Omar Ghattas: One Page Summary of CV

- **Education**: BSE (1984), MS (1986), PhD (1988), Postdoc (1989), Civil Eng/Comp Mechanics, Duke University
- **Positions**
  - Assist. (89-94), Assoc. (94-01), Full Professor (01-05), Civil Engr/Biomed Engr, Carnegie Mellon University
  - Jackson Chair of Computational Geosciences, Professor of Geological Sciences & Mechanical Engineering, and Director, Center for Computational Geosciences & Optimization, ICES, Univ of Texas at Austin (05–)
- **Publications** (Google Scholar)
  - 141 refereed articles (SISC, JCP, CMAME, Inverse Prob, IJNME, SINUM, SC'XX, JUQ, Inv Prob Imag, ...)
- **Mentoring**
  - 33 PhD students, 23 postdocs. Have gone on to become faculty at NYU (Courant), NCSU (Math), UT-Austin (Aerospace), Bonn (Math), UT-Austin (ME), Naval Postgraduate School (Applied Math), Utah (Computing), UC Merced (Applied Math), UT-Austin (CE), GaTech (CS&E), Middle East Technical Univ (CE), Crete (CE), Baylor (Math), Washington Univ (EE), UNCC (Eng), Mokwon Univ (Arch Eng); and research staff at ExxonMobil, ORNL, MIT Broad Inst, Microsoft, Schlumberger, Samsung, McKinsey, Hyundai, LLNL, GE, Boeing, ANSYS, Caltech, eBay, Facebook, Dimensional Fund, CGG, COMAC, UTRC, Argonne
- **Service**
  - *Editorial board member* (former & current) of 17 publications, including SIAM CS&E book series; SIAM J Scientific Computing, SIAM News, Inverse Problems, Research in Mathematical Sciences, CMAME, Intl. J. Uncertainty Quantification, Parallel & Distributed Computing, Intl. J. Geomathematics, Data Science, etc.
  - *Co-chair of 16 and member of organizing/program committee of 59 conferences/workshops in CS&E*, including 2003 SIAM CS&E; 2004 SIAM Parallel; 2005 Sandia Large Scale Robust Opt; 2005 SIAM CS&E; 2006 SIAM Parallel; 2007 Sandia/NSF/AFOSR UQ and Inv Probs; 2008 TeraGrid; 2011 SIAM Geosci; 2011 IMA Inv Probs and UQ; 2012 SIAM Parallel; 2013 SIAM CS&E; SC14; 2018 SIAM Imaging Science
  - *Service on 42 national/international scientific and professional committees*, including National Academies V&V/UQ and Models of the World Committees, SIAM CS&E founding Program Director, Co-chair NSF CS&E Task Force, SIAM Program Committee, CIG Science Steering & Executive Committees, SIAM Imaging Science Program Director, multiple prize committees (SIAM Geoscience, SIAM Imaging, IEEE Fernbach), advisory boards for multiple initiatives/institutions in US, UK, Germany, France, Ecuador, Saudi Arabia
- **Select Awards and Honors** (many joint with students/postdocs/collaborators)
  - *Keynote or plenary lecturer at 44 international conferences*, including SciCADE03, DD03, ASCE EMC03, SIAM OP05, SciDAC05, USNCCM05, VECPAR06, SIAM GS07, HPCS07, AIP07, ParCFD08, WAVES11, USNCCM13, ENUMATH13, MOPTA13, PASC14, SIAM AN14, SciCADE15, IMR15, PRACE16, GAMM/DMV16, VECPAR16, EAGE-HPC17, SIAM UQ18, ECCM/ECFD18, MAFELAP19, ICIAM19
  - 2019 *SIAM Geosciences Career Prize*
  - 2019 *SIAM Computational Science & Engineering Best Paper Prize*
  - Winner, 2015 *Gordon Bell Prize* for scalable multigrid algorithms for parallel implicit solution of highly heterogeneous, anisotropic, nonlinear PDEs, with application to mantle convection
  - *SIAM Fellow*, Class of 2014, for "contributions to optimization of systems governed by partial differential equations and leadership to promote computational science and engineering."
  - Finalist, 2012 *Gordon Bell Prize* for scalable algorithms for parallel solution of high-dimensional Bayesian inverse problems and uncertainty quantification, with application to global full waveform inversion
  - 2012 *Joseph C. Walter Excellence Award*, Jackson School of Geosciences, UT Austin
  - Two papers selected for Highlights of journal *Inverse Problems* (FWI in 2008, Hessian analysis in 2012)
  - Finalist, 2010 *Gordon Bell Prize* for scalable algorithms for parallel adaptive mesh refinement, with application to wave propagation and mantle convection
  - Finalist, 2008 *Gordon Bell Prize* for parallel algorithms for modeling global mantle convection
  - *2004-2005 Carnegie Tech Outstanding Research Award* for forward & inverse earthquake modeling
  - Winner, 2003 *Gordon Bell Prize* for scalable algorithms for forward & inverse earthquake modeling
  - *SC 2002 Best Technical Paper Award* for parallel inverse wave propagation
  - *1998 Allen Newell Award for Research Excellence* for earthquake ground motion modeling on supercomputers

