PhD Thesis title: Optimization-Based Image Reconstruction from a Small Number of Projections

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ABSTRACT:

As X-ray computed tomography (CT) is widely used in medicine, radiation dose from CT scanning has become a significant concern regarding patient health. A great deal of effort from both industry and academia has been devoted to the development of approaches to reducing the CT-imaging dose. A natural way of reducing the CT-imaging dose is to lower the number of projection views at which data are acquired. The use of reduced projection views may also lead to a shorter imaging time in step-and-shoot and/or stationary-source CT, thus improving the work flow and minimizing potential motion artifacts. Data collected at sparsely distributed projection views pose a challenging image-reconstruction problem. The application of conventional analytic-based algorithms such as the filtered-backprojection (FBP) algorithms to sparse-view data can result in prominent streak artifacts because they require densely sampled projection data. On the other hand, optimization-based algorithms may yield images with improved quality over those obtained by use of the analytic-based algorithms when they are applied to the large amount of data typically collected in current applications. Optimization-based algorithms are also more flexible in accommodating imaging conditions of practical significance than analytic-based algorithms.

There has been renewed interest in the development and evaluation of optimization-based algorithms for image reconstruction in CT because optimization-based algorithms can potentially reconstruct images with minimized artifacts from sparse-view data. It has been demonstrated that optimization-based algorithms that exploit certain image-sparsity properties may yield CT-reconstruction images of practical utility from sparse-view projection data. The adaptive-steepest-descent projection-onto-convex-set (ASD-POCS) algorithm is one of the optimization-based algorithms which reconstruct images through solving a constraint optimization problem that specifies an image solution. In this PhD study, we investigated and developed image-reconstruction algorithms of the ASD-POCS type and applied them to reconstructing images from data collected with non-diagnostic CT scanners in applications representing different data conditions for the purpose of reduction of imaging dose or improvement of image quality. The developed reconstruction algorithms were tailored to those different systems, with image-quality characterization studies being performed. The results of these studies demonstrate that ASD-POCS-type algorithms can yield quality images from much less data than

those required by analytic-based algorithms in current imaging applications. The results also suggest that even for low-signal-to-noise-ratio (SNR) data, optimization-based algorithms can yield images of quality comparable to, or improved over, those obtained with the currently used analytic-based algorithms, in particular in terms of reduction of background noise and improvement of image contrast.

This dissertation research demonstrates the potential of optimization-based algorithms in the reconstruction of images of practical utility from data collected at projection views that are significantly fewer than those being used in current CT imaging. Optimization-based algorithms may hold promise in reducing the radiation dose involved in CT imaging.

References to author publications that relate specifically to the dissertation:

J. Bian, J. H. Siewerdsen, X. Han, E. Y. Sidky, J. L. Prince, C. A. Pelizzari, and X. Pan,"Evaluation of sparse-view reconstruction from flat-panel-detector cone-beam CT," *Physics in Medicine and Biology*, Vol. 55, pp 6575-6599, 2010

J. Bian, X. Han, E. Y. Sidky, G. Cao, J. Lu, O. Zhou, and X. Pan, "Investigation of sparse data mouse imaging using micro-CT with a carbon-nanotube-based X-ray source," *Tsinghua Science and Technology*, Vol. 15, pp 74-78, 2010

X. Han, **J. Bian**, D. R. Eaker, T. L. Kline, E. Y. Sidky, E. L. Ritman, and X. Pan, "Algorithm-enabled low-dose micro-CT imaging," *IEEE Transactions on Medical Imaging*, Vol. 30, pp 606-620, 2011

D. Xia, X. Xiao, **J. Bian**, X. Han, E. Y. Sidky, F. De Carlo, and X. Pan, "Image Reconstruction from sparse data in synchrotron-radiation-based micro-tomography," *Review of Scientific Instruments*, Vol. 82, pp 043706, 2011

J. Bian, X. Han, K. Yang, E. Y. Sidky, J. M. Boone and X. Pan, "A preliminary study of image reconstruction from low-dose data in dedicated breast CT," *Proceedings of IEEE Nuclear Science Symposium and Medical Imaging Conference*, pp 2566-2568, 2011

J. Bian, X. Han, K. Yang, E. Y. Sidky, J. M. Boone, and X. Pan, "A preliminary investigation of reduced-view image reconstruction from low-dose breast CT data," *Proceeding of SPIE*, Vol. 8313, 831325,2012

X. Han, **J. Bian**, E. L. Ritman, E. Y. Sidky, and X. Pan, "Optimization-based reconstruction of sparse images from few-view projections," *Physics in Medicine and Biology*, (in press), 2012

J. Bian, J. Wang, X. Han, E. Y. Sidky, L. Shao, and X. Pan, "Optimization-based image reconstruction from sparse-view data in offset-detector CBCT," *Physics in Medicine and Biology*, (submitted), 2012