3D GPU-based implementation of the contrast source inversion for breast lesion detection

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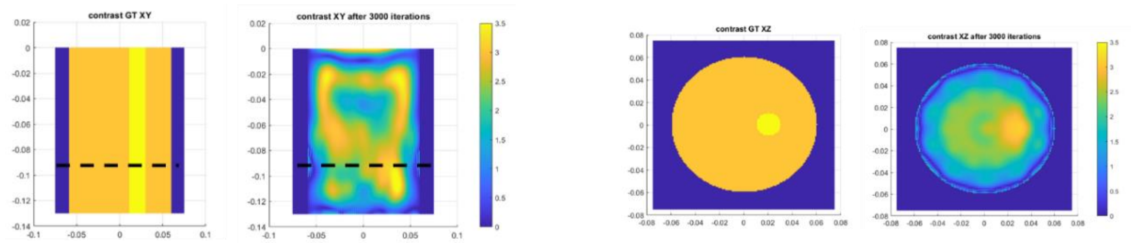
In microwave tomography, applying a proper inversion method to the measured data may result in quantitative imaging of the electrical properties (EPs) at the frequencies of the used electromagnetic radiation. Some physiopathological statuses of the breast tissue can be distinguished based on the estimated EPs [1]. A previous approach presented in [2] reports preliminary results obtained with a two-dimensional implementation of the Contrast Source Inversion (CSI) method [3] applied to simulated data. This work aims to discuss the transition to a 3D algorithm. Some optimization techniques in the MATLAB environment have been applied to the 2D version to reduce time consumption, which becomes a predominant variable with 3D data. Namely, computationally expensive operations on large data have been transferred to GPU (NVIDIA A 100 80 GB). This leads to an advantage especially for the FFT, which is performed in every iterative step. The efforts have permitted to reduce the execution time of each iterative step, reaching a speed-up factor of about 25 with respect to the CPU (Intel Xeon Gold 6430 2.10 GHz 512 GB RAM) version of the code. To obtain preliminary results about the feasibility of the 3D imaging method for detecting dielectric properties, a virtual experiment was performed. The transmit-receive setup is composed of a transmitting antenna that assumes ten equidistant positions around a cylindrical phantom, and a receiving antenna assuming forty equidistant positions around it. A heterogeneous phantom was considered, with electrical properties that emulate the ones of a healthy breast (σ = 0.1 and εr = 4), and a longitudinal cylindrical inclusion (r = 1 cm), whose high electrical properties simulate those of a breast lesion (σ = 1 and εr = 15). The incident electric field was obtained through the simulation of a Horn antenna fed at the frequency of 5 GHz, performed in Sim4Life. Total electric fields were computed in the receiving antennas' locations and a homogeneous initial guess (σ = 0.01 and εr = 3) was adopted. An additive regularization in the CSI cost functional was introduced to overcome the image artifacts induced by the ill-posedness of the inverse scattering problem. Figure 1 provides results obtained after 3,000 iterations of CSI (about 2.5 hours of execution).



(a) **(b)**

Figure 1. Expected and reconstructed maps of contrast in the vertical section (a) of the phantom and in the transverse section (b) of the phantom corresponding to the one highlighted by the black line in (a) (section of measurement).

The reconstruction is given by only one section of receivers. Although the overall reconstruction is noisy, in the considered section the inclusion is localized correctly. Future developments include the improvement of the performance of the code and its stability with respect to the input non-ideality, as well as the analysis of different scenarios and multiple frequencies.

1. Y. Cheng and M. Fu, "Dielectric properties for non-invasive detection of normal, benign, and malignant breast tissues using microwave theories", Thoracic cancer, 9(4), pp. 459–465, 2021.

2 Alessandra Ronca, Alessandro Arduino, Luca Zilberti, Oriano Bottauscio and Gianluigi Tiberi, "Assessment of the Feasibility of Breast Lesion Detection with Contrast Source Inversion for Microwave Tomography: A Virtual Experiment", EUCAP conference 2024.

3. P. Van den Berg and A. Abubakar, "Contrast Source Inversion Method: State of Art", vol. 34, pp. 189-218, 2001.