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Compressive Sensing for Spectral Domain Optical Coherence Tomography

Dissertation Defense by

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Abstract

Spectral domain optical coherence tomography (SD OCT) imaging with high axial resolution and a large imaging depth requires a large number of sampling points in the spectral domain. This requires a high-resolution spectrometer with a large linear array camera which leads to a large amount of k-space measurements and a long data acquisition time that makes the imaging susceptible to unavoidable motion artifact. Furthermore such devices can be expensive and require high-speed electronics.

In this dissertation, compressive sensing (CS) SD OCT that reconstructs the images using only a portion of the k-space measurements required by the classical Shannon/Nyquist rate was proposed and studied. Several advanced CS SD OCT algorithms have been developed and evaluated. First, modified non-uniform discrete Fourier transform (MNUDFT) matrix was proposed, which enables CS SD OCT using under-sampled non-linear wavenumber spectral data. Second, the noise reduction using Modified-CS was studied which shows that the averaged Modified-CS SD OCT results in better image quality in terms of SNR, local contrast and contrast to noise ratio (CNR), compared to the classical averaging method. Third, a novel three dimensional (3D) CS SD OCT sampling pattern and reconstruction procedure was proposed. The novel 3D approach enables efficient volumetric image reconstruction using the k-space measurements under-sampled in all three directions and reduces the amount of required measurements to less than 20% of that required by regular SD OCT.

CS SD OCT is commonly solved by an iterative algorithm that requires numerous matrix-vector computation, which is computationally complex and time-consuming if solved on CPU-based systems. However, such computation is ideal for parallel processing with graphics processing unit (GPU) which can significantly reduce its computation time. In this dissertation, real-time CS SD OCT was developed on a conventional desktop computer architecture having three GPUs. The GPU-accelerated CS non-uniform in k-space SD OCT and real-time CS SD OCT with dispersion compensation were also proposed and implemented using the same computer architecture.

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