Computer Science
Defense

Large-Scale Inverse Problems in Imaging: Two Case Studies

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Abstract: Solving inverse problems is an important part of scientific computing. As computers become more powerful, solutions to increasingly larger problems are sought, allowing for more accurate representations of real-world applications. We consider solving large-scale inverse problems, ranging from linear to fully nonlinear. We look at aspects common to inverse problems, such as their ill-posedness, and see how regularization can help produce meaningful results. We discuss a number of different methods for solving while providing regularization. One such technique is to solve using an iterative method but stop the iterations early, before convergence is fully achieved. Iterative solvers are particularly useful for large-scale inverse problems as computations can be done in parallel. Trilinos is a mathematical software library for solving problems coming from many fields of scientific computing. One particular package, Belos, provides both an abstract framework and concrete implementations of various iterative solvers. We have implemented two additional solvers within the Belos framework, LSQR and MRNSD, which can be used to solve linear inverse problems.

We then consider two different case studies, where we wish to solve a large-scale linear inverse problem. In the first study, we want to remove patient motion blur from positron emission tomography (PET) images when motion information is tracked and recorded during the scan. We describe how this problem can be formulated as a linear equation, then we solve it using the solvers we implemented. We also look at a number of results, seeing how the reconstruction improves as more motion information is included in our model. The second case study comes from the field of adaptive optics. Here we wish to determine the distortion caused by the atmosphere when imaging using ground-based telescopes. Sensors are able to obtain noisy estimates of the gradients of the distortion, resulting in a Kronecker product-structured linear least squares problem. We describe a solving method that employs Tikhonov-type regularization by exploiting properties of the Kronecker product and utilizing the generalized singular value decomposition (GSVD). Our approach includes constructing a preconditioner off-line and then applying a few iterations of preconditioned LSQR.

Monday, June 6, 2011, 11:00 am
Mathematics and Science Center: W302

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