Shanker Balasubramaniam

Associate Chair, CMSE; Professor, Department of Electrical and Computer Engineering
bshanker@egr.msu.edu | 517.432.8136 | 428 S. Shaw Lane, Room 2214

BIO SKETCH

Shanker Balasubramaniam (B. Shanker) is Associate Chair of the Department of Computational Mathematics, Science and Engineering; and a professor in the Department of Electrical and Computer Engineering at Michigan State University.

Dr. Shanker is a Fellow of IEEE, elected for his contributions in computational electromagnetics. He was an associate editor for *IEEE Antennas and Wireless Propagation Letters* (AWPL), is an associate editor for *IEEE Transactions on Antennas and Propagation*, and is a full member of the USNC-URSI Commission B. He has authored/co-authored more than 350 journal and conferences papers, and presented a number of invited talks.

From 1993 to 1996, he was a research associate in the Department of Biochemistry and Biophysics at Iowa State University, where he worked on the molecular theory of optical activity. From 1996 to 1999, he was with the Center for Computational Electromagnetics at the University of Illinois at Urbana-Champaign as a visiting assistant professor, and from 1999-2002 with the Department of Electrical and Computer Engineering at Iowa State University as an assistant professor.

B. Shanker received his B'Tech from the Indian Institute of Technology, Madras, India, in 1989, and his M.S. and Ph.D. in 1992 and 1993, respectively, from Pennsylvania State University.

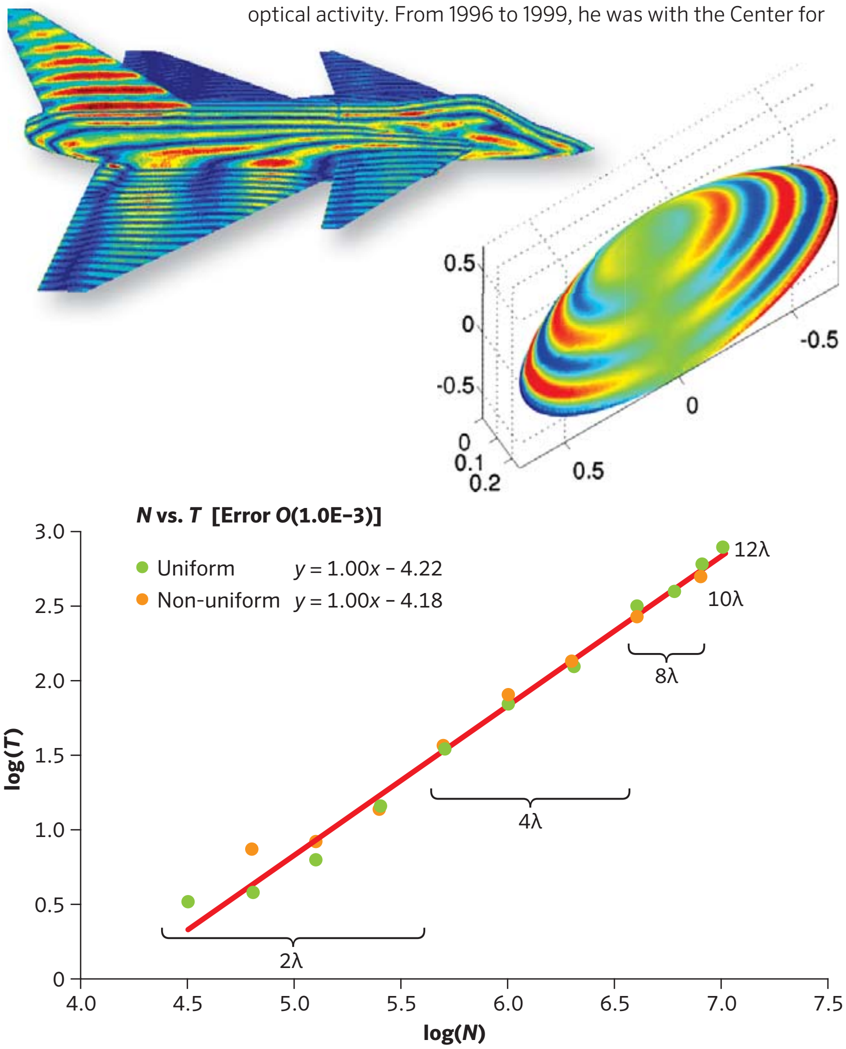

FIGURE 1. Scattering from large structures (64λ aircraft and 20λ reflector antenna) with millions of degrees of freedom and depiction of linear cost scaling algorithms

