Shreyas Sunil Gaikwad

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RESEARCH INTERESTS

Computational Glaciology	PDE-constrained Inverse Problems	Uncertainty Quantification
Machine Learning	Ice-Ocean Interactions	Data Assimilation
High-Performance Computing	Open Source Software Dev.	Automatic Differentiation

EDUCATION

Ph.D. in Computational Science, Engineering and Mathematics, 2019-2024
The University of Texas at Austin
Thesis: *Bayesian Inversion Over Long Time Scales for the Greenland Ice Sheet*
GPA: 4.0/4.0

M.S. in Computational Science, Engineering and Mathematics, 2019-2021
The University of Texas at Austin
GPA: 4.0/4.0

B.Tech in Mechanical Engineering with Honors, 2015-2019
Minor in Computer Science
Indian Institute of Technology Bombay
Thesis: *Computational Analysis of Subcooled Boiling*
GPA: 9.32/10.0, Department Rank: 4/150

RESEARCH EXPERIENCE

Graduate Research Assistant, CRIOS, UT Austin   2020-Present
Advisor - Dr. Patrick Heimbach

- Integrated the open source Automatic Differentiation (AD) tool Tapenade with the SICOPOLIS ice sheet model source code in order to generate the adjoint and tangent linear codes. The adjoint calculation of the gradient is exponentially faster than the finite differences calculation.

- Developing a computational framework for glaciological parameter inversion and uncertainty quantification.

- Leveraging Deep Learning to reduce the computational cost of simulating sea ice in the general ocean circulation model, MITgcm.

- Examining the similarities between adjoint models and eXplainable-AI techniques (XAI) for deep learning emulators such as Layerwise Relevance Propagation (LRP) in the earth system context.

Deep Learning Intern, Ansys   Summer 2024
Advisor - Jay Pathak, Senior RnD Director, CTO Central Team

- Developed unified Neural Radiance Field (NeRF) to implicitly represent multiple, diverse object geometries.

- Built scalable GenAI pipeline in PyTorch with 106 million parameters using unified NeRF and 3D-aware diffusion models to enable novel 3D object generation from single camera views of object geometries.

- Achieved 3D object generation time of 5 minutes for novel, user-provided single camera-view images.

Visiting Scholar, Argonne National Laboratory   Summer 2022
Advisor - Dr. Sri Hari Krishna Narayanan, Dr. Patrick Heimbach, Dr. Michel Schanen

- Open source software development in Julia, interfacing Enzyme and MPI for a mountain glacier code. Identified fundamental bugs in Enzyme and reported as Minimum Working Examples (MWEs).

- First ever (in multiple attempts) successful integration of the open source AD tool Tapenade with the MITgcm general circulation model source code, providing an alternative to a proprietary version that costs $\sim \$14{,}000$ per license per annum.

Undergraduate Research Assistant, IIT Bombay   2018-2019
Advisor - Dr. Janani Srree Muralidharan

- Simulated air-water multiphase flow around nuclear rods, analyzing trends in void fraction distribution for different turbulence models and solvers in OpenFOAM.

Undergraduate Research Assistant, IIT Bombay   Summer 2017
Advisor - Dr. Shivasubramanian Gopalakrishnan

- Simulated the impact of a subsonic, thin stream of air striking the surface of the water, to mirror the industrial process of purification of molten steel, leveraged axial symmetry to reduce computation time.

Undergraduate Research Assistant, IIT Bombay   Summer 2017
Advisor - Dr. S.K. Maiti

- Developed codes in MATLAB to detect the position of transverse cracks with 95% accuracy in Euler-Bernoulli as well as Timoshenko beams using any three modes of natural vibration.

