International Workshop on
Medical Ultrasound Tomography
London, 27-29 June 2022
NPL National Physical Laboratory UCL Imperial College London

Contribution ID: **39** Type: **not specified**

Ray-based inversion accounting for scattering for biomedical ultrasound tomography

Wednesday, June 29, 2022 10:00 AM (20 minutes)

Most approaches to sound speed estimation in full waveform ultrasound tomography fit computationally expensive wave equation solvers to the measured time series. The computational cost of inversions therefore becomes a significant hurdle, especially for 3D tomography. This problem is exacerbated when using a sparse rotating detector array as the efficiency of such solvers does not change as the number of receivers decreases, but scales only with the number of emitters. Furthermore, it can be challenging to incorporate the directional responses of the ultrasound transducers into these models efficiently, often a key requirement to reduce model mismatch. Here we propose an inversion approach [1] that uses the full measured waveform but fits an efficient forward model based on two-point ray tracing [2]. It scales with both the number of sources and receivers, and can straightforwardly account for sensors'directional response. Whereas time-of-flight based inversion approaches that use rays only account for refraction, this approach also accounts for first-order scattering through the use of a Hessian matrix in the inversion, and for geometric spreading through the use of Green's law. Frequency-dependent (power law) absorption and dispersion are also accounted for in the model. The approach is based on a second-order iterative minimisation of the difference between the measurements and a model based on a ray-approximation to the heterogeneous Green's function. Using a second-order iterative minimisation scheme, applied stepwise from low to high frequencies, the effects of scattering are incorporated into the inversion. The method is demonstrated using ultrasound data simulated using the k-Wave toolbox [3] and for a realistic breast phantom [4].

[1] A Javaherian, B T Cox, 2021, Ray-based inversion accounting for scattering for biomedical ultrasound tomography,, Inverse Problems, 37 (11), 115003.
[2] A Javaherian, F Lucka and B T Cox, 2020, Refraction-corrected ray-based inversion for three-dimensional ultrasound tomography of the breast, Inverse Problems, 36 125010.
[3] B E Treeby and B T Cox, 2010, k-Wave: MATLAB toolbox for the simulation and reconstruction of photoacoustic wave fields, J. Biomed. Opt. 15 021314.
[4] Y Lou, W Zhou, T P Matthews, C M Appleton and M A Anastasio, 2017, Generation of anatomically realistic numerical phantoms for photoacoustic and ultrasonic breast imaging J. Biomed. Opt. 22 041015.

Preferred Contribution Type

Presentation

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