

# Pranav Gupta — Curriculum Vitae

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## Education

### Indian Institute of Technology (IIT) Bombay

(Nov 2022 - Present)

- Major in Mechanical Engineering
- Minor in Systems and Control Engineering
- Minor in Robotics

## Publications

**Pranav Gupta**, Anastasia Bizyaeva, Ravi Banavar: "Estimates on the domain of validity for Lyapunov-Schmidt reduction"; accepted to the **IEEE Conference on Decision (CDC) and Control 2024, Milano**

## Research Experience

### Bounds of validity for Lyapunov-Schmidt reduction

(Nov 2023 - Present)

Guide: Prof. Ravi Banavar, Dept. of Systems and Control Engineering

- Established bounds on the domain of validity on the **Lyapunov-Schmidt Reduction** for **bifurcation analysis in finite dimension** systems derived using bounds on the implicit function theorem in calculus
- Demonstrated application to a **Recurrent Neural Network model** with a **pitchfork bifurcation**
- Awarded the prestigious **Undergraduate Research Award** for conducting the above-stated research
- Currently investigating applications for analysing bifurcations in **Multiagent Signed Social Networks**

## Key Projects

### Team AeRoVe | UMIC, IIT Bombay

(May 2023 - Present)

Guide: Prof. Dhwanil Shukla, Dept. of Aerospace Engineering

- **Senior Engineer** in the **Motion Planning and Controls** subsystem of **Team AeRoVe** working on developing & implementing control algorithms for advanced **aerial autonomy** on quadrotors and VTOLs
- Reviewed literature on quadrotor dynamics, derived its state space model using **Newton-Euler equations**
- Established high-level automatic control on a quadrotor with **Pixhawk** flight controller using **MAVROS** scripts with physics-complete **Gazebo** simulations bridged with **SITL** autopilots like **ArduPilot** and **PX4**
- Established low-level custom **Model Predictive Control** on a quadrotor using **casadi** to achieve optimal waypoint navigation and a **Model Reference Adaptive Control** to tackle model/parameter uncertainties
- Contributed to industrial collaboration with **Mahindra** for prototyping **aerial solar farm inspection** technology and **Eigenform Dynamics** to develop stabilising control software for **firefighting drones**
- Currently developing an **analytical dynamical model** of a **Tailsitter VTOL** aircraft to be simulated alongside the attitude control law for its quadrotor hover to fixed wing mode transition in **Simulink**
- Started preliminary research into **AUVSI Foundation's IARC Mission 10**, which involves employing an **autonomous drone swarm** to map and safely guide a human operator through an **active minefield**

### Ri4rover | Team AeRoVe | Purdue University

(January - June 2024)

- Placed **1st** internationally in **ri4rover**, organised by Purdue University, funded by the NSF and IEEE-CS
- Led a team of 4 to develop **motion planning and control** software for a quadrotor to autonomously search for and navigate to an **unknown GPS-denied maze's** exit to be implemented on an **IRIS-LiDAR** quadrotor simulated in **Gazebo Garden** using the **PX4** flight stack with **ROS2** powered autonomy
- Successfully implemented onboard **LiDAR-based** maze mapping from scratch in simulation and tested **2D LiDAR SLAM** on a **Raspberry Pi 5** with a **DTOF-STL27L LASER** LiDAR sensor on a quadrotor
- Developed an optimal **random maze solver** with anti-wall collision based on the **A\* Search algorithm**

## DRONEacharya — Institute Technical Summer Project | *ITC, IIT Bombay* (April - August 2023)

*Aerial Vision guided Autonomous Zero-Perception Rover for object detection, collection and deposition*

- Led a team of 4 to ideate, design and realise **DRONEacharya**, a drone-rover swarm system in which a camera drone detects and localises golf balls on a field and guides a rover to collect them time optimally
- Designed closed-loop rover **navigation and position control** in **MATLAB**, integrated with **ArUco** detection and ball detection with **OpenCV** and **ROS2** communication between the rover and **MATLAB**
- Configured **serial communication** between **Raspberry Pi 3B+** and **Arduino Uno R3** onboard the rover to establish **closed loop control** on the angular velocity of **encoder DC motors** powering the wheels

## AstroTinker Bot | e-Yantra Robotics Competition (Sept 2023 - Feb 2024)

- Used **Intel Quartus Prime** to write and implement **Verilog HDL** modules on a **Intel Cyclone-IV FPGA**, such as **UART** protocol data transmitter and receiver designed as a **finite state machine**
- Implemented **Dijkstra's algorithm** in **C** for optimal path planning between nodes on the given game map
- Implemented the **RV32I** ISA in a single-cycled modular **RISC-V** CPU with **Verilog HDL** from scratch to load and execute the path planning **C** code after being compiled down into an **RV32I ISA** hexdump

## Miscellaneous Projects

### Deep Learning based State Estimation for Robot | *ME228 — Course Project* (April 2024)

- Developed a **data-driven full state observer** for a 2-wheel differential drive robot to achieve **robust trajectory tracking** through a **PID controller** making use of the state estimates from the observer
- Used **CUDA** to train **Gated Recurrent Unit (GRU)** networks written with **tensorflow**, using **KerasTuner** to automatically pick an effective 2-layer model from a basket of semi-trained models
- Generated synthetic training and testing data by simulating the dynamical model in MATLAB's **Simulink**

