High-fidelity, High-performance Integral Equation Solver for Time-Harmonic Maxwell's Equations

Brian MacKie-Mason and Zhen Peng
Department of Electrical & Computer Engineering, University of New Mexico, NM 87131-0001, USA

Ever-increasing fidelity and accuracy needs for mission-critical electromagnetic (EM) applications have been pushing the problem sizes towards extreme scales. This puts a high premium on investigation of parallel and scalable integral equation (IE) simulators with optimal computational complexity. Moreover, increasing demands are being placed on an integrated design and analysis environment, which require new computational tools to be well integrated into design processes.

This work investigates an adaptive, parallel, and scalable integral equation solver for extremely large and multi-scale EM modeling and simulation. A complicated surface model is decomposed into a collection of components, all of which are discretized independently and concurrently using a discontinuous Galerkin (DG) boundary element method. An additive Schwarz domain decomposition method is employed next for the efficient and robust solution of linear systems resulting from discontinuous Galerkin discretizations. This work leads to a rapidly-convergent integral equation solver that is scalable for large multi-scale objects. Furthermore, it serves as a basis for parallel and scalable computational algorithms to reduce the time complexity via advanced distributed computing systems.

The first of three appealing parallel simulation capabilities is high data locality. This consists of embarrassingly parallel model preparation, concurrent mesh generation, and trivially parallel subdomain solutions. All large-scale data structures will be evenly distributed among processors. The next appealing capability is a dynamic workload distribution strategy. The geometry-adaptive DG discretizations will be automatically partitioned into a balanced computational partitioning based on the number of processors available and the local memory size. The final capability will be quasi-optimal convergence of the iterative solution. Numerical experiments illustrate that the iteration counts of preconditioned systems depend logarithmically on the electrical size of the object, the number of subdomains, and the mesh density.

Finally, to fully exploit the recent success of multi-core processors and massively parallel distributed memory supercomputers, we have considered a hybrid MPI/OpenMP implementation of proposed algorithms. Numerical experiments are performed on large computer clusters to characterize the performance of the proposed method. The capability and benefits of the resulting algorithms are exploited and illustrated through different types of real-world applications on high performance computing systems.