Mixed Precision Iterative Solver for the Solution of Large Systems of Linear Equations in Electromagnetic Exploration

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Abstract

Large systems of linear equations are present in every branch of science, for computational fluid dynamics to astrophysics, just to name a few. The discretization of partial differential equations yields large sparse systems of linear equations that need to be solved to estimate the state of the model. Krylov subspace methods are among the most popular iterative methods to solve such systems. These kind of solvers offer many advantages, like an easy implementation and good convergence properties when combined with proper preconditioners. However, from the computational point of view they are inefficient tools, mainly due to the low arithmetic intensity and the bad quality of memory accesses. Mixed precision methods, like iterative refinement, can offer a performance boost in some situations. This technique uses two nested solvers to solve the system of equations. The inner solvers performs the heavy computational work in low precision, while the outer loop refines the solution using a higher precision. Due to a more compact data representation of the data, the inner solver is able to achieve high bandwidth at each level of the memory hierarchy. Also, modern processors are able to perform more operations per clock cycle when processing single precision data. The convergence rate of the solver is also improved when certain conditions are guaranteed for the coefficient matrix.
Our work demonstrates the use of a mixed-precision iterative solver on multi-core processors for electromagnetic geophysical exploration, achieving up to 1.7x performance increment with a minimum work investment. This concept is particularly interesting for throughput-oriented processors when making redundant calculations in order to improve the quality of memory accesses is an effective approach for many problems. Along with the results of the solver, insights about the use of these techniques and convergence criteria are analyzed.