Highly Parallel Implementation and Optimization of Domain Decomposition Based Algorithms

L. Říha*, T. Brzobohatý and A. Markopoulos

* IT4Innovations National Supercomputing Center,
VŠB-Technical University of Ostrava,
Studentská 6231/1B 708 33 Ostrava – Poruba Czech Republic (IT4I)
Email: lubomir.riha@vsb.cz - Web page: http://industry.it4i.cz/

ABSTRACT

We describe an implementation and scalability results of a hybrid FETI (Finite Element Tearing and Interconnecting) solver based on our variant of the FETI type domain decomposition method called Total FETI. In our approach a small number of neighbouring subdomains is aggregated into clusters, which results into a smaller coarse problem. Current implementation of the solver ESPRESO is focused on the optimal performance of the main CG solver, including: implementation of communication hiding and avoiding techniques for global communications; optimization of the nearest neighbour communication – multiplication with global gluing matrix; and optimization of the parallel CG algorithm to iterate over local Lagrange multipliers only.

ESPRESO is an ExaScale PaRallel FETI SOlver developed at IT4Innovations. Main focus of the development team is to create a highly efficient parallel solver which contains several FETI based algorithms including new Hybrid Total FETI method suitable for parallel machines with tens or hundreds of thousands of CPU cores. The solver is based on highly efficient communication layer on top of pure MPI. The layer was developed specifically for FETI solvers and uses several state-of-the-art communication hiding and avoiding techniques to achieve better scalability.

The current version of our implementation has been successfully tested together with PermonCube problem generator on the HLRS Hermit Cray XE6 machine running on up to 9261 CPU cores and successfully solving problem of size over 1 billion of unknowns. Another large scale benchmarks were executed on SurfSara Cartesius supercomputer, where 1.6 billion unknown problem was decomposed into 8000 sub-domains and solved using the same number of CPU cores. All these large scale tests were performed using FETI method and it is expected, that using Hybrid Total FETI algorithm the solver will scale to tens or hundreds of thousands of cores using MPI + OpenMP hybrid parallelization technique. The performance is also demonstrated on the real world benchmarks.

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