Nirmal J. Nair

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Education

University of Illinois at Urbana-Champaign, Urbana, IL — 2018–Dec 2022 (exp)
Ph.D., Aerospace Engineering — GPA: 3.96/4.0
Concentration: Computational Science and Engineering

University of Illinois at Urbana-Champaign, Urbana, IL — 2016–2018
M.S., Aerospace Engineering — GPA: 4.0/4.0

Indian Institute of Technology Gandhinagar, Gujarat, India — 2012–2016
B.Tech. (*Honors*), Mechanical Engineering — GPA: 9.24/10.0

Interests

- Computational fluid dynamics
- Numerical modeling
- High performance computing
- Deep learning
- Reinforcement learning
- Reduced-order modeling

Experience

University of Illinois at Urbana-Champaign — Urbana, IL
Graduate Research Assistant — Sept 2018–present
Ph.D. thesis adviser: Prof. Andres Goza

Project: Computational fluid dynamics (CFD) of an aeroelastic flap for flow control

- Computationally modeled the multi-physics flow over an airfoil mounted with a bio-inspired aeroelastic flap for improving aerodynamic performance.
- Performed a multi-dimensional parametric study, k-means clustering and detailed data analysis to identify features that enhanced aerodynamic lift up to 27%.
- Collaborated with a research group at Princeton University to correlate CFD simulations with wind-tunnel experiments.

Project: Machine learning for state estimation and active flow control

- Developed a nonlinear state estimation approach where real-time sensor data was used to accurately predict the full-flow state using deep neural networks.
- Currently using deep reinforcement learning for designing a closed-loop controller for active flow control of an airfoil mounted with a controllable aeroelastic flap.
- Utilized methodologies such as proximal policy optimization, principal component analysis and multi-layer perceptrons on PyTorch.

Project: High performance computing and development of efficient algorithms

- Developed a scalable multi-physics (fluid-structure interaction) solver involving the Navier-Stokes and Newton's equations using PETSC and MPI.
- Designed an efficient algorithm that addressed a critical computational bottleneck related to the computation of a fluid-structure coupling matrix.
- Achieved 4–10x increase in serial computational speed and ∼84% parallel strong scaling efficiency.

Sandia National Laboratories — Livermore, CA
Computer Science Research Institute Summer Intern — June–August 2019
Adviser: Dr. Kevin Carlberg

Project: Transfer learning for enabling convergence of reduced-order models (ROM)

- Formulated an adaptive refinement strategy to guarantee convergence of nonlinear ROMs built using deep convolutional autoencoders on TensorFlow.

- Developed methodologies for efficiently retraining selected weights of the autoencoder and real-time augmentation of the latent space.

University of Illinois at Urbana-Champaign Urbana, IL
Graduate Research Assistant Aug 2016–Aug 2018
M.S. thesis adviser: Dr. Maciej Balajewicz
Project: Data-driven reduced-order modeling of fluid flows

- Identified a critical drawback of linear ROMs in accurately predicting fluid flows that are dominated by advection and strong discontinuities.
- Developed a hyper-reduced, physics-based ROM where solutions are obtained by a nonlinear transformation of a linear subspace using collected flow data.
- Achieved 300-10000x increase in computational speed while incurring only $\sim$1% error when tested on several CFD problems.

California Institute of Technology Pasadena, CA
Summer Undergraduate Research Fellow May–July 2015
Project: Thermoelectric generators for waste heat scavenging in aircraft

- Designed and fabricated a thermal-electrical prototype consisting of a thermoelectric generator, heat fin and electronics to generate electricity from waste heat.
- Powered a wireless temperature sensor from a temperature difference of 5° K.

IIT Gandhinagar India
Summer Research Intern May 2014–April 2015
Project: Stability analysis of thermal boundary layers

- Performed local stability analysis to quantify the effect of heating on viscosity and the stability characteristics of axisymmetric thermal boundary layers.

Publications

1. **N.J. Nair** and A. Goza. Fluid-structure interaction of a bio-inspired passively deployable flap for lift enhancement. *Preprint arXiv:2203.00037*, 2022. (Under review at *Physical Review Fluids*).
2. **N.J. Nair** and A. Goza. A strongly coupled immersed boundary method for fluid-structure interaction that mimics the efficiency of stationary body methods. *Journal of Computational Physics*, 110897, 2022.
3. **N.J. Nair**, Z. Flynn and A. Goza. Numerical study of multiple bio-inspired torsionally hinged flaps for passive flow control. *Fluids*, 7(2), 44, 2022.
4. **N.J. Nair** and A. Goza. Leveraging reduced-order models for state estimation using deep learning. *Journal of Fluid Mechanics*, 897, 2020.
5. **N.J. Nair** and M. Balajewicz. Transported snapshot model order reduction approach for parametric, steady-state fluid flows containing parameter-dependent shocks. *International Journal for Numerical Methods in Engineering*, 2019; 117:1234–1262.