Summary of Recent Research Activities and Interests

In my group we have been working on the development and analysis of efficient computational methods for forward solvers, Bayesian inversion, optimal experimental design, and optimal design/control under uncertainty that scale both algorithmically and in parallel for complex large-scale models. These methods have been demonstrated to scale out to the largest problem sizes ever tackled in their respective categories (to the best of our knowledge). For "outer loop problems" (deterministic and Bayesian inversion, OED, optimal control, uncertainty quantification), the cost of these methods—measured in number of forward problem solves—is independent of the parameter, data, and optimization variable dimensions. We have applied these methods to challenging problems in the geosciences, including regional and global earthquake modeling, global mantle convection, polar ice sheet dynamics, flow in fractured reservoirs, subsurface poroelasticity, atmospheric transport, and others.

- **Adaptive scalable forward solvers for highly heterogeneous, nonlinear, anisotropic PDE problems**
  - *Scalable hybrid multigrid (spectral/geometric/algebraic) and primal-dual Newton algorithms for parallel implicit solution of strongly heterogeneous, anisotropic, and nonlinear PDEs*. Linear and nonlinear iterations demonstrated to be independent of problem size. Weak-scaled up to 1.6M cores (LLNL Sequoia IBM BG/Q system) and 600B DOF with 97% parallel efficiency, and applied to non-Newtonian global mantle convection and non-Newtonian polar ice sheet flows with up to 10^9 variation in effective viscosity. Recognized by 2015 ACM/IEEE Gordon Bell Prize (major prize in supercomputing) and 2008 Bell Finalist. Representative publications (numbers refer to those in my CV): [18, 24, 27, 28, 31, 44, 47, 64, 65, 73]
  - *Scalable parallel adaptive mesh refinement (AMR) algorithms* based on forests of octrees, and supporting general geometry, high-order approximation, and continuous/discontinuous Galerkin approximation. Scaled to 1.6M cores and 600B DOF with negligible overhead for coarsening, refinement, mesh partitioning, and 2:1 octree balance. Applied to wave propagation, mantle convection, transport, and non-Newtonian ice flow. Publicly released as widely-used p4est library (http://p4est.org), which has been integrated into deal.II and PETSc libraries. Recognized by 2010 Gordon Bell Finalist. Pubs: [30, 54, 57, 64, 65, 72, 73]
- **Computational methods for complex PDE-based deterministic and Bayesian inverse problems**
  - *Scalable inexact Newton-CG algorithms for PDE-based deterministic inverse problems.* Combines adjoint-based matrix-free Hessian actions with Krylov solution and regularization preconditioning to yield inverse solution at cost (measured in forward PDE solves) that is independent of the parameter and data dimensions, and depends only on the *information dimension*, i.e., the number of modes in parameter space informed by the data. Primal-dual TV regularization for discontinuous media and vector TV similarity regularization for joint inverse problems. Applications to inverse problems in seismic wave propagation (first 3D high resolution full waveform inversion in 2002), ice sheet flow (first 3D continental scale Antarctic inversion in 2015), mantle convection, poroelastic subsurface flow, and atmospheric transport (likely largest PDE-governed inverse problem ever solved with 135M parameters). Recognized by 2003 Gordon Bell Prize. Publications: [12, 13, 17, 23, 31, 33, 36, 41, 46, 48, 77, 79, 85, 94, 96, 97, 105, 116]
  - *Scalable PDE-constrained Bayesian inversion algorithms*. Hessian-based exploitation of geometry of posterior covariance to accelerate MCMC sampling, combined with randomized SVD for low-rank approximation of data misfit Hessian, making Bayesian inference tractable for certain classes of inverse problems with up to 1M uncertain parameters. Applied to regional and global seismic wave propagation, mantle convection, non-Newtonian ice flow, poroelastic subsurface flow, atmospheric transport, and turbulent flow inverse problems. Recognized by 2012 Gordon Bell Finalist. Released as hIPPYlib library (https://hippylib.github.io). Pubs: [15, 19, 22, 31, 32, 37, 38, 40, 41, 46, 49, 52, 55, 56, 59]
- **Computational methods for PDE-constrained optimization under uncertainty**
  - *Scalable algorithms for PDE-constrained optimal control and design under uncertainty*, made tractable using variance reduction based on Taylor approximation and randomized algorithms for mean/variance estimation. Scaled to over 1M uncertain parameters and 200K control variables and demonstrated to scale (in number of PDE solves) independent of parameter and control variable dimensions. Applied to optimal control and design of subsurface flow, acoustic metamaterials, and turbulent flow. Publications: [9, 16]
  - *Scalable PDE-constrained Bayesian optimal experimental design algorithms* to optimize data acquisition systems for Bayesian inverse problems, made tractable by Laplace approximation and randomized algorithms for estimation of expected information gain. Scaled to 16K uncertain parameters and 1K experimental design parameters and applied to optimal well placement for subsurface flows. Publications: [25, 26, 35]