Dhairya Malhotra

Contact Information

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Research Interests

- **Parallel and distributed computing:** parallel algorithms, high performance computing, performance optimization, OpenMP, MPI, CUDA.
- **Scientific computing:** integral and differential equations, elliptic partial differential equations, boundary and volume integral equations in complex geometries, advection-diffusion equation, octrees, high-order methods, fast algorithms, fast multipole method, fast fourier transform.
- **Applications:** N-body problems, electromagnetic and acoustic scattering, incompressible Stokes equations, porous media flow, complex fluids, electrostatics, magnetohydrodynamics.

Education

University of Texas at Austin, Austin, Texas USA

- *Ph.D. in Computational and Applied Mathematics* **December 2017**
  Fast integral equation solver for variable coefficient elliptic PDEs in complex geometries
  Thesis advisor: George Biros
- *M.S. in Computational and Applied Mathematics* **Dec 2014**

Indian Institute of Technology Delhi, New Delhi, India

- *Integrated M.Tech. in Mathematics and Computing* **July 2011**

Research Experience

Center for Computational Mathematics, Flatiron Institute, NY

- *Research Scientist* **Sep 2020 – present**

Courant Institute of Mathematical Sciences, New York University, NY

- *Postdoctoral Associate* **Sep 2017 – Aug 2020**
  Developed a solver for computing force-free magnetic fields in toroidal geometries and applied it to computing ideal MHD stepped pressure equilibrium.

University of Texas at Austin, Austin, Texas USA

- *Graduate Research Assistant*, *Advisor: Prof. George Biros* **Sep 2011 – Aug 2017**
  Developed a highly optimized, parallel FMM library for evaluating volume potentials and applied it to solve variable coefficient elliptic BVP. Developed parallel algorithms for efficient simulation of concentrated vesicle suspensions.

Georgia Institute of Technology, Atlanta, Georgia USA

- *Student Summer Intern*, *Advisor: Prof. George Biros* **Summer 2010**
- *Student Summer Intern*, *Advisor: Prof. George Biros* **Summer 2009**

Risoe National Laboratory, Denmark

- *Student Summer Intern*, *Advisor: Dr. Andreas Alpers* **Summer 2008**

Awards and Honors

- ACM SIGHPC Outstanding Dissertation Award 2018
- ACM/IEEE-CS George Michael Memorial HPC Fellowship 2015

- NIMS Graduate Research Fellowship (academic year 2014-2015)
- Third place at TACC-BP Parallel Programming Contest (2014)
- Bronze medal at ACM Student Research Competition. (ACM/IEEE Supercomputing, 2013)
- Association for Computing Machinery, Gordon Bell Prize (2010)

Software

- **BIEST** Boundary integral equation solver for Taylor states in toroidal geometries
- **PVFMM** Parallel fast multipole method for particle and volume potentials
- **TbSLAS** Parallel octree based semi-Lagrangian advection-diffusion solver in 3D
- **HykSort** New variant of hypercube quicksort on distributed memory architectures
- **AccFFT** GPU accelerated parallel FFT library

Publications

- Mochamad Asri, *Dhairya Malhotra*, Jiajun Wang, George Biros, Lizy K. John, Andreas Gerstlauer. Hardware Accelerator Integration Tradeoffs for High-Performance Computing: A Case Study of GEMM Acceleration in N-Body Methods. IEEE Transactions on Parallel and Distributed Systems, 2021 (accepted). DOI:10.1109/TPDS.2021.3056045 (pdf)

- Wen Yan, Eduardo Corona, *Dhairya Malhotra*, Shravan Veerapaneni, Michael Shelley. A scalable computational platform for particulate Stokes suspensions. Journal of Computational Physics, 2020. DOI:10.1016/j.jcp.2020.109524

- *Dhairya Malhotra*, Antoine Cerfon, Michael O'Neil, Evan Toler. Efficient high-order singular quadrature schemes in magnetic fusion. Plasma Physics and Controlled Fusion, 2019. DOI:10.1088/1361-6587/ab57f4

- *Dhairya Malhotra*, Antoine Cerfon, Lise-Marie Imbert-Gérard, Michael O'Neil. Taylor states in stellarators: A fast high-order boundary integral solver. Journal of Computational Physics, 2019. DOI:10.1016/j.jcp.2019.06.067

- Arash Bakhtiari, *Dhairya Malhotra*, Amir Raoofy, Miriam Mehl, Hans-Joachim Bungartz, George Biros. A parallel arbitrary-order accurate AMR algorithm for the scalar advection-diffusion equation. Proc. ACM/IEEE Supercomputing, Salt Lake City, UT. 2016. DOI:10.1109/SC.2016.43

- *Dhairya Malhotra*, George Biros. Algorithm 967: A distributed-Memory fast multipole method for volume potentials. ACM Transactions on Mathematical Software (TOMS), 2016. DOI:10.1145/2898349

- Amir Gholami, *Dhairya Malhotra*, Hari Sundar, George Biros. FFT, FMM, or Multigrid? A comparative study of state-of-the-art Poisson solvers for uniform and non-uniform grids in the unit cube. SIAM Journal on Scientific Computing, 2016. DOI:10.1137/15M1010798

- *Dhairya Malhotra*, George Biros. PVFMM: A parallel kernel independent FMM for particle and volume potentials. Communications in Computational Physics, 2015. DOI:10.4208/CICP.020215.150515SW

