Pranay Katyal

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Robotics Engineering graduate student specializing in autonomous multi-agent systems, working with advanced control theory (GCBFs, CBFs) and with deep learning for perception and planning. Proven expertise in ROS2-based autonomy stacks, optical flow navigation, and distributed coordination algorithms. Seeking CPT Co-op (January 2026) and Full-time (May 2026) opportunities in aerial robotics, autonomous vehicles, or multi-robot systems specializing in controls and planning.

Education

Worcester Polytechnic Institute, MA, USA — August 2024 – Present
Master of Science in Robotics Engineering — **GPA: 3.77/4.0**

Chandigarh University, PB, India — July 2019 – June 2023
Bachelor of Science in Mechatronics Engineering — **GPA: 3.4/4.0**

Skills

- **Programming & Core Tools:** Python, C++, MATLAB, ROS2 (Humble, Jazzy, Foxy), Docker, Git, PLC (Ladder)
- **Autonomy & Control:** Control Barrier Functions (CBF/GCBF), PID/LQR Control, State Estimation (UKF, EKF), RRT* Planning, Trajectory Optimization, Consensus Algorithms, Visual Servoing
- **Machine Learning & Vision:** PyTorch, TensorFlow, RAFT Optical Flow, U-Net, ResNet, LSTM/RNN, Depth Estimation, Motion Parallax, PnP Pose Estimation, Object Detection
- **Robotics Platforms:** CrazyFlie 2.0 Quadcopter, AWS DeepRacer, OpenManipulatorX (4-DOF), Kinova Gen3 (6-DOF), Event-based Cameras (GenX320), Dynamixel Motors, IMU Sensors, Tello Quadcopter
- **Simulation & Development:** VizFlyt, Gazebo, OMPL, Simulink, Fusion 360, ANSYS, Jupyter Notebook, UiPath Studio
- **Computing Infrastructure:** WPI Turing HPC Cluster (NVIDIA A30 GPU), NVIDIA RTX 4080
- **Professional Skills:** Team Leadership, Project Management, Technical Communication, Research Collaboration, Teaching & Mentoring

University Projects

Async vs Sync Consensus for Multi-Agent Formation Control with GCBFs — August 2025 – December 2025

- Developed distributed multi-agent control system comparing synchronous and asynchronous consensus protocols (alpha=0.3, 0.7) for 5-drone pentagon formation tracking moving targets through obstacles with realistic constraints (8m visual range, 6m communication range, 0.02s timestep).
- Implemented Graph-Based Control Barrier Functions (GCBFs) for distributed collision avoidance with local QP optimization (OSQP solver) achieving $O(n \cdot k)$ complexity vs $O(n^2)$ centralized approaches, maintaining 2.0m safety distance with zero CBF violations across all test scenarios.
- Demonstrated asynchronous protocol superiority at alpha=0.7 with better stability, faster tracking, and 50% lower control effort (0.024 vs 0.048 $m \cdot s^{-2}$) compared to synchronous, though experiencing increased drift (8.7m vs 7.5m), validating event camera-based non-RF communication for interference-free multi-robot coordination.

Autonomous Navigation through Windows and Gaps using Optical Flow — November 2025 – December 2025

- Developed modular three-phase navigation architecture combining RAFT optical flow with TS2P (Temporally Stacked Spatial Parallax) algorithm for bidirectional course traversal through rectangular windows and irregular gaps.
- Implemented skill based Navigation (eg Scan, Recenter, Align, Explore) with separate forward/return modules handling textured and featureless window faces.
- **Achieved 3rd place in class** with complete bidirectional navigation in 264.6 seconds simulation time and 0.729s inference time, demonstrating robust gap detection without depth data using pure RGB optical flow.

Monocular Depth Estimation with Transfer Learning — November 2025 – December 2025

- Reproduced M4Depth temporal depth estimation framework fusing sequential camera images with GPS/IMU data, training on synthetic MidAir dataset (550 images) and attempting transfer to real-world UseGeo dataset (828 images).
- Achieved 2.65m RMSE and 98.6% accuracy (delta less than 1.25) on synthetic data after 71 epochs with pretrained checkpoint.
- Discovered critical pose format incompatibility preventing transfer learning.

