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Improved Reverberation Noise Suppression in the Aperture Domain Using 3D Fully Convolutional Neural Networks: In Vivo and Phantom Experiments

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Background, Motivation and Objective

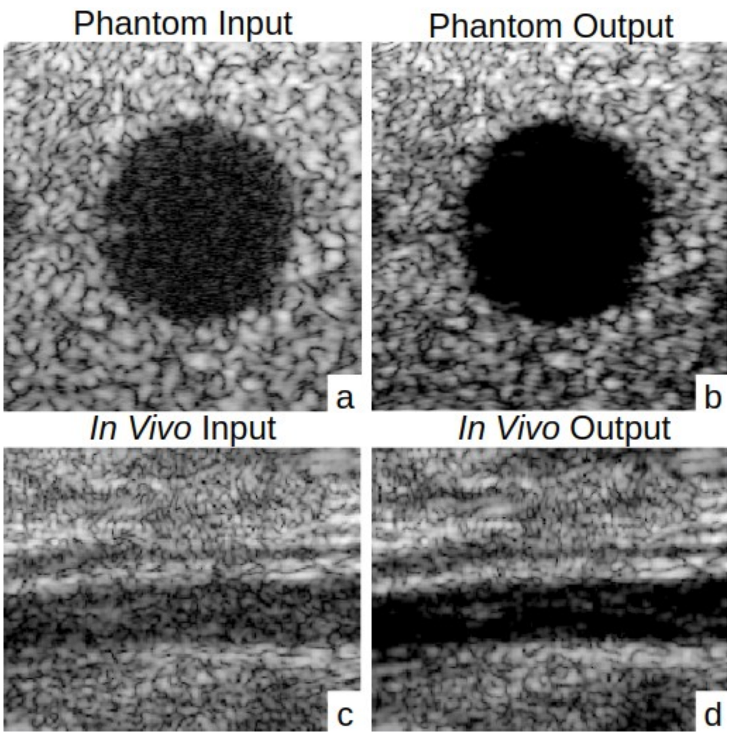
Reverberation clutter is diffuse image noise induced from multiple reflections between tissue layers that diminishes the quality of the channel signals and resulting image, which effects the performance of techniques that rely on these signal and image data, such as phase aberration correction, speed of sound estimation and flow estimation. Previously, we introduced a 3D fully convolutional neural network (FCNN) that performed well in removing reverberation clutter in channel signals, but performed poorly in anechoic regions. Here, we introduce several modifications to our 3D FCNN to improve functionality and generalize to in vivo data.

Statement of Contribution/Methods

To train the network, Field II Pro was used to simulate full synthetic aperture channel data on a range of shapes, echogenicities, and anechoic regions. Reverberation noise in the range of-20 to 10 dB and thermal noise in the range of -20 to 5 dB was added to the simulated channel data. These pairs of image channel data, before and after adding noise, were used to train a custom 3D FCNN to remove the reverberation and thermal noise across all (transmit and receive) channel data. To improve overall performance, various architectures and loss functions for the neural network optimization were also explored.

The network was tested on an ATS 549 phantom and in vivo on the common carotid artery of three subjects using a L12-3v transducer on a Verasonics Vantage 256 system. Clutter was induced on the phantom data by placing fatty bovine tissue between the transducer and phantom.

Results/Discussion



The FCNN showed significant reduction in reverberation in the phantom data channel signals, verified by an increase in normalized correlation with the reference channel signals from 0.69 to 0.92 for the input and output channel signals, respectively. Images generated from the phantom data before and after the network are shown in Figs. a and b, and images for an in vivo carotid artery in Figs. c and d. Across 5 anechoic phantom lesions, the lesion CNR was increased from 1.47 to 1.55, generalized CNR was increased from 0.84 to 0.98, lag one coherence improved from 0.84 to 0.98, and the lesion contrast was increased from -15.8 to -33.4 dB. In addition, the reverberation noise in the carotid was suppressed, showing the network’s ability to generalize to in vivo data.