PUBLICATIONS AND TALKS

JOURNAL ARTICLES

Detlef Stammer, Daniel E. Amrhein, Magdalena Alonso Balmaseda, Laurent Bertino, Massimo Bonavita, Carlo Buontempo, Nico Caltabiano, Francois Counillon, Ian Fenty, Raffaele Ferrari, Yosuke Fujii, **Shreyas Sunil Gaikwad**, Pierre Gentine, Andrew Gettelman, Ganesh Gopalakrishnan, Patrick Heimbach, Hans Hersbach, Chris Hill, Shinya Kobayashi, Armin Köhl, Paul J. Kushner, Matthew Mazloff, Hisashi Nakamura, Stephen G. Penny, Laura Slivinski, Susann Tegtmeier, and Laure Zanna (2024). "Earth system reanalysis in support of climate model improvements", *Bulletin of the American Meteorological Society.*

Helen Pillar, **Shreyas Gaikwad**, Patrick Heimbach (2024). "Pairing Neural Networks with Adjoints for Flexible Investigation and Robust Attribution of Ocean Variability", *In Preparation for submission to Geophysical Research Letters.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Jean-Michel Campin, Helen Pillar, An Nguyen, Jan Hückelheim, Paul Hovland, Patrick Heimbach (2024). "MITgcm-AD v2: Open source tangent linear and adjoint modeling framework for the oceans and atmosphere enabled by the Automatic Differentiation tool Tapenade", *Future Generation Computer Systems, 2024.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Liz Curry-Logan, Ralf Greve, Patrick Heimbach (2023). "SICOPOLIS-AD v2: linearized forward and adjoint modeling framework for ice sheet modeling enabled by automatic differentiation tool Tapenade", *Journal of Open Source Software 8, no. 83 (2023): 4679.*

CONFERENCE PROCEEDINGS

Laurent Hascoet, Jean-Luc Bouchot, **Shreyas Gaikwad**, Sri Hari Krishna Narayanan, Jan Hückelheim (2024). "Profiling checkpointing schedules in adjoint ST-AD", *Submitted to 8th International Conference on Algorithmic Differentiation, 2024.*

INVITED TALKS

Shreyas Gaikwad, Helen Pillar, Tim Smith, Nora Loose, Sri Hari Krishna Narayanan, Jean-Michel Campin, Laurent Hascoet, Patrick Heimbach (2023). "Computational Science To Enable Digital Twins Of The Ocean", *6th SIAM Texas-Louisiana Sectional Meeting (SIAM TX-LA), 2023.*

ORAL PRESENTATIONS

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "MITgcm-AD: Open Source Inverse Modeling Framework for the Oceans using the AD tool Tapenade", *ECCO Annual Meeting, 2024.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "MITgcm-AD: Open Source Inverse Modeling Framework for the Oceans using the AD tool Tapenade", *25th EuroAD Workshop, 2023.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "MITgcm-AD: Open Source Inverse Modeling Framework for the Oceans using the AD tool Tapenade", *WCRP Workshop MIT, 2023.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "SICOPOLIS-AD v2: Inverse modeling framework for ice sheet modeling enabled by automatic differentiation", *AGU Annual Meeting, 2022.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "SICOPOLIS-AD v2: Inverse modeling framework for ice sheet modeling enabled by automatic differentiation", *Scientific Committee on Antarctic Research 10th Open Science Conference (SCAR-OSC), 2022.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Liz Curry-Logan, Ralf Greve, Patrick Heimbach. "SICOPOLIS-AD V2: Inverse Modeling Framework for Ice Sheet Modeling enabled by Automatic Differentiation", *Machine Learning for Polar Regions Workshop, 2022.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Liz Curry-Logan, Ralf Greve, Patrick Heimbach. "SICOPOLIS-AD v2: An open-source tangent-linear and adjoint modeling framework for ice-sheet simulation enabled by the AD tool Tapenade", *24th EuroAD Workshop, 2021.*

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Michel Schanen, Patrick Heimbach. "MITgcm-AD: Open Source Inverse Modeling Framework for the Oceans using the AD tool Tapenade", *Summer Argonne Students Symposium (SASSy), 2022.*

