Siddharth Nair

Ph.D. | Control, Optimization, Machine Learning

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Interests

Optimal Control, Large-scale + Robust Optimization, Machine Learning, Robotics, Transport and Logistics

Education

Ph.D. in Controls — *University of California, Berkeley*
Minors: Optimization, Machine Learning — *August 2018 – May 2024*
Advisor: Prof. Francesco Borrelli

B.Tech + M.Tech in Aerospace Engineering — *Indian Institute of Technology Bombay*
Minor: Systems and Control Engineering — *July 2013 – August 2018*
Awards: Institute Silver Medal for graduating with the highest GPA in Aerospace Engineering, Undergraduate Research Awards 1 & 2 for Bachelor's thesis and research

Work Experience

Senior AI Engineer — *WideSense Inc*
Simulation-based Optimization and Analysis of Electric Vehicle Fleets — *Jan'24 – Present*

- Optimized transit fleet operations (fleet composition, depot configuration) for various public transit agencies ($2+ million savings) using a digital twin for electric vehicle fleets to simulate charging, driving and garage management for operations guidance and design of public transit fleets.
- Built charge models for electric buses from vehicle telematics data using deep learning and PyTorch.
- Developed smart charging strategies for electric vehicle fleets and Column Generation sub-routines for integrated vehicle and crew scheduling.

Graduate Student Researcher — *UC Berkeley*
Data-driven Techniques for Robust, Efficient Predictive Control for Autonomous Vehicles — *Aug'18 - May'24*

- **Supervised Learning for Accelerating Control Computation**
  - Developed a hierarchical architecture for scalable real-time MPC in complex, multi-modal traffic scenarios (12x speedup in solve times), comprising two key components: 1) RAID-Net, a novel attention-based Recurrent Neural Network that predicts relevant interactions between agents using Lagrangian duality, and 2) a reduced MPC problem that safely eliminates irrelevant constraints, enhancing computational efficiency. [IV'24][Code]
  - Developed a supervised learning framework for fast solution of combinatorial optimization problems with *a priori* certification of prediction quality, and competitive performance against state-of-the-art solvers (Gurobi, Mosek, SCIP, GLPK) for real-time mixed-integer MPC. [L-CSS'23][Code]
- **Collision Avoidance for Autonomous Driving with Uncertain, Multi-Modal Predictions**
  - Developed convex MPC formulations for autonomous driving with uncertain, multi-modal predictions of vehicles for collision avoidance. Our approach shows marked improvement over state-of-the-art in both Hardware-in-Loop experiments and CARLA simulations along metrics of mobility, comfort, conservatism, and computational efficiency. [TCST'24, IV'23, CDC'22, AVEC'22, ITSC'22][Experiment Video][Code]
- **Robust Learning-based Model Predictive Control for Nonlinear Systems**
  - Developed efficient algorithms for using trajectory data to approximate system dynamics, value functions and terminal constraints for synthesizing Robust MPC policies for nonlinear systems to iteratively improve performance while ensuring safe operation. Tested our approach for autonomous racing using 1/10 and full-scale vehicles using ROS. [arxiv'23, NMPC'21, IFAC'20, ECC'20][1/10 Scale Experiment, Full-scale Experiment][Code]

Undergraduate Research *IIT Bombay*
Geometric Methods for Control and Planning *Jan'15 - June'18*

- **Master's Thesis**: Developed variational integrators for mechanical systems on Lie groups, numerically solved discrete optimal control problems using adjoint-based methods. [NOLCOS'19]
- **Bachelor's Thesis**: Developed a coordinate-free formulation for cooperative control of quadrotors carrying a ball on a plate system slung via tethers. [ACC'19]
- *Independent research*: Developed coverage algorithms for path-planning using Hilbert's space-filling curve. [CDC'17]

Undergraduate Internships/Projects
State Estimation and Navigation

- **Internship @ Drona Aviation, SINE, IIT Bombay**, Fall 2017 | Implemented algorithms in C++ for state estimation and trajectory generation for a nano-quadrotor.
- **Internship @ Aerospace Systems Lab, University of Texas, Arlington**, Summer 2016 | Developed an object-oriented framework to simulate spacecraft formations, and developed algorithms for consensus in the presence of communication delays.
- **Internship @ Autonomous Vehicles Lab, Indian Institute of Science, Bangalore**, Summer 2015 | Developed, analyzed, and implemented algorithms for UAV circumnavigation with range-only measurements.
- **Institute Technical Summer Project @ IIT Bombay**, Summer 2014 | Developed an interface to remotely control a fixed-wing aircraft using phone gestures [*Aeromodeling Project Winner*]

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

Publications

Ph.D. Thesis	**SN**, "Data-Driven Predictive Control Beyond Linearity: An Autonomous Driving Perspective", Dissertation, University of California, Berkeley, 2024
TCST'24	**SN***, Lee*, H., Joa*, E., Lin, T., Wang, Y., Tseng, E.H., Borrelli, F., "Predictive Control for Autonomous Driving with Uncertain, Multi-modal Predictions", *IEEE Transactions on Control Systems Technology*, 2024
IV'24	Kim*, H., **SN***, Borrelli, F., "Scalable Multi-modal Model Predictive Control via Duality-based Interaction Predictions", *IEEE Intelligent Vehicles Symposium*, 2024
L-CSS'23	Russo*, L., **SN***, 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., **SN**, Wahlberg, B. "Interaction and Decision Making-aware Motion Planning using Branch Model Predictive Control ", *IEEE Intelligent Vehicles Symposium*, 2023
CDC'22	**SN**, 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 **SN**, 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 **SN***, 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 **SN**, Rosolia, U., Borrelli, F., "Output-Lifted Learning Model Predictive Control", *IFAC Conference on Nonlinear Model Predictive Control*, 2021 **(Keynote Talk)**

IFAC'20 **SN**, Bujarbaruah, M., Borrelli, F., "Modeling of Dynamical Systems via Successive Graph Approximations", IFAC World Congress, 2020

ECC'20 Bujarbaruah*, M., **SN***, Borrelli, F., "A Semi-Definite Programming Approach to Robust Adaptive MPC under State Dependent Uncertainty", *European Control Conference*, 2020

NOLCOS'19 **SN**, Banavar, R.N., "Discrete Optimal Control of Interconnected Mechanical Systems", *IFAC Symposium on Nonlinear Control Systems*, 2019

ACC'19 **SN**, Banavar, R.N., Maithripala, D.H.S., "Control Synthesis for an Underactuated Cable Suspended System Using Dynamic Decoupling", *American Control Conference*, 2019

CDC'17 **SN**, Sinha, A., Vachhani, L., "Hilbert's Space-filling Curve for Regions with Holes", *IEEE Conference on Decision and Control*, 2017

AAS'17 **SN**, Subbarao, K., "Attitude Control of Spacecraft Formations subject to Distributed Communication Delays", *AAS/AIAA Space Flight Mechanics Meeting*, 2017

Preprints/Reports

arxiv'23 **SN**, Borrelli, F., "Robust Output-Lifted Learning Model Predictive Control", *submitted to IEEE Transactions on Automatic Control*

arxiv'22 **SN**, Stüerz, Y. "Control of Uncertain PWA systems using DC Decompositions"

arxiv'19 Byun*, J., Jain*, K.P., **SN***, Xu*, H., Zha*, J., "Predictive Control for Chasing a Ground Vehicle using a UAV"

Working Papers

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

Tajbakhsh*, A., **SN**, Ologan, D., Zhu, Z., Sheth, A., Borrelli, F., Biegler, L.T., Johnson, A.M. "Conflict-based Search for Scalable Multi-modal motion planning"