Saurabh S. Sawant, Ph.D.

Center for Computational Sciences and Engineering (CCSE)
Applied Mathematics and Computational Research Division (AMCRD)
Lawrence Berkeley National Laboratory, Berkeley, CA 94720.

☎ +1-(814)-777-7497
✉ SaurabhSawant@lbl.gov
saurabh-s-sawant.github.io

Summary

- 10+ years of experience in developing highly scalable software using C++, message-passing-interface (MPI), and GPUs for diverse scientific applications:
  - Specialization in hypersonic flows during Ph.D. projects.
  - Focus on nanoelectronics while contributing to open-source software during postdoctoral work.
- Skilled in diverse modeling techniques, including:
  - Specialization in kinetic methods for high-temperature gas dynamics.
  - Expertise in matrix-based algorithms for quantum transport in nanomaterials.
  - Experience in linear stability analyses of compressible flows.
- 7+ years of experience contributing to collaborative, interdisciplinary projects.

Education

Ph.D. *May 2022*
Department of Aerospace Engineering, University of Illinois Urbana-Champaign
Thesis: **The development of kinetic models and simulation methods to study molecular fluctuations, modal response, and shock-laminar separation bubble instabilities**
https://www.ideals.illinois.edu/items/124505
Cumulative GPA: 3.76 on a scale of 4

M.S. *Dec. 2015*
Department of Aerospace Engineering, University of Illinois Urbana-Champaign
Thesis: **Development of AMR octree Direct Simulation Monte Carlo (DSMC) approach for shock dominated flows.**
https://www.ideals.illinois.edu/items/91247
GPA: 3.87 on a scale of 4

B.E. *Aug. 2011*
Department of Mechanical Engineering, Vidyavardhini's College of Engineering & Tech., Mumbai University, India.
Thesis: **Efficiency analysis of Aerospike nozzles.**
Class: First Class

Research Experience

Detailed description of my work is provided at: saurabh-s-sawant.github.io/projects/

Postdoctoral Scholar *Jan. 2022- Present*
Center for Computational Sciences and Engineering (CCSE)
Applied Mathematics and Computational Research Division (AMCRD)
Lawrence Berkeley National Laboratory, Berkeley, CA-94709, USA.
Supervisor: Dr. Andrew Nonaka

I am a part of a DOE-funded collaborative project entitled, "Codesign and Integration of Nanosensors on CMOS", which aims to build a CMOS chip that will serve as a nanoscale photon sensor using carbon nanotubes functionalized with quantum dots for sensing photons. On the computational front, my contribution is two-fold: nanoscale modeling of carbon nanotube field effect transistor (CNTFET) configurations with a large number of nanotubes, and microscale modeling transmission lines on a chip carrying electromagnetic waves. The specific contributions for these two works are summarize below:

- **(Ongoing) Exascale modeling of self-consistent quantum transport through nanomaterials**
  - Developed a 3D, open-source, electrostatic-quantum transport framework (eXstatic) using the AMReX library, modern C++, GPUs, message-passing-interface (MPI). 🔗 https://github.com/AMReX-Microelectronics/eXstatic
  - Quantum transport is modeled using the nonequilibrium Green's function (NEGF) method that uses matrix-based algorithms at its core.
  - Self-consistency between electrostatic potential and charge is achieved using Broyden's modified second algorithm parallelized on CPUs and GPUs.
  - Performed weak-scaling studies up to 512 NVIDIA A100 GPUs on NERSC's Perlmutter supercomputer.
  - The solver is used to model fully 3D, aperiodic arrangement of finite number of nanotubes.
- **Characterization of microscale transmission lines using Maxwell's equations.**
  - Developed a workflow to compute scattering ($\boldsymbol{S}$) parameter that signifies the amount of power transmitted, reflected, and lost when electromagnetic waves traverse through microscale transmission lines.
  - Incorporated the workflow in the open-source, electrodynamics solver, ARTEMIS. 🔗 https://github.com/AMReX-Microelectronics/artemis
  - Demonstrated the workflow to compute $\boldsymbol{S}$-parameter of a part of newly proposed transmission line to carry signals from carbon nanotubes to IC inputs.
  - Performed weak-scaling of ARTEMIS up to 2048 NVIDIA A100 GPUs on NERSC's Perlmutter supercomputer.
  - Implemented diagnostics in the ARTEMIS Maxwell solver to compute voltage and current from the electric and magnetic fields as a function of time.

