Novel ultrasound signal processing methods for attenuation estimation

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Variations in the acoustic properties of ultrasound waves as they propagate through soft tissue contain information regarding the pathological state of tissue scanned. In this dissertation we examine the spectral characteristics of ultrasound attenuation and propose novel signal processing methods for estimating the attenuation coefficient.

Attenuation in ultrasound refers to the reduction in amplitude of the ultrasound wave as a function of distance. We focus on examining spectral variations introduced due to attenuation in soft tissues using ultrasound pulse-echo systems. We develop and evaluate three new attenuation estimation algorithms, two based in the spectral domain, namely the spectral cross-correlation method based on the spectral shift concept, a hybrid method that incorporates the benefits of both the spectral difference and shift approaches and finally an improved time-domain based algorithm using narrowband bandpass filtering techniques.

The proposed spectral shift method, referred as the spectral cross-correlation algorithm, compares entire power spectra instead of the spectral centroid or the center frequency shift. It therefore provides more robust and stable estimation of the attenuation coefficient from the power spectrum. The proposed hybrid spectral domain estimation method incorporates the benefits while reducing the limitations associated with both the spectral shift and spectral difference methods for attenuation estimation. The hybrid method unlike the spectral difference methods is independent of backscatter variations and provides robust attenuation coefficient estimation with fewer spectral noise artifacts when compared to the centroid downshift based algorithms. Ultrasound simulation and experimental results using tissue mimicking phantom demonstrate that the estimation accuracy of the proposed methods are better than spectral shift method (centroid downshift method), while also providing stable estimation at boundaries with variations in the backscatter when compared to the spectral difference method (reference phantom method).

Estimation results for *in-vivo* liver and breast data also demonstrate that proposed estimation methods outperform the classical frequency-domain estimation methods in terms of accuracy and precision. Promising results are obtained for the differentiation malignant tumors from benign masses and to characterize the diffuse tissue properties using the attenuation coefficient estimates.