Tobin Isaac

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Curriculum Vitæ

June 20, 2022

Education

- Ph.D., Computational Science, Engineering and Mathematics, U.T. Austin, August 2015.
  Dissertation: "Scalable, Adaptive Methods for Forward and Inverse Problems in Continental-Scale Ice Sheet Modeling" (*T. I.*, 2015), advised by Omar Ghattas and Georg Stadler.
- B.A. *(summa cum laude)*, Computational and Applied Mathematics, Rice University, May 2007.

Employment

- Computational Mathematician, MCS Division, Argonne National Laboratory, May 2022–
- Assistant Professor, Computational Science and Engineering, Georgia Tech, August 2017–May 2017
- Postdoctoral Scholar, Computation Institute, U. Chicago, June 2015–May 2017
- Graduate Research Assistant for Omar Ghattas, U.T. Austin, September 2013–May 2015
- DOE Computational Science Graduate Fellow, September 2009–August 2013
- ICES CAM Fellow, U.T. Austin, August 2007–August 2009

Awards and Honors

- Catherine M. and James E. Allchin Assistant Professorship, Georgia Tech, 2020–2022
- Winner, SIAM Computational Science and Engineering Best Paper Prize, 2019, for "Scalable and Efficient Algorithms for the Propagation of Uncertainty from Data through Inference to Prediction for Large-scale Problems, with Application to Flow of the Antarctic Ice Sheet" (*T. I.*, Petra, et al., 2015).
- Winner, SIAM/Supercomputing Early Career Prize, 2016, "for superb contributions to high-performance computational science at the interface of applied mathematics, computer science, software, and continuum physics."
- Winner, ICES Outstanding Dissertation Award, 2016, for "Scalable, Adaptive Methods for Forward and Inverse Problems in Continental-Scale Ice Sheet Modeling" (*T. I.*, 2015).
- Winner (with others), ACM Gordon Bell Prize, 2015, for "An Extreme-Scale Implicit Solver for Complex PDEs: Highly Heterogeneous Flow in Earth's Mantle" (Rudi, Malossi, et al., 2015).
- Winner (with others), ACM Best Poster Prize, 2014, for "Parallel High-Order Geometric Multigrid Methods on Adaptive Meshes for Highly Heterogeneous Nonlinear Stokes Flow Simulations of Earth's Mantle" (Rudi, Sundar, et al., 2014).
- Winner, 4th Bavarian Graduate School of Computational Engineering Student Paper Prize, 2013, for "Advanced Simulation of Polar Ice Sheets: Meshing, Parallel Adaptivity, High-order Discretization, Robust Scalable Solvers, and Inversion for Basal Boundary Conditions" (*T. I.*, 2013b).
- Finalist (with others), ACM Gordon Bell Prize, 2010, for "Extreme-Scale AMR" (Burstedde, Ghattas, et al., 2010).

Research Interests

- *Applied math and numerical analysis:*
  - Developing Bayesian inversion techniques for models governed by large, complex systems: in particular, scalable sampling and posterior-approximation techniques for quantifying and propagating the uncertainty in discretization-dependent parameter fields.
  - Developing optimal (or efficient) high performance solvers (linear and nonlinear) for implicit PDEs and coupled multiphysics systems of PDEs.
- *Computer science, data structures and software:*
  - Data structures and algorithms for finite element and discontinuous Galerkin methods, with emphases on parallel partitioning, octree-based methods, adaptivity, and efficient memory movement.
- *Applications:*
  - Ice sheet modeling and coupled ice sheet/climate simulation.
  - Atmospheric modeling and weather prediction.
  - Tokamaks and magnetohydrodynamics.
  - Other multiphysics, multiscale problems.

Publications

J. Go and *T. I.* (2022). "Robust Expected Information Gain for Optimal Bayesian Experimental Design Using Ambiguity Sets". *Proceedings of the Thirty-Eighth Conference on Uncertainty in Artificial Intelligence*. ARXIV: 2205.09914. accepted.

G. Bruer and *T. I.* (2022). "Inferring ice sheet damage models from limited observations using CRIKit: the Constitutive Relation Inference Toolkit". *SIAM Journal on Scientific Computing*. ARXIV: 2204.09748. Submitted.

