

# Hari Sundar

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## Research Focus

The central focus of my research is the development of such computationally optimal *parallel, high-performance algorithms*, both discrete and continuous, that are efficient and scalable on state-of-the-art architectures. It is driven by applications in *biosciences* and *geophysics*, such as cardiovascular mechanics, medical image analysis, and seismic wave propagation. My research has resulted in the development of state-of-the-art distributed algorithms for *adaptive mesh refinement, geometric multigrid, fast Gauss transform* and *sorting*.

## Education

- |      |  |                            |
|------|--|----------------------------|
| 2009 | PhD, Bioengineering  | University of Pennsylvania |
|      | Thesis: Spatio-Temporal Deformation Analysis of Cardiac MR Images. |                            |
|      | Advisor: Christos Davatzikos & George Biros                        |                            |
| 2000 | B.ENG., Control Systems  | University of Delhi        |

## Experience

- |           |  |                            |
|-----------|--|----------------------------|
| 2011-     | <i>Research Associate</i>  | ICES, University of Texas  |
|           | multigrid methods, parallel and distributed algorithms, seismic wave propagation, distributed sorting, inverse problems                          |                            |
| 2008-2011 | <i>Research Scientist</i>  | Siemens Corporate Research |
|           | image registration, computer assisted surgery, image segmentation, gaze tracking, biomechanics, surgical simulation, augmented reality           |                            |
| 2003-2008 | <i>Research Assistant</i>  | University of Pennsylvania |
|           | large-scale PDE constrained optimization, adaptive mesh refinement, parallel and distributed computing, cardiac biomechanics, image registration |                            |
| 2002-2003 | <i>Research Associate</i>  | Siemens Corporate Research |

point cloud matching, image-based guidance for electrophysiological procedures

2000-2002

*Graduate Assistant*

Rutgers University

Shape Matching, Graph Matching, Skeletal Shape Representaion

### Teaching

*Parallel Algorithms for Scientific Computing,*

Spring 2012, Spring 2013

University of Texas at Austin. Co-Instructed with George Biros.

### Grants

*Sponsor: DOE MMICCs* (Senior Investigator)

Title: *DiaMonD: An Integrated Multifaceted Approach to Mathematics at the Interfaces of Data, Models, and Decisions.*

Award amount: \$5,425,000 (total for UT Austin)

Grant# : 11145687

Project Period: 1/1/2013 - 12/31/2017

*Sponsor: NSF* (Senior Investigator)

Title: Algorithms and Architectures for Multiresolution Applications.

Grant# : 1337393

Award amount: \$749,801

Project Period: 10/1/2013 - 09/30/2016

### Refereed Publications

- submitted 1. HARI SUNDAR, GEORG STADLER, GEORGE BIROS, *Comparison of Multigrid Algorithms for High-order Continuous Finite Element Discretizations*, submitted to Journal of Scientific Computing.
2. HARI SUNDAR, GEORG STADLER, OMAR GHATTAS, GEORGE BIROS, *Distributed Multigrid Algorithms for High-order Continuous Finite Element Discretizations*, submitted to SIAM Journal on Scientific Computing.
3. AMIR GHOLAMINEJAD, DHAIRYA MALHOTRA, HARI SUNDAR, GEORGE BIROS, *FFT, FMM, or Multigrid? A comparative study of state-of-the-art Poisson solvers*, submitted to IEEE International Parallel & Distributed Processing Symposium 2014.
4. JESSE KELLY, HARI SUNDAR, OMAR GHATTAS, *Solution of the Acoustic-Elastic Wave Equation on a Heterogeneous, MIC-Accelerated Supercomputer*, submitted to IEEE International Parallel & Distributed Processing Symposium 2014.
5. JITHIN JOSE, SREERAM POTLURI, HARI SUBRAMONI, XIAOYI LU, DHABALESWAR PANDA, KARL SCHULZ, HARI SUNDAR, *Designing Scalable Out-of-core Sorting with*

*Hybrid MPI+OpenSHMEM Programming Models*, submitted to IEEE International Parallel & Distributed Processing Symposium 2014.

