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Towards 3D Brain Imaging in Small Animals using Full-Waveform Inversion

Full-waveform inversion (FWI) is an iterative image-reconstruction technique used in exploration seismology to produce high-quality tomographic images for acoustic properties of the subsurface by minimising the misfit between acquired and modelled data. FWI has also been shown to have some exciting applications in ultrasound imaging of soft tissue, including breast cancer diagnosis, however the method has yet to be applied to brain-imaging in small animal models where hard tissue is present and 3D reconstruction is required. Here we demonstrate the feasibility of 3D small-animal transcranial tomography using FWI *in silico* and implement our FWI algorithm to reconstruct an *in vitro* acoustic brain phantom in 2D using data acquired with independently translated medical transducers.

In this study a pair of 96-element linear probes (P4-1, ATL) were each assigned a set of 3-axis motors for independent translation, allowing for a larger imaging region and for 3D acquisitions to be performed. To test this experimental setup, an *in silico* mouse brain and skull acoustic model was created and placed between two 1152-element plane arrays, each representing the translation of a linear array over 12 positions (with 2.5 mm spacing), as shown in Fig1.a. A synthetic 3D dataset of this scene was produced so that the velocity model could be reconstructed using a robust 3D FWI algorithm. To mitigate cycle skipping due to the skull tissue, a starting model consisting of the mouse skull and homogenous water (1500 ms-1) was used. To demonstrate this method using real data, we acquired a 2D dataset of a half-scale 2.5D brain phantom made using a polyvinyl alcohol cryogel to mimic brain tissue. By translating both probes vertically when acquiring data, a two-plane array consisting of 960 elements was formed, from which a subset of 240 were selected as sources. Element delays and positions were calibrated by time of flight optimisation using a watershot dataset and the velocity model was reconstructed using our 2D FWI algorithm.

Fig1.b shows FWI results of the mouse brain and skull model. When compared to the ground truth, a relative error of 0.110 % has been achieved (starting model relative error = 2.562 %). In Fig1.c-d the photo of the brain phantom and the reconstructed velocity model can be seen to closely match. In future work we will introduce rotation to further improve our transducer scanning sequence and apply our method to image *ex-vivo* brain and skull tissue.

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