Graduate Research Assistant *Aug. 2014- Dec. 2021*
Department of Aerospace Engineering
University of Illinois Urbana-Champaign, Champaign, IL-61801, USA
Advisor: Professor Deborah Levin

During M.S. & Ph.D., I have contributed to multiple projects in the field of hypersonics, funded by AFOSR, ONR, DoD, NASA, which include,

- development of a massively scalable Direct Simulation Monte Carlo (DSMC) solver for modeling shock-wave/boundary-layer interactions (SWBLIs)
- study of linear instability mechanism in hypersonic laminar separation bubble and their interaction with shocks
- characterization of molecular fluctuations in the internal structure of shocks
- multi-scale modeling of thermal protection material on spacecraft's heatshield
- helping a junior graduate student in his project on studying dust lifting mechanisms in electrostatic discharge plasma

A brief overview of my Ph.D. projects is given below.

- **Kinetic modeling of shock-wave/boundary-layer interactions**
  - Developed a 3-D, Direct Simulation Monte Carlo solver entitled SUGAR (Scalable Unstructured Gas-dynamic Adaptive mesh-Refinement) using C++ & message-passing-interface (MPI).
  - Implemented Adaptive Mesh Refinement (AMR) technique on octree grids, in conjuction with embedded boundaries, Morton-based space-filling curve strategy for improved load-balance, strategies for performance improvement and run-time memory optimization for adaptively refined grids.
  - Implemented thermal non-equilibrium models for rotational and vibrational energy relaxation.
  - Demonstrated ideal strong scaling speed-up up to 4096 processors and weak scaling efficiency of 87% for 8192 processors for a hypersonic flow with shock resolved using AMR.
  - Carried out 3-D simulations of shock-wave/boundary-layer interactions over a double wedge using 20,000 processors & over two million node-hours on supercomputers, NSF's Bluewaters, TACC's Stampede2, FRONTERA, DoD's Onyx.
- **DSMC investigation of linear instability mechanism in a laminar hypersonic seperated flow.**
  - Carried out spanwise periodic simulation of Mach 7 flow of nitrogen over a 30°-55° double wedge at $Re_1 = 5.22 \times 10^5$ m^{-1} (above 60 km alitude).
  - Modeled surface rarefaction effects and the translational, rotational, vibrational nonequilibrium.
  - Applied data-driven techniques such as proper-orthogonal decomposition to reduce noise as well as obtain dominant modes in these flows.
  - Studied the coupling of linear instability of 3-D laminar separation bubble with separation and detached shocks and concluded that a linear instability mechanism leads to spanwise corrugation of shocks and the presence of low-frequency unsteadiness of the triple point at a Strouhal number, $St \sim 0.02$.
- **Development of a kinetic approach to studying low-frequency fluctuations in a one-dimensional shock.**
  - Studied two-orders of mangitude lower frequency fluctuations of macroscopic flow parameters in the internal shock structure of argon compared to freestream.
  - Developed a Lotka-Volterra type two-energy-bin dynamical model to predict differences in frequencies and showed that the bimodality of energy density function in a shock is responsible for lower frequencies in shocks.
  - Characterized the frequencies in terms of range of Strouhal numbers, $St = 0.002-0.02$, which remains consistent across Mach 2-10.
  - Derived an analytical formula for the bimodal energy distribution function in the form of non-central chi-squared (NCCS) distributions.
  - Established a semi-analytical model based on NCCS distributions to predict the average low frequency of fluctuations in shocks.
- **Development of a framework for stability analysis of internal shock structure.**
  - Formulated linear stability framework for studying modal analysis of planar shocks using Navier-Stokes equations as well as using more accurate Mott-Smith model to account for bimodality in shocks.
  - Solved eigenvalue problem to predict modal response of 1-D shock structure against small-amplitude perturbations.

- **Modeling of multi-scale thermal response of an AVCOAT-like thermal protection system.**
  - Carried out DSMC simulations of gas transport through the microstructure of an AVCOAT-like ablative heatshield.
  - Obtained permeability and tortuosity for the AVCOAT material.
  - Developed a random walk model for coupled convection, conduction, and radiation through the microstructure.
  - Studied the thermal response of AVCOAT material with spatially varying thermophysical properties at high temperatures using the loosely-coupled DSMC-random walk model and compared it with finite-volume approaches.
- **Dust lifting in electrostatic discharge.**
  - Implemented capability to model dust particles in the open-source FLASH solver, used to model charged particle-fluid interactions by a junior graduate student.

Achievements

Attendee for Argonne Training Program on Extreme Scale Computing *2022*
Argonne National Laboratory
Recipient of FRONTERA Leadership Resource Allocation *2020-2022*
University of Illinois Urbana-Champaign
Recipient of AE Outstanding Graduate Student Fellowship *2020*
University of Illinois Urbana-Champaign
Selectee for MAVIS Future Faculty Fellows (MF3) Program *Fall 2019–2020*
University of Illinois Urbana-Champaign
Recipient of the Best Undergraduate Project *2011*
Vidyavardhini's College of Engineering, Mumbai University, India

Teaching Experience

Teaching Assistant (TA)
Department of Aerospace Engineering
University of Illinois Urbana-Champaign, Champaign, IL-61801, USA.

