Ayush Agrawal

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Education

Indian Institute of Technology Bombay *(July '17 - May '21)*

Bachelor of Technology in Mechanical Engineering

- **GPA: 9.37/10**
- Conferred with a **Minor degree** in Systems and Control Engineering *(2021)*
- Secured a perfect semester performance index, **SPI: 10/10**, in final semester of B.Tech curriculum *(2021)*
- Awarded an **AP grade** for exemplary performance in **Strength of Materials** (3 out of 162) *(2019)*

Publications

- **Ayush Agrawal**, A. Negi, D. Joshi. "Exploring capabilities of hydraulic actuators to achieve vehicle ride targets in frequency range beyond their operational bandwidth," Symposium of Internation Automotive Technology (SIAT), Pune, India, 2024.† † *Accepted for publication*
- **Ayush Agrawal**, M. Bharatheesha, S. Kolathaya, "Formation control of differential-drive robots with input saturation and constraints on formation size," 62nd IEEE Conference on Decision and Control (CDC), Singapore, 2023.† DOI: https://doi.org/10.36227/techrxiv.21984998 † *Accepted for publication*

Professional Experience

Vehicle Controls Engineer | Jaguar Land Rover India Pvt. Ltd. *(July '23 - Present)*

Project Supervisor: Nipun Payagala | Dept. of Chassis & Motion Controls Systems

- **Aim:** Design a ride enhancement controller[1] for the active suspension system executable on the chassis control module of **L460 Range Rover**. Account for the limitations posed by the hydraulic actuators and vehicle structure
- Leading the model-based development of discrete-time optimal controller, improving ride performance by **62%**
- Leveraged **Control Barrier Functions** to model the constraints imposed by geometry and endurance limit of vehicle structure on the wheel travel and suspension actuation forces, respectively, hence preventing structural failure

Graduate Mechanical Engineering Trainee | Jaguar Land Rover India Pvt. Ltd. *(Aug '21 - July '23)*

JLR's Active Suspension Technology *(June '22 - Present)*	◦ ***Aim***: Design a controller for JLR's upcoming suspension technology adept at boosting ride & handling by eliminating body's motion due to road undulations, cornering, and braking ◦ Enhanced the primary ride quality by **34%** in **L460** vehicle model using LQR control with only three feedback signals - rate of change of heave, pitch, and roll of body $(\dot{x},\ \dot{\theta},\ \dot{\phi})$ ◦ Optimized the controller using μ-synthesis in **MATLAB** to achieve system performance targets even in the presence of network delays, sensor noise, and parametric uncertainties ◦ Simulated **pre-emptive suspension** system using model predictive control with road profile scanners, reported **>90%** improvement in both primary and secondary ride quality
Crash Pulse Prediction *(Nov'21 - May'22)*	◦ ***Aim***: Create a **MATLAB-based physics engine** capable of rapidly assessing the crash-worthiness of a given vehicle against a full-width rigid barrier as per **Euro NCAP** norms ◦ Devised a technique to generate 1-D model of the front crumple zone of any vehicle ◦ Developed a physics engine which simulates the vehicle's crash kinematics for a given crumple zone design, computes safety metrics, and compares them against legal norms ◦ Utilized the tool's capability to save time in CAD model development of **Panthera**'s BIW, and benchmark the crashworthiness of **EMA** against **Lucid Air**, **BMW iX**, and **Merc. EQS**
Performance Benchmarking of BEVs *(Aug'21 - Nov'21)*	◦ ***Aim***: To benchmark the prospective performance of Land Rover's new EV platform ***Electric Modular Architecture (EMA)*** against battery electric vehicles (BEVs) launched till 2021 ◦ Performed an exhaustive comparative analysis on EV efficiency, battery capacity, and range to benchmark **EMA** against the performance specs of **40 BEVs** mainly **Tesla** and **BMW** ◦ Investigated the implications of a larger battery span on the vehicle's crashworthiness in a SORB test, proposed a solution to achieve safety targets even with larger battery span

[1] Actual details of the controller are kept confidential

Research Internships

Robot Programming and Controls Engineer | *AI & Robotics Technology Park, Bangalore* *(May '21 - Aug '21)*
Formation control of differential-drive robots with input saturation and constraint on formation size

