PhD Thesis title: "Maximizing the information content of dual energy x-ray and CT imaging"

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ABSTRACT:

Computed tomography (CT) has become an essential tool in modern medicine since its introduction in the early 1970s. It generates cross-sectional images of the body's x-ray attenuation by measuring the transmission of x-rays in many directions. Because CT uses ionizing radiation, a governing principle is to use the least amount of radiation dose that still provides diagnostic-quality images. One approach to ensure that dose is appropriately used is to explore the information content of CT scans.

This work examines efficient methods for encoding, storing, and extracting information from CT scans, especially as they pertain to spectral x-ray imaging. CT systems that can take advantage of the different attenuation properties of x-rays at different energies can provide additional diagnostic information, known as dual energy imaging. A new technique called Synthetic CT is introduced that enables images from CT protocols other than what was acquired to be retrospectively synthesized. With this tool, the information contained within a dual energy scan can be used to demonstrate the effect of protocol selection on image quality and dose distribution. In addition to experimentally validating the developed synthetic CT theory, further efforts have led to image-based synthetic CT, incorporation of electronic noise models for ultra low dose simulation, and a simple graphical user interface that demonstrates the flexibility of synthetic CT.

We also explored an important spectral imaging technology – photon counting detectors with energy discrimination capabilities. In principle, these detectors capture all the spectral information of transmitted x-rays by counting the number of photons at each energy. Optimal configurations of ideal photon counting detectors are first investigated, leading to the elegant discovery that two energy-dependent weighted counts can form a sufficient statistic for dual energy imaging. In practice, photon counting detectors have count rate limitations and imperfect spectral responses. The performance of realistic photon counting detectors is modeled and compared to conventional dual kV techniques. We found that both optimized photon counting and dual kV systems can significantly increase the dose efficiency of dual energy imaging.

References to author publications that relate specifically to the dissertation:

A. S. Wang, C. Feng, and N. J. Pelc, "Image-based synthetic CT: simulating arbitrary low dose single and dual energy protocols from dual energy images," Proc. SPIE: Physics of Medical Imaging **8313**, 831352 (2012).

A. S. Wang and N. J. Pelc, "A comparison of dual kV energy integrating and energy discriminating photon counting detectors for dual energy x-ray imaging," Proc. SPIE: Physics of Medical Imaging **8313**, 831332 (2012).

A. S. Wang and N. J. Pelc, "Synthetic CT: Simulating arbitrary single and dual energy protocols from a dual energy scan," Med. Phys. **38**, 5551-5562 (2011). (Editor's Pick)

A. S. Wang, D. D. Harrison, V. Lobastov, and J. E. Tkaczyk, “Pulse pileup statistics for energy discriminating photon counting x-ray detectors,” Med. Phys. **38**, 4265-4275 (2011). (Editor’s Pick)

A. S. Wang and N. J. Pelc, “Sufficient statistics as a generalization of binning in spectral x-ray imaging,” IEEE Trans. Med. Imag. **30**, 84-93 (2011).

A. S. Wang and N. J. Pelc, “Understanding and controlling the effect of lossy raw data compression on CT images,” Med. Phys. **36**, 3643-3653 (2009).