Estimation of the Attenuation Coefficient from Ultrasonic Radio-Frequency Signals Using Deep Neural Networks

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Background, Motivation and Objective

Quantitative measures of the ultrasonic attenuation coefficient (AC) can be used for characterization and discrimination of pathological tissues. Current AC estimators compute certain features of backscattered radio-frequency (RF) echoes (e.g. mean signal frequency) and use them to calculate the AC based on various tissue models derived from physics. In this work we present a novel and model free approach to the AC estimation based on deep learning. We develop a deep neural network that can estimate the AC directly from the RF data.

Statement of Contribution/Methods

We consider the AC estimation as a regression problem, which can be addressed using a multi-layer neural network. First, we used Field II program to generate large amounts of training and validation RF data based on simulations including a piston transducer and tissue mimicking phantoms. We acquired 15360 independent RF lines for the phantom AC values of 0.1, 0.2, …, 1.5 [dB/(MHz*cm)]. Next, the sliding window technique was applied to generate 1D RF data patches, which were used as inputs to the network. Performance for the 1D patches of length k equal to 0.1, 0.2, 0.5 and 1 [cm] was evaluated. The network was trained to predict the AC value utilized to generate the phantom RF data by minimizing the mean absolute error. To additionally improve the training, we applied dropout technique. Moreover, we performed an exhaustive search to select better performing model hyper-parameters. After the training, the performance of our neural network was evaluated using RF data collected from a physical, homogeneous phantom with a piston transducer similar to the one used for the simulations.

Results/Discussion

The neural network was able to accurately predict the AC values for the simulated RF data. In the case of the physical phantom, AC of 0.7, the estimated AC values (mean value +/- standard deviations) were equal to 0.96 (+/- 0.22), 0.84 (+/- 0.32), 0.83 (+/- 0.19) for the window size values of 0.2, 0.5, 1 cm, respectively. We achieved the least biased estimation using large window size of 1 cm. Our preliminary results confirmed the feasibility of using deep learning to estimate the AC directly from the RF data. Methods based on neural networks have the potential to improve the estimation of the quantitative ultrasound parameters by utilizing information hidden in raw backscattered ultrasonic echoes.

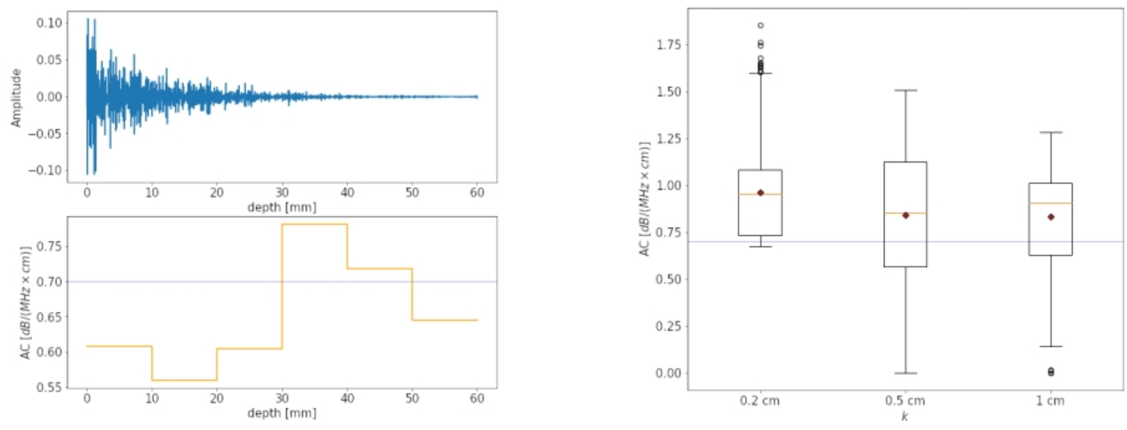

Figure 1: Example RF signal and estimated AC values (left); boxplot of AC values estimated by the model. Blue horizontal line indicates true AC value (0.7).