- 2013 6. HARI SUNDAR, DHAIRYA MALHOTRA, KARL SCHULTZ, *Algorithms for High-throughput Disk-to-Disk Sorting*, Proceedings of SC13, ACM/IEEE Computer Society, Denver.
- 7. HARI SUNDAR, DHAIRYA MALHOTRA, GEORGE BIROS, *HykSort: a new variant of hypercube quicksort on distributed memory architectures*, Proceedings of ICS-13, ACM International Conference on Supercomputing, Eugene, OR.
- 2012 8. DAVID RIVEST-HENAUULT, HARI SUNDAR, MOHAMED CHERIET, *Non-Rigid 2D/3D Registration of Coronary Artery Models with Live Fluoroscopy for Guidance of Cardiac Interventions*, IEEE Transactions on Medical Imaging, 31(8), 1557-1572.
- 9. HARI SUNDAR, GEORGE BIROS, CARSTEN BURSTEDDE, JOHANN RUDI, OMAR GHATTAS, GEORG STADLER, *Parallel Geometric-Algebraic Multigrid on Unstructured Forests of Octrees*, Proceedings of SC12, ACM/IEEE Computer Society, Salt Lake City.
- 10. YANG GAO, HARI SUNDAR, *Coronary Arteries Motion Modeling using X-Ray Images*, SPIE Medical Imaging, San Diego, California (2012).
- 11. AMIT KALE, VIPIN GUPTA, HARI SUNDAR, *A robust and accurate approach to automatic blood vessel detection and segmentation from angiography x-ray images using multi-stage random forests*, SPIE Medical Imaging, San Diego, California (2012).
- 2011 12. PARMESHWAR KHURD, LEO GRADY, HARI SUNDAR ET AL., *Global Error Minimization in Image Mosaicing Using Graph Connectivity and its Applications in Microscopy*, Journal of Pathology Informatics, 2(2) 8.
- 2010 13. RAHUL SAMPATH, HARI SUNDAR, SHRAVAN VEERAPANENI, *Parallel Fast Gauss Transform*, Proceedings of SC2010, ACM/IEEE Computer Society, New Orleans. **Best Paper Finalist.**
- 14. YING ZHU, YANGHAI TSIN, HARI SUNDAR, *Image-Based Respiratory Motion Compensation for Fluoroscopic Coronary Roadmapping*, Springer Lecture Notes in Computer Science, MICCAI, 6363(3): pp 287-94.
- 15. MATTHIAS SCHNEIDER, HARI SUNDAR, JOACHIM HORNEGGER, CHENYANG XU, *Model-Based Respiratory Motion Compensation for Image-Guided Cardiac Interventions*, Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (CVPR).
- 16. RUI LIAO, YUNHAO TAN, HARI SUNDAR, MARCUS PFISTER, ALI KAMEN, *An Efficient Graph-Based Deformable 2D/3D Registration Algorithm with Applications for Abdominal Aortic Aneurysm Interventions*, Medical Imaging and Augmented Reality, Beijing, China (2010).

