

Siddharth Nair

Ph.D. Candidate | Control, Optimization, Machine Learning

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Interests

Model Predictive Control, Motion Planning, Large-scale and Robust Optimization, Machine Learning

Education

Ph.D. in Controls

Department of Mechanical Engineering

Advisor: Prof. Francesco Borrelli

Minors: Optimization, Machine Learning

University of California, Berkeley

August 2018 – Present

B.Tech + M.Tech

Major: Aerospace Engineering

Minor: Systems and Control Engineering

Awards: Institute Silver Medal for graduating with the highest GPA in Aerospace Engineering,
Undergraduate Research Awards 1 & 2 for Bachelor's thesis and research

Indian Institute of Technology Bombay

July 2013 – August 2018

Work Experience

WideSense Inc.

Berkeley, California

Routing and simulation for electric vehicle fleet management

January 2024-Present

Internship

Drona Aviation

SINE, IIT Bombay

Implemented algorithms in C++ for state estimation and trajectory generation for a nano-quadrotor.

Sep-Nov 2017

Internship

Aerospace Systems Lab

University of Texas, Arlington

Developed an object-oriented framework in MATLAB to simulate spacecraft formations, and developed algorithms for consensus in the presence of communication delays.

Summer 2016

Internship

Autonomous Vehicles Lab

Indian Institute of Science, Bangalore

Developed, analyzed, and implemented algorithms for UAV circumnavigation with range-only measurements on a Dubin's vehicle.

Summer 2015

Internship

Projects

Supervised Learning for Mixed Integer Linear Programs with Optimality Certificates

Relevant papers: L-CSS'23 [\[Code\]](#)

2022 – Present

UC Berkeley

- Developed a supervised learning framework for fast solution of combinatorial optimization problems with *a priori* certification of prediction quality.
- Collected a dataset of Branch-and-Bound solution trees for a motion planning problem and trained Deep Neural Networks using PyTorch and Random Forests using scikit-learn for strategy prediction.
- Demonstrated favourable performance of our approach compared to state-of-the-art solvers (Gurobi, Mosek, SCIP, GLPK) for real-time mixed-integer MPC.
- **Ongoing:** End-to-End learning for solving Mixed-integer Convex Problems

Collision Avoidance for Autonomous Driving with Uncertain, Multi-Modal Predictions 2021 – Present
Relevant Papers: ITSC'22, AVEC'22, CDC'22, IV'23 [[Experiment Video](#)][[Code](#)] UC Berkeley

- Developed convex formulations of MPC for autonomous driving with uncertain, multi-modal predictions of surrounding vehicles for collision avoidance.
- Evaluated our approach on the CARLA simulator and on a full-scale vehicle using ROS 2, with multi-modal predictions from [Multipath](#).
- Demonstrated marked improvement over prevailing approaches over a rubric proposed in collaboration with Ford, which assesses mobility, comfort, conservatism, and computational efficiency.
- **Ongoing:** Accelerating the MPC solution for complex traffic scenarios using Imitation Learning with Duality-based Safety certification

Robust Learning-based Model Predictive Control for Nonlinear Systems 2018-2022
Relevant Papers: IFAC'20, ECC'20, NMPC'21, arxiv'23 [[Experiment Video](#)][[Code](#)] UC Berkeley

- Developed computationally efficient algorithms for using trajectory data to approximate system dynamics, value functions and terminal constraints for synthesizing Robust MPC policies for nonlinear systems.
- Implemented convex optimization-based modelling techniques in Python, MATLAB and tested our approach on a 1/10 scale vehicle, and a [full-scale vehicle](#) using ROS for autonomous racing.
- Demonstrated numerically, and experimentally, the theoretical guarantees of our approach: iterative performance improvement, constraint satisfaction, and convergence to the desired goal, while enjoying reduced computational effort.

Geometric Methods for Control and Planning 2016-2019
Relevant Papers: CDC'17, ACC'19, NOLCOS'19 IIT Bombay

- Master's Thesis: Developed variational integrators for mechanical systems on Lie groups, numerically solved discrete optimal control problems using adjoint-based methods.
- Bachelor's Thesis: Developed a coordinate-free formulation for cooperative control of quadrotors carrying a ball on a plate system slung via tethers, and synthesized geometric control policies for stabilization.
- Independent research: Developed coverage algorithms for path-planning using Hilbert's space-filling curve.

