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Optimal Basis For Ultrasound Rf Apertures: Applications to Real-Time Compression and Beamforming

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Abstract

Modern medical ultrasound machines produce enormous amounts of data, as much as several gigabytes/sec in some systems. The challenges of generating, storing, processing and reproducing such voluminous data has motivated researchers to search for a feasible compression scheme for the received ultrasound radio frequency (RF) signals. Most of this work has concentrated on the digitized data available after sampling and A/D conversion. We are interested in the possibility of compression implemented directly on the received analog RF signals; hence, we focus on compression of the set of signals in a single receive aperture. We first investigate the model-free approaches to compression that have been proposed by previous researchers that involve applications of some of the well-known signal processing tools like Principal Component Analysis (PCA), wavelets, Fourier Transform, etc. We also consider Bandpass Prolate Spheroidal Functions (BPSFs) in this study. Then we consider the derivation of the optimal basis for the RF signals assuming a white noise model for spatial inhomogeneity field in tissue. We first derive an expression for the (time and space) autocorrelation function of the set of signals received in a linear aperture. This is then used to find the autocorrelation's eigenfunctions, which form an optimal basis for minimum mean-square error compression of the aperture signal set. We show that computation of the coefficients of the signal set with respect to the basis is approximated by calculation of real and imaginary part of the Fourier Series coefficients for the received signal at each aperture element, with frequencies slightly scaled by aperture position, followed by linear combinations of corresponding frequency components across the aperture. The combination weights at each frequency are determined by the eigenvectors of a matrix whose entries are averaged cross-spectral coefficients of the received signal set at that frequency. The principal eigenvector generates a combination that corresponds to a variation on the standard delay-and-sum beamformed aperture center line, while the combinations from other eigenvectors represent aperture information that is not contained in the beamformed line. We then consider how to use the autocorrelation's eigenfunctions and eigenvalues to generate a linear minimum mean-square error beamformer for the center line of each aperture. Finally, we compare the performances of the optimal compression basis and to that of the 2D Fourier Transform.

First Advisor

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