Friday, September 14

Free Short Course on
HIGHER ORDER METHOD OF MOMENTS FOR PARALLEL AND ACCURATE SOLUTION OF MULTISCALE STRUCTURES
8:40-12:40

Instructor

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(with participation from Y. Zhang, D. Donoro, W. Zhao and M. Salazar)

The course will start with the description of the mathematical equations and the unique properties of the higher order basis functions in the context of the solution of Integral Equations in computational electromagnetics. The theory and the solution methodology of using Surface Integral Equations (SIEs) for analysing the radiation and scattering from composite metallic and dielectric structures in the frequency domain will be introduced first, followed by the unique properties of the higher order basis functions. The higher order basis functions involved in this case are nothing but simple polynomials of varying degrees. These basis functions are now used to describe the unknowns over electrically large subdomain patches, in contrast to the conventional piecewise linear basis functions over sub wavelength patches. Use of these higher order basis - namely use multiple basis functions over the same electrically large patch — in contrast to use of a single basis over an electrically small patch, can lead to a significant reduction in the total number of unknowns in addition to several other interesting properties. Typically, for a higher order basis, only 10–20 unknowns per wavelength squared of surface area are needed, leading to a reduction of an order of the magnitude of the size of the impedance matrix that needs to be solved. The advantage of the use of the higher-order polynomials as basis functions is that they can also be adapted to deal with extremely nonuniform mesh sizes, which range from approximately 10^{-6} λ to 2 λ in electrical size. Thus, they are quite suitable and very flexible for modeling multiscale structures. The mesh density and the number of unknowns are reduced when compared with the piecewise basis functions. The lower/upper (LU) decomposition is used to solve the matrix equation to ensure the solution accuracy of the method of moments. Numerically, the resulting matrix equation dealing with the impedance matrix is solved using a parallel higher-order method of moments (HOMoM) with a newly developed reduced-communication, lower-upper (RCLU) decomposition solver. For example, the presented method using 201,600 central processing unit (CPU) cores on (dethroned in 2016 - now ranked number 2 supercomputer of the world) Tianhe-2 located in Guangzhou, China can solve a full complex dense matrix equation with 1.06 million unknowns for the surface-current distribution using the classical lower-upper (LU) solver in approximately half an hour. This is accomplished using a new electromagnetic simulator called HOBBIES (Higher Order Basis Based Integral Equation Solver). HOBBIES is based on a parallel In-Core and Out-of-Core integral-equation solver and has a personal pre- and postprocessor called GiD. GiD is used to create the geometrical and topological information of the model, define the run environment required by the solver and display results returned by this solver. HOBBIES presents some important features such as multiplatform and multilanguage environment, definition of models using symbolic variables, automatic optimization of objectives and the option of execute simulations on high performance cluster. The efficiency and scalability of a parallel higher-order method of moments will also be illustrated for example, using up to 4096 CPU cores on a supercomputer for the analysis of radiation and scattering of a microstrip patch phased array antenna mounted on full scale airplanes. Both the scattering and radiation problems are simulated to demonstrate the efficiency and scalability of the algorithm. Numerical results show that one can achieve above 60% efficiency when the used memory to the total memory ratio is larger than 15%, and the scalability can reach a theoretical value between $O(N^2)$ and $O(N^3)$, where N is the number of unknowns. Due to its high efficiency and excellent scalability, the algorithm is able to accurately solve large complex electromagnetic problems including composite and multi-scale structures.