Rajpal Singh

rajpalsingh@iisc.ac.in | +91 7780835834 | Google Scholar | Github | LinkedIn

Education

Doctor of Philosophy, *Mechanical Engineering*, Indian Institute of Science (IISc), Bengaluru, **CGPA: 9.6/10**. 2020 – 2026* (*expected)

- **Thesis**: *Adaptive Data-Driven Koopman Paradigms for Robust Control of Nonlinear Systems.*

Bachelor of Technology, *Mechanical Engineering*, National Institute of Technology (NIT), Srinagar, **CGPA: 9.193/10**. 2016 – 2020

- **Major Project**: *Development of a Five-Link Manipulator as a Haptic-Assisted Writing Kit (HAWK)*.

Publications

Journal Papers

- **R. Singh***, C.K. Sah*, J. Keshavan, "*Adaptive Koopman Embedding for Robust Control of Nonlinear Dynamical Systems*", The International Journal of Robotics Research, 2025.
- C.K. Sah*, J. Keshavan, **R. Singh***, "*ASACK: Adaptive Safe Active Continual Koopman Learning for Uncertain Systems with Contractive Guarantees*", arXiv preprint, 2026 (under review).
- C.K. *, **R. Singh*** , J. Keshavan, "*Real-time constrained tracking control of redundant manipulators using a Koopman-zeroing neural network framework*", IEEE Robotics and Automation Letters, 2024.
- A. Singh , **R. Singh**, J. Keshavan, "*Deep Robust Koopman Learning from Noisy Data*", arXiv preprint, 2026 (under review).
- **R. Singh**, J. Keshavan, "*Approximation-Free Robust Tracking Control of Unknown Redundant Manipulators With Prescribed Performance and Input Constraints*", IEEE Transactions on Systems, Man, and Cybernetics: Systems, 2024.
- **R. Singh**, J. Keshavan, "*A Provably Constrained Neural Control Architecture with Prescribed Performance for Fault-Tolerant Redundant Manipulators*", IEEE Access, 2022.
- C.K. Sah*, **R. Singh***, J. Keshavan, "*An Overview of Data-Driven Paradigms for Identification and Control of Robotic Systems*, Journal of the Indian Institute of Science, 2024.

Conference Papers

- **R. Singh**, A. Singh, C.S. Kashyap, J. Keshavan,"*Generalized Momenta-Based Koopman Formalism for Robust Control of Euler-Lagrangian Systems*", IEEE ICRA, 2026.
- M. Tayal, **R. Singh**, J. Keshavan, S. Kolathaya,*Control Barrier Functions in Dynamic UAVs for Kinematic Obstacle Avoidance: A Collision Cone Approach*, American Control Conference (ACC), 2024.

Book Chapter

- **R. Singh**, C.K. Sah, J. Keshavan, *Data-Driven Approaches to Real-Time Constrained Tracking Control of Redundant Manipulators*", Assistive Robotics, Vol. 2, Taylor & Francis.

Projects

Context based Koopman Embeddings for Parameterized Families of Dynamical Systems 2025-Ongoing

- Developing a *context-conditioned* Koopman framework that parameterizes lifted linear dynamics by latent variables estimated online from state control history, enabling adaptive prediction and control under changing operating conditions.

Safe Continual Active Koopman Learning for Uncertain Systems with Guarantees 2025-Ongoing

- Developed online adaptation laws for time-varying Koopman operator models with provable uniform ultimate boundedness guarantees, establishing explicit contraction bounds on parameter error under bounded dynamic drift.
- Integrated the adaptation law with D-optimal active learning MPC that jointly optimizes trajectory tracking and regressor conditioning with control barrier function safety constraints, guaranteeing persistent excitation and robust closed-loop stability.

