Fast Algorithms and Parallel Computing: Solution of Extremely Large Real-Life Problems in Computational Electromagnetics

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Abstract

Accurate simulations of real-life electromagnetics problems with integral equations require the solution of dense matrix equations involving millions of unknowns. Solutions of these extremely large problems cannot be achieved easily, even when using the most powerful computers with state-of-the-art technology. Instead, we have been solving some of the world’s largest integral-equation problems in computational electromagnetics by employing fast algorithms implemented on parallel computers. Most recently, we have achieved the solutions of larger than $1,000,000,000 \times 1,000,000,000$ (one billion!) dense matrix equations! This achievement is an outcome of a multidisciplinary study involving physical understanding of electromagnetics problems, novel parallelization strategies (computer science), constructing parallel clusters (computer architecture), advanced mathematical methods for integral equations, fast solvers, iterative methods, preconditioners, and linear algebra.

In this talk, following a general introduction to our work in computational electromagnetics, I will continue to present fast and accurate solutions of large-scale electromagnetic modeling problems involving three-dimensional geometries with arbitrary shapes using the multilevel fast multipole algorithm (MLFMA) and parallel MLFMA. Some complicated real-life problems, such as scattering from realistic aircraft, involve geometries that are larger than 1000 wavelengths. Accurate solutions of such problems can be used as reference data for high-frequency techniques. Solutions of extremely large canonical benchmark problems involving sphere and NASA Almond geometries will be presented, in addition to the solution of complicated objects, such as dielectric photonic crystals. Solving the world’s largest metamaterial problems, red blood cells, and computational electromagnetics problems has important implications in terms of obtaining the solution of previously intractable physical, real-life, and scientific problems in various areas, such as (subsurface) scattering, optics, bioelectromagnetics, metamaterials, nanotechnology, remote sensing, etc. For more information: www.abakus.computing.technology.

Prof. Levent Gürel (Fellow of IEEE, ACES, and EMA) received the M.S. and Ph.D. degrees from the University of Illinois at Urbana-Champaign (UIUC) in 1988 and 1991, respectively, in electrical and computer engineering. He worked at the IBM Thomas J. Watson Research Center, Yorktown Heights, New York, in 1991-94. During his 20 years with Bilkent University, he served as the Founding Director of the Computational Electromagnetics Research Center (BILCEM) and a professor of electrical engineering. He is also an Adjunct Professor at UIUC. Prof. Gürel is the Founder and CEO of ABAKUS Computing Technologies, a company that is geared towards advancing the use of cutting-edge computing technologies for solving difficult scientific problems with important real-life applications and societal benefits. Among the recognitions of Prof. Gürel’s accomplishments, the two prestigious awards from the Turkish Academy of Sciences (TÜBA) in 2002 and the Scientific and Technological Research Council of Turkey (TÜBİTAK) in 2003 are the most notable. He is conferred the UIUC ECE Distinguished Alumni Award in 2013. He is named an IEEE Distinguished Lecturer for 2011-2014 and was invited to address the 2011 ACES Conference as a Plenary Speaker. Since 2003, Prof. Gürel has been serving as an associate editor for Radio Science, IEEE Antennas and Wireless Propagation Letters, IET Microwaves, Antennas & Propagation, JEMWA, PIER, ACES Journal, and ACES Express.

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