Convolutional Neural Network Based Blind Estimator of Phase-aberrated Point Spread Function for Ultrasound Imaging

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Background, Motivation and Objective

This research focuses on the estimation of point spread function (PSF) from beamformed RF data with phase aberration for ultrasound imaging. By means of deconvolution with the PSF, the interested tissue structures have chances to be imaged with high spatial resolution and contrast overcoming the physical limits of diffraction and finite pulse length. However, even with prior knowledge of the system setup, the PSF cannot be well determined before clinical scanning, typically for technically difficult bodies, because of inevitable phase aberration issues resulting from the speed of sound inhomogeneity nature of human tissues. Thus, blind phase-aberrated PSF estimation directly from the ultrasound imaging data is beneficial for deconvolution with clinical scanning.

Statement of Contribution/Methods

In this work, we propose a novel convolutional neural network based blind estimator of phase-aberrated PSF. We train a modified U-Net that takes a beamformed RF patch in a speckle region as the input and predicts its corresponding PSF with phase aberration. The objective of the network is to deconvolve the scatterer distribution and recover the underlying PSF. Based on near field phase screen model, we simulated RF phase aberrated PSF using the K-wave simulation toolbox by altering the phase-aberration profile across array elements. The PSFs and their corresponding beamformed RF data in speckle regions formed the training pairs. Since the network was trained using the mean squared error loss function which calculated pixel-wise differences, the PSFs should be well aligned. We found that alignment with the center of mass of the PSFs yielded the most robust performance because phase-aberrated PSFs are often asymmetric. Afterward, the training pairs were used to train the neural network in an end-to-end and supervised setting.

Results/Discussion

The neural network was tested using the unseen simulated pairs and showed promising results (see Fig. 1). In comparison with cepstrum-based approaches, the network could estimate the asymmetric, phase-aberrated and out-of-focus PSFs. Note that in this work we assume the PSFs are spatially-invariant in the input RF patch and patch-wise estimation can be used to estimate the spatially-variant PSFs of the entire imaging field of view.

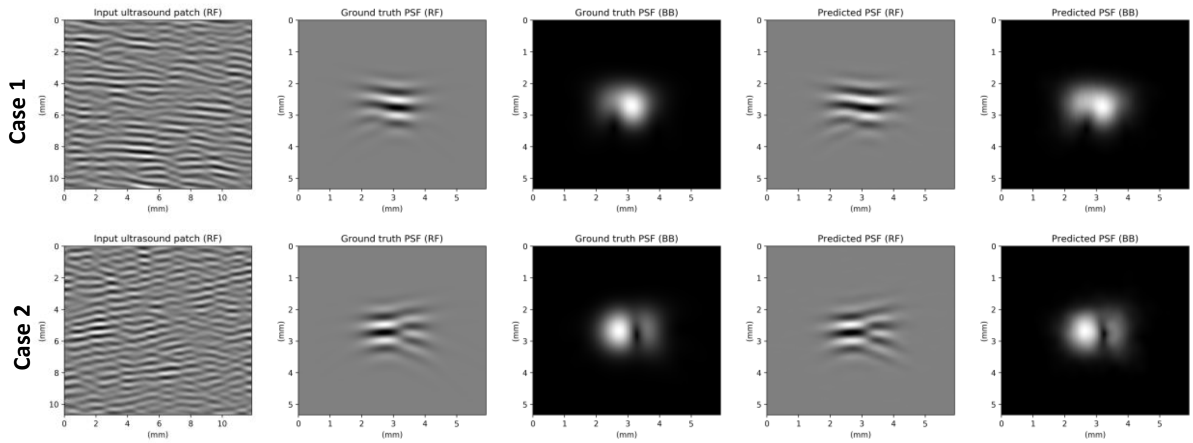

Fig 1. Column 1: neural network input – ultrasound beamformed RF patches with phase aberration. Column 2: Ground-truth phase aberrated PSF. Column 4: Estimated PSFs. Columns 3 and 5 are the envelope-detected PSFs only for visualization purpose. The maximum phase errors in case 1 and case 2 are $\pi/2$ at the imaging center frequency.