POSTERS

Shreyas Gaikwad, Sri Hari Krishna Narayanan, Laurent Hascoet, Liz Curry-Logan, Ralf Greve, Patrick Heimbach (2022). "SICOPOLIS-AD v2 and MITgcm-AD: linearized forward and adjoint modeling framework for ice sheet and ocean modeling enabled by automatic differentiation tool Tapenade", *14th Joint Laboratory for Extreme Scale Computing (JLESC) Workshop.*

HONORS AND AWARDS

- **ACDC+GRISO Summer School**, prestigious climate dynamics summer school in Greenland.   2023
- **Peter O'Donnell Fellow**, Awarded Fellowship worth $24,000 by the Oden Institute.   2019-2020
- **Ph.D. Preliminary Exam**, Cleared exams in applied maths, scientific computing, and maths modeling. 2020
- **AP grade**, in Computer Graphics, awarded rarely for exceptional insights.   2018
- **AP grade**, in Heat Transfer, awarded rarely for exceptional insights.   2017
- **KVPY Fellow**, Conferred by Govt. of India for demonstrating aptitude for research, (Rank - 27/50,000). 2015
- **IISc UG Admission offer**, India's top research institution, offered admission due to KVPY selection. 2015
- **JEE Advanced qualification**, Stage II entrance exam for the IITs, Ranked 509/150,000.   2015
- **JEE Main qualification**, Stage I entrance exam for the IITs, Ranked 983/1.5 million candidates.   2015
- **INChO qualification**, Indian National Chemistry Olympiad, ranked top 1% among 30,000 students.   2015
- **INSPIRE Scholar**, Scholarship for top 1 percentile in state high school exams.   2015
- **BITSAT Qualification**, Entrance exam for the BITs, estimated rank top 200/300,000.   2015
- **Bhaskar Genius Scholar**, Top 20 rank in India among 50,000 students.   2012
- **MCSE PSS Scholar**, Awarded by Maharashtra State Council of Examination (99.9995 percentile).   2011

OTHER RESEARCH PROJECTS

Machine Learning Applications in Geophysics   Spring 2021

- Developed CNNs in **Keras** for earthquake detection using data from stations, with **96% validation accuracy**.

- Developed U-Nets in **Keras** for seismic faults detection through image segmentation, with **97% test accuracy**.

- Leveraged Autoencoders in **Keras** to aid clustering through dimensional reduction into the latent space.

- Built pipeline to pick mudrocks from real wireline logs using ML algorithms, with **87% test accuracy**.

Physics-Informed Machine Learning   Spring 2021

- Trained a Deep Neural Network in **PyTorch** to emulate a partial differential equation (PDE) based glacier model by leveraging **higher-order derivatives of the PyTorch computational graph**.

- Enriched the framework using an expanded computational graph to infer unknown PDE parameters.

Laplacian 2D Finite Difference (FD) Solver Application   Fall 2020

- Features: OOP (C++), Solver (gauss, jacobi, PETSc), tests (bats, Travis CI, docker), 98% code coverage (lcov), 0% memory errors (valgrind), build (autotools), HPC env (SLURM), parser & logger (GRVY).

SOFTWARE CONTRIBUTIONS

All of these tools are constantly under development.

- **SICOPOLIS-AD v2**, a new inverse modeling framework for the ice sheet model SICOPOLIS that is enabled by source transformation using the open-source Automatic Differentiation (AD) tool Tapenade.

- **MITgcm-AD**, a new inverse modeling framework for the general circulation model MITgcm that is enabled by source transformation using the open-source Automatic Differentiation (AD) tool Tapenade.

- **ARGOVIS**, developed OOP-based Python tools for interactive plotting and binning of Argo data.

- **Enzyme**, Identified fundamental bugs in Enzyme, reported as MWEs here and here by Dr. Michel Schanen (my co-advisor at Argonne).