R. Egan, A. Guittet, F. Temprano-Coleto, *T. I.*, F. J. Peaudecerf, J. R. Landel, P. Luzzatto-Fegiz, C. Burstedde, and F. Gibou (2021). "Direct numerical simulation of incompressible flows on parallel Octree grids". *Journal of Computational Physics* 428. DOI: 10.1016/j.jcp.2020.110084.

T. I. (2021). "Unifying the geometric decompositions of full and trimmed polynomial spaces in finite element exterior calculus". *Mathematics of Computation*. ARXIV: 2112.02174. Submitted.

A. C. Yonge, M. R. Kunz, B. Rakesh, *T. I.*, R. Fushimi, and A. J. Medford (2021). "TAPsolver: A Python package for the simulation and analysis of TAP reactor experiments". *Chemical Engineering Journal*. DOI: 10.1016/j.cej.2021.129377.

T. I. (2020). "Recursive, parameter-free, explicitly defined interpolation nodes for simplices". *SIAM Journal on Scientific Computing*. DOI: 10.1137/20M1321802.

T. I. and H. Suh (2020). "Evaluation of a Minimally Synchronous Algorithm for 2:1 Octree Balance". *SC20: The International Conference for High Performance Computing, Networking, Storage and Analysis*. DOI: 10.1109/SC41405.2020.00027.

C. Burstedde, J. Holke, and *T. I.* (2018). "On the Number of Face-Connected Components of Morton-Type Space-Filling Curves". *Foundations of Computational Mathematics*. DOI: 10.1007/s10208-018-9400-5.

T. I. (2018b). "A mixed finite element for weakly-symmetric elasticity". ARXIV: 1802.02976.

A. Mueller, M. Kopera, S. Marras, L. C. Wilcox, *T. I.*, and F. Giraldo (2018). "Strong Scaling for Numerical Weather Prediction at Petascale with the Atmospheric Model NUMA". *International Journal of High Performance Computing Applications*. DOI: 10.1177/1094342018763966.

M. F. Adams, E. Hirvijoki, M. G. Knepley, J. Brown, *T. I.*, and R. Mills (2017). "Landau Collision Integral Solver with Adaptive Mesh Refinement on Emerging Architectures". *SIAM Journal on Scientific Computing* 39, pp. C452–C465. DOI: 10.1137/17M1118828.

H. Zhu, N. Petra, G. Stadler, *T. I.*, T. J. R. Hughes, and O. Ghattas (2016). "Inversion of geothermal heat flux in a thermomechanically coupled nonlinear Stokes ice sheet model". *The Cryosphere* 10, pp. 1477–1494. DOI: 10.5194/tc-10-1477-2016.

T. I. and M. G. Knepley (2015). "Support for Non-conformal Meshes in PETSc's DMPlex Interface". ARXIV: 1508.02470.

T. I., G. Stadler, and O. Ghattas (2015). "Solution of Nonlinear Stokes Equations Discretized by High-order Finite Elements on Nonconforming and Anisotropic Meshes, with Application to Ice Sheet Dynamics". *SIAM Journal on Scientific Computing*, B804–B833. DOI: 10.1137/140974407.

J. Rudi, A. C. I. Malossi, *T. I.*, G. Stadler, M. Gurnis, P. W. J. Staar, Y. Ineichen, C. Bekas, A. Curioni, and O. Ghattas (2015). "An Extreme-Scale Implicit Solver for Complex PDEs: Highly Heterogeneous Flow in Earth's Mantle". *SC15: The International Conference for High Performance Computing, Networking, Storage and Analysis*. DOI: 10.1145/2807591.2807675. **ACM Gordon Bell Prize winner**.

T. I., C. Burstedde, L. C. Wilcox, and O. Ghattas (2015). "Recursive Algorithms for Distributed Forests of Octrees". *SIAM Journal on Scientific Computing* 37.5, pp. C497–C531. DOI: 10.1137/140970963.

