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Ultrasound Computed tomography for early breast cancer detection

I. INTRODUCTION

Every year around 8 million new cases of Breast Cancer are reported in the world. This is the most frequent malignant tumor in women and one of highest mortality rates [1]. However, survival rates are nearly 100% if detected at early stages [2]. For this reason, mammogram screening programs were developed. However, mammography presents radiation risk and moderate sensitivity, especially in dense breast tissue, which is more likely to develop cancer [3]. A promising alternative are the Ultrasound Computed Tomography USCT systems. In the most common scheme of USCT, the patient lays face down on a couch with the breast inside a water tank surrounded by a ring array of ultrasound transducers [4]. When a transducer of the ring emits an ultrasound pulse, the other transducers record the scattered and transmitted signals. These signals are analyzed and processed to recover the acoustical properties of the medium they went through. UCTS allow obtaining images of both the reflection (standard US images) and transmission of the US in the body. The last mentioned modality allows obtaining images of the speed of sound of the tissues. The speed of sound is well correlated with the tissue density and therefore, it can provide similar structural information to X-ray mammograms [5]. Consequently, imaging the speed of sound could provide an interesting alternative to detect breast cancer, avoiding the radiation and painful compression present in X-ray mammography.

The potential of these systems as a main diagnostic tool is currently limited by the large computational cost required for image reconstruction. Several methods have been proposed for reconstructing USCT images from the recorded signals. The methods that solve the wave equation (called Full Wave Inversion methods) [6] obtain the best results in terms of accuracy, resolution and artefacts control, but their computational burden limits its application in the clinical practice. There are faster reconstruction methods based on approximate models, such as the ray-tracing algorithms [6] but consequently they are hampered by a worst resolution.

In this work, we compare the performance of several reconstruction methods for USCT to reconstruct the speed of sound. Several regularizations and numerical strategies will be presented to speed up and improve the calculations. The presented methods will be applied to the reconstruction of both simulated and real data obtained in a simple prototype of USCT system.

II. METHODS

We will present three methods to reconstruct the speed of sound maps. First, a straight-rays Filtered Back projection (FBP) algorithm will be evaluated. Second an iterative bent-ray algorithm based in the Maximum likelihood and Entropy Maximization ML-EM together with the Fast Marching Method will be analyzed [7]. The use of bent-rays allow taking into account the refraction experienced by the wave front when transmitting across different media. Finally, a full wave inversion FWI method based in the use of the Adjoint field will be also presented [6]. Some regularizations were also studied to improve the performance of the bent-ray algorithm.

The methods were tested with both simulated and experimental data. The simulated data was obtained with a full wave code [8] and a numerical breast phantom. For the experiments, we used our first prototype of USCT system. It is based on a pair of independent 128-element, 3.2 MHz array transducers mechanically moved describing a 100 mm radius circle. An agar-glycerin-gelatin phantom was employed for these tests. For simulations 256 emitter-receiver pairs and a field of view (FOV) of 100 mm were used. For experimental data 23 Fan Beams covering an angle of 60 º (equivalent to 160 receivers per emitter) and a FOV of 200 cm were employed. The images were reconstructed in 2D mode with 1 mm pixel.

We evaluated four quality parameters in the reconstructed images: detectability, uniformity, resolution and contrast.

III. RESULTS AND CONCLUSION

Three codes for image reconstruction in USCT were implemented. First, a straight-ray code based in the FBP method was studied. The calculation time per slice with this method is ~0.3sec. The quality parameters analyzed for this method demonstrates its dependence on the employed frequency for the initial signal.

Second, a ben-rays code was also developed. The obtained images with both simulated and experimental data

present correct quality parameters and can be obtained in a reasonable amount of time (~6min/slice), and the regularizations applied improve significantly the performance of the method.
Finally the full wave code implemented present the beast quality parameters of all the presented methods but consequently, its calculation time per slice is significantly higher (~15 min). Nevertheless it is very competitive with the current calculation times reported by other works [6].
These results are encouraging and we are currently working on methods to further improve them. We are confident that the possibility of having quantitative US images in a reasonable time will expand the applications of this technique.
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Summary

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