A robust Multi-Level Domain Decomposition Preconditioner for Reservoir Simulation scalable on Many-Core architecture

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Abstract

In the evolution of High Performance Computing, multi-core and many-core systems are a common feature of new hardware architectures. The introduction of very large number of cores at the processor level is really challenging because it requires to handle multi level parallelism at various levels either coarse or fine to fully take advantage of the offered computing power. The induced required programming efforts can be fixed with parallel programming models based on the data flow model and the task programming paradigm [1]. Nevertheless many of standard numerical algorithms must be revisited as they cannot be easily parallelized at the finest levels. Iterative linear solvers are a key part of petroleum reservoir simulation as they can represent up to 80% of the total computing time. In these algorithms, the standard preconditioning methods for large, sparse and unstructured matrices – such as Incomplete LU Factorization (ILU) or Algebraic Multigrid (AMG) – fail to scale on shared-memory architectures with large number of cores. Recently, multi-level domain decomposition (DDML) preconditioners [2], based on the popular Additive Schwarz Method (ASM), have been introduced. Their originality resides on an additional coarse space operator that ensures robustness and extensibility. Their convergence properties have been studied mainly for linear systems arising from the discretization of PDEs with Finite Element methods. In this paper, we propose an adaptation for reservoir simulations, where PDEs are usually discretized with cell centered finite volume schemes. We discuss on our implementation based on the task programming paradigm with a data flow model [3]. We validate our approach on linear systems extracted from realistic petroleum reservoir simulations. We study the robustness of our preconditioner with respect to the data heterogeneities of the study cases, the extensibility regarding the model sizes and the scalability of our implementation regarding the large number of cores provided by new KNL processors or multi-nodes clusters. Finally we benchmark this new preconditioner to the ILU0 and the AMG preconditioners, the most popular ones in reservoir simulation.

References

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