Ultrasound transducer identification enables high-resolution tomographic brain imaging

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Background, Motivation and Objective

Full-waveform inversion (FWI) has recently emerged as a technique to quantitatively image the human brain with high resolution. However, even though FWI has shown great promise *in silico*, realistic acquisition conditions introduce a series of uncertainties that cannot be fully considered using existing schemes. This could lead to a degradation of resolution and accuracy, and even make the solution of the inverse problem impossible.

One such sources of uncertainty is related to the behaviour of transducers, which existing schemes assume to be point-like, while also neglecting their inherent electro-acoustic response. Consequently, we extend traditional FWI algorithms by using a technique for the characterisation of transducers that ensures a highly accurate modelling of their response. Subsequently, we explore the impact that uncertainties in transducer behaviour have on the resulting reconstructions.

Statement of Contribution/Methods

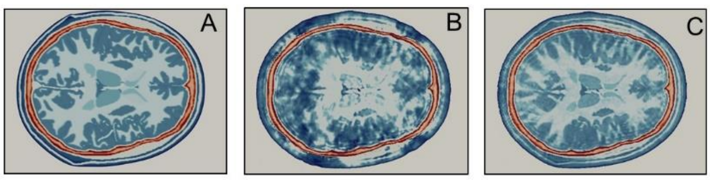
The proposed technique generalises traditional FWI schemes through the addition of a secondary optimisation problem whose aim is to find a suitable transducer model from measurements while honouring the full wave equation. This leads to transducer models that are best suited for techniques such as FWI or optoacoustic tomography, in which close agreement between experimentally acquired and numerically modelled data is needed.

The technique is validated on experimental measurements acquired using disk transducers of different diameters, with and without lenses, and results are compared to those obtained using common modelling approaches: neglected response, deconvolution and holography/backpropagation, in terms of errors in both magnitude and phase.

The impact on FWI of uncertainties in transducer behaviour is explored using a numerical head phantom by comparing the quality of the reconstructions when transducer response is correctly or incorrectly modelled.

Results/Discussion

Figure 1-A to C suggest that a high degree of certainty about transducer response is needed for FWI to be applied under realistic acquisition conditions. The recovered transducer models (Figure 1-D and E) lead to the conclusion that the proposed technique can achieve superior transducer identification performance than commonly employed ones.



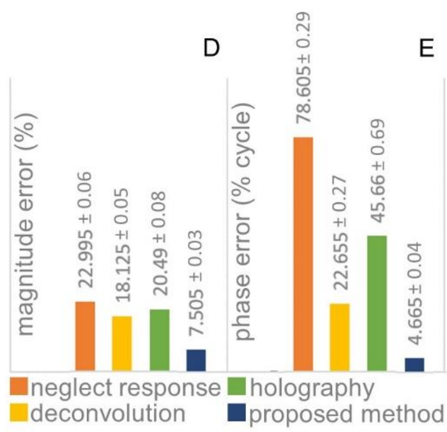


Figure 1. Numerical head phantom (**A**) whose FWI reconstruction is degraded by uncertainties in transducer behaviour (**B**); reconstruction quality is recovered when introducing correct transducer models (**C**). Comparison of different methods for transducer identification applied to a 16 mm disk transducer in terms of magnitude error (**D**) and phase error as percentage of a cycle (**E**), calculated over 16762 spatially independent samples of the wavefield.