### Quadrotor with a Manipulator Arm | *SC618 — Course Project* (Nov 2023)

- Led a team of 3 to develop a model and graphical simulation of a **quadrotor** with a mounted **2-dof arm** equipped with a **manipulator** using the industry standard **Wolfram System Modeller** environment.
- Successfully interfaced model with high level control commands using the **OpenModelica** framework
- Compared simulated results with analytical results derived using the **Lagrangian** formalism of mechanics

### Swarm Robotics and Path Planning | Summer of Code — *WnCC, IITB* (May - July 2023)

- Reviewed custom messages and services in **ROS2 Iron Irwini** for the **ROS-TCP Bridge** with the **Unity** engine as well as literature on **Graph-Theoretic Methods for Multi-Agent Coordination**
- Implemented a **virtual-potential** based simulation of **lattice-boids** in **MATLAB** and successfully achieved **stable flocking** between agents that were otherwise programmed to move inertially at random

### Control Theory Bootcamp | Learner's Space — *ERC, IITB* (May - July 2023)

- Established **PID** control on a *"ball-on-seesaw"* system complete with actuator and state limitations in **pygame**, tuned using the **Ziegler-Nichols** method to achieve an optimum settling time of **0.42s**
- Developed a **2-wheeled self-balancing rover** in **Simulink** from scratch using the **Simscape Multidomain** package and established **PID** control on the same to accomplish waypoint navigation

## Positions of Responsibility

### Teaching Assistant | *SC639 - Mathematical Structures for Control* (August - December 2024)

- Conducted regular **tutorial sessions** for a batch of 140+ students (ranging all the way from sophomore undergraduates up to PhD students), helping them with conceptual understanding and problem solving
- Provided assistance to the instructor in **course logistics** by **proctoring exams** and evaluating **assignments** and **examination** answer scripts and organising **crib sessions** to resolve grading grievances

- Presenting and handling an annual multi-phase **technical expenditure budget** of **1.5 million INR** to the Student Technical Projects Committee, and procuring **travel funds** from relevant institute channels
- Spearheading formation of a **business team** to handle **sponsorships**, **social media/web**, **industrial collaborations** to improve team **financial operations**, **publicity** and attract **industrial** client projects
- Conducted multiple **orientation sessions** followed by **recruitment drive interviews** for freshmen and sophomores to select eligible candidates from a pool of **100+ freshmen** and **80+ sophomores**
- Presented the team's **technical prowess** and **vision** in multiple institute open technology **exhibitions**

## Key Courses Taken

|                        |   |
|------------------------|---|
| Department Courses     | Microprocessors and Automatic Control, Kinematics and Dynamics of Machines, Fluid Mechanics, Solid Mechanics, Heat Transfer, Applied Thermodynamics, Thermal & Chemical Processing of Materials, Mechanical Processing of Materials, Engineering Mechanics, Mathematical Methods in Engineering |
| Minor/Elective Courses | Embedded Control & Robotics, Estimation on Lie Groups, Analytical and Geometric Dynamics, Signals and Feedback Systems  |
| Lab Courses            | Manufacturing Processes, Fluid Mechanics, Solid Mechanics, MakerSpace   |
| Online Certifications  | Introduction with MATLAB (Coursera), Aerial Robotics (Coursera)   |

## Technical Proficiencies

|                |  |
|----------------|--|
| Programming    | C, C++, python, MATLAB, Simulink, Verilog HDL, bash/zsh, Java      |
| Software Tools | Git, Ubuntu, QGC, ArduPilot, Mission Planner, Intel Quartus Prime  |
| Hardware Tools | Nvidia Jetson, Raspberry Pi, Vicon MoCap, Arduino, Holybro PixHawk |
| Frameworks     | ROS2 Humble, ROS1 Noetic, MAVROS, ArduPilot, PX4, Gazebo           |
| Libraries      | eigenCPP, PyTorch, TensorFlow, Keras, casadi, NumPy, Pandas        |

## Extracurricular Activities

|           |   |
|-----------|---|
| Sports    | <ul style="list-style-type: none"><li>• Received professional swimming training, securing multiple laurels and a best of <b>31s (50m)</b></li><li>• Awarded the <b>SHO 1st Dan</b> distinction by the <b>Shotokan Karate Association of India</b></li></ul>   |
| Technical | <ul style="list-style-type: none"><li>• Mentored 2 teams of 4 freshmen each in the <b>XLR8 competition</b> to design and make a remote controlled <b>4WD rover</b> using an <b>ESP32 <math>\mu</math>-controller</b> to navigate challenging terrain</li><li>• Awarded an honorable mention in <b>trustlabCTF</b>, a 6 hour long <b>cross-domain cybersecurity</b> offline <b>Capture The Flag</b> contest conducted by <b>TrustLab, IITB</b></li><li>• Developed PyTorch implementations of the DQN, DDQN, D3QN algorithms from scratch that successfully solved Gynmasium's LunarLander-v3 and CartPole-v1 environments</li></ul> |
| Institute | <ul style="list-style-type: none"><li>• Placed <b>1st out of 100+</b> in <b>Re-Decrypt</b>, a competition of cracking a series of <b>challenging riddles</b> embedded within various <b>research papers</b>, conducted by EnPoWeR IITB</li><li>• Volunteered to deliver online academic aid to financially weak students in remote places, scripted and recorded edu-audiobooks for 10th graders from NCERT texts through <b>NSS</b></li></ul>  |
| Others    | <ul style="list-style-type: none"><li>• School robotics team lead for the <b>FIRST Tech Challenge</b> for the Rover Ruckus theme</li></ul>  |

## References

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