RESEARCH INTERESTS

Computational electromagnetics; frequency and time domain integral equation–based methods; multi-scale fast multipole methods, fast transient methods, parallel algorithms; higher order finite element and integral equation methods; ISO-geometric analysis, propagation in complex media; mesoscale electromagnetics; particle and molecular dynamics as applied to multiphysics and multiscale problems

LAB(S)/GROUP(S)

Electromagnetics Research Group, Applied Computational Electroscience (ACES) Subgroup

WEBSITE

http://www.egr.msu.edu/~bshanker

GROUP MEMBERS

MSU COLLABORATORS: E. Rothwell, L. C. Kempel, P. Chahal, C. Piermorocci, Y. Tong, B. Mahanti, H. Lee, J. Albrect, J. Verboncouer. PHD STUDENTS: Jie Li, Scott O'Connor, Zane Crawford (DOE CSG Fellow), Connor Glosser, Steve Hughey. UNDERGRADUATE STUDENTS: Bowen Tan, Alex Chamberly, Bailey Winter.

CURRENT RESEARCH FOCUS

Developing mathematically rigorous, novel computational methods with provable algorithmic efficiency to solve a range of problems in electroscience is the focus of the ACES group. This pursuit relies on advancing three inter-related areas: applied mathematics, applied physics, and computer science. In what follows, we shall briefly elucidate some of the recent advances made by our group.

1. Rapid evaluation of Green's kernels for a number of different potentials. Integral equations based analysis methods play a critical role in solution of a number of physical systems ranging from molecular dynamics to astrophysics to electrostatics to electromagnetics. These systems are set up using the appropriate Green's function, and the resulting cost and memory complexity. If time is involved, as in the wave equation or diffusion equation, the cost scales as $O(N_t^{\alpha} N_s^2)$, where N_t and N_s are the number of temporal and spatial degrees of freedom, and $0 \leq \alpha \leq 2$. Over the years, we have developed mathematically rigorous algorithms with provable error bounds that scale as $O(N_s \cdot \log^{\alpha} N_s)$ and $O(N_t \cdot \log^{\alpha} N_t N_s \cdot \log^{\alpha} N_s)$. These algorithms have been applied to a number of problems ranging from molecular dynamics to acoustics to electromagnetics. Provably scalable parallel algorithms for large multiscale analysis that rely on these methods have also been developed.

2. Isogeometric integral equation solvers and shape/topology optimization. Integral equation solvers form the backbone of analysis in both acoustics and electromagnetic scattering problems. Methods developed rely definition of physical quantities on piecewise continuous description of the domain. The state of art is dramatically different in computer graphics community where geometric descriptions with higher order of continuity abound. Using the same set of basis for both geometric description as well as defining physical quantities on these description has manifold advantages, from (i) seamless h-adaptivity to (ii) local refinement to (iii) morphing and (iv) shape/topology optimization.

