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Deep-Learning-Driven Low Frequency Extrapolation for Full-Waveform Inversion Breast Imaging

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Full-waveform inversion (FWI) is a promising ultrasound computed tomography (USCT) alternative to X-ray mammography for breast cancer screenings. This reconstruction method can recover high quality acoustic models at sub-wavelength resolutions by modelling the full wave propagation of ultrasonic waves to minimise the misfit between numerically generated and observed USCT data. This allows clinically useful images to be recovered while using frequencies low enough to image the whole breast without using ionising X-rays, which pose a non-negligible risk of inducing breast cancer. However, FWI tends towards local minima when the phase shift between synthetic and observed data exceeds a half-cycle. Medical transducers do not typically image at frequencies that meet this criterion for breast imaging problems. We therefore propose the application of a U-Net based low frequency extrapolation convolutional neural network (CNN) to overcome bandwidth limited hardware.

Imaging was performed using the dual P4-1 probe system seen in Figure 1b. These probes are among the lowest frequency medical probes available. Despite this, P4-1 data appears to be bandlimited, as seen by the unsuccessful P4-1 data reconstructions (see Figure 1c and 1d). Conversely, synthetic data generated using a broadband source wavelet resulted in successful reconstructions (see Figure 1c), suggesting this USCT data meets the half-cycle criterion. The CNN was trained to predict the broadband equivalent of P4-1 input data by supervised learning. Training data consisted of ~7 million paired bandlimited (input) and broadband (target) chunks of USCT data (256 times samples, 96 traces). These were sampled from synthetic datasets from imaging random slices of 3D numerical breast models. 15 additional test datasets were generated using breast slices not used during training. Experimental imaging data of a CIRS breast phantom was acquired using the dual-probe system.

Synthetic extrapolated FWI reconstructions were found to closely match broadband FWI reconstructions in all 15 test cases (see Figure 1c). The mean root mean square (RMS) difference between true breast models and the bandlimited, broadband and extrapolated reconstructions were found to be 34.76 ± 2.67 ms-1, 9.35 ± 1.17 ms-1 and 8.61 ± 0.93ms-1 respectively. Given that the RMS for broadband and extrapolated cases were comparable and lower than the bandlimited RMS, this suggests that the CNN predicted low frequency content was sufficient to meet the half-cycle criterion. Experimental breast phantom FWI reconstructions closely matched CT images of the phantom (see Figure 1d). This suggests that the low frequency extrapolation was also successful in the experimental case.

Preferred Contribution Type

Presentation

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