Multilevel techniques lead to accurate numerical upscaling and scalable robust solvers for reservoir simulation

This paper demonstrates an application of element-based Algebraic Multigrid (AMGe) technique developed at LLNL (19) to the numerical upscaling and preconditioning of subsurface porous media flow problems. The upscaling results presented here are further extension of our recent work in 3. The AMGe approach is well suited for the solution of large problems coming from finite element discretizations of systems of partial differential equations. The AMGe technique from 10,9 allows for the construction of operator-dependent coarse (upscaled) models and guarantees approximation properties of the coarse velocity spaces by introducing additional degrees of freedom associated with non-planar interfaces between agglomerates. This leads to coarse spaces which maintain the specific desirable properties of the original pair of Raviart-Thomas and piecewise discontinuous polynomial spaces. These coarse spaces can be used both as an upscaling tool and as a robust and scalable solver. The methods employed in the present paper have provable O(N) scaling and are particularly well suited for modern multicore architectures, because the construction of the coarse spaces by solving many small local problems offers a high level of concurrency in the computations. Numerical experiments demonstrate the accuracy of using AMGe as an upscaling tool and comparisons are made to more traditional flow-based upscaling techniques. The efficient solution of both the original and upscaled problem is also addressed, and a specialized AMGe preconditioner for saddle point problems is compared to state-of-the-art algebraic multigrid block preconditioners. In particular, we show that for the algebraically upscaled systems, our AMGe preconditioner outperforms traditional solvers. Lastly, parallel strong scaling of a distributed memory implementation of the reservoir simulator is demonstrated.

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