Conference Talks and Proceedings

Invited

1. **N.J. Nair** and A. Goza. Active flow control of a covert-inspired deployable flap strategy using reinforcement learning. *USNC, TAM*, 2022. (Accepted).
2. A. Goza and **N.J. Nair**. Effects of flap-vortex interactions on the lift of an airfoil mounted with a passively deployable flap. *DisCoVor, EPFL*, 2022. (Accepted).
3. **N.J. Nair** and M. Balajewicz. Transported snapshot model order reduction approach for parametric, steady-state fluid flows containing parameter dependent shocks. *SIAM CSE*, 2019.

Contributed

1. A.K. Othman, **N.J. Nair**, A. Sandeep, A. Goza and A.Wissa. Numerical and experimental study of a covert-inspired passively deployable flap for aerodynamic lift enhancement. *AIAA Aviation*, 2022. (Accepted)
2. **N.J. Nair** and A. Goza. Effects of Torsional Stiffness and Inertia on a Passively Deployable Flap for Aerodynamic Lift Enhancement. *AIAA Scitech Forum*, 2022.
3. **N.J. Nair** and A. Goza. Approaching the efficiency of stationary-body methods in a strongly coupled immersed boundary framework for fluid-structure interaction. *APS, Division of Fluid Dynamics*, 2021.
4. **N.J. Nair** and A. Goza. Numerical study of a passively deployable flap for aerodynamic flow control. *APS, Division of Fluid Dynamics*, 2020.
5. **N.J. Nair** and A. Goza. Integrating sensor data into reduced-order models with deep learning. *APS, Division of Fluid Dynamics*, 2019.
6. **N.J. Nair** and M. Balajewicz. Physics based interpolation for steady parametric partial differential equations. *APS, Division of Fluid Dynamics*, 2017.
7. **N.J. Nair** and U. Shah. A simple computational tool for studying acoustic waves in nonlinear medium. *ASME, IDETC*, 2017.
8. **N.J. Nair** and V. Narayanan. Effect of viscosity stratification on stability of axisymmetric boundary layer. *APS, Division of Fluid Dynamics*, 2015.

Honors & Awards

Kuck Computational Science and Engineering Scholarship, UIUC	2022
AE Outstanding Graduate Student Fellowship, UIUC	2020
Conference Grant, APS DFD	2019
SIAM Conference Student Award, SIAM CSE	2019
Conference Award for Graduate Students, UIUC	2017
MSNDC Conference Student Grant, ASME IDETC	2017
Commencement award for 'Best Performance in the core subjects of Engineering Graphics, Manufacturing and Workshop Practice', IIT Gandhinagar	2016
Summer Undergraduate Research Fellowship, Caltech	2015
Dean's List, IIT Gandhinagar	2013, 2014, 2015
Merit cum Means Scholarship, IIT Gandhinagar	2012, 2013, 2014
Winner of Ricoh Printer Design Challenge, IIT Gandhinagar	2014

Selected Projects

Aeroacoustics of vortex shedding around a stalled airfoil, UIUC Spring 2021

- Predicted noise due to vortex shedding around an airfoil by numerically solving the Ffowcs Williams-Hawkings equation using the Farassat Formulation 1A.

Nonlinear modal decomposition of transient fluid flows, UIUC Spring 2020

- Developed a nonlinear modal decomposition framework to identify meaningful flow structures in transient fluid flows using deep convolutional autoencoders.

Commercial software for computational fluid dynamics

- Performed CFD simulations on Ansys Fluent to study passive flow control using vortex generators on an Onera M6 wing at UIUC in Fall 2016.
- Simulated non-Newtonian blood flow in an artery using Star CCM+ to study the effect of blockages on blood pressure at IIT Gandhinagar in Spring 2016.

Skills

Programming: Python, MATLAB, Fortran, C.
Machine Learning: PyTorch, TensorFlow, Stable Baselines.
High Performance Computing: PETSC, MPI, OpenMP.
CFD and CAD: Ansys Fluent, Star CCM+, Autodesk Inventor.
Miscellaneous: Git (Version Control), Simulink, Latex.

Leadership

University of Illinois at Urbana-Champaign Urbana, IL

Coordinator, Upward Bound June–July 2021

- Designed and co-organized a two-day glider building workshop for high school students from underrepresented and minority groups.
- Facilitated the procurement of supplies required for the activity and led one of the online Zoom sessions to guide the students through the workshop.

Teaching Assistant Fall 2019, Fall 2020

- Led regular office hours, exam revision sessions and created tutorial problems to aid the students in the AE433: Aerospace Propulsion course.
- Listed in the "List of Teachers Ranked as Excellent for Fall 2019" at UIUC.

Mentor

- As a senior graduate student, mentored newly admitted graduate students on the software architecture of our group.
- Mentored and supervised an undergraduate student on their research project on numerical modeling and CFD in summer 2017.

IIT Gandhinagar India

Events Coordinator, Amalthea' 13 May–Oct 2013

- Led a team of 21 students to plan and organize various technical events at Amalthea'13, the annual technical summit of IIT Gandhinagar.

College Soccer Player 2013–2015

- Member of the IIT Gandhinagar soccer team and participated at two annual Inter-IIT tournaments.
- Captain of one of the five teams in an intra-college soccer league.

Undergraduate Lead Teaching Assistant Fall 2013

- Designed and led the lab sessions on using Autodesk Inventor in the Engineering Graphics course for freshman students.