# Santosh Rajkumar

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## Education

**The Ohio State University (tOSU),** Columbus, OH – *Ph.D. in Mechanical Engineering* (GPA 4.0/4.0) — Aug 2023 – Present
**Miami University,** Oxford, OH – *M.S. in Mechanical Engineering* (GPA: 4.0/4.0) — Jan 2021 – Jun 2023
**National Institute of Technology (NIT),** Silchar, Assam, India – *B.S. in Electrical Engineering* — Aug 2013 – May 2017

Selected Graduate Coursework : *Reinforcement Learning, Robust Control, Optimal Control, Nonlinear Systems, Nonlinear Dynamics, Adv Mathematical Methods, Intro to AI, Robotics: Design & Modeling, Finite Element Analysis.*

## Research Experience

**Graduate Research Associate** — SOAR Lab, tOSU — **Aug 2023 – Present**

- **Robust Linear MPC for Nonlinear Systems with Learning-Based RPI Sets (**Ongoing Work)
  - Designing a robust QP-based MPC framework for a class of nonlinear systems *(quasi-linearizable systems)* that admit guaranteed one-step conversion, without Jacobian linearization.
  - Learning *Robust Positively Invariant (RPI)* sets online via a critic-only Adaptive Dynamic Programming (ADP) scheme, avoiding conservative polytope-based invariant set computation.
  - Estimating uncertainty in real-time and tightening constraints adaptively to ensure recursive feasibility and robust satisfaction of safety-critical state and input limits.
- **Koopman-based Data-Free Real-Time Model Predictive Control (MPC) for Quadrotors**
  - Developed a data-free Koopman-lifted model for quadrotor dynamics that preserves control input dimension.
  - Achieved over 100% improvement in translational motion prediction accuracy with a 26% reduction in lifted state dimension compared to state-of-the-art methods.
  - Introduced *KQ-LMPC*, the first analytically derived (data-free) Koopman-based linear MPC framework for quadrotor control.
  - Demonstrated tracking performance comparable to nonlinear MPC while reducing computation time by approximately 2–4x.
  - Experimentally validated on a quadrotor platform (Jetson NX + PX4 + Vicon) (Video Demo).
- **Data-Driven Dynamics Learning from Noisy Partial Measurements for Output Regulation**[†]
  - Developed a Koopman bilinear model with a neural decoder (KBM-NL), formulated as a Hidden Markov Model for robustness to noise and partial observability.
  - Designed a customized neural *Expectation–Maximization* (EM) algorithm to jointly identify the KBM-NL dynamics and latent inference distribution from noisy, actuated trajectories.
  - Achieved output regulation via Model Predictive Control (MPC) constructed on the learned KBM-NL surrogate model.
  - Demonstrated superior prediction accuracy and stability on Duffing oscillator benchmarks, with strong generalization to unseen trajectories.
- **Model-Free Output Regulation under Noisy Partial Observations using Adaptive Dynamic Programming (ADP)**
  - Eliminated need for *belief, observer, or model knowledge*, enabling *model-free output-feedback control* for non-linear systems.
  - Designed a *critic-only ADP algorithm* using a Lyapunov–based Q-function for optimal control learning.
  - Introduced a *persistence-of-excitation mechanism* via learned derivative feedback, *wihtout an initial stabilizing controller*.
  - Enforced closed-loop stability during learning using Lyapunov-constrained temporal-difference (TD) learning.
  - Developed a stable on-policy *value iteration scheme* with **no replay memory or large basis functions**.
  - Demonstrated output regulation on a cart-pole system.

[†] Presented as a late breaking poster at the **2025 American Control Conference, Denver**, CO (Link to Poster).

**Graduate Student Researcher** — Miami University — **Sep 2021 – May 2023**

- **Modeling and Experimental Haptics for Touch Surfaces** (Thesis Research)
  - Developed in-house finite element (FE) models for large-area touch displays (1D bar & 2D plate) with spring–damper boundaries to study vibrotactile response and mode shaping.
  - Designed a multifrequency excitation strategy using Electrostatic Resonant Actuators (ERAs) to achieve localized haptic rendering with minimal actuator hardware.
  - Fabricated working prototypes and validated FE predictions experimentally using vibration analysis with $>90\%$ agreement.
  - Proposed an energy-based control strategy to position and steer localized haptic feedback across arbitrary surface locations.
  - Optimized actuator placement and boundary compliance to enhance elimination of haptic "dead zones."

## Selected Publications


1. **Rajkumar, S.M.**, Yang, C., Gu, Y., Sheng, C., Hovakimyan, N., Goswami, D. *Real-Time Linear MPC for Quadrotors on SE(3): An Analytical Koopman-based Realization.** **IEEE Robotics and Automation Letters (RA-L)**, Accepted, 2025. (to appear)
   *To be presented at 2026 IEEE International Conference on Robotics & Automation (ICRA), Vienna, Austria.
2. **Rajkumar, S.M.**, Goswami, D. *Data-Driven Output Regulation From Partial Noisy Measurements: An Adaptive Dynamic Programming Approach.* **AIAA SciTech 2026 Forum**, Accepted. (to appear)
3. **Rajkumar, S.M.**, Singh, K.V., Yang, T.H. and Koo, J.H., 2023. *Modeling and experimental evaluation of haptic localization using electrostatic vibration actuators.* IEEE Access, 11, pp.18582-18589.
4. **Rajkumar, S.M.**, Chakraborty, S., Dey, R., Deb, D. *Online Delay Estimation and Adaptive Compensation in Wireless Networked System: An Embedded Control Design.* **International Journal of Control, Automation and Systems (IJCAS)**, 18, pp.856–866, 2020.


## Technical Skills

**Programming:** Python, MATLAB, R. **Optimization & Auto-Differentiation Tool-chains:** *acados*, ACADO, CasADi, cvxpy.
**Robotics:** ROS2, Gazebo, PX4 Autopilot, Linux. **Machine Learning:** PyTorch, scikit-learn. **Others:** LaTeX, Git.

## Other Experiences

**Graduate Teaching Assistant,** Miami University, Oxford, OH — Jan 2021 – May 2023
**Senior Automation Engineer,** Indian Oil Corproration Limited (Fortune #127 2025), Nagaland, India — Jun 2017 – Dec 2020