3D Ultrasound Breast Automated Acquisition System

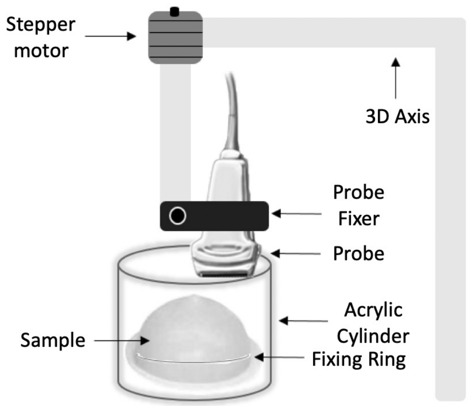
Vivian A. S. Luccas*[1], Mehran Azimbagirad**[2], Antonio Adilton O. Carneiro[1]
[1] *Physics Department - University of São Paulo, Ribeirão Preto, Brazil.*
[2] *Department of Computing and Mathematics - University of São Paulo, Ribeirão Preto, Brazil.*

Resumo: Normalmente a avaliação mamária é realizada por mamografia. Tal metodologia é eficaz no diagnóstico precoce de células tumorais, e deve ser repetido anualmente por mulheres, geralmente, a partir dos 40 anos de idade. Porém ela também apresenta por desvantagens a deposição de doses no paciente – estudos recentes avaliam o potencial de risco de câncer de mama induzido por mamografia –, além de desconforto na compressão das mesmas. A ultrassonografia também é uma técnica comumente utilizada nos exames de rotina. Os avanços ultrassônicos têm melhorado circunstancialmente a qualidade da imagem e a capacidade de identificar alterações nas estruturas mecânicas dos tecidos. Com o ultrassom, é possível gerar diferentes modalidades de imagens (modo-B, Doppler e elastográfico). Uma de suas limitações é a obtenção à mão livre que dificulta a reprodutibilidade. Nesse projeto, apresentamos um protocolo para imageamento automático ultrassônico mamário, usando um braço robótico, capaz de gerar um volume tridimensional da mama.
Palavras-chave: ultrassom, mama, mamografia, Arduino, 3D.
Abstract: *Normally mammary evaluation is performed by mammography scans. This method is efficient in diagnoses early tumors stages, and must be annually repeated by women, usually, by the age of 40. However it has its disadvantages such as dose deposition in patients – recent studies have shown the potential cancer induction by mammography scans – besides the uncomfortable of breast compression. Also the ultrasonography is a common technique applied in clinical routines. Advances in ultrasound have improved image quality and its capability of perception changes in mechanical tissue properties. With ultrasound, it's possible to generate different images modalities (B-mode, Doppler and elastography). One of its limitations is the free-hand acquisition which difficults reproducibility. In this project, we present a protocol for automatic breast imaging by ultrasound, using a robotic arm, capable of generating volumetric tridimensional mammary images.*
Keywords: *ultrasound, breast, mammography scan, Arduino, 3D.*

Introduction: Breast cancer is the second most common cancer[1]. If the tumor is diagnosed in early stages, the rate of cure is around 95,2%[2]. Thereat, at age of 40, women start acquiring mammography scans annually – which uses radiation energy to explore breast tissue looking for tumors or lesions. This kind of exam compresses breast against platforms to enhance image quality[3]. But, for that reason, it is considered as painful, turning into quitting of breast exams by women[4]. Besides that, there are some studies which correlates radiation doses by mammography scans to breast cancer incidence[5]. And there is some others that consider mammography scans (MS) aren't enough by itself in diagnosing some cases of breast cancer. I.e., MS isn't the best exam modality to evaluate breast for some cases – yet in high fatty density breast or in younger women, which MS seems to not really find lesions by itself, mostly because of the physics behind of the technique[6]. By other hand, there's medical ultrasound (US). US is a very common exam in clinical routine to diagnostic and characterize breast masses[6], and is already been used to complement mammography scans[7] - it has a 93% sensitivity for detection of mammary masses[8]. Its usage is less uncomfortable and brings lower risks to the patient[9]. But, as well known, handheld US (HHUS) is a highly operator dependent skills modality, requiring skillful probe manipulation, mental ability[10], and a great anatomy knowledge, and is non-reproducible exam[11]. Some studies have shown that the diagnostic performance of an automated acquisition system was higher than that of HHUS in respect of specificity and accuracy[11]. For that reason, many authors have been trying to develop automatic positioning and probe manipulation aiming to better images quality and precise diagnoses[12], and 3D images[13]. Nevertheless, most of ultrasound robotic arms are expensive and uses high tech devices in order to control it. This paper describes a new acquisition module for breast imaging which is painless, safer, precise, low budget and has a great quality image. Results were obtained using a breast phantom (Gphantom LLC.) Potential and limitations of this technique are then discussed.