17. MATTHIAS SCHNEIDER, HARI SUNDAR, *Automatic global vessel segmentation and catheter removal using local geometry information and vector field integration*, IEEE International Symposium on Biomedical Imaging, Rotterdam, Netherlands (2010).
- 2009 18. HARI SUNDAR, HAROLD LITT, DINGGANG SHEN, *Estimating Consistent Myocardial Motion by 4D Image Warping*, Pattern Recognition, (42) 11, pp 2514-2526.
- 2008 19. HARI SUNDAR, RAHUL S. SAMPATH, GEORGE BIROS, *Bottom-Up Construction and 2:1 Balance Refinement of Linear Octrees in Parallel*, SIAM Journal on Scientific Computing, 30(5) .
20. HARI SUNDAR, CHRISTOS DAVATZIKOS, GEORGE BIROS, *Biomechanically-Constrained 4D Estimation of Myocardial Motion*, Springer Lecture Notes in Computer Science, MICCAI, 5762(2): pp 257-65.
21. HARI SUNDAR, ALI KHAMENE, LIRON YATZIV, CHENYANG XU, *Automatic Image-based Cardiac and Respiratory Cycle Synchronization and Gating of Image Sequences*, Springer Lecture Notes in Computer Science, MICCAI, 5762(2): pp 281-88.
22. LUC DUONG, RUI LIAO, HARI SUNDAR, BENOIT TAILHADES, ANDREAS MEYER, CHENYANG XU, *Curve-based 2D-3D registration of coronary vessels for image guided procedure*, SPIE Medical Imaging, San Diego, California (2009).
23. RAHUL S. SAMPATH, SANTI S. ADAVANI, HARI SUNDAR, ILYA LASHUK, GEORGE BIROS, *Dendro: Parallel Algorithms for Multigrid and AMR Methods on 2:1 Balanced Octrees*, Proceedings of SC2008, ACM/IEEE Computer Society, Austin, Texas.
- 2007 24. HARI SUNDAR, DINGGANG SHEN, GEORGE BIROS, CHENYANG XU, CHRISTOS DAVATZIKOS, *Robust estimation of Mutual Information using Spatially Adaptive Meshes*, Springer Lecture Notes in Computer Science, MICCAI, 4791(1): pp 950-58.
25. HARI SUNDAR, RAHUL S. SAMPATH, SANTI S. ADAVANI, CHRISTOS DAVATZIKOS, GEORGE BIROS, *Low-constant Parallel Algorithms for Finite Element Simulations using Linear Octrees*, Proceedings of SC2007, ACM/IEEE Computer Society, Reno, Nevada, **Best Student Paper Finalist**.
- 2006 26. HARI SUNDAR, DINGGANG SHEN, GEORGE BIROS, HAROLD LITT, CHRISTOS DAVATZIKOS, *Estimating myocardial fiber orientations by template warping*, IEEE International Symposium on Biomedical Imaging, Arlington, Virginia (2006).
27. HARI SUNDAR, ALI KHAMENE, CHENYANG XU, FRANK SAUER, CHRISTOS DAVATZIKOS, *A Novel 2D-3D Registration Algorithm for Aligning fluoroscopic images with 3D pre-operative CT/MR images*, SPIE Medical Imaging, San Diego, California, (2006).
- 2005 28. DINGGANG SHEN, HARI SUNDAR, ZHONG XUE, YONG FAN, HAROLD LITT, *Consistent Estimation of Cardiac Motions by 4D Image Registration*, Springer Lecture Notes in Computer Science, MICCAI, 3750(2): pp 902-10.

29. CHARLES R. BRIDGES, KAPIL GOPAL, DAVID E. HOLT, CHARLES YARNALL, STEVEN COLE, ROCHELLE B. ANDERSON, XIAOQING YIN, ANTHONY NELSON, BENJAMIN W. KOZYAK, ZHONGLIN WANG, JAMES LESNIEWSKI, LEONARD T. SU, DANIELLE M. THESIER, HARI SUNDAR, HANSELL H. STEDMAN, *Efficient myocyte gene delivery using complete cardiac surgical isolation in situ*, Journal of Thoracic and Cardiovascular Surgery, 2005:130:1364.
- 2003 30. H. SUNDAR, D. SILVER, N. GAGVANI AND S. DICKINSON, *Skeleton Based Shape Matching and Retrieval*, Proceedings of the Shape Modeling International 2003. (**over 450 citations**)
- 2002 31. D. SILVER, H. SUNDAR AND N. GAGVANI, *Shape Based Culling for Volume Graphics*, Eurographics Workshop on Rendering, Pisa, Italy (2002).

#### Invited Talks

- 2013 *Geometric Multigrid for high-order discretizations*, 16th Copper Mountain Conference on Multigrid Methods, Copper Mountain, UT.
- 2013 *Parallelization Strategies for High-order Discretized Hyperbolic PDEs*, SIAM Conference on Computational Science and Engineering, Boston, MA.
- 2010 *Applications of projective registration for peripheral CTO*, Interventional Radiology, University of Virginia Medical Center, Charlottesville, VA.
- 2009 *Image-based guidance for the crossing of Chronic Total Occlusions*, Thoraxcentrum, Erasmus Medical Center, Rotterdam, Netherlands.
- 2008 *A biomechanical model of the human heart incorporating myocardial fiber orientations*, NSF ERC, Computer-Integrated Surgical Systems and Technology, Johns Hopkins University, Baltimore, MD.
- 2005 *Characterizing Coronary shape variations using Kernel PCA*, Section for Biomedical Image Analysis, University of Pennsylvania, Philadelphia, PA.
- 2004 *Point to Surface Registration for EP Procedures*, Siemens Corporate Research, Princeton, NJ.
- 2003 *2d-3d Registration for X-Ray Interventions*, Siemens Workshop, Stanford University, Palo Alto, CA.
- 2002 *3D Shape Matching using Skeletal Graphs*, Workshop on Shape Matching, Princeton University, Princeton, NJ.
- 2001 *Fast Volume Rendering using space leaping*, Princeton Plasma Physics Laboratories, Princeton, NJ.

