Tanmay Dokania

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Indian Institute of Technology Bombay **(2020 - '24)**
Bachelor of Technology in Electrical Engineering **GPA: 9.89/10**
- *Minor in Systems and Control Engineering* (SysCon) **GPA: 10.0/10**
- *Minor in Machine Intelligence and Data Science* (C-MInDS) **GPA: 10.0/10**

Research Interests

- **Theory**- Geometric and Learning-based Control, State Estimation, Stochastic and Distributed optimization
- **Applications**- Robotics, Power Systems, Decentralized systems, Autonomous vehicles, Cyber-Physical Systems

Academic Achievements and Honors

- **Ranked 1** in the Department of Electrical Engineering amongst **203** students (Present)
- Awarded **Institute Academic Award** for **3 years** for exceptional academic performance (2020-'22)
- Conferred with All-India Rank **280** out of 250,000 participants in **JEE (Advanced) 2020** (2020)
- Awarded **5 AP grades (Course Topper)** in different Electrical Engineering and SysCon courses (2021-'23)
- Recipient of MITACS GRI and DAAD-WISE scholarship to pursue research in Canada and Germany (2023)

Research Experience

1) Consensus for Nonholonomic Multiagent System using Projected Gradients **(Dec '22 - Present)**
Guide*: Prof. Ravi N. Banavar, Systems and Control Engineering, IIT Bombay*
Aim: *To extend geometric controllers for single agent to multiagent systems and achieve position-consensus*
- Designed appropriate **Morse function** to achieve **asymptotic convergence** to a position for a single agent
- Utilized **switching control** to introduce time-varying and discontinuous feedback to achieve exponential convergence to a position for a nonholonomic agent in simulations
- Extended the controller for a **multi-agent** system, achieving **exponential position-consensus**

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2) Safety Guarantees in Imitation Learning **(May '23 - Present)**
Guide*: Prof. Florian Shkurti, Computer Science Department, University of Toronto, Canada*
Aim: *To design an online filter for the control inputs to avoid unsafe states, which improves iteratively*
- Conducted extensive literature survey on **Lipchitz Neural Networks**, the use of Normalizing Flows to learn stochastic differential equations and design of **NN controllers** for linear systems using Linear Matrix Inequalities
- Examined **subspace projection** techniques of learning dynamics to impose stability architecturally
- Recreated the results of in-Distribution Barrier Function **(iDBF)** on a custom toy problem
- Improved the safety framework of iDBF by generating contrastive distribution using **Normalizing Flows**

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3) Bearing-based Formation Control for Obstacle Avoidance **(Jan '23 - May '23)**
Guide*: Prof. Dwaipayan Mukherjee, Electrical Engineering Department, IIT Bombay*
Aim: *To design decentralized controllers for obstacle avoidance based on the measured bearing of the obstacles while retaining a desired formation.*
- Studied state-of-art formation control algorithms under position, distance, and bearing-based measurements
- Learned about concepts of **bearing rigidity**, minimal rigidity, and **persistence** for formations
- Designed bearing-based **barrier functions** to develop controller filters after partitioning the regions
- Developed ideas of **smooth** "AND" and "OR" for combining different barrier functions

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4) Angular Momentum-based Steering Laws for Control of CMGs **(Dec '22 - May '23)**
Guide*: Dr. Abhilash Mony, Inertial Systems Unit, Indian Space Research Organisation (ISRO)*
Aim: *To analyze existing angular momentum-based approaches for singularity avoidance of Control Moment Gyroscopes, which are observed when the space of torque inputs reduces dimensionally*
- Proposed a novel torque distribution function for **singularity evasion** after extensive literature review
- Developed understanding of different techniques used for the control of Control Moment Gyroscopes
- Examined **singularities** encountered due to alignment of CMGs and developed generalizations of new and old approaches in a common mathematical framework using geometrical insight

Selected Technical Projects

1) Gas Leakage Detection using Nanosaur and Jetson Nano (Best Project Award) **(Jan-Apr '23)**
Guide*: Prof. Siddharth Tallur, Electrical Engineering Department, Mumbai*
- Led a three-membered to ideate and implement modifications to a mobile robot by interfacing multiple **gas sensors** on a **custom PCB** and plotting real-time data on a remote device communicating via WiFi
- Designed housing to enable secure mounting of IMX219-83 **stereo camera** and wheels to improve traction
- Integrated VSLAM using ORBSLAM2 in the existing software framework to build a map of the surroundings

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2) Guidance and Control Laws in Three Body Pursuit **(May-Jul '22)**
Guide*: Prof. Dwaipayan Mukherjee, Electrical Engineering Department, IIT Bombay*
- Developed strategies for an attacking missile to capture a target while evading a defender missile
- Formulating the problem as a **safety-critical system** with the application of **Zeroing and Reciprocal Control Barrier functions** to guarantee safety from the defender
- Developing new guidance law which maximizes performance and ensures safety using **quadratic programming** after analysis of existing and widely used laws for **missile guidance**

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3) Estimation on Lie groups **(Jan-May '23)**
Guide*: Prof. Ravi N. Banavar, Systems and Control Engineering, IIT Bombay*
- Learned about the use of **equivariant filters** for highly nonlinear problems like Visual SLAM
- Simulated and analysed **Kalman** filters and a **gradient-based** rotational estimator for a satellite

