Departmental Seminar: Electrical and Computer Engineering

Speaker: Joseph Hecker
Instructor: Dr. Siddhartha Sikdar
When: Thursday April 12, 2018 at 10:00 in ENGR 3202

Title: Displacement Estimation in Pulsed-Wave Ultrasound Based on Analysis of the Phase Spectra

Abstract:
Ultrasonic imaging provides a means of non-invasive analysis of biological structures and their motion. Tissue displacement estimation is critical in a number of applications. Elastography imaging involves analysis of tissue motion to derive information on clinically relevant mechanical properties of the tissue. Imaging of cardiac wall motion and of arterial wall motion have also been extensively investigated. Other emerging applications include functional brain imaging, where tissue pulsation provides physiologically relevant information about activation of brain regions. Therefore, over the past several decades a number of methods have been developed to robustly estimate tissue displacement.

The performance of these methods is impacted by speckle, a term used to describe the constructive and destructive interference that occurs as the transmitted signal propagates through tissue and undergoes specular and diffuse reflections from a multitude of scatterers. To overcome estimation errors induced by speckle, spatial and temporal averaging is typically applied, imposing practical limitations on the spatial and temporal resolution achievable by displacement estimation methods. Applications requiring large fields of view are particularly limited in terms of achievable acquisition frame rates further limiting performance. Systems reliant on averaging suffer from loss of spatial-temporal resolution, increased bias from adjacent samples in both time and space, and risk of corruption from errors caused by phase aliasing.

This research examines the problem of maintaining high spatial and temporal resolution while providing resiliency to estimator errors imparted by speckle and aliasing. This dissertation explores the fundamental assumptions of the underlying signal models on the processing algorithms used to calculate displacement in the presence of speckle and in scenarios with limited temporal sample support. The displacement estimation problem is derived in terms of the received signals' phase spectra which presents some advantages over conventional time-delay and phase-delay based displacement estimation methods and provides an opportunity to develop a number of phase spectrum-based displacement estimation algorithms. In this work, a specific displacement estimation algorithm is developed based on linear regression of the Doppler phase spectra with respect to radio frequency. This method is shown to enhance the analysis of tissue motion in the presence of speckle by providing a measure of estimator reliability and by providing increased robustness to estimator bias and phase aliasing. These benefits are commonly reserved for frequency-domain techniques requiring higher temporal sample support but are achieved here with only two samples. Examples of the estimator applied to simulated and experimentally collected data are shown.