- Ahmed Khawaja, Jiajun Wang, *Dhairya Malhotra*, Andreas Gerstlauer, George Biros and Lizy John. Performance analysis of HPC applications with irregular tree data structures. Proc. IEEE International Conference on Parallel and Distributed Systems, Hsinchu, Taiwan. 2014. DOI:10.1109/PADSW.2014.7097837

- *Dhairya Malhotra*, Amir Gholami, George Biros. A volume integral equation Stokes solver for problems with variable coefficients. Proc. ACM/IEEE Supercomputing, New Orleans, LA. 2014. DOI:10.1109/SC.2014.13 **(Finalist for Best Student Paper)**

- Hari Sundar, *Dhairya Malhotra*, Karl W. Schulz. Algorithms for high-throughput disk-to-disk

sorting. Proc. ACM/IEEE Supercomputing, Denver, CO. 2013. DOI:10.1145/2503210.2503259

- Hari Sundar, *Dhairya Malhotra*, George Biros. HykSort: a new variant of hypercube quicksort on distributed memory architectures. Proc. 27th International Conference on Supercomputing, Eugene, OR. 2013. DOI:10.1145/2464996.2465442

- Abtin Rahimian, Ilya Lashuk, Aparna Chandramowlishwaran, *Dhairya Malhotra*, Logan Moon, Rahul Sampath, Aashay Shringarpure, Shravan Veerapaneni, Jeffrey Vetter, Richard Vuduc, Denis Zorin, and George Biros. Petascale direct numerical simulation of blood flow on 200k cores and heterogeneous architectures. Proc. ACM/IEEE Conf. Supercomputing (SC), New Orleans, LA. 2010. DOI:10.1109/SC.2010.42 **(Winner, Gordon Bell Prize)**

Technical Reports

- *Dhairya Malhotra*, Abtin Rahimian, Denis Zorin, George Biros. A parallel algorithm for long time-scale simulation of concentrated vesicle suspensions in three dimensions.

- Amir Gholami, Judith Hill, *Dhairya Malhotra*, George Biros. AccFFT: A library for distributed-memory FFT on CPU and GPU architectures. arXiv:1506.07933.

Invited Talks

- "Integral equation methods for computing stepped pressure equilibria in stellarators". SIAM PD, December 2019.

- "A boundary integral equation solver for computing Taylor states in toroidal geometries". AAPPS-DPP, November 2019.

- "A high-order BIE solver for computing Taylor states in stellarators". International Congress on Industrial and Applied Mathematics, July 2019.

- "Computing magnetohydrodynamic equilibria in stellarators". Applied Inverse Problems, July 2019.

- "Scalable integral equation methods for problems with moving boundaries". SIAM CSE, February, 2019.

- "A boundary integral solver for computing force-free fields in stellarators". Plasma Physics Seminar - University of Maryland, November, 2018.

- "PVFMM: A parallel kernel-independent FMM library for particle and volume potentials". Numerical Algorithms Seminar - Flatiron Institute, November, 2018.

- "An integral equation based method for computing magneto-hydrodynamic equilibrium". International Conference on Spectral and High-Order Methods, July, 2018.

- "Integral equation methods for problems with moving boundaries". Applied Mathematics Seminar - Yale University, March, 2018.

- "Parallel simulation of concentrated vesicle suspensions in 3D". BIRS-CMO Workshop on Complex Creeping Fluids: Numerical Methods and Theory, October 2017.

- "Fast integral equation solver for elliptic PDEs in complex geometries". SIAM CSE, February 2017.

- "A parallel arbitrary-order accurate AMR algorithm for the scalar advection-diffusion equation". ACM/IEEE Supercomputing, November 2016.

- "Fast solvers for complex fluids". SIAM Parallel Processing for Scientific Computing, April 2016.
- "A volume integral equation solver for elliptic PDEs in complex geometries". SIAM Parallel Processing for Scientific Computing, April 2016.
- "PVFMM: A parallel fast multipole method for volume potentials". SIAM CSE, March 2015.
- "A parallel volume integral equation Stokes solver for flows in complex geometries". SIAM CSE, March 2015. **(Finalist for BGCE Best Student Paper)**
- "A volume integral equation Stokes solver for problems with variable coefficients". ACM/IEEE Supercomputing, 2014. **(Finalist for Best Student Paper)**
- "A volume integral equation solver for boundary value problems with highly heterogeneous coefficients". SIAM Conference on Parallel Processing for Scientific Computing, February 2014.
- "A petascale fast multipole method for volume potentials". SIAM Annual Meeting, July 2013.
- "A parallel fast summation algorithm for volume potentials". SIAM CSE, February 2013.

Poster Presentations

- "BIEST: A fast high-order BIE solver for computing stepped pressure equilibria in stellarators". Sherwood Fusion Theory, April 2019.
- "BIEST: A high-order boundary integral equation solver for computing Taylor states". Simons Collaboration on Hidden Symmetries and Fusion Energy Annual Meeting, March 2019.
- "A distributed-memory fast multipole method for volume potentials". ACM/IEEE Supercomputing, 2013. (**Bronze Award, ACM Student Research Competition**)
- "A massively parallel adaptive fast multipole method for volume potentials". SIAM Annual Meeting, 2012.

Teaching

New York University

- *MATH-GA.2012-001, CSCI-GA 2945.001* (Co-taught with Georg Stadler) **Spring 2019**
  Advanced Topics in Numerical Analysis: High Performance Computing