Optical Flow-Based Gap Detection and Navigation — October 2025 – November 2025

- Implemented RAFT optical flow neural network for texture-invariant gap detection using motion parallax, achieving 89-95% IoU segmentation accuracy regardless of foreground/background texture similarity.
- Developed visual servoing controller using optical flow magnitude thresholding and connected component analysis to identify largest enclosed gap and compute pixel-displacement control commands.
- Successfully validated approach on Blender-generated test dataset and VizFlyt simulation, completing navigation in 35 seconds with 40ms inference rate (25Hz) and 10px goal-reaching accuracy.

LSTM-Based 3D Dubins Trajectory Prediction — October 2025 – November 2025

- Developed rotation-invariant LSTM architecture for 3D Dubins airplane path prediction using body-frame representation, trained on 1,053,091 synthetic trajectories with variable-length sequences.
- Implemented 3-layer LSTM (256 hidden units) with sequence-to-sequence design generating complete trajectories from 4D

input (goal position + climb angle) using masked MSE loss.
- Achieved 5.52m average error (approximately 2%), 14.59m maximum error (approximately 6%), and 16.70m endpoint error across 100 diverse test cases with various headings and climb angles.

Deep Learning-Based Window Detection for Drone Navigation September 2025 – October 2025

- Developed U-Net semantic segmentation model trained on 10,000 Blender-generated synthetic images with extensive augmentation (Gaussian noise, blur, color jitter, elastic transform) for robust window frame detection.
- Achieved 1cm goal-reaching accuracy and 21ms inference time through visual servoing pipeline combining semantic segmentation, PnP pose estimation, and depth-based control scaling.
- Successfully deployed perception stack on VizFlyt simulator running on Turing HPC cluster, completing 3-window navigation course in 35 seconds with real-time RGB-D processing.

Quadrotor Path Planning and Trajectory Optimization September 2025 – October 2025

- Implemented RRT* path planning with 79% waypoint reduction (48 to 10 nodes) and 94.7% path efficiency, coupled with 7th-order polynomial minimum-snap trajectory generation for smooth quadrotor flight.
- Achieved 5mm final positioning accuracy and 1.5cm average tracking error using cascaded PID control (position/velocity/angular rate) based on PX4 architecture.
- Successfully integrated navigation stack with VizFlyt photorealistic simulator on WPI Turing HPC cluster (NVIDIA A30 GPU), completing missions in 15.3 seconds with zero collisions.

Vehicle Classification via ResNet18 Transfer Learning September 2025 – October 2025

- Applied two-phase transfer learning with pretrained ResNet18 for 10-class vehicle classification: 20 epochs frozen backbone followed by 30 epochs full fine-tuning with 10x reduced learning rate.
- Achieved 96.0% validation accuracy on limited dataset of 1,400 training images through extensive data augmentation (random flips, color jitter, rotation, crops) and weight decay regularization.
- Demonstrated effective transfer learning with minimal overfitting (training 95.4%, validation 96.0%), completing training in 22 minutes on NVIDIA RTX 4080.

Unscented Kalman Filter for Attitude Estimation August 2025 – September 2025

- Implemented Unscented Kalman Filter (UKF) for nonlinear attitude estimation using quaternion representation, sigma point generation, and iterative quaternion mean computation via gradient descent.
- Achieved superior performance over Complementary and Madgwick filters through probabilistic fusion of gyroscope and accelerometer measurements with process/measurement noise tuning.
- Demonstrated expertise in handling quaternion constraints (unit norm preservation), 6D/7D state space transformations, and sequential measurement updates for improved numerical stability.

Neural Network Control Allocator for Ship Thrusters August 2025 – September 2025

- Implemented LSTM encoder-decoder architecture for ship thruster control allocation, replacing computationally expensive Sequential Quadratic Programming with fast neural network inference.
- Trained on 1 million synthetic samples with composite loss function enforcing physics consistency, actuator limits, rate constraints, energy minimization, and forbidden sector penalties.
- Achieved less than 6% error for sway, yaw, and mixed force commands, demonstrating fast adaptable control allocation, though performance degraded to 42% error on large surge requests.

IMU Sensor Fusion for Orientation Tracking August 2025

- Implemented attitude estimation using gyroscope integration, accelerometer-based tilt estimation, and complementary filter sensor fusion on 6-DOF IMU data.
- Achieved sensor calibration through SLERP (Spherical Linear Interpolation) to synchronize IMU and Vicon motion capture timestamps in software.
- Demonstrated understanding of coordinate frame transformations (ZYX Euler angles), bias correction, and drift mitigation techniques for orientation tracking.