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4) Simulation and Stability Analysis of Spinning Rigid Bodies **(Jan-Apr '22)**
Guide*: Prof. Ravi N. Banavar, Systems and Control Engineering, IIT Bombay*
- Demonstrated the stability and instability of the three equilibrium points associated with an asymmetrical body
- Simulated 3D animation of the phenomenon of **unstable rotation** about the intermediate axis using Plotly

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5) Control Systems Laboratory **(July-Nov '22)**
Guide*: Prof. Dwaipayan Mukherjee, Electrical Engineering Department, IIT Bombay*
- Designed a lead-lag compensator for active noise cancellation in a headphone after experimentally obtaining the Bode plot for the open loop system
- Achieved a 20dB attenuation at 100Hz with gain and phase margin of 10.2 dB and 50^o respectively
- Designed a PID controller for a line-following robot to cover a track with redundant turnings in 30 secs
- Designed a set point tracking controller for a DC motor after smoothening the feedback

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6) Music Genre Classification using Various Machine Learning **(Mar-Apr '22)**
Guide: Prof. Biplab Banerjee, CMinDS, IIT Bombay
- Coordinated a **four-membered team** to use the feature extracted data for performing prediction using Decision Trees, Random Forests, Support Vector Machines, Naive Bayes, K-Nearest Neighbours
- Fine-tuning **hyper-parameters** of the models to maximize test performance and maintain low variance and low bias and drafted a report recording all the observations and results

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7) Stability Analysis of a Nuclear Reactor **(Nov-Dec '21)**
Nuclear Safety Analysis and Research Group, Atomic Energy Regulatory Board, Mumbai
- Computed the set of temperature feedback parameters required for stability of the state space model
- Designed and tuned a PID controller for a linearized lumped reactor with a point reactor kinetic model

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8) Design of a Multicycle and a Pipelined Processor **(Apr-May '22)**
Guide: Prof. Virendra Singh, Electrical Engineering Department, IIT Bombay
- Designed a **Six-Stage Pipelined processor**, which was optimized for performance using **hazard mitigation** and a Multi-cycle processor with a given **RISC ISA**
- Designed a **Lookup Table** for branch prediction and a **feed-forward** logic to increase the **throughput** of the pipelined processor for a wide variety of instruction combinations
- Implemented the complete design of the two processors on **VHDL** using **Quartus Prime** and verified the performance for a complex set of instructions

Teaching & Mentorship Experience

1) Teaching Assistant — *Linear Algebra* **(Jan-Apr '23)**
Prof. Jugal K. Verma, Mathematics Department, IIT Bombay
- Entrusted with the responsibility of conducting weekly tutorials for **35** first-year students
- Primary duties include clearing student doubts, grading, and managing attendance

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2) Education Outreach Volunteer — *Vidya India (Non-profit NGO)* **(Nov '21 - Apr '22)**
Organization committed to empowering underprivileged children, youth and women through holistic education
- Conducted weekly interactive lectures for underprivileged high school students to make learning easy
- Mentored a high school student and helped design a suitable timetable to manage school exams

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3) Projector Mentor — *Introduction to Machine Intelligence* **(Apr - Jul '22)**
Summer of Code, Web and Coding Club, IIT Bombay
- Mentored a group of **10 students** to help them learn and build systems using Reinforcement Learning
- Prepared and distributed **comprehensive resources** starting from the very basics to implementing **Deep Q Networks** and **Neural Networks** in Python
- Designed a **Capstone project** to implement an environment and an agent that learns to act optimally using a model-free approach - **Q-Learning**

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4) Student Mentor — *Department Academic Mentorship Program* **(Jun '21 - Present)**
Selected as a part of a 46-membered team out of 125+ applicants based on interviews and peer reviews
- Mentored **6 sophomores** and helped them strike a balance between academics and extracurriculars
- Acting as the **first point of contact** in order to actively bridge the gap between faculty and students
- Part of the Academic Rehabilitation Program, which aims to help students facing substantial academic difficulties
- Improved the dissemination of knowledge about the department by **updating blogs & course reviews**

Extracurricular Activities

- Performed as **vocalist** and **guitarist** in multiple cultural events organised by the Music club of IIT Bombay
- Studied **Sanskrit** language for **5 years** as a subject in secondary school
- Active donor and volunteer in blood donation drives conducted at institute and local hospital
- Participated in Online Physics Olympiad 2020 with two other students with **World Rank 6** in the Open Round and **World Rank 8** in the Invitational Round

Relevant Coursework & Technical Skills

Control Systems	Linear and Nonlinear Dynamical Systems, Estimation on Lie Groups, Identification, Mathematics for Control, Analytical and Geometric Dynamics
Mathematics	Random Processes, Applied Linear Algebra, Calculus, Complex Analysis, Differential Equations, Game Theory
Optimization & Learning	Stochastic & Distributed Optimization, Intelligent and Learning Agents, Machine Learning
Electrical Engineering	Digital Systems, Signal Processing, Power Engineering, Analog Circuits, Microprocessors, Electronic Devices & Circuits, Error Correcting Codes, EM Waves
Languages & Tools	C++, Python, MATLAB, ROS, LaTeX, Git, VHDL, Assembly, SolidWorks
Libraries & Packages	NumPy, Pandas, SciPy, Matplotlib, PyTorch, OpenCV

References

Prof. Ravi N. Banavar
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Prof. Florian Shkurti
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