PhD Thesis title: "Retrieving information from scattered photons in medical imaging"

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ABSTRACT:

In many medical imaging modalities, as photons travel from the emission source to the detector, they are scattered by the biological tissue. Often this scatter is viewed as a phenomenon that degrades image quality, and most research is focused on designing methods to either discard the scattered photons or correct for scatter. However, the scattered photons also carry information about the tissue that they pass through, which can perhaps be extracted. In this research, we investigate methods to retrieve information from the scattered photons in two specific medical imaging modalities: diffuse optical tomography (DOT) and single photon emission computed tomography (SPECT). To model the scattering of photons in biological tissue, we investigate using the Neumann-series form of the radiative transport equation (RTE). Since the scattering phenomena are different in DOT and SPECT, the models are individually designed for each modality. In the DOT study, we use the developed photon-propagation model to investigate signal detectability in tissue. To study this detectability, we demonstrate the application of a surrogate figure of merit, based on Fisher information, which approximates the Bayesian ideal observer performance. In the SPECT study, our aim is to determine if only the SPECT emission data acquired in list-mode (LM) format, including the scattered-photon data, can be used to compute the tissue-attenuation map. We first propose a path-based formalism to process scattered photon data, and follow it with deriving expressions for the Fisher information that help determine the information content of LM data. We then derive a maximum-likelihood expectation-maximization algorithm that can jointly reconstruct the activity and attenuation map using LM SPECT emission data. While the DOT study can provide a boost in transition of DOT to clinical imaging, the SPECT study will provide insights on whether it is worth exposing the patient to extra X-ray radiation dose in order to obtain an attenuation map. Finally, although the RTE can be used to model light propagation in tissues, it is computationally intensive and therefore time consuming. To increase the speed of computation in the DOT study, we develop software to implement the RTE on parallel computing architectures, specifically the NVIDIA graphics processing units (GPUs).

References to author publications that relate specifically to the dissertation:

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- **Abhinav K**. **Jha**, Eric Clarkson, Matthew A. Kupinski, "Signal detection in diffuse optical tomography: An ideal-observer framework", Hopkins Imaging Conference, 2013

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- **Abhinav K. Jha**, Eric Clarkson and Matthew A. Kupinski, "Modeling light propagation in tissue using the radiative transport equation", Pan-American Advanced Studies Institute on Frontiers in Imaging Science, Bogota, Colombia, 2011.