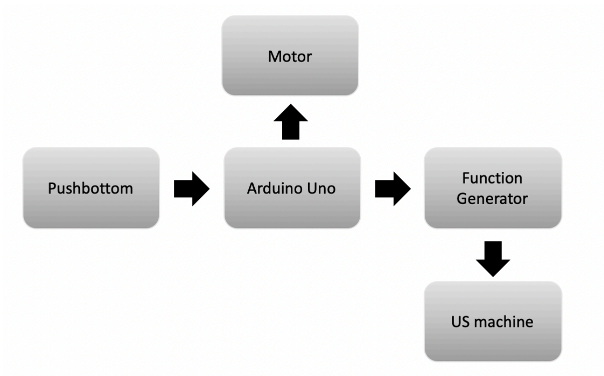
Methods: In order to simulate the system as performed in real patients and for evaluation of the 3D US image acquisition module, we use a commercial breast phantom made of paraffin-gel (Gphantom, LLC), with eleven different inclusions simulating breast lesions. For the mechanical system design, we use a linear probe (L14-5/38 – UltraSonix) which has a physical footprint of 4.00 x 39.00 mm^2, attached to a robotic arm (Figure 1). It was also attached to a stepper motor (KTC-HT23-401-D, Kalatec) that rotated around its axis by steps of 1.44 degrees. Breast phantom was placed inside an acrylic cylinder filled with water. Transducer was submerged inside of water. Phantom and transducer didn't touch each other – water was used as coupling source. Probe was attached to the US machine (UltraSonix) to acquire raw data for each step and then processed. We controlled the whole system by an Arduino Uno (AU). AU was coded in C++ and direct the rotation system and acquisition by an TTL pulse (5V pp, 40 ns, 1MHz) from function generator (FG) to trigged US (Sonix RP). In order to energize stepper motor, we used a Driver (STR8) and a 40V source.

Figure 1 - Scheme of mechanical system.



Source: Author* (2019).

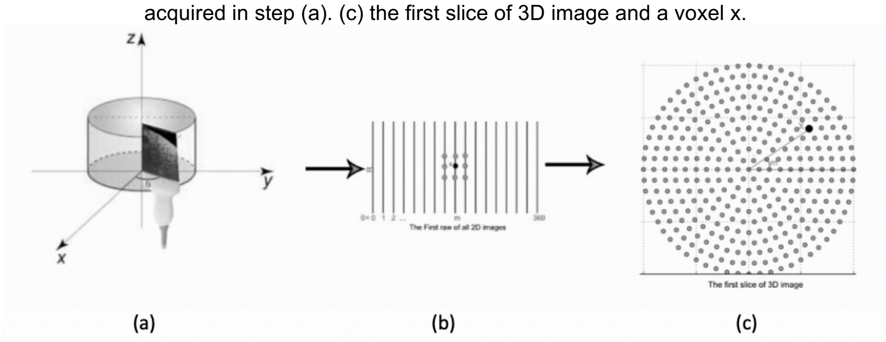
Figure 2 - Acquisition steps diagram.



Source: Author* (2019).

After preparation of image sequences using the filters, let them in a polar system. That means each 2D image will be assumed in a radius R and an angle θ (Figure 3 - a). Let separate all first raw of image sequence. In order to reconstruct the first slice of 3D image which is a planar (Figure 7, c), for each pixel (or voxel in 3D view), there is a distance with the center named x and an angle m. To estimate the intensity of point x in 3D volume image, we used a 3×3 the neighbors of x and a 2D interpolation method B-Spline to estimate x intensity level. This approach was used for the second to the last raw.

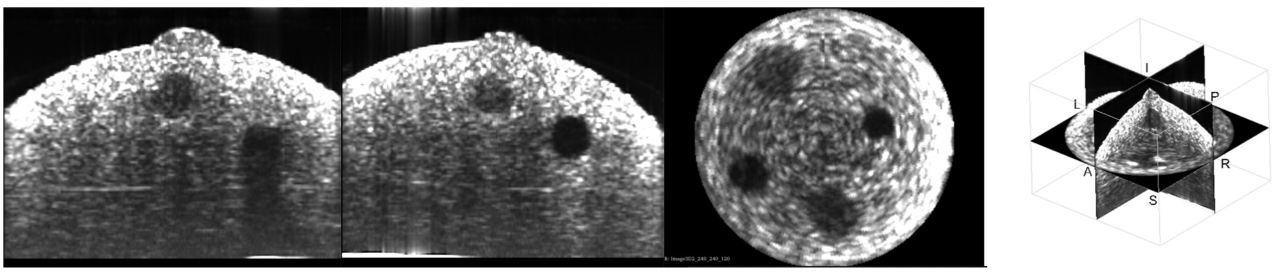
Figure 3 - Reconstruction strategy for an acquisition protocol. (a) one acquisition protocol by rotation. (b) the first row of all 2D images acquired in step (a). (c) the first slice of 3D image and a voxel x.



