Acoustic Imaging for Human Thorax Using Contrast Source Inversion

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Acoustic imaging, especially the ultrasound imaging, has become an essential biomedical imaging tool because of its non-invasive, non-ionization and relatively low cost. Although ultrasound has been widely used, thoracic ultrasound imaging has generally considered as a challenge. This is because the strong attenuation of acoustic wave in the lungs makes the conventional ultrasound at 2-10 MHz impossible to penetrate into the chest. Recently, Rueter *et al.* [1] studied the low frequency ultrasound propagation in human thorax and suggested that ultrasound at 0.01-1MHz can propagate through the thorax at a speed of more than 1000m/s, thus can be used for pulmonary imaging.

In this paper, we further study the feasibility of thorax imaging using low-frequency ultrasound based on contrast source inversion (CSI) [2]. The physical model of acoustic imaging was established based on acoustic wave equation. The inhomogeneity in target density makes the relationship between the contrasts and the total pressure highly nonlinear. To reduce this nonlinearity, we introduce two contrast sources to ensure the symmetry of the equation, such that the inverse problem can be solved efficiently by alternately updating two contrast sources and two contrasts. Moreover, to improve the stability of the algorithm, we applied the multiplicative regularization scheme with two additive regularization factors. The reconstructed compressibility, attenuation, and density of a human thorax model based on the acoustic scattered field at 39 kHz are shown in Figure 1. From the inversion results, we can see that the algorithm can quantitatively reconstruct compressibility and qualitatively reconstruct attenuation and density of human thorax with good accuracy.

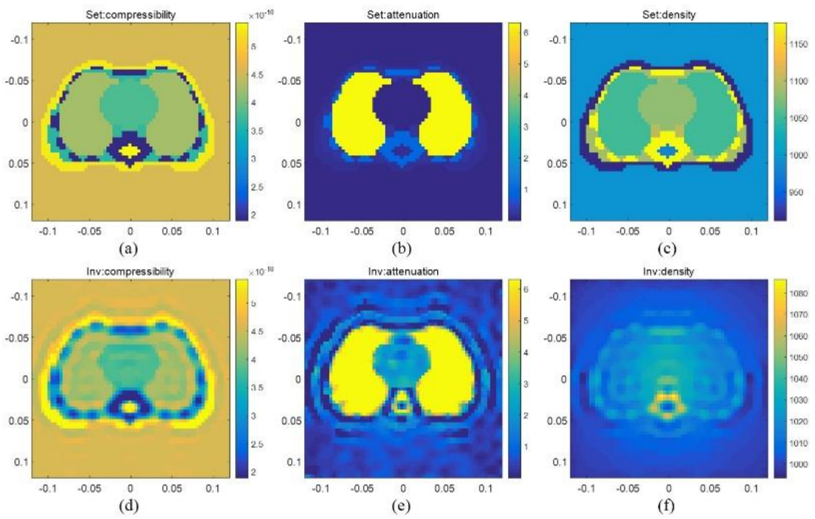

Figure 1. Model settings and inversion results for human thorax (a) set compressibility (b) set attenuation (c) set density (d) inverse compressibility (e) inverse attenuation (f) inverse density.

1. D. Ruter, H.-P. Hauber, D. Droeman, P. Zabel, and S. Uhlig, “Low-frequency ultrasound permeates the human thorax and lung: a novel approach to non-invasive monitoring,” Ultraschall in der Medizin-European Journal of Ultrasound, 31, 1, 2010, pp. 53-62, doi:10.1055/s-0028-1109482.

2. P. M. van den Berg and R. E. Kleinman, “A contrast source inversion method,” Inverse Problems, 13, 6, July 1997, pp. 1607-1620.