Computer Science Aspects of Fast Solvers in Applications

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Solving huge systems of equations requires an optimal solver, i.e., the memory requirements and the time for solving should be proportional to the number of unknowns. Recent research has enhanced multigrid methods and algebraic multigrid methods (AMG) which are now fulfilling these requirements for many problem classes, i.e., 3D Maxwell equations.

Although AMG possesses the above optimal properties a commercial user could be dissatisfied of the computational performance in comparison to highly optimized standard solvers. A lot of performance can be gained by designing data structures with respect to state-of-the-art computer architectures, parallelization and redesign of numerical algorithms.

The parallelization needs some modifications in the coarsening process such that the inter grid transfer operators fulfill a certain condition on the pattern of the interpolation/restriction. This guarantees that the parallel AMG is only a simple modification of the sequential AMG. The presented parallelization strategy for AMG results in very good speedups.

Discretized differential equations have to be solved several thousand times inside the solution process of an inverse problem. We got for this special application of AMG a significant gain in CPU time (factor 4 and more) due to additional acceleration of our code PEBBLES by simultaneous handling of several data sets, cache aware programming and by merging of multigrid subroutines. Together with a parallelization, the solution time of the original code was accelerated from 8 days to 5 hours on a 12 processor parallel computer.

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