Saurabh S. Sawant, Ph.D.

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Summary

- 9+ years of experience in developing massively scalable, MPI/GPU-enabled scientific software with adaptive mesh refinement (AMR) capability for hypersonics (Ph.D. projects in Aerospace Engineering) and micro/nano-electronics (Postdoctoral projects)
- 9+ years of experience in modeling molecular gas transport, thermal transport, and instabilities in hypersonic flows, recently acquired experience in modeling electromagnetics for microelectronics and quantum transport for nanoelectronics
- 3+ years of experience in applying data-driven methods such as proper orthogonal decomposition and solving eigenvalue problems arising from modal analysis in fluid dynamics

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

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

I am a part of a DOE-funded 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 side, my contribution is two-fold: at nanoscales, modeling a large array of carbon nanotube field effect transistors functionalized with quantum dots, and at microscales, modeling transmission lines on a chip carrying electromagnetic waves.
My specific contributions for these two works are summarize below:

- **(Ongoing) Multi-physics modeling of Carbon Nanotube Field Effect Transistors (CNTFETs) used as nanosensors on a photodetector chip.**

- Developed the 3D **ex**ascale electro**static** (eXstatic) solver using the AMReX library for solving Poisson's equation with embedded boundaries
  https://github.com/AMReX-Microelectronics/eXstatic
- Performed weak-scaling of eXstatic up to 2048 NVIDIA A100 GPUs on NERSC's Perlmutter supercomputer
- Presently, developing a self-consistently coupled quantum transport module in eXstatic using the Nonequilibrium Green's function (NEGF) method with the guidance of Dr. François Léonard from the photonics group in Sandia National Laboratories at Livermore, CA.
- The solver will be applied to simulate an array of CNTFETs functionalized with quantum dots and compute the current-voltage characteristics

- **Characterization of microscale transmission lines using the ARTEMIS Maxwell solver.**
  - 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
    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

I have contributed to multiple projects in the field of hypersonics, funded by AFOSR, ONR, DoD, NASA, which involved development of a massively scalable Direct Simulation Monte Carlo (DSMC) solver for modeling shock-dominated flows, 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, modeling thermal response of spacecraft's heatshield microstructure, and helping a junior graduate student in his project on studying dust lifting mechanisms in electrostatic discharge plasma.

A brief overview of these projects is given below. **For more detailed description of my Ph.D. work, please visit:** www.saurabhsawant.net/phd-projects

- **Development of a scalable DSMC solver entitled, SUGAR (Scalable Unstructured Gas-dynamic Adaptive mesh-Refinement), to simulate hypersonic shock-boundary layer interactions.**
  - Developed a 3-D MPI-based DSMC solver with Adaptive Mesh Refinement (AMR) in octree-based collision grids and implemented performance improvement strategies tailored for simulations of hypersonic flows.
  - Implemented Morton-based space-filling curve and run-time memory optimization technique 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.

- **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, which was 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, 2021*
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 a conference article for the *31st Rarefied Gas Dynamics* conference *Spring 2019*
Reviewed a journal article for *Acta Astronautica* *2022*

Reviewed two journal articles for the *Theor. and Comput. Fluid Dyn.* *2021-2022*

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 Video presentation

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 Video presentation

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

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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., 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.**, ***11^{th} 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**, ***9^{th} 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***.

References

Dr. Andrew Nonaka
Professional relationship: Postdoctoral advisor and supervisor
Affiliation: Group Lead
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Berkeley, CA-94720, USA
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Dr. François Léonard
Professional relationship: Co-advisor and collaborator during postdoctoral work on the quantum transport code development for photon detector application
Affiliation: Distinguished Member of Technical Staff
Nanoelectronics and Nanophotonics Group
Sandia National Laboratories
Livermore, CA-94551, USA
✉ fleonar@sandia.gov

Prof. Huck Beng Chew
Professional relationship: Co-advisor and collaborator for Ph.D. project on the modeling of thermal transport in ablative materials
Affiliation: Department of Aerospace Engineering
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Dr. Ann Almgren
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Affiliation: Department Head
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