Higher-Order Finite Element Code for Electromagnetic Simulation on HPC Environments

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Abstract

We present the experience on the use of MUMPS as direct solver in our in-house electromagnetic code based on the Finite Element Method (FEM) called HOFEM: Higher Order Finite Element Method. The code is used for research purposes in tasks related to the modeling of electromagnetic wave propagation phenomena, e.g., analysis of waveguides, microwave passive devices, antennas, Radar Cross Section prediction and so on. It makes use of higher-order curl-conforming finite elements and a special technique for mesh truncation in open domain problems (scattering and radiation phenomena) among other features.

With respect to the implementation, the code has been written from scratch to adopt high performance computing (HPC) paradigms such as message passing interface (MPI) and open multi-processing (OpenMP) in order to use HPC environments in an efficient way. The language used for HOFEM is FORTRAN 2003 making use of some features of object oriented programming (OOP) paradigm with a strong emphasis on code maintenance.

HOFEM makes use of the direct approach methodology when solving the electromagnetic problem. Among the sparse direct solvers available for researchers, HOFEM has interface with direct solvers, being MUMPS mainly used. The FEM matrix is passed to MUMPS in distributed assembled format. Regarding this point, different strategies of matrix partitioning have been tested: from partition based on the distribution of the elements between the processes to partition based on the distribution of the matrix rows. Sparse-right-hand-side MUMPS' feature is used, solving the problem by blocks of RHS (typically 10-20 RHS each time) to alleviate the memory issue of having a centralized solution when solving extremely large problems. Out-of-core flag is intensively used in this case.

At present, the solver is able to manage problems of several tens of millions of unknowns on more than one thousand cores. The distributed solution feature is planned to be used in the near future; in this context, the distributed right-hand-sides feature would be very welcome.