Benchmarking Advanced IK Algorithms March 2025 – May 2025

- Implemented Product of Exponentials method for forward kinematics and multiple inverse kinematics algorithms (Newton-Raphson, Damped Least Squares, Gradient Descent) in MATLAB.
- Modeled velocity kinematics, quintic trajectory generation, and performed inverse and forward dynamics using Recursive Newton-Euler algorithm.
- Carried out a benchmark study of modern IK algorithms (SVDDLS, IDLS, PSO) on a 6 DoF Kinova Gen3 arm, integrating real-time control via Meta VR headset.
- Led the SVDDLS implementation by translating research into code, enabling precise arm manipulation using VR-derived poses.

Chance-Constrained RRT Motion Planning with OMPL Integration March 2025 – May 2025

- Integrated a Chance-Constrained Rapidly-exploring Random Tree (CCRRT) algorithm with the Open Motion Planning Library (OMPL) in C++ for robust path planning.
- Utilized Docker for reproducible development and Applied collision checking in configuration space for static obstacles.
- Achieved less than 1-second planning times and evaluated performance under varying probabilistic safety constraints.
- Introduced OMPL's integration in the CCRRT and Led core algorithm development; contributed to project report and algorithm analysis.

Control of 4-DoF OpenManipulatorX Robotic Arm November 2024 – December 2024

- Led a team of 3 members throughout the project, ensuring efficient collaboration and task delegation.
- Developed and implemented position and velocity kinematics for the 4-DOF robotic arm using ROS2, achieving seamless motion control.
- Integrated Dynamixel motors with a PD controller, optimizing motor control in effort control mode to ensure precise and responsive movement.
- Achieved 97.5% control accuracy with repeatable, high-precision motions, significantly improving the arm's performance in complex tasks.

Quadrotor Controller Implementation (CrazyFlie 2.0) November 2024 – December 2024

- Designed and Tuned PD and LQR controllers for the CrazyFlie 2.0 quadcopter using MATLAB, enhancing control stability.
- Demonstrated 10-second path tracking for both controller designs, validating their effectiveness in real-time applications.
- Leveraged LQR control strategy to provide up to 17.28% faster performance compared to PD controllers, improving flight efficiency and precision.

Design and Testing of Robotic Dog (SPOT) January 2024 – March 2024

- Engineered and tested a robotic dog (SPOT) using Fusion 360 for design and ANSYS for load analysis, enhancing structural performance and reliability under various conditions.
- Ensured the robot could withstand static loads of up to 1000g, maintaining reliable performance in various real-world scenarios.

Professional Experience

Research Assistant, Multi-Robot Communication and Simulation January 2025 – Present

- Collaborated in the Automata Lab under Prof. Kevin Leahy, focusing on synchronous and asynchronous communication protocols for multi-robot systems.
- Developed and implemented simulation frameworks to model and validate communication strategies, ensuring scalability and robustness in dynamic environments.
- Created advanced visualizations to provide actionable insights into system performance and protocol effectiveness.
- Demonstrated the reliability and efficiency of the proposed communication methods through comprehensive mathematical modeling and simulation analysis.
- Used AWS Deepracer with Ros2 Teleop and Nav2 pkgs for Control, Utilised GenX320 Events Camera sensors on the Deepracer for detection and communication.

Grading Assistant, **WPI - Multi Robot Systems RBE510** August 2025 – Present

- Assisting in the grading of Multi Robot Systems RBE510, supporting graduate students in mastering complex concepts of multi robot system domain.
- Helping students work on concepts that they have trouble with.

Graduate Assistant, **WPI - Control Systems 3011** September 2024 – March 2025

- Assisted in the instruction of Control Systems 3011, supporting 60 students in mastering complex concepts.
- Conducted Lab sessions to help Students improve MATLAB Proficiency.
- Delivered personalized guidance to about 15 students weekly, enhancing understanding of complex control systems concepts and contributing to a class average increase from 75% to 90% on assessments.

Leadership Experience

Secretary, **IEEE-RAS WPI Chapter** January 2025 – Present

- Coordinated events, workshops, and technical talks to promote robotics research and student engagement.
- Managed communications between faculty, industry speakers, and 50+ student members, ensuring smooth event execution.
- Collaborated with executive board members to plan outreach initiatives and increase chapter participation by 30%.

GitHub Portfolio **LinkedIn Profile**