T. I., N. Petra, G. Stadler, and O. Ghattas (2015). "Scalable and Efficient Algorithms for the Propagation of Uncertainty from Data through Inference to Prediction for Large-scale Problems, with Application to Flow of the Antarctic Ice Sheet". *Journal of Computational Physics* 296, pp. 348–368. DOI: 10.1016/j.jcp.2015.04.047.

T. I. (2015). "Scalable, Adaptive Methods for Forward and Inverse Problems in Continental-Scale Ice Sheet Modeling". Dissertation. University of Texas at Austin. URL: http://catalog.lib.utexas.edu/record=b9055744.

C. Michoski, D. Meyerson, *T. I.*, and F. Waelbroeck (2014). "Discontinuous Galerkin Methods for Plasma Physics in the Scrape-off Layer of Tokamaks". *Journal of Computational Physics* 274, pp. 898–919. DOI: 10.1016/j.jcp.2014.06.058.

T. I., C. Burstedde, and O. Ghattas (2012a). "Low-Cost Parallel Algorithms for 2:1 Octree Balance". *IEEE 2012 International Parallel & Distributed Processing Symposium (IPDPS)*, pp. 426–437. DOI: 10.1109/IPDPS.2012.47.

C. Burstedde, O. Ghattas, M. Gurnis, *T. I.*, G. Stadler, T. Warburton, and L. C. Wilcox (2010). "Extreme-Scale AMR". *SC10: The International Conference for High Performance Computing, Networking, Storage and Analysis*. DOI: 10.1109/SC.2010.25. **ACM Gordon Bell Prize finalist**.

S. F. Feng, *T. I.*, and N. Xiao (2006). "A Simulation-Driven Approach for a Cost-Efficient Airport Wheelchair". *UMAP Journal* 27.3, pp. 399–411. URL: http://eaton.math.rpi.edu/faculty/Kramer/MCM/2006mcmsolutions.pdf#page=219. **Outstanding Winner, MAA Award, COMAP's Mathematical Contest in Modeling**.

Select Presentations

H. Suh and *T. I.* (2020). *Evaluation of a Minimally Synchronous Algorithm for 2:1 Octree Balance*. Presentation at Supercomputing '20.

M. Knepley and *T. I.* (2020). *AMR During PDE-Constrained Optimization using PETSc*. Presentation at SIAM Conference on Parallel Processing for Scientific Computing.

T. I. (2019). *H-Div Conforming Methods for Geodynamic Stokes Flow*. Presentation at SIAM Conference on Computational Science and Engineering.

T. I., N. Petra, G. Stadler, and O. Ghattas (2019). *SIAG CSE Best Paper Prize Lecture: Propagating Uncertainty from Data to Prediction with a Model of the Antarctic Ice Sheet*. Presentation at SIAM Conference on Computational Science and Engineering.

T. I. (2018a). *Extensions of Multipoint Mixed Finite Elements*. Poster at PETSc User Meeting.

T. I. and M. Knepley (2018). *Structured and Unstructured Adaptivity in PETSc*. Presentation at SIAM Conference on Parallel Processing for Scientific Computing.

H. Zhu, *T. I.*, G. Stadler, and O. Ghattas (2017). *Nonliner solvers for Stokes thermomechanical ice models*. Presentation at SIAM Conference on Mathematical and Computational Issues in the Geosciences.

T. I. (2017). *Writing Discretization-Neutral Applications with DM*. Presentation at PETSc User Meeting.

M. Knepley, M. Jadamec, and *T. I.* (2017). *Multilevel Inference with PETSc*. Presentation at SIAM Conference on Computational Science and Engineering.

T. I. (2016). *Current and Planned AMR Support in PETSc*. Presentation at PETSc User Meeting.

— (2014). *Scalable, adaptive methods for forward and inverse modeling of continental-scale ice sheet flow*. Doctoral Showcase at SC14: the International Conference for High Performance Computing, Networking, Storage and Analysis. Poster. URL: http://users.ices.utexas.edu/~tisaac/posters/sc14.pdf.

J. Rudi, H. Sundar, *T. I.*, G. Stadler, M. Gurnis, and O. Ghattas (2014). *Parallel High-Order Geometric Multigrid Methods on Adaptive Meshes for Highly Heterogeneous Nonlinear Stokes Flow Simulations of Earth's Mantle*. Poster at SC14: the International Conference for High Performance Computing, Networking, Storage and Analysis. Poster. URL: http://users.ices.utexas.edu/~johann/site_data/presentations/rudi_poster_sc14.pdf. **ACM Best Poster winner**.

