Solution of Large CEM Problems with Parallel Multi-Level Fast Multipole Algorithm (MLFMA)†

Levent Gürel* and Özgür Ergül
Department of Electrical and Electronics Engineering
Bilkent University, TR-06800, Bilkent, Ankara, Turkey
E-mail: lgurel@bilkent.edu.tr, ergul@ee.bilkent.edu.tr

In this talk, an overview of our efforts to solve large problems of computational electromagnetics (CEM) will be presented. In particular, our work on building parallel PC clusters, parallelization of the multi-level fast multipole algorithm (MLFMA), iterative solvers, preconditioners, and integral-equation formulations will be emphasized.

Our ultimate goal is to solve very large numerical problems, which are obtained from mathematical formulations of real-life electromagnetic problems. Examples of real-life CEM problems are radiation from electronic devices into living organisms, crosstalk and interference in high-speed chips, imaging and diagnosis of subcutaneous tumors or underground oil reserves, and designing radar-eluding scattering-free stealth targets.

We consider *dense* matrix equations of the type Ax=b, where the dimensions of the matrices are in the order of *millions*. These matrix equations are obtained from the discretizations of the mathematical formulations of the CEM problems.

In order to solve large problems, advances in both solution algorithms and computer hardware should be utilized. The fast multipole method (FMM) and its multi-level version, the MLFMA, are two of the preferred choices for the solution algorithm due to their reduced computational complexities and memory requirements. As for the hardware, a parallel architecture is preferred due to its increased computing power. Consequently, this choice of hardware forces a parallel implementation of the MLFMA.

Since the MLFMA and the FMM are both iterative techniques, it is imperative to keep the number of iterations as low as possible for any given problem. As with any iterative solution, the number of iterations naturally depends on the choices of the iterative solver, the preconditioner, and the initial guess. In addition, the number of iterations also depends on the underlying features of the matrix equation to be solved. These features are determined by numerous other choices, such as the analytical formulation method (e.g., the use of electric-field, magnetic-field, or combined-field boundary conditions), representation of the problem geometry (e.g., open or closed surfaces, sharp edges, thin structures, order of approximation), and the discretization method (e.g., fineness of the mesh, choice of the basis and testing functions).

Our efforts to reduce the number of iterations will be presented within the context of electric-field integral equation (EFIE), magnetic-field integral equation (MFIE), and combined-field integral equation (CFIE). The effects of various iterative solvers and preconditioners on the iteration counts will also be addressed.

---

† This work was supported by the Turkish Academy of Sciences in the framework of the Young Scientist Award Program (LG/TUBA-GEBIP/2002-1-12), by the Scientific and Technical Research Council of Turkey (TUBITAK) under Research Grant 103E008, and by contracts from ASELSAN and SSM.