantom elaboration was the UltraPure™ Agarose from Invitrogen Company.

- **Neutral Detergent:** it makes a homogeneous solution because the corn oil formed a non-homogeneous solution with the other materials. We used neutral detergent with a pH of 7.0, from HYCLIN-PLUS Company.
- **Corn Oil:** it mimics breast fat properties. The corn oil is from SIGMAS Company.
- **Ethanol** (99.5%)**:** it modifies the US speed propagation.

The concentrations of the breast cancer phantom are listed in Table 1 and those of the breast phantom in Table 2.

Table 1. Breast Cancer Phantom concentrations.

Breast Cancer Phantom	Concentrations
Bi-Distilled water	32.6 ml
Ethanol	30.0 ml
Agarose	0.8 g

Table 2. Breast Phantom concentrations.

Breast Phantom	Concentrations
Bi-Distilled water	32.6 ml
Corn Oil	97.8 ml
Neutral Detergent	19.6 ml
Agarose	2.9 g

1.2 Phantom elaboration

The procedure to prepare phantoms that emulates breast and breast cancer acoustic properties is the next:

1.2.1 Breast Cancer Phantom

1) Make a solution with the bi-distilled water and the agarose in a beaker.
2) Heat the mixture up to approximately 80 ℃. During the heating process, keep stirring the mixture.
3) Remove the beaker from the heater, add the Ethanol and continue stirring for two minutes.
4) Pour the mixture into a mold and left it until it gets cold and coagulate perfectly. In this case, we used a Christmas sphere with the aid of a syringe, Figure 1 (a), and when the phantom got coagulate, we remove the mold, Figure 1 (b).

Figure 1. (a) Christmas sphere mold. (b) Christmas sphere mold removing.

1.2.2 Breast Phantom

1) Make a solution with all the breast phantom components in a beaker.
2) Stir the mixture vigorously during 10 min.
3) Heat the mixture up to 80 ℃. During the heating process, keep stirring the mixture.
4) Remove the beaker from the heater and continue stirring until the mixture gets 38 ℃ and a white texture like glue is obtained.
5) Pour the mixture into a mold and put it inside the breast cancer phantom; left the breast phantom mixture gets cold.

1.3 Phantom characterization

In order to know the propagation speed of the sound in both phantoms, we measured it with the technique called “Through-Transmission”. Through-Transmission is a test technique in which US energy is transferred through the object of interest and received by a receptor transducer on the opposite side. Variations in the received signal amplitude with the receptor transducer are taken as indications of variations in material continuity [6].

The phantom characterization was made in an indoor temperature of 27 ℃ and a 3.5 MHz transducer was used. The breast phantom, with the breast cancer phantom inside, was placed in a thermostatic bath in a temperature of 37 ℃ in order to mimic the body temperature.

II. Image acquisition

The image acquisition was made with commercial US equipment (Prosound 6, Aloka), Figure 2. A convex transducer probe (3-6 MHz and 82° scanning angle) was used and moved with a mechanical positioner with a resolution of 0.1 mm, Figure 3, in a thermostatic bath at 37 ℃ with bi-distilled water.

III. Image improvement

3.1 CLAHE

Each image taken with the US scanner is enhanced with the CLAHE technique. CLAHE is a local improvement technique which divides the original image in small tiles, rather than the entire image, such that each histogram is calculated from each tile. Then, the pixel intensity is transformed to one value proportional to the local histogram (equalization function), but it is limited to the maximal level. In this way, CLAHE increases the improvement in homogenous areas and avoids the noise amplification [7].

Figure 2. Prosound 6, Aloka.

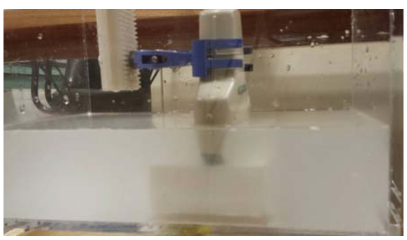


Figure 3. Mechanical positioner with the convex transducer calibrated probe.

3.2 Gabor Function

After improving the images with the CLAHE technique, the images are filtered using the Gabor function. The Gabor functions are special filters that have been widely used in texture segmentation because it is possible to tune in them to a specific central frequency and orientation. In US images, the more relevant components are around the central frequency pulse so these kinds of filters are used to remove the "speckle" in ultrasonography [1].

In the space domain, the Gabor filter is defined by its impulse response:

$$h(x,y) = \frac{1}{2\pi{\sigma_g}^2} e\left(-\frac{{x_\theta}^2+{y_\theta}^2}{2{\sigma_g}^2}\right)\cos\big(2\pi k(x_\theta + y_\theta)\big) \quad (1)$$

Where:

$$x_\theta = xcos\theta + ysin\theta \quad (2)$$
$$y_\theta = ycos\theta - xsin\theta \quad (3)$$

The Gabor function, $h(x,y)$, is a sinusoid centered at a frequency $k > 0$, modulated by Gaussian enclosure with a variance ${\sigma_g}^2 > 0$ and an orientation θ, where x and y are the pixel location.