3. Light-matter interaction. Rigorous quantum mechanical modeling of light-matter interaction is vital to the analysis of numerous processes, ranging from resonant energy transfer in light-harvesting/light-generation applications, to the generation and preservation of entanglement between qubits in quantum information applications. Here, quantum emitters such as molecules, optically active defects, or quantum dots can interact over large distances by way of their mutual coupling to the electromagnetic field. The nature of this second-order interaction is a complex function of the electromagnetic environment. Multiphysics solvers are being used to study Liouville equations describing the dynamics of quantum emitters coupled through the electromagnetic field, wherein the field-mediated interaction parameters can be extracted from classical solutions to the Maxwell equations in realistic material environments. Ongoing work includes development of higher order transparent boundary conditions for the analysis of strong light-matter coupling in high-Q cavities, as well as

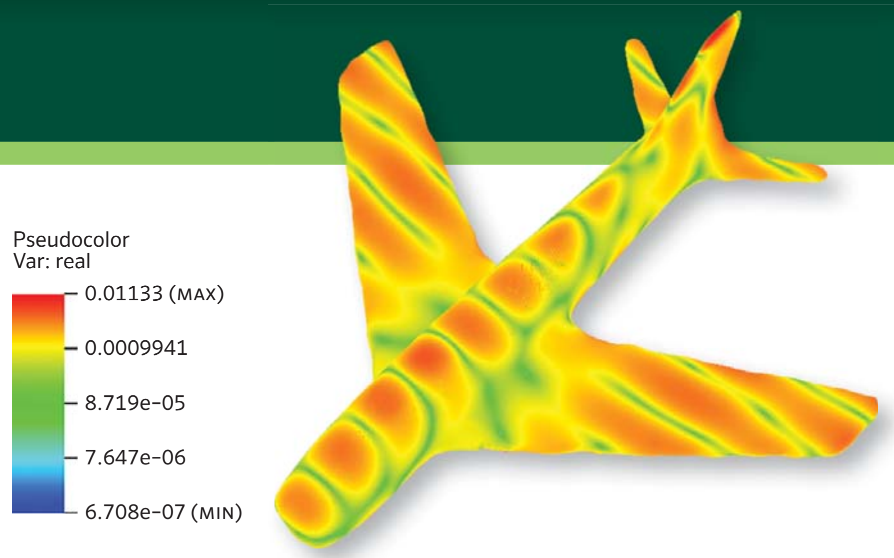

FIGURE 2. Currents on a toy plane.

cavity design and optimization for the generation of maximally entangled states.

4. Dynamics of microbubbles. Another intriguing problems that we have recently started investigating is understanding the dynamics of microbubbles. These find several applications ranging from imaging as an ultrasound contrast agent, microbubble to drug delivery to noninvasive therapy or even in genetic engineering. The fundamental problem is to accurately understand dynamics of microbubbles in the presence of ultrasound. We are actively investigating a series of problems of increasing complexity: single bubble motion, bubble deformation due to pressure, combined bubbles dynamics, and ultrasound steering, etc.

5. Other research. In addition to the aforementioned areas, we have pioneered the development of stable time domain integral equation solvers, a technology that remained an unsolved problem for more than four decades. We have recently made significant inroads into multiscale and multiphysics modeling of plasma-reactors, and accelerators that include electromagnetics, plasma physics, fluid flows, and heat transfer.

RESEARCH SUPPORT

Air Force Office of Scientific Research (AFOSR), Air Force Research Laboratory (AFRL), National Science Foundation (NSF), General Electric (GE), National Institutes of Health (NIH)

RECENT PUBLICATIONS

A.J. Pray, N.V. Nair, Y. Begin, K. Cools, H. Bagci, B. Shanker, "A Stable Higher Order Space-Time Galerkin Scheme for Time Domain Integral Equations," *IEEE Transactions on Antennas and Propagation*, 62, 6183–6191 (2014).

D. Dault, N.V. Nair, B. Shanker, "The Generalized Method of Moments for Electromagnetic Boundary Integral Equations," *IEEE Transactions on Antennas and Propagation*, 62, 3174–3188 (2014).

M. Vikram, B. Shanker, S. Aluru, "A Scalable Parallel Wideband FMM for Efficient Electromagnetic Simulations on Large Scale Clusters," *IEEE Transactions on Antennas and Propagation*, 59, 2565–2577 (2011).

B. Shanker, H. Huang, "Accelerated Cartesian Expansions: An $O(N)$ method for rapid computation of potentials of the form R^{ν} for all real ν," *J. Comp. Phys*, 226, 732–753 (2007).