- **Incompressible Flows (AE 311)** *Spring 2020*
  Instructor: Professor Laura Villafane Roca
- **Aerospace Flight Mechanics (AE 202)** *Fall 2019*
  Instructor: Professor Huy Tran
- **Incompressible Flows (AE 311)** *Spring 2019*
  Instructor: Professor Theresa Saxton-Fox
- **Rocket Propulsion (AE 434)** *Spring 2018*
  Instructor: Professor Deborah Levin
  Duties for last four TAs: Preparing homework and exam solutions, holding office hours, conducting python workshops, and lectures when instructor is traveling.

Research Associate *Dec. 2012–July 2013*
Department of Mechanical Engineering,
Indian Institute of Technology Bombay, Mumbai, Maharashtra-400076, India

- **Created open-source tutorials and conducted workshops on OpenFOAM & Salome software.**
  Advisor: Professor Shivasubramanian Gopalakrishnan
  Project: FOSSEE, National Mission on Education through Information and Communication Technology, Sponsored by MHRD, Government of India.
  Link: http://www.spoken-tutorial.org/list_videos?view=1

&foss=OpenFOAM&language=English

Lecturer
Atharva College of Engineering, Mumbai University, India. *Jan.–July. 2012*

- **Engineering Drawing and CAD software packages**
  Duties: Teaching first-year students of Mechanical Engineering, conducting workshops for CAD software packages, holding office hours, preparing homework and exams.

Professional Service

Reviewed two journal articles for the *Theor. and Comput. Fluid Dyn.* *2021-2022*
Reviewed a journal article for *Acta Astronautica* *2022*
Reviewed a conference article for the *31st Rarefied Gas Dynamics* conference *Spring 2019*

Journal Publications

Sawant, S. S., Yao, J., Jambunathan, R., & Nonaka, A. (2023) **Characterization of Transmission Lines in Microelectronic Circuits Using the ARTEMIS Solver.** ***IEEE Journal on Multiscale and Multiphysics Computational Techniques***, vol. 8, pp. 31-39.
doi:10.1109/JMMCT.2022.3228281

Sawant, S. S., Theofilis, V., & Levin, D. A. (2022) **On the synchronisation of three-dimensional shock layer and laminar separation bubble instabilities in hypersonic flow over a double wedge.** ***Journal of Fluid Mechanics***, 941, A7.
doi:10.1017/jfm.2022.276

Sawant, S. S., Levin, D. A., & Theofilis, V. (2022) **Analytical prediction of low-frequency fluctuations inside a one-dimensional shock.** ***Theoretical and Computational Fluid Dynamics.***, 36, 25-40.
doi:10.1007/s00162-021-00589-5

Klothakis, A., Quintanilha, H., & Sawant S. S., Protopapadakis, E., Theofilis V., & Levin D. A. (2022) **Linear stability analysis of hypersonic boundary layers computed by a kinetic approach: a semi-infinite flat plate at $4.5 \leq M_\infty \leq 9$.** ***Theoretical and Computational Fluid Dynamics.***, 36, 117-139.
doi:10.1007/s00162-021-00601-y

Sawant, S. S., Levin, D. A., & Theofilis, V. (2021) **A kinetic approach to studying low-frequency molecular fluctuations in a one-dimensional shock.** ***Physics of Fluids***, 33 (10), 104106.
doi:10.1063/5.0065971

Marayikkottu, V. A., Sawant, S. S., & Levin, D. A. (2021) **Study of particle lifting mechanisms in an electrostatic discharge plasma.** ***International Journal of Multiphase Flows***, 137, 103564.
doi:10.1016/j.ijmultiphaseflow.2021.103564

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2019) **Multi-scale thermal response modeling of an AVCOAT-like thermal protection material.** ***International Journal of Heat and Mass Transfer***, 133, 1176-1195.
doi:10.1016/j.ijheatmasstransfer.2018.12.182

Harpale, A., Sawant, S. S., Kumar, R., Levin, D. A., & Chew, H. B. (2018) **Ablative thermal protection systems: Pyrolysis modeling by scale-bridging molecular dynamics.** ***Carbon***, 130, 315-324.
doi:10.1016/j.carbon.2017.12.099

Sawant, S. S., Tumuklu, O., Jambunathan, R., & Levin, D. A. (2018) **Application of adaptively refined unstructured grids in DSMC to shock wave simulations.** ***Computers & Fluids***, 170, 197-212.
🔗 doi:10.1016/j.compfluid.2018.04.026

