University Ph.D. Dissertation Defense

Department of Electrical Engineering

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Advancing Ultrasound Image Reconstruction through Fourier-Domain Beamforming and Local Sound Speed Estimation

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Date: Thursday, December 4, 2025

Time: 2:00 pm

Location: Building 200, Room 034 (200-034)

Zoom Link:
https://stanford.zoom.us/j/92274439937?pwd=HJWgbct765NXwhPj60W5WIDwI7gS2w.1

Ultrasound is a portable and low-cost imaging modality commonly used clinically. Traditionally, images are reconstructed from channel data using a beamforming process known as delay-and-sum (DAS), where the received signals in time are corresponded to different spatial locations in the medium, assuming a constant propagation speed. This algorithm involves simple steps that work well for general imaging cases but can be slow or inexact for advanced medical imaging applications.

This presentation first covers a new method to reduce the computational cost of reconstruction via Fourier beamforming. While DAS requires many time-domain interpolation operations, frequency-domain approaches can be more computationally efficient. I present an ultrasound adaptation of a radar Fourier-domain beamformer called the chirp scaling algorithm (CSA), which avoids interpolations by simply performing Fourier transforms and element-wise matrix multiplications. Performance comparisons with other beamformers show that CSA has similar image quality as other methods but greatly reduced CPU runtime.

Secondly, the presentation contains new approaches for ultrasound sound speed estimation to improve images. Improper image focusing causes aberration, reducing image quality especially *in vivo*. Modern aberration correction involves estimating a 2D (local) sound speed map of the medium to calculate more accurate beamforming time delays. I present an approach that uses a neural network to estimate sound speed specifically for liver imaging. To create an accurate dataset for network training, we first segmented high-resolution abdominal volumes and

randomly sampled them to simulate data acquisitions. We then performed supervised training on a neural network to obtain sound speed predictions from beamformed data. The network could produce rapid abdominal media estimates with up to wavelength-magnitude resolution and values within expected literature ranges.

Another estimation approach is to directly optimize image quality per acquisition with respect to the local sound speed. By using auto-differentiation software to implement a frequency-domain beamformer that more accurately models wave propagation while filtering out clutter, this more general gradient-descent-based optimization results in improved image resolution and less sound speed estimation bias compared to other sound speed estimators for data from cluttered or highly varied media. Overall, these results show potential for improving challenging clinical imaging scenarios.