Project Supervisor: Dr. Mukunda Bharatheesha | *Accepted Manuscript*

- Proposed a **novel nonlinear feedback control law** which guarantees stable tracking of time-varying reference trajectory for a differential-drive robot and obeys the limits on the linear and angular velocity of the robot
- Analytically proved the boundedness of robot's velocity and the stability of robot dynamics under proposed control action by establishing ultimate boundedness of position errors (e_x, e_y, e_θ) using **Lyapunov analysis**
- Utilized the **virtual structure method** to extend the proposed controller for the formation control of differential drive robots and proposed **constraints on formation size** necessary for safe navigation of the robotic formation
- Performed simulations in **MATLAB/Simulink** to verify the outcomes of theoretical stability analysis and assess the performance of the proposed controller for a single differential-drive robot, and circular formations of robots

MITACS Globalink Research Internship | *University of Toronto, Canada* *(Apr '20 - Aug '20)*
Seismic response of vertical post-tensioned connection for modular steel structures

Project Guide: Prof. Oya Mercan | *Report*

- Performed seismic analysis of conventional steel structures with welded joints using **FE model** to validate the experimental force displacement behaviour of the structure through numerical **Skeleton curve**
- Simulated the recently introduced vertical post-tensioned connection for MSB in **ABAQUS** to authenticate its **self-centring** and **higher energy dissipation capabilities** with **91%** accuracy relative to experimental results.
- Conducted an exhaustive study on **contact and fracture modelling** by analyzing surface discretization and damage evolution criteria to achieve **99.75% accuracy** in frictional dissipation

Research and Technical Projects

Reduced-order controllers for Leader-follower consensus of linear multi-agent systems *(June '20 - Dec '20)*

Project Guide: Prof. Vivek Natarajan | *B.Tech. Project (BTP)* | *Report* *Systems & Control Eng., IIT Bombay*

Leaderless consensus of linear multi-agent system (MAS) has been solved via state-space based control laws. This work aims to develop frequency-domain-based distributed reduced-order controllers to achieve the Leader-follower consensus of MAS.

- Utilized the technique of **simultaneous stabilization** to derive sufficient conditions which guarantee output feedback state consensus of n^{th} order linear agents under time-invariant communication topology
- Designed a **reduced-order low-gain control algorithm** based on relative output measurement of neighboring agents to achieve state consensus of the leader and followers in a homogeneous MAS
- Discovered the intrinsic potential of **frequency-domain based controllers** in ensuring state consensus of MAS in the presence of known, uniform, and arbitrarily large **communication and input delays** in the network
- Deployed **MATLAB Control Systems Toolbox** to simulate the consensus trajectory for a system of $\mathrm{N} = 5$ agents (1 Leader and 4 followers) with time-invariant network topology consisting of 4^{th} order dynamics

MAPLE based solver for stress analysis of a loaded elastic cavity *(May '19 - July '19)*

Project Guide: Prof. Tanmay Bhandakkar | *Research Project* | *Report* *Mechanical Engineering, IIT Bombay*

- Developed a solver in **MAPLE** employing general **Michell solution** to obtain the solution field for a two-dimensional infinite annular domain with generalized internal traction boundary condition
- Simulated the problem in **ABAQUS** using a symmetric model for continuous, piecewise continuous, point load distribution to verify the results obtained through the numerical model in MAPLE
- Explored and verified **Saint Venant's Principle** for statically equivalent uniform & linear piecewise continuous load distribution by analyzing the stress distribution using **MATLAB** plots

Image Creating Robotic Arm *(May '18 - July '18)*

Institute Technical Summer Project | *Certificate* *Electronics & Robotic Club, IIT Bombay*

- Designed the structure of **RR planar** manipulator using **U-shaped Aluminium** brackets, and performed FEM simulations in **ABAQUS** to determine the requisite torque capacity of the servo motors
- Developed an algorithm for the movement of actuators supporting the arm by utilizing the **bit-Matrix** obtained by processing the Canny Edge Detected image on **MATLAB**
- Determined the joint space trajectory using **Inverse Dynamics** and programmed **Arduino UNO** micro controller to trace the edges of the image in the task space through servo actuators

