Siddharth Nair

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

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Interests

Model Predictive Control, Motion Planning, Robust Optimization, Machine Learning

Education

Ph.D. in Controls — *University of California, Berkeley*
Department of Mechanical Engineering — *August 2018 – Present*
Advisor: Prof. Francesco Borrelli
Minors: Optimization, Machine Learning

B.Tech + M.Tech — *Indian Institute of Technology Bombay*
Major: Aerospace Engineering — *July 2013 – August 2018*
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

Selected Projects

Supervised Learning for Mixed Integer Linear Programs with Optimality Certificates — *2022 – Present*
Relevant papers: L-CSS'23 *[Code]* — *UC Berkeley*

- Developed a supervised learning framework for fast solution of Mixed Integer Linear Programs (MILPs) for MPC using parametric strategies and with sub-optimality quantification for the solution predictions.
- Collected a dataset of MILP solution tree instances 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 MILP solvers (Gurobi, Mosek, SCIP, GLPK) for real-time mixed-integer MPC.

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 Stochastic, Robust, and Distributionally Robust MPC for autonomous driving with 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 along axes of mobility, comfort, conservatism, and computational efficiency.

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	Python, C++, Julia
Tools	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

Selected 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)**
arxiv'23	**Nair, S.H.**, Borrelli, F., "Robust Output-Lifted Learning Model Predictive Control", *submitted to IEEE Transactions on Automatic Control*, 2023
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