Source: Author** (2019).

Results: Breast phantom data were acquired and the tridimensional images were built as shown in figure 4. The breast phantom had eleven inclusions. These inclusions were irregular, with different shape, size, volume and one echogenicity (i.e. made of different materials). All phantom's inclusions were found in our system as expected. No reconstructions incoherencies or discontinuities could be identified.

Figure 4 - Breast phantom images: (a) sagittal image in US; (b) coronal image in US; (c) axial image in US; (d) 3D image in US



(a) (b) (c) (d)

Source: Authors*,** (2019).

Discussion and Conclusion: This study outcomes results as expected: we could be able to yield a great 3D ultrasound image with a low cost equipment, controlled by Arduino Uno. It was tested in a commercial breast phantom. Results have shown the potential of this acquisition module. Unfortunately, because this system uses a regular linear probe, with 4.00 cm footprint, the FOV is restricted to 8.00 cm. It means that, using this modality of transducer, only small sizes of breasts (probably to 42C – USA) can be imaged. Besides that, women should be laid down still for about two and a half minutes. For this reason, in next studies we are going to try to improve the acquisition velocity or attach a breathing monitor in order to evaluate this system in humans.

References:

1. Society AC. Cancer Facts & Figures 2018. *Papermak Conf Proc Tech Assoc Pulp Pap Ind*. 1986:233-236. doi:10.1182/blood-2015-12-687814
2. Siegel RL, Miller KD, Jemal A. Cancer Statistics, 2017. *CA Cancer J Clin*. 2017;67(1):7-30. doi:10.3322/caac.21387
3. Bauab S de P. Mamografia digital: um caminho sem volta. *Radiol Bras*. 2005;38(3):iii-iv. doi:10.1590/S0100-39842005000300001
4. Júnior RF, Fiori WF, Ramos FJ de F, Godinho E, Rahal RMS. Desconforto e dor durante realização da mamografia. *Rev Assoc Médica Bras*. 2006;52(5):333-336.
5. Al. M et. Benefits versus Risks from Mammography. *Dep Radiol Univ New Mex*. 1997;79(3):903-909.
6. Gharekhanloo F, Haseli MM, Torabian S. Value of ultrasound in the detection of benign and malignant breast diseases: A diagnostic accuracy study. *Oman Med J*. 2018;33(5):380-386. doi:10.5001/omj.2018.71
7. Kenneth J. W. Taylor, Christopher Merritt, Catherine Piccoli, Robert Schmidt, Glenn Rouse, Bruno Fornage, Eva Rubin, Dianne Georgian-Smith, Fred Winsberg BG and EM. Ultrasound as a complement to mammographyand breast examination to characterize breast masses. *Ultrasound Med Biol*. 2002;28(1):36-39.
8. Lister D, Evans AJ, Burrell HC, et al. The accuracy of breast ultrasound in the evaluation of clinically benign discrete, symptomatic breast lumps. *Clin Radiol*. 1998. doi:10.1016/S0009-9260(98)80167-0
9. Effects T. Biological Effects of Diagnostic Ultrasound: A Review 1. 1978;(October 1977):479-483.
10. Chevallier P, Ruitort F, Denys A, et al. Influence of operator experience on performance of ultrasound-guided percutaneous liver biopsy. *Eur Radiol*. 2004;14(11):2086-2091. doi:10.1007/s00330-004-2407-0
11. Jeh SK, Kim SH, Choi JJ, et al. Comparison of automated breast ultrasonography to handheld ultrasonography in detecting and diagnosing breast lesions. *Acta radiol*. 2016;57(2):162-169. doi:10.1177/0284185115574872
12. Patlan-Rosales PA, Krupa A. A robotic control framework for 3-D quantitative ultrasound elastography. *Proc - IEEE Int Conf Robot Autom*. 2017:3805-3810. doi:10.1109/ICRA.2017.7989440
13. Morgan MR, Broder JS, Dahl JJ, Herickhoff CD. Versatile Low-cost Volumetric 3D Ultrasound Platform for Existing Clinical 2D Systems. *IEEE Trans Med Imaging*. 2018;37(10):2248-2256. doi:10.1109/TMI.2018.2821901