SELECT GRADUATE COURSEWORK

Data Science and HPC - Machine Learning applications in Geophysics, Foundational Techniques in Machine Learning, Engineering Data Mining, Design and Analysis of Algorithms, Tools and Techniques in Computational Science, Numerical Methods for Differential Equations, Numerical Linear Algebra, High Performance Scientific Computing, Operating Systems.

Inverse Problems and UQ - Uncertainty Quantification in Computational Models, Computational & Variational Methods for Inverse Problems (observer).

Mathematics - Functional Analysis, Partial Differential Equations, Analytical Methods.

Fluid Dynamics - Physical Oceanography, Mathematical Modeling in Science and Engineering, Computational Fluid Dynamics, Galerkin Methods.

COMPUTATIONAL SKILLS

Languages - Python (scikit-learn, Keras, PyTorch, FENICS, xarrays, numpy, autograd, Pandas), Julia (MPI, Enzyme), C++ (GRVY, MASA, HDF5, PETSc), Fortran-77/90.

Softwares - MATLAB, Scilab, Solidworks, ANSYS, ADAM, OpenFOAM, Simulink, LaTeX, Tapenade, MITgcm, SICOPOLIS.

HPC and other tools - OpenMP, MPI, CUDA, SLURM, Github, Docker, Shell scripting, Travis-CI, Autotools, Valgrind, HTML, CSS, Jekyll, lcov.

Summer Schools

Advanced Climate Dynamics Courses (ACDC) + Greenland Ice Sheet Ocean (GRISO) Summer School, Disko Island, Greenland, 2023.

Trustworthy Artificial Intelligence for Environmental Science (TAI4ES) Summer School, 2022.

Trustworthy Artificial Intelligence for Environmental Science (TAI4ES) Summer School, 2021.

Professional Memberships

Society of Industrial and Applied Mathematics (SIAM)

International Association of Cryospheric Sciences (IACS)

American Geophysical Union (AGU)

Indian Society of Arctic Researchers (ISAR)

Arctic Research Consortium of the United States (ARCUS)

Association of Polar Early Career Scientists (APECS)

Seismological Society of America (SSA)

Volunteer, Mentorship, Leadership, Teaching and Community Experience

Volunteer Experience

Volunteer: CURED, Techfest-2016, IIT Bombay, Conducted 178 diabetes screening camps across 20 cities in a team of 100+, conducting more than 65,000 screenings in a day as part of CURED (Can You Really Escape Diabetes?), a PAN-India level initiative to raise awareness about diabetes.

Volunteer: Educational Outreach, National Service Scheme, IIT Bombay, Mentored and taught 25 underprivileged students of secondary school over a period of one year (2015-2016) as part of the Educational Outreach program of National Service Scheme.

Volunteer: UT Girl Day 2024, Going to help organize and demonstrate to 500+ elementary and middle school kids and their parents how to conduct simple yet powerful experiments to understand the role of sea ice and glacial melts in the changing Arctic climate and explore observational and modeling tools fundamental to many CRIOS research projects.

Mentorship Experience

Mentor: Oden Institute for Computational Engineering and Sciences   2022-2023

- Mentored a first-year Oden Institute graduate student (Bugra Yalcin), served as a contact point for becoming acclimated to the program.

Mentor: UT Austin SIAM Applied Math Mentorship Program   2021-2022

- Mentored 2 students (Martin Vu and Nan Shelden), with broad focus on careers in applied mathematics.

Mentor: Department Academic Mentorship Program (DAMP), IIT Bombay   2018-2019

One of the 23 student mentors selected out of 85 applicants, selections based on interviews and peer reviews.

- Mentored 6 students for a smooth transition to department curriculum, motivating their academic and personal endeavors (Students mentored - Rishabh D'Souza, Ameya Mittal, Pranesh Parmar, Nishant Kumar, Harshit Madan, Swastik Sahoo).
- Part of the team tasked with suggesting modifications to the curriculum if necessary after consultation with the HoD, Faculty Advisors, and Professors.

