COMPUTATIONAL ELECTROMAGNETICS – PAST, PRESENT AND THE FUTURE

In the last few decades, we have witnessed numerous breakthroughs been made in Computational electromagnetics (CEM). Together with advancements in computational hardware, today, it is quite common to solve full-wave three-dimensional electromagnetic wave problems with hundreds of millions or even billions unknowns.

In the past, research was mainly focused on individual CEM technique, such as finite difference time domain (FDTD), finite element methods (FEMs), and the integral equation methods (IEs). To name a few: For FDTD, we have seen successful developments on dispersive material modeling, sub-gridding techniques, higher order finite difference schemes, higher order Absorbing Boundary Conditions (ABCs) and Perfectly Matched Layer (PML); on the FEM side, vector finite element, tree-cotree splitting, four potential AV formulations, multi-grid preconditioners, hybrid finite element boundary integral (FEBI) for mesh truncation, and of course the application of PML as well; on the IEs, there are the RWG-H(div) conforming basis functions, the Calderon identities and the Calderon preconditioners, and most significantly, we have been awed by the fast computational techniques developed in IEs: such as FFT based methods, and the multi-level fast multipole method (MLFMM).

In the present, CEM research continues on the hybridization of various numerical techniques, and the vibrant research on the domain decomposition method (DDM) symbolizes such an effort. Conformal and non-conformal DDMs, Finite Element Tearing and Interconnecting (FETI) Algorithms, DDM for repetitions, Robin and higher order transmission conditions, and multi-solver DDMs are active research topics today. Additionally, in an effort to mitigate the restrictions of the meshing required by the conventional conformal numerical methods, the CEM research starts to break away from the past by proposing non-conformal methods. To name just a few, we have Discontinuous Galerkin Time Domain (DGTD) methods, the Integral Equation Discontinuous Galerkin (IEDG) method, and the meshless methods. Moreover, we have also seen various innovative approaches to parallelize CEMs in order to fully utilize high performance computing platforms today.

Finally, what about the future? Nobody really knows. Particularly, as we have seen in the past, human's imagination can always take us to unforeseen new terrains. However, from my personal perspectives, I offer the following possibilities: Geometry is the Mesh, Multi-scale computations both in space and in time, multi-physics computations to integrate different mathematical physics within a unified computational frame, and truly employ CEM as a part of the scientific computing to explore new physics and phenomena.

In this talk, I would like to take us through this amazing journey from the past to the present, and finally offer my personal views of the future.