Numerical Analysis and Scientific Computing Dissertation Defense

Numerical Approaches for Large-Scale Ill-Posed Inverse Problems

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Abstract: Ill-posed inverse problems arise in a variety of scientific applications. Regularization methods exist for computing stable solution approximations, but many of these methods are inadequate or insufficient for solving large-scale problems. This work addresses these limitations by developing advanced numerical methods to solve ill-posed inverse problems and by implementing high-performance parallel code for large-scale applications. Three mathematical models that frequently arise in imaging applications are considered: linear least squares, nonlinear least squares, and nonlinear Poisson maximum likelihood. Hybrid methods are developed for regularization of linear least squares problems, variable projection algorithms are used for nonlinear least squares problems, and reconstruction algorithms are investigated for nonlinear Poisson based models. Furthermore, an efficient parallel implementation based on the Message Passing Interface (MPI) library is described for use on state-of-the-art computer architectures. Numerical experiments illustrate the effectiveness and efficiency of the proposed methods on problems from image reconstruction, super-resolution imaging, cryo-electron microscopy reconstruction, and digital tomosynthesis.

Thursday, March 19, 2009, 4:00 pm
Mathematics and Science Center: W303

Mathematics and Computer Science
Emory University