Prior image constrained image reconstruction in emerging computed tomography applications

Stephen T. Brunner

Under the supervision of Dr. Guang-Hong Chen

At the University of Wisconsin-Madison

Wednesday, July 24, 2013 at 9 am in HSLC 1345

Advances have been made in computed tomography (CT), especially in the past five years, by incorporating prior images into the image reconstruction process. In this dissertation, we investigate prior image constrained image reconstruction in three emerging CT applications: dual-energy CT, multi-energy photon-counting CT, and cone-beam CT in image-guided radiation therapy. First, we investigate the application of Prior Image Constrained Compressed Sensing (PICCS) in dual-energy CT, which has been called ``one of the hottest research areas in CT." Phantom and animal studies are conducted using a state-of-the-art 64-slice GE Discovery 750 HD CT scanner to investigate the extent to which PICCS can enable radiation dose reduction in material density and virtual monochromatic imaging. Second, we extend the application of PICCS from dual-energy CT to multi-energy photon-counting CT, which has been called ``one of the 12 topics in CT to be critical in the next decade." Numerical simulations are conducted to generate multiple energy bin images for a photon-counting CT acquisition and to investigate the extent to which PICCS can enable radiation dose efficiency improvement. Third, we investigate the performance of a newly proposed prior image constrained scatter correction technique to correct scatter-induced shading artifacts in cone-beam CT, which, when used in image-guided radiation therapy procedures, can assist in patient localization, and potentially, dose verification and adpative radiation therapy. Phantom studies are conducted using a Varian 2100 EX system with an on-board imager to investigate the extent to which the prior image constrained scatter correction technique can mitigate scatter-induced shading artifacts in cone-beam CT. Results show that these prior image constrained image reconstruction techniques can reduce radiation dose in dual-energy CT by 50\% in phantom and animal studies in material density and virtual monochromatic imaging, can lead to radiation dose efficiency improvement in multi-energy photon-counting CT, and can mitigate scatter-induced shading artifacts in cone-beam CT in full-fan and half-fan modes.