IV. Segmentation

In order to discriminate between the breast cancer area, the region on interest, and the rest of the image, the watershed transform was used that is a widely used technique in medical image processing. In imaging processing, and more precisely in mathematical morphology, the gray scale images are considered topographic reliefs. In the topographic representation of an image, the height of each point corresponds with the pixel level intensity. This representation is very adequate for recognizing the best effect of the Watershed transform over an image due to the ridges that divides the different areas, in the image; they are called the watersheds regions [8].

V. Interpolation

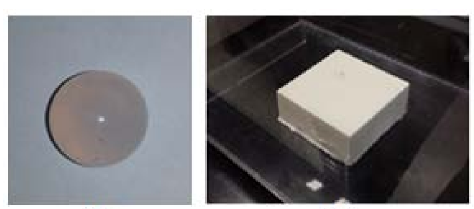
Once we have already segmented all the images taken with the scanner and have placed them in a $3x3$ array, the next step is to interpolate between them in order to reconstruct a 3D image.

Interpolation consists in constructing a function p belonging to a finite dimensional linear space from a given set of data. Usually, the interpolation data are obtained by sampling another function and, in that case, it is said that p interpolates f, in the sense that both functions coincide on that data set [9].

RESULTS

I. Phantom elaboration

From the phantom elaboration, we obtained a breast cancer phantom, Figure 4 (a), and a breast phantom, Figure 4 (b); the measured mechanical properties are shown in Table 3.



(a) (b)

Figure 4. (a) Breast cancer phantom. (b) Breast phantom

Table 3. Breast Phantom and Breast Cancer Phantom mechanical properties.

Phantom	**Dimensions** $[mm]$	**Density** $[Kg\ m^{-3}]$	**Speed of propagation** $[m\ s^{-1}]$	**Impedance** $[Kg\ m^{-2}\ s^{-1}]$
Breast cancer phantom	12 ± 2*	541	1596	863436
Breast phantom	$100x100x30 \pm 2$	510	1476	752760

*Diameter

II. Image acquisition

The Figure 5 shows an example of the images acquired where we can appreciate the breast phantom and the breast cancer phantom in a 2D US image.

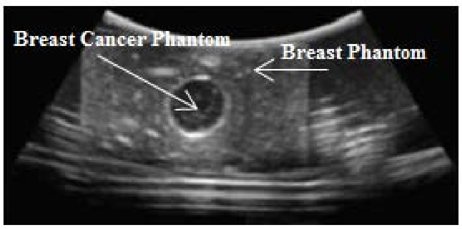


Figure 5. Breast Phantom and Breast Cancer Phantom in a 2D US image.

III. Image improvement

All the US images were improved with the CLAHE technique and the Gabor function. The Figure 6 shows the improvement with these two techniques where the contour improvement is visible.

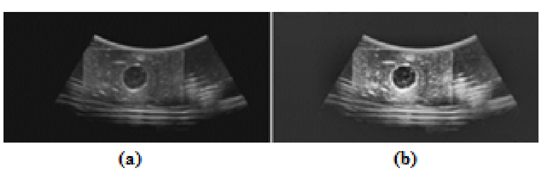


Figure 6. (a) US image. (b) US Image improved.

IV. Segmentation

Each US image was segmented and after that a $3x3$ array was created with the images contour. The Figure 7 (b) shows the US image segmentation and the Figure 8 shows the $3x3$ array.

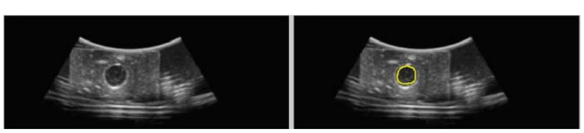


Figure 7. (a) US image. (b) Us image segmented.

V. Interpolation

The final step was to interpolate between the $3x3$ array. We obtained a sphere with $11\ mm$ diameter in the image reconstruction; Figure 9 shows the interpolation result.

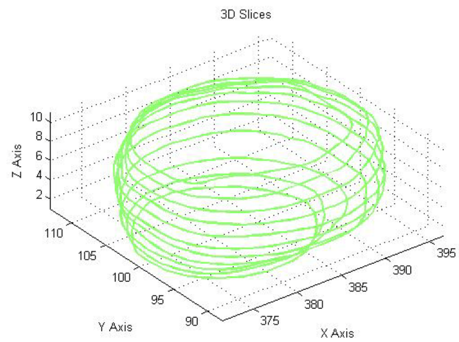


Figure 8. $3x3$ array formed with all the contours of the segmented images .

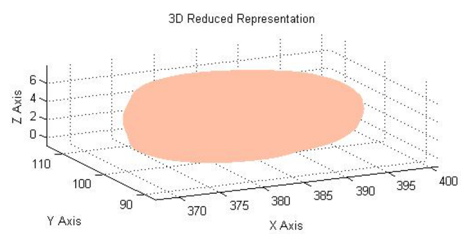


Figure 9. Image interpolation.

CONCLUSION

We developed a methodology to reconstruct 3D volumes which bases its functionality in the US images improvement (CLAHE and Gabor functions), the segmentation (watershed transform) and the interpolation. From this new technique, we obtained 91.66% of accuracy in the 3D reconstruction process and comparing the propagation speed of the sound from our phantoms with the obtained results in the research paper of Cuiping Li et al., [10], we obtained 96.34 % in breast phantoms and 96.99 % in breast cancer phantoms of similarity by using common and cheap materials.

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