Adaptive Koopman Embedding for Robust Control of Complex Nonlinear Systems 2023-2025

- Developed an *adaptive Koopman embedding framework* for robust control of nonlinear dynamical systems, *combining offline neural embeddings with online adaptation* to *improve out of distribution generalization*, *enhance robustness* to intrinsic and environmental changes, and *make linear Koopman models more viable* for complex nonlinear systems.
- Demonstrated the superior performance of the approach through extensive simulations on diverse systems, including coupled pendulums, serial manipulators, and planar quadrotors as compared to the state-of-the-art alternatives.

Generalised Momenta Based Koopman with Linear GESO 2024-2025

- Developed a *momentum-based* Koopman operator framework for Euler–Lagrange systems, using an implicit state-space representation with generalized positions and momenta to decouple linear actuation from nonlinear dynamics, and integrated *Generalized Extended State Observer* (GESO) to enhance robustness against unmodeled dynamics and external disturbances.
- Achieved improved *prediction accuracy and reduced computational burden compared to bilinear* and standard linear Koopman models, validated experimentally on robotic manipulators for robust real-time control.

Bilinear Koopman Models with ZNNs for Control of Robotic Manipulators 2023-2024

- Developed a *deep neural bilinear Koopman-Zeroing Neural Network* (ZNN) framework for real-time constrained tracking of redundant manipulators with input and safety constraints.
- Achieved faster computation, and improved tracking accuracy compared to traditional Bilinear Koopman-NMPC, demonstrating real-time performance in simulation and experiments with control loop frequency of up to *800 Hz*.

Control Barrier Functions in UAVs for Kinematic Obstacle Avoidance 2023-2024

- Developed a novel *Control Barrier Function* (CBF) formulation utilizing collision cones to ensure safe navigation of quadrotors by constraining relative velocities to avoid collision-prone vectors.
- Demonstrates real-time implementation of the proposed CBF through *Quadratic Programs* (QPs), validated via PyBullet simulations and hardware experiments on Crazyflie 2.1, showcasing effectiveness in dynamic environments.

ZNN-based control of Underdertermined Systems 2022-2024

- Developed an *optimal ZNN* control framework control of redundant manipulators, *guaranteeing prescribed performance and strict input constraint satisfaction.*
- Extended the approach to manipulators with *unknown kinematics with performance guarantees for convergence of estimated kinematics.*
- Demonstrated robust trajectory tracking, constraint adherence, and fault tolerance, validated through both simulations and hardware experiments, outperforming traditional approaches.

Position of Responsibility

Teaching Assistant, *Introduction to ROS*, MS Ramaiah Institute of Technology, Bengaluru. March - May 2025

Teaching Assistant, *Robotics and AI*, MS Ramaiah Institute of Technology, Bengaluru. June - Sep 2024

Teaching Assistant, *Robot Mechanics*, NIT, Srinagar. Oct - Dec 2022, Sept - Nov 2023

Teaching Assistant, *Robotics: Control and Vision*, NIT, Srinagar. Mar - Jul 2023, 2024

Teaching Assistant, *A Practical introduction to Data Analysis*, IISc, Bengaluru. Aug - Dec 2023

Academic Service

Reviewer: Reviewer: IEEE TSMC, IEEE TNNLS, IEEE TIE, IEEE CDC, ECC, AIR, Nonlinear Dynamics, ICCPS

Technical Skills

Research Expertise: Koopman Operator Methods, Model Predictive Control, Control Barrier Functions, Zeroing Neural Networks.
Programming: Python, MATLAB, C++, PyTorch, ROS, CasADi, OSQP.
Experimental Platforms: UAVs, Robotic Manipulators, UGVs.

Achievements

Prime Minister's Research Fellowship, IISc Bengaluru. Jan 2022 - Oct 2025

Dr Arkal Shenoy Research Endowment Award, IISc, Bengaluru. Nov 2024

Best Presentation Award, EECS Research Student Symposium, IISc, Bengaluru. April 2025

Branch Gold Medal, NIT Srinagar. July 2020