ITC 2024 Cairo Invited Talk

Fast Algorithms of Computational Electromagnetics: From Fast Fourier Transform and Fast Multiple Method to Hierarchical Matrices and Tensor Trains

Prof. Vladimir Okhmatovsk
Dept. of Electrical and Computer Engineering,
University of Manitoba, Canada
E-mail: vladimir.okhmatovski@umanitoba.ca
Web: https://umanitoba.ca/engineering/faculty-staff/electrical-and-computer-engineering-faculty-and-staff/vladimir-okhmatovski

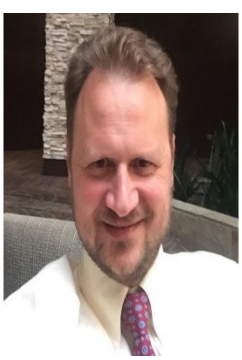
ABSTRACT

In the mid-90s the fast algorithms ushered a new era into the field computational science at large and computational electromagnetics (CEM) in particular. The iterative fast algorithms based on FFT and Fast Multiple Method (FMM) enabled solution of boundary element radiation and scattering problems of unprecedented sizes exceeding billions of unknowns, while capturing underlying physics with full-wave rigour and controlled precision. Such drastic increase in capacity of the pertinent surface and volume integral equation solvers became possible due to reduction of their computational cost from O(N^2) and O(N^3) to O(NlogN), earning the FMM the title of 'top 10 algorithms of the 20th century'.

In following two decades, the fast iterative methods made their way into commercial tools providing engineers worldwide with revolutionary new modeling capabilities. Their extensive use, however, also revealed significant challenges encountered by the iterative methods due to lack of convergence caused by the resonant physical wave phenomena as well as the often-poor conditioning of matrix equations stemming from the underlying integral equation formulations and/or their discretization schemes. To address the convergence challenges plaguing the iterative fast solvers, the fast direct methods based on the theory and algorithms of the hierarchical matrices (H-matrices) were developed in the 2000s. These methods greatly alleviated convergence problems associated with the FMM and FFT methods by offering robust preconditioners consuming O(NlogN) CPU time and memory comparable to the computational resources required for fast evaluation of the dense matrix-vector products.

In this talk intended for a broad audience we will give an overview of the above iterative and direct fast algorithms and demonstrate examples of their use in a broad variety of practical applications of electrical and computer engineering ranging from transient electromagnetic analysis of power systems, to signal integrity analysis in high-speed digital interconnects, to solution of large-scale scattering problems. The recently emerged fast iterative and direct methods based on restructuring of the pertinent dense matrices of BEMs into multi-dimensional tensors and revealing further data redundancies in them will be presented to demonstrate the latest revolutionary promise in computational science to further reduce the state-of-the-art O(NlogN) CPU and memory costs to O(logN).

BIO



Prof. Vladimir Okhmatovski is a Professor with the Department of Electrical and Computer Engineering, University of Manitoba, Canada. His research interests are the fast algorithms of electromagnetics, high-performance computing, modeling of interconnects, and inverse problems. He has worked extensively on computational electromagnetics projects with Sonnet, Cadence, Intel, CEMWorks, Resonant, DND Canada, and other industry and government agencies. Prof. Okhmatovski co-authored a book on electromagnetic analysis in layered media, and over 200 technical papers and patents in the areas of computational and applied electromagnetics. He was a recipient of the 2017 Intel Corporate Research Council Outstanding Researcher Award, Outstanding ACES Journal Paper Award, and received various other honours. Prof. Okhmatovski is a Registered Professional Engineer in the Province of Manitoba, Canada.