

Gaurav Kumar

Senior Undergraduate, Indian Institute of Technology Kanpur

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Education

- **Bachelor of Technology GPA: 9.11/10** **Indian Institute of Technology Kanpur**
Major: Aerospace Engineering, Minor: Control Systems (expected) July 2023
- **Grade XII: 95.4/100** **Kendriya Vidyalaya Asansol**
Stream: Science July 2019

Publications

- **Coulomb Staged-Docking with Electrospray Thrusters using Predefined-Time Control** **Review: JGCD**
Gaurav Kumar and Dipak Kumar Giri Sept. 2022
 - Proposed a novel method of staged-docking that utilizes electrostatic actuation of the charged target and chaser equipped with staged bipolar electrospray thrusters in binary switching mode.
 - A predefined-time sliding mode controller is derived with a fixed time converging sliding manifold, which guarantees pre-set time convergence with robustness to unmodeled perturbations and system uncertainties.
 - Fixed point static numerical optimization is carried out for minimizing the electrospray current and voltage.
 - The result is compared with a Lyapunov-based control to demonstrate the superiority of the proposed technique.
- **On-Track Optimal Rendezvous and Docking of Spacecrafts using Hybrid Coulomb Control** **IAC 2022**
Gaurav Kumar, Dipak Kumar Giri and Shashi Ranjan Kumar Sept. 2022
 - Developed a rendezvous and docking system of spacecrafts using optimal hybrid Coulomb actuation.
 - Proposed a improved method of calculating Coulomb interaction and coupling with chaser dynamics.
 - The optimal controller is compared with an existing voltage feedback control for both linear and non-linear simulations in MATLAB.
- **MagLev based 3-DOF experimental Platform for Autonomous Spacecraft Rendezvous and Docking** **IAC 2022**
Nitika Jaggi, Gaurav Kumar, Aditya Prakash, Priyank Dubey and Dipak Kumar Giri Sept. 2022
 - Hardware in the loop magnetic levitation based robotic spacecraft test bed platform is developed.
 - Optimal thrusting mechanism using solenoid valve is designed and integrated into the dynamics in Simscape
 - Multiple guidance and control algorithms for on-orbit proximity operations are tested.

Work Experience

- **Computer Modelling of Spacecraft Constellations at artificial L1 Lagrange Point** **[MITACS GRI]**
Mentor: Alex Ellery, Carleton University, Ottawa, Ontario, Canada May. 2022 –Jul. 2022
 - Novel method of using solar sail constellation at Sun-Earth artificial L1 Lagrange point in the shape of Fresnel lens is proposed for mitigating the process of climate change.
 - Method of differential correction is applied on third order approximation of orbits to get exact periodic orbits in the vicinity of the artificial equilibrium point
 - Family of periodic orbits with different period and amplitude is observed by varying the solar sail β parameter and is used to model the reference trajectory for parametric equation of the Fresnel lens formation
 - Optimal formation control algorithm is designed using multi-objective genetic algorithm NSGA-II with solution selection from Pareto optimal set using TOPSIS.

- **Undergraduate Research Programme- SURGE'21, IIT Kanpur** [Report]
Mentor: Dipak Kumar Giri, IIT Kanpur Jun. 2021 – Aug. 2021
 - Optimal control for high precision rendezvous and docking of Coulomb satellites