Dissertation Defense

Matrix Computations and Optimization for Spectral Computed Tomography

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Abstract: In the area of image science, the emergence of spectral computed tomography (CT) detectors highlights the concept of quantitative imaging, in which not only reconstructed images are offered, but also weights of different materials that compose the object are provided. For distinct types of detectors and noise, various models and techniques are produced to capture different features. In this thesis, we focus on optimization, preconditioning and model development of spectral CT. For simple energy discriminating detectors, a nonlinear optimization framework is built on a Poisson likelihood estimator and bound constraints. A nonlinear interior-point trust region method is implemented to compute the solution. For energy-windowed spectral CT, a nonlinear least squares approach is proposed to describe the problem and under bound constraints, a two-step method using the projected line search and the trust region approach, incorporated with a stepwise preconditioner, is used to solve the problem. In addition, a weighted least squares formulation is derived from the Gaussian noise assumption and another preconditioner that is based on rank-1 approximation is inserted to obtain robust reconstruction. The Fast Iterative Shrinkage-Thresholding Algorithm (FISTA), along with a projection step, is used to calculate the solution iteratively. Compared with a direct solver, a two-step model is developed using an ancillary variable. With this two-step model, a row-wise computational method is proposed, which further reduces memory requirements and improves solution accuracy. Numerous numerical experiments are conducted to indicate the strength of methods and real-life examples are presented to show possible applications.

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