PhD Thesis title: 'Statistical image reconstruction for quantitative computed tomography'

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ABSTRACT:

Statistical iterative reconstruction (SIR) algorithms for x-ray computed tomography (CT) have the potential to reconstruct images with less noise and systematic error than the conventional filtered backprojection (FBP) algorithm. More accurate reconstruction algorithms are important for reducing imaging dose and for a wide range of quantitative CT applications. The work presented herein investigates some potential advantages of one such statistically motivated algorithm called Alternating Minimization (AM). A simulation study is used to compare the tradeoff between noise and resolution in images reconstructed with the AM and FBP algorithms. The AM algorithm is employed with an edge-preserving penalty function, which is shown to result in images with contrast-dependent resolution. The AM algorithm always reconstructed images with less image noise than the FBP algorithm. Compared to previous studies in the literature, this is the first work to clearly illustrate that the reported noise advantage when using edge-preserving penalty functions can be highly dependent on the contrast of the object used for quantifying resolution. A polyenergetic version of the AM algorithm, which incorporates knowledge of the scanner's x-ray spectrum, is then commissioned from data acquired on a commercially available CT scanner. Homogeneous cylinders are used to assess the absolute accuracy of the polyenergetic AM algorithm and to compare systematic errors to conventional FBP reconstruction. Methods to estimate the x-ray spectrum, model the bowtie filter and measure scattered radiation are outlined which support AM reconstruction to within 0.5% of the expected ground truth. The polyenergetic AM algorithm reconstructs the cylinders with less systematic error than FBP, in terms of better

image uniformity and less object-size dependence. Finally, the accuracy of a post-processing dual-energy CT (pDECT) method to non-invasively measure a material's photon cross-section information is investigated. Data is acquired on a commercial scanner for materials of known composition. Since the pDECT method has been shown to be highly sensitive to reconstructed image errors, both FBP and polyenergetic AM reconstructions are employed. Linear attenuation coefficients are estimated with residual errors of around 1% for energies of 30 keV to 1 MeV with errors rising to 3% - 6% at lower energies down to 10 keV. In the ideal phantom geometry used here, the main advantage of AM reconstruction is less random cross-section uncertainty due to the improved noise performance.

References to author publications that relate specifically to the dissertation:

1. J. D. Evans, D. G. Politte, B. R. Whiting, J. A. O'Sullivan, and J. F. Williamson, "Noise-resolution tradeoffs in x-ray CT imaging: a comparison of Penalized Alternating Minimization and Filtered Backprojection algorithms," Med Phys **38** (3), 1444-1458 (2011).

2. J. D. Evans, D. G. Politte, B. R. Whiting, J. A. O'Sullivan, and J. F. Williamson, "Effect of contrast magnitude and resolution metric on noise-resolution tradeoffs in x-ray CT imaging: a comparison of non-quadratic penalized alternating minimization and filtered backprojection algorithms," Proc. of SPIE - Physics of Medical Imaging **7961**, 79612C (2011).

3. J. Evans, J. O'Sullivan, D. Politte, G. Lasio, J. Williamson, *Reconstruction from experimentally acquired transmission CT sinograms with the polyenergetic Alternating Minimization algorithm using an equivalent x-ray spectrum estimated from transmission measurements*. Med. Phys. **36**(6), p. 2738. Oral Presentation at AAPM 51st Annual Meeting (2009).