For latest updates, please visit: 🔗 saurabh-s-sawant.github.io/publications/

Refereed Conference Proceedings

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2022). **Linear Instability of Shock-Dominated Laminar Hypersonic Separated Flows. In: Sherwin, S., Schmid, P., Wu, X. (eds)** ***IUTAM Laminar-Turbulent Transition.*** IUTAM Bookseries, vol 38. Springer, Cham.
🔗 doi:10.1007/978-3-030-67902-6_57

Conference Publications

Klothakis, A., Sawant S. S., Quintanilha, H., Theofilis V., & Levin, D. A. (2021). **Slip Effects on the Stability of Supersonic Laminar Flat Plate Boundary Layer.** ***AIAA Scitech 2021 Forum*** (Paper No. 1659).

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2020). **Analysis of Spanwise Perturbations in Laminar Hypersonic Shock-Boundary Layer Interactions.** ***AIAA Scitech 2020 Forum*** (Paper No. 0108).

Marayikkottu, V. A., Sawant, S. S., Levin, D. A., Huang, C., Schoenitz, M., & Dreizin, E. (2020). **Comparison of numerical simulations of inert particle transport in an electrostatic discharge with experimental results.** ***AIAA Scitech 2020 Forum*** (Paper No. 1798).

Marayikkottu, V. A., Sawant, S. S., Rao, P., & Levin, D. A. (2019). **Study of inert simulated particle transportation in a moving shock/pressure wave generated by electrostatic discharges.** ***AIAA Scitech 2019 Forum*** (Paper No. 0631).

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2018). **Micro-scale thermal response modeling of Avcoat-like TPS.** ***2018 AIAA Aerospace Sciences Meeting*** (Paper No. 0495).

Sawant, S. S., Harpale, A., Jambunathan, R., Beng Chew, H., & Levin, D. A. (2017). **High fidelity and multi-scale thermal response modeling of an Avcoat-like TPS.** ***55^{th} AIAA Aerospace Sciences Meeting*** (Paper No. 0438).

Sawant, S. S., Tumuklu, O., Jambunathan, R., & Levin, D. A. (2017). **Novel use of AMR Unstructured Grids in DSMC Compressible Flow Simulations.** ***47^{th} AIAA Thermophysics Conference*** (Paper No. 4028).

Sawant, S. S., Jambunathan, R., Tumuklu, O., Korkut, B., & Levin, D. A. (2016). **Study of shock-shock interactions using an unstructured AMR octree DSMC code.** ***54^{th} AIAA Aerospace Sciences Meeting*** (Paper No. 0501).

Sawant, S. S., Korkut, B., Tumuklu, O., & Levin, D. A. (2015). **Development of an amr octree dsmc approach for shock dominated flows.** ***53^{rd} AIAA Aerospace Sciences Meeting*** (Paper No. 0070).

Poster Presentations and Talks

Sawant, S. S., Yao, J., Jambunathan, R., Léonard F., & Nonaka, A. (2019). **A Highly Scalable NEGF Solver for Modeling Time-Dependent Quantum Transport in Nanomaterials.** ***The APS March Meeting 2023, Las Vegas, Nevada, USA***.

Sawant, S. S., Yao, J., Jambunathan, R., Léonard F., & Nonaka, A. (2019). **Multiscale Modeling of Carbon Nanotube Field Effect Transistors (CNTFETs) for Pho-**

todetection. ***Fourth CS-Area Postdoc Symposium, Lawrence Berkeley National Laboratory, Berkeley, USA***. Video

Sawant, S. S., Tumuklu, O., Theofilis, V., & Levin, D. A. (2019). **Linear instability of shock-dominated laminar hypersonic separated flows.**, ***IUTAM Symposium on Laminar-Turbulent Transition 2019, London, UK***.

Sawant, S. S., Rao, P., Harpale, A., Chew, H. B., & Levin, D. A. (2019). **Multi-scale thermal response modeling of an AVCOAT-like thermal protection material.**, ***11th Ablation Workshop, University of Minnesota, Minneapolis, MN***.

Rao, P., Sawant, S. S., Harpale, A., Chew, H. B., & Levin, D. A. (2017). **Hybrid Walker Approach to Conduction-Radiation Coupling in Micro-Scale Ablation Modeling**, ***9th Ablation Workshop, Montana State University, Bozeman, MT***.

Sawant, S. S., Jambunathan R., and & Levin, D. A. (2018). **Multi-scale Gas Dynamic and Thermal Response Modeling of Ablative Thermal Protection Systems**, ***31st Rarefied Gas Dynamics Conference, Glasgow, Scotland***.