Skills and Key Coursework

Programming Tools	Python, C++, Julia MATLAB, ROS, PyTorch, Casadi
Control	Constrained Optimal Control, Stochastic Control, Hybrid and Nonlinear Systems, Adaptive Control, Differential Geometric Control, Sliding Mode Control
Optimization	Convex Optimization, Robust Optimization, Nonlinear Programming and Algorithms
Machine Learning	Deep Reinforcement Learning, Theoretical Statistics
Robotics	State Estimation, Navigation and Guidance, Control for Legged Robots, Flight Dynamics
Mathematics	Numerical Analysis, Numerical Integration, Advanced Matrix Computations, Real Analysis, Topology, Measure Theory, Functional Analysis

Publications

- L-CSS'23** Russo*, L., **Nair*, S.H.**, Glielmo, L., Borrelli, F., "Learning for Online Mixed-Integer MPC with Parametric Optimality Certificates", *IEEE Control Systems Letters*, 2023 (**Invited Paper**)
- IV'23** Oliveira, R., **Nair, S.H.**, Wahlberg, B. "Interaction and Decision Making-aware Motion Planning using Branch Model Predictive Control ", *IEEE Intelligent Vehicles Symposium*, 2023

- CDC'22** **Nair, S.H.**, Tseng, E.H., Borrelli, F., "Collision Avoidance for Dynamic Obstacles with Uncertain Predictions using Model Predictive Control", *IEEE Conference on Decision and Control*, 2022
- AVEC'22** **Nair, S.H.**, Govindarajan, V., Lin, T., Wang, Y., Tseng, E.H., Borrelli, F., "Stochastic MPC with Dual Control for Autonomous Driving with Multi-Modal Interaction-Aware Predictions", *International Symposium on Advanced Vehicle Control*, 2022
- ITSC'22** **Nair*, S.H.**, Govindarajan*, V., Lin, T., Meissen, C., Tseng, E.H., Borrelli, F., "Stochastic MPC with Multi-modal Predictions for Traffic Intersections", *International Conference on Intelligent Transportation Systems*, 2022
- NMPC'21** **Nair, S.H.**, Rosolia, U., Borrelli, F., "Output-Lifted Learning Model Predictive Control", *IFAC Conference on Nonlinear Model Predictive Control*, 2021 **(Keynote Talk)**
- IFAC'20** **Nair, S.H.**, Bujarbaruah, M., Borrelli, F., "Modeling of Dynamical Systems via Successive Graph Approximations", *IFAC World Congress*, 2020
- ECC'20** Bujarbaruah*, M., **Nair*, S.H.**, Borrelli, F., "A Semi-Definite Programming Approach to Robust Adaptive MPC under State Dependent Uncertainty", *European Control Conference*, 2020
- NOLCOS'19** **Nair, S.H.**, Banavar, R.N., "Discrete Optimal Control of Interconnected Mechanical Systems", *IFAC Symposium on Nonlinear Control Systems*, 2019
- ACC'19** **Nair, S.H.**, Banavar, R.N., Maithripala, D.H.S., "Control Synthesis for an Underactuated Cable Suspended System Using Dynamic Decoupling", *American Control Conference*, 2019
- CDC'17** **Nair, S.H.**, Sinha, A., Vachhani, L., "Hilbert's Space-filling Curve for Regions with Holes", *IEEE Conference on Decision and Control*, 2017
- AAS'17** **Nair, S.H.**, Subbarao, K., "Attitude Control of Spacecraft Formations subject to Distributed Communication Delays", *AAS/AIAA Space Flight Mechanics Meeting*, 2017

Preprints/Reports

- arxiv'24** Kim*, H., **Nair*, S.H.**, Borrelli, F., "Scalable Multi-modal Model Predictive Control via Duality-based Interaction Predictions"
- arxiv'23** **Nair*, S.H.**, Lee*, H., Joa*, E., Lin, T., Wang, Y., Tseng, E.H., Borrelli, F., "Predictive Control for Autonomous Driving with Uncertain, Multi-modal Predictions", *submitted to IEEE Transactions on Control Systems Technology*, 2023
- arxiv'23** **Nair, S.H.**, Borrelli, F., "Robust Output-Lifted Learning Model Predictive Control", *submitted to IEEE Transactions on Automatic Control*, 2023
- arxiv'22** **Nair, S.H.**, Stürz, Y. "Control of Uncertain PWA systems using DC Decompositions", *arXiv:2209.12990*, 2022
- arxiv'19** Byun*, J., Jain*, K.P., **Nair*, S.H.**, Xu*, H., Zha*, J., "Predictive Control for Chasing a Ground Vehicle using a UAV", *arxiv:1905.09396*, 2019

Working Papers

Nair*, S.H., Kim*, H., Borrelli, F., "Safe Supervisors for Scalable Multi-agent MPC"

Nair, S.H., Russo, L., Glielmo, L., Borrelli, F., "End-to-End Learning for Rapid Mixed-Integer Model Predictive Control with Parametric Optimality Certificates"