Full-wave Scattering at One Million Wavelength Objects

Jan Fostier and Femke Olyslager*
Department of Information Technology, Ghent University,
Sint-Pietersnieuwstraat 41, 9000 Ghent, Belgium

The Multilevel Fast Multipole Algorithm (MLFMA) has shown to be a viable method to solve large Method of Moments (MoM) scattering problems with prescribed accuracy. If the number of unknowns in the MoM problem is N then the MLFMA provides a solution requiring $O(N \log N)$ time and memory resources. Recently parallel implementations using so-called hierarchical k-space partitioning have allowed the solution of three-dimensional scattering problems at objects of 100 to 150 wavelengths in size (Ö. Ergül and L. Gürel, Hierarchical parallelization strategy for multilevel fast multipole algorithm in computational electromagnetics, *Electronics Letters*, 44(1), pp. 3–5, Jan. 2008). Such problems require in the order of 100 million unknowns. An important aspect of parallelization of the algorithm is its scalability as the number of processors increases (J. Fostier and F. Olyslager, A provably scalable parallel multilevel fast multipole algorithm, *Electronics Letters*, 44(19), pp. 1111–1113, Sep. 2008). Scalability means that if the number of processors increases proportionally with the number of unknowns that the total CPU-time is not larger than $O(\log N)$. Most parallelization schemes for the MLFMA resort to a synchronous algorithm. Synchronous means that at a given point in time all processors are doing the same type of operations in the MLFMA algorithm such as translations, aggregations, disaggregations or communications. Recently we have developed a new asynchronous parallelization strategy that uses a priority queue task management paradigm (J. Fostier and F. Olyslager, "An Asynchronous Parallel MLFMA for Scattering at Multiple Dielectric Objects," *IEEE Transactions on Antennas and Propagation*, 56(8), pp. 2346–2355, Aug. 2008.). Although from an implementation point of view more complex than the synchronous implementations the asynchronous implementation has shown to yield higher parallel efficiencies when considering multiple object scattering and using slower inter node communication networks.

In this contribution we wish to report on the first new fully scalable asynchronous parallel algorithm for the MLFMA using hierarchical k-space partitioning. It consists of a two-dimensional scattering implementation. Obviously the two-dimensional case allows for the simulation of much larger objects in terms of wavelengths for a given number of unknowns. However, the two-dimensional case also involves a number of problems such as a much higher number of levels in the MLFMA algorithm, the slow decay of the Green function as function of the distance leading to less diagonal dominance and convergence problems of the iterative solution of the MoM system. Among other examples we will show the scattering at a perfectly electric conducting circular cylinder with a diameter of one million wavelengths requiring 31 million of unknowns. This problem is more than two orders of magnitude larger than what has been published before. The problem was simulated on 64 AMD 2Ghz Opteron cores connected by an Ethernet switch and required more than 200 GByte of memory using double precision calculations. Our implementation is available as open source under GPL license (http://www.openfmm.net).