Mentor: Academic Rehabilitation Program, IIT Bombay   2018-2019

- Counselled an academically weak student on a one-on-one basis, helping him to clear his academic backlogs as part of the Academic Rehabilitation Program.

Informal career mentorship   2018-Present

- Mentored over 10+ students broadly about future careers in STEM, interview preparation, and resume reviews.

- Mentored students include Aditya Patil (currently at Ketto), Rushikesh Borse (currently at George Mason University), Raj Lakhani (currently at University of Michigan Ann Arbor), Ritwik Kadu (currently at Flipkart), Devendra Waghulde (currently at BTS), Nishant Jannu (currently at Stanford University), Anonymous (currently at Lear corporation, prefers not being named).

LEADERSHIP EXPERIENCE

Senior Advisor, Austin Chapter of SIAM   2023-Present

President, Austin Chapter of SIAM   2022-2023

- Hosted NREL, Sandia National Laboratories, AMD as part of our Industry Seminar Series.

- Helped organize Applied Maths Mentorship Program, which comprised 40 mentors and 50 mentees in total.

- Helped fund and mentor 3 teams of undergraduates for the COMAP Mathematical Contest in Modeling (MCM) / Interdisciplinary Contest in Modeling (ICM).

- Initiated the Recent Graduate Series of talks by Oden Institute Alumni.

Vice President, Austin Chapter of SIAM   2021-2022

- Hosted ANSYS, Two Sigma, Julia Computing, StriveWorks, Cerfe Labs (ARM), and Sandia National Laboratories as part of our Industry Seminar Series.

- Hosted Dr. Howard Stone (Donald R. Dixon '69 and Elizabeth W. Dixon Professor and the Department Chair of the Mechanical and Aerospace Engineering at Princeton University) for a talk on "Beauty in Research and Intersections with Teaching" as part of our Distinguished Seminar Series.

- Quadrupled our followers on Instagram and increased our Facebook following by 30%.

- Helped organize Applied Maths Mentorship Program, which comprised 34 mentors and 47 mentees in total.

- Nominated as finalist for Best Graduate Organization category of Swing Out Awards, for the second year in a row.

TEACHING EXPERIENCE

Graduate Teaching Assistant, UT Austin   Fall 2022
Course - *Intro. to Mathematical Modeling in Science and Engineering I*, ***Advisor*** - *Dr. Patrick Heimbach*

- Responsible for grading assignments, conducting recitation and office hours, as well as full lectures in the absence of the instructor.

COMMUNITY PARTICIPATION

Full course lecture, Introduction to Mathematical Modeling in Science and Engineering I 2022

Instructor: Patrick Heimbach

My lecture covered the material around Lagrangian and Eulerian derivatives, as well as the proof of the Reynolds' Transport Theorem.

ARGOVIS Hackathon   2022

I helped develop OOP-based Python tools for interactive plotting and binning of Argo data. The Jupyter Notebook will soon be available and help the community to better analyze and visualize the Argo data.

Guest Lecture, Physical Oceanography   2021

Instructor: Patrick Heimbach

My guest lecture "Scaling Analysis" focused on 1) an overview of how scaling analysis is performed and 2) on how it can help greatly simplify the governing equations of ocean flow by eliminating most of the terms.

Industry Experience

KITES Intern, ITC Limited Summer 2018

ITC Limited is India's largest FMCG conglomerate; I interned in the packaging section of its only fully owned flour plant in Uluberia, West Bengal, India

- Achieved Manpower Reduction in Primary Packing Machines by 50%.
- Secondary Packing Machines worth a total of $165,000 made operational using PDCA-cycle-based improvements.

Junior Design Engineer, IIT Bombay Racing 2016-2017

A team of students which fabricates an electric race car for Formula Student U.K

- Developed 3-D CAD models for gearbox in SolidWorks and carried out FEA simulations in ANSYS to help select optimum gear ratio.
- Routed the cooling system on SolidWorks Routing, reducing weight and increasing ease of priming of the pumps.

References

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