## Students

### PHD STUDENTS

1. Co-supervision (with Mohamed Cheriet) of Ph.D. thesis of David Rivest-Henault, École de Technologie Supérieure, Montreal, Canada.
2. Co-supervision (with Omar Ghattas) of Ph.D. thesis of Jesse Kelly, University of Texas at Austin.

### UNDERGRADUATE STUDENTS

1. Supervision of diploma thesis of Matthias Schneider, University of Erlangen-Nürnberg, Erlangen, Germany.
2. Yang Gao, University of Waterloo, Canada.
3. Ashwin Rao, University of Texas at Austin.

## Graduate Courses Taken

Computer Architecture, Design & Analysis of Data Structures & Algorithms, Operating Systems, Computational Geometry, Computer Networks, Numerical Methods, Computer Graphics, Computer Vision, Artificial Intelligence, Machine Learning, Parallel Algorithms for Scientific Computing, Algebraic Topology

## Honors and Awards

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|-----------|--|
| 2008-     | Multiple patents awarded and pending approval by the USPTO (filed by Siemens AG). Please see <a href="https://www.google.com/search?tbm=pts&amp;q=ininventor:Hari+Sundar">https://www.google.com/search?tbm=pts&amp;q=ininventor:Hari+Sundar</a> for a complete list of patents. |
| 2010      | Best Paper finalist, ACM/IEEE SuperComputing 2010. (Best paper in Math Library Parallelization)  |
| 2007      | Best Student Paper finalist, ACM/IEEE SuperComputing 2007. (Best paper in PDE Applications)  |
| 2003-2007 | Siemens-Penn Fellowship for Ph.D. studies.   |

## Professional Activities

- **Reviewer** for the following journals: IEEE Transactions on Medical Imaging, IEEE Transactions on Biomedical Engineering, IEEE Transactions on Image Processing, ACM Transactions on Mathematical Software, Medical Image Analysis, The Visual Computer, Signal, Image & Video Processing, .

- **Reviewer** for the following Conferences: Supercomputing, ICCV, CVPR, IPDPS, MICCAI, ISBI.
- Member on the Stampede User Advisory Committee at the Texas Advanced Computing Center (TACC), 2013-.

### Software Development

The below codes build on MPI for distributed memory parallelism and are written in C/C++. Most implementations were started from a clean sheet of paper to ensure optimal parallel scalability of each component, and few external libraries are used. Currently, some codes are modified towards OpenMP and SIMD.

- The ALPS Toolkit, 2007-present (with C. Burstedde, T. Issac, G. Stadler, T. Tu and L.C. Wilcox): a collection of MPI based C libraries for large scale  $h$ -adaptive finite elements with applications in the geosciences.
- `mangl1`, 2008-present (with T. Bui-Thanh, C. Burstedde, T. Issac, G. Stadler and L.C. Wilcox): a high order  $h$ -adaptive discretization library supporting discontinuous and continuous Galerkin finite elements. `mangl1` includes solvers for high-order, discontinuous Galerkin wave propagation and a geometric multigrid solver, which have both shown close-to-optimal scalability to more than 220,000 cores.
- Dendro: A C++ library for constructing and balancing octrees in parallel. It also generates hexahedral meshes from the octrees and extends PETSc's distributed array framework to support octree-based meshing. Basic routines for solving PDEs on such meshes using the finite element method are also provided.
- `hykSort`: Highly scalable distributed sorting and selection library. The package implements BitonicSort, MergeSort, SampleSort and HykSort. The code is highly tuned and provides parallelism using MPI, OpenMP and SIMD vectorization.
- `pfgt`: Fast adaptive parallel algorithms to compute the sum of  $N$  Gaussians at  $M$  points using the fast Gauss Transform. We use parallel octrees and a new scheme for translating the plane-waves to efficiently handle non-uniform distributions.

### References

<b>Prof. George Biros</b> , University of Texas, Austin	biros@ices.utexas.edu
<b>Prof. Christos Davatzikos</b> , Univ. of Pennsylvania	christos@rad.upenn.edu
<b>Prof. Omar Ghattas</b> , University of Texas, Austin	omar@ices.utexas.edu
<b>Prof. Ulrich Rüde</b> , University of Erlangen-Nürnberg	ulrich.ruede@fau.de

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