T. I., N. Petra, G. Stadler, and O. Ghattas (2014). *Statistical Inversion for Basal Parameters for the Antarctic Ice Sheet*. 3rd SIAM Conference on Uncertanty Quantification. Presentation. URL: http://users.ices.utexas.edu/~tisaac/slides/uq14.pdf.

T. I., C. Burstedde, and O. Ghattas (2014). *Hybrid Quadtree/Octree AMR for Anisotropic Domains*. 16th SIAM Conference on Parallel Processing for Scientific Computing. Presentation. URL: http://users.ices.utexas.edu/~tisaac/slides/pp14.pdf.

T. I., O. Ghattas, G. Stadler, and N. Petra (2013). *Scalable adaptive methods for forward and inverse continental ice sheet modelling*. 46th Annual Fall Meeting, American Geophysical Union. Presentation.

T. I. (2013a). *Ice Sheets and Octrees*. DOE CSGF Annual Program Review. Presentation.

T. I., G. Stadler, and O. Ghattas (2013). *Discretizations and Solvers for the Stokes Equations of Ice Sheet Dynamics*. 12th SIAM Conference on Mathematical and Computational Issues in the Geosciences. Presentation. URL: http://users.ices.utexas.edu/~tisaac/slides/gs13.pdf.

T. I. (2013b). *Advanced Simulation of Polar Ice Sheets: Meshing, Parallel Adaptivity, High-order Discretization, Robust Scalable Solvers, and Inversion for Basal Boundary Conditions*. SIAM Conference on Computational Science and Engineering. Presentation. **Winner of the 4th BGCE Best Student Paper prize**.

T. I., O. Ghattas, and G. Stadler (2012). *Techniques for Solving the Stokes Equations of Ice Sheet Dynamics at Continental Scale*. 45th Annual Fall Meeting, American Geophysical Union. Presentation.

T. I., C. Burstedde, and O. Ghattas (2012b). *Low-Cost Parallel Algorithms for 2:1 Octree Balance*. 26th IEEE International Parallel and Distributed Processing Symposium. Presentation. URL: http://users.ices.utexas.edu/~tisaac/slides/ipdps12.pdf.

Software

- p4est (p4est.org): A library for highly-scalable parallel adaptive mesh refinement based on the forest-of-octrees approach. See my contribution statistics at https://github.com/cburstedde/p4est/commits?author=tisaac. Publications: Rudi, Malossi, et al., 2015; *T. I.*, Burstedde, Wilcox, et al., 2015; *T. I.*,

Burstedde, and Ghattas, 2012a; Burstedde, Ghattas, et al., 2010.
I developed an anisotropic refinement extension to the library, discussed in Mueller et al., 2018; *T. I.*, Stadler, and Ghattas, 2015.

- mangll: An open source high-order *h*-adaptive nodal discontinuous Galerkin library. Publications: Burstedde, Ghattas, et al., 2010.
- DofColumns (bitbucket.org/tisaac/dofcolums): A preconditioner plugin I wrote for PETSc that handles anisotropic smoothed-aggregation algebraic multigrid. Publications: *T. I.*, Stadler, and Ghattas, 2015.
- deal.II (dealii.org): A widely used open source finite element library. I added support for distributed meshes with periodic domains. Publications: Michoski et al., 2014.
- PETSc (www.mcs.anl.gov/petsc): the Portable, Extensible Toolkit for Scientific Computing. See my contribution statistics at https://www.openhub.net/p/485176/contributors/2083815053608004.
I extended the library's unstructured mesh representation (DMPlex) to support non-conformal meshes. Publications: *T. I.* and M. G. Knepley, 2015.
- recursivenodes (tisaac.gitlab.io/recursivenodes): A python package implementing an explicitly defined interpolation nodes for simplices. Publications: *T. I.*, 2020.
- CRIKit (crikit.science): The Constitutive Relation Inference Toolkit. Publications: Bruer and *T. I.*, 2022.