A Complex-valued Convolutional Neural Network for Phase-Aberrated Ultrasound Point Spread Function Estimation

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Background, Motivation and Objective

Conventional point spread function (PSF) estimation methods assume a constant global speed of sound in tissue, but actually it is inhomogeneous giving rise to phase-aberrated PSFs. The estimated PSFs affect the performance of post-processing such as phase aberration correction significantly. In our recent work, we showed a UNet-like convolutional neural network using radio frequency (RF) ultrasound patches to estimate the corresponding phased-aberrated PSFs. However, most clinical systems access to beamformed baseband instead of RF data. In this work, we alternatively propose a complex-valued convolutional neural network that directly takes into account complex calculation. It is more comprehensive that can process not only amplitude but also phase components. Additionally, baseband data requires much lower sampling rate, so the data size and cost at front-end can be reduced greatly.

Statement of Contribution/Methods

We simulated RF ultrasound PSFs using Field II simulation toolbox. The aberrated speckles are generated by randomly distributed scatterers and sound-velocity inhomogeneous PSFs with different phase-aberration profile. Then, these RF speckles and PSFs are demodulated and applied a lowpass filter to baseband. Baseband data can be advantageous to process decimation by a proper factor that suffices sampling theorem. The network was trained in a supervised method and tested using validation set. It takes baseband speckle patches as inputs and predicts associated baseband aberrated PSFs in the same size. Complex-valued mean squared error loss function and Adam optimizer were used to update parameters based on reducing pixel-wise difference.

Results/Discussion

Results are displayed in B-mode with a dynamic range of 40 dB. It appears that the complex-valued network produces aberrated PSFs with a high similarity near the location of main lobe, albeit with slightly deformed sidelobe. Although complex-valued convolutional neural networks have more complicated computation with respect to real-valued ones under the same architecture due to the interaction between the real and imaginary channels. In a narrowband setting, owing to decreased data size, it makes up the defect to some degree and can be utilized on more application.

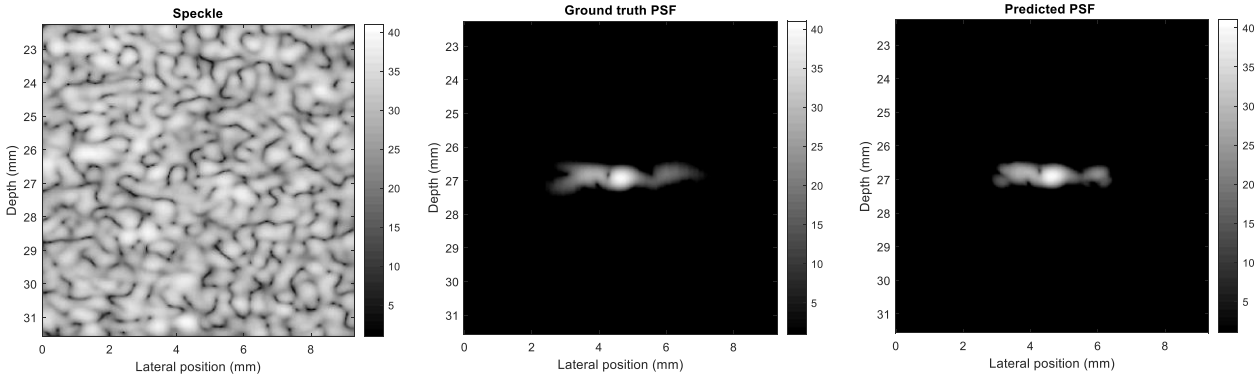

Fig 1. B-mode images of phase-aberrated speckle patch, PSF, and predicted PSF are derived from baseband training pairs and predictions.