A New Class of Iterative Solvers with Applications to Computational Electromagnetics

Jogender Nagar* and Marinos N. Vouvakis
ECE Department, University of Massachusetts, Amherst, USA

The rapid progress of technology drives a need to model, solve and understand ever larger and more complex problems using Computational Electromagnetics (CEM). The most popular methods such as the Boundary Element Method (BEM) or Finite Element Method (FEM) rely on the solution of a linear system of equations whose size grows with electrical size and model complexity, and there's a point where the cost of direct solvers becomes prohibitive. For complex real-world problems, iterative solvers are the only viable alternative, case in point are modern fast solvers based on Domain Decomposition Methods (DDMs) in which non-stationary iterative solvers are used to iterate on variables that reside only on substructures. Despite their low memory footprint, non-stationary iterative solvers for nonsymmetric matrices are not robust or their efficiency is severely affected by the matrix condition number (which worsens as the complexity of the problem increases). There have been many attempts to improve robustness, including well-conditioned re-formulations of the underlying physical or numerical models, as well as preconditiong strategies. These approaches can be successful, but it is difficult to strike the right balance between efficiency and effectiveness. An alternative and more general approach is to revisit the actual iterative solver itself. An ideal iterative solver for non-symmetric matrices common in CEM would exhibit two seemingly incompatible properties: a short-term recurrence (for ease of parallelization and low memory requirements) and some sort of strong error minimization property (for fast convergence and robustness). There have been many attempts to achieve a balance between the two, including restarted methods, truncated methods and high-order stabilization polynomials. Unfortunately, these methods do not satisfy a global optimality requirement (E. D. Sturler et al., NASA Conf. Pub. 3224, pp. 111-125, 1993) and often lead to a lack of stability in finite arithmetic (G. L.G. Sleijpen et al., E. Trans. on Num. Anal., vol. 1, pp. 11-32, 1993).

This work will present a non-stationary iterative solver which exhibits short-term recurrence, is stable in finite arithmetic when combined with inexpensive preconditioners, and has an error minimization property that approaches the ideal Generalized Minimum Residual (GMRES) using minimal computational overhead (typically less than 1% more memory than Bi-CGSTAB(1)). The talk will first discuss the most popular non-stationary iterative solvers, explaining their advantages and disadvantages in the context of CEM. Then the proposed iterative solver will be presented and compared with other solvers. Finally, results for a wide variety of CEM methods and models, including signal integrity, antenna radiation and scattering will showcase the efficiency and robustness of the solver.