Domain Decomposition Methods via Integral Equations in Electromagnetics

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Domain Decomposition Methods (DDMs) for Finite Element Method (FEM) have matured to the point of exhibiting high robustness, while maintaining numerical and parallel scalability (J. Nagar et al. IEEE AP-S, 2013). Unfortunately, they solve for the electric fields that could reside in the unbounded 3D space, thus requiring artificial (often inexact) domain truncation methods and volumetric meshing which is time consuming and often unreliable. In addition, these methods introduce dispersion error, and therefore are not ideal for electrically large problems. On the contrary, the Boundary Element (BE) solution of Integral Equations (IEs) only requires surface meshing, exactly satisfies the Silver-Müller radiation condition but leads to dense matrices, thus it is challenging to devise scalable and robust parallel IE solvers. In the electromagnetics community, there have been numerous attempts to develop DDM solvers for IEs, most notably the Equivalence Principle Algorithm (M.-K. Li et al., AP-S International Symposium, pp. 2897-2900, 2006) and the IE-DDM (Z. Peng et al., IEEE Trans. on Ant. and Prop., vol. 59, no. 9, pp.3328-3338, 2011). In the former case, the equivalence principle is used to reformulate the problem on a set of electric and magnetic current unknowns (J and M) on the boundary of the domains, whereas in the latter case, carefully constrained (lossy) J/Ms are introduced inside PECs effectively regularizing the IE matrix equation and enabling a block diagonal preconditioner. In both cases the domain interactions remain global, thus the matrix is fully dense.

This work will present a novel DDM formulation for IEs that leads to a blockwise sparse matrix equation, thus enabling an efficient parallel solution. This method can be considered as the middle-of-the-road between full-blown FEM and BEM, where BEM is used within domains and DD-FEM apparatus across domains. As expected, the method inherits the best of both worlds. More importantly, the method uses single domain boundary traces, e.g. only J or M, thus minimizing the storage and enhancing parallel potential.

The talk will first explore the current landscape of parallel Computational Electromagnetics (CEM) solvers, and justify the development of the new method. Next, the formulation will be presented, outlining methods of avoiding interior resonances, treaments of dielectrics, PECs, and other boundary conditions, followed by efficient iterative solution strategies amenable to parallel processing. Finally, results which showcase the validity, accuracy and efficiency of the method will be presented.