Prominent Academic Projects

Control design of ABB-IRB 1600 - A 6-DoF Industrial Robotic Manipulator *(Jan '20 - Apr '20)*

Project Guide: Prof. Abhishek Gupta | Course Project | Report *Robotics*

- Modelled the manipulator dynamics using **MATLAB Robotics Toolbox** and implemented **PD controller with gravity compensation** to track the joint space trajectory planned using quintic polynomial
- Minimized steady-state error of **1.8%** in **Independent Joint Control** by introducing **Joint Space Inverse Dynamics Controller** to achieve **99.8% accuracy** in set point tracking and path planning problem

Electrochemical discharge based micro-milling using pulsed current *(Aug '19 - Nov '19)*

Project Guide: Prof. Pradeep Dixit | Course Project *Manufacturing Processes II*

- Executed over **20 experiments** to analyze the surface profile and dimension of the **microfluidic channel** fabricated on glass through **Electrochemical discharge machining** for biomedical applications
- Investigated and graphically displayed the variation of output parameters (depth of cut, the width of cut, overcut, surface finish) with the process parameters (tool-electrode gap, concentration of alkali, and feed rate)
- Determined the optimal tool-electrode gap for a maximum width of cut and provided a quantitative explanation for the variations through **Gaussian heat distribution** for single point cutting tool

Scholastic Achievements

- Conferred with the **MITACS - Globalink Research Internship** for performing research in Canada *(2020)*
- Secured **All India Rank 150** in **JEE Mains** out of 1.2 million candidates *(2017)*
- Achieved **All India Rank 711** in **JEE Advanced** out of 150,000 candidates *(2017)*
- Awarded the prestigious **KVPY fellowship** by **IISC Banglore** with **All India Rank 710** *(2017)*
- Recipient of scholarship by **National Testing Agency** through **AISEE** *(2017)*

Teaching and Mentorship Experience

Academic Mentor | *Department Academic Mentorship Programme (D-AMP)* | *Certificate* *(Mar '19 - Apr '20)*

An initiative to help sophomores strike a balance between academics and extracurricular activities in the institute

- Selected in a team of **33 out of 95+ applicants** aiding over **185 students** in their academic concerns
- Mentored and guided a batch of **7 sophomores** in their academic, personal and extra-curricular endeavours
- Underwent a training workshop on mentoring and rapport building by **TATA Institute of Social Sciences**

Undergraduate Teaching Assistant

PH108 | Basics of Electricity and Magnetism | Prof. Mithun Mitra *(Jan '19 - Apr '19)*

MA106 | Linear Algebra | Prof. Jugal Verma and Prof. Sandip Singh *(Jan '20 - Mar '20)*

- Conducted weekly tutorials for a batch of **50+ students**, focussing on concept discussion and problem solving
- Part of **10+ member** team responsible for brain storming and implementing strategies for better topic coverage
- Evaluated the students performance regularly & collaborated with the instructor for better teaching tactics

Technical Skills

Programming Languages	C, C++, Python
Numerical Analysis and Simulation	MATLAB, MAPLE, ROS (Kinetic), CarMaker 8.1
CAD/CAM/CAE Skills	SolidWorks, ABAQUS, ANSYS, G-code and M-code for CNC

Extracurriculars

Workshop	◦ Completed a **16 hours** workshop on **Automobile Mechanics** by **ESSAR Group, India** *('18)*
MOOCs	◦ Aerial Robotics | **UPenn** | Coursera ◦ Dynamics and Control | **UPV** | edX *('20)*
Sports	◦ Completed **80+ hours** of intermediate-level training in **Hockey** under NSO *('17-'18)*
Volunteering	◦ Showcased the construction & working of electronic sensors in a boot camp by **ERC** *('18)*
Tech Clubs	◦ Mentored 4 freshmen in the **Annual RC-Plane** competition by the **Aeromodeling Club** *('18)* ◦ Developed a blue-tooth controlled wheeled bot in **XLR8** competition by **Robotics Club** *('17)*