UNIVERSITY of HOUSTON | ENGINEERING

Department of Biomedical Engineering

Friday, July 24th, 2020

10:00 AM

Defense held online via Zoom

Nathaniel R. Fredette

PhD Dissertation Defense

Dr. Mini Das, Faculty Advisor

"Multi-Material Discrimination Using Photon Counting Spectral Computed Tomography"

Abstract

Quantitative volumetric mapping of multiple materials with spectral computed tomography (CT) has applications in many areas including biomedical imaging, defense and security, geophysical imaging of rock composition and in materials and chemical imaging. Dual or multi-kVp x-ray exposure when using an energy-integrating detector has been proposed and demonstrated in the past for biomedical imaging. Dose and imaging time along with insufficient spectral separation limits their applications and ability for accurate quantitation. When using photon counting spectral detectors (PCDs), some of these limitations can be overcome. However, low dose and computationally efficient mechanisms to yield volumetric maps of more than two or three materials remain to be a significant challenge. Recently, our group has proposed a multi-step method for material decomposition where each material is decomposed one-by-one in a step-wise fashion with focus on one material at each step. Experimental implementation of this method adds new challenges including reliable detector spectral corrections. This work presents initial simulation studies, experimental validation and detailed methods to successfully implement this multi-material decomposition technique. Here we show examples with virtual separation of up to six materials in simulations and five materials in experiments on our benchtop spectral CT system. For comparison, a conventional single-step decomposition is also performed on the same synthetic and experimental data. Results show a significant reduction in decomposition errors with low noise over the single-step approach. In addition, a biological specimen of a chicken heart was injected with tantalum and gadolinium and multi-step decomposition was also successfully conducted on this sample. These studies offer validations required for robust utility of the method in imaging applications requiring separation of multiple materials. Finally, photon counting spectral computed tomography along with material decomposition is applied to the problem of bone density quantification in an arthritic mouse model to show clinical applicability of the technique. Although sample sizes remain small at these early stages, discernment between arthritis and control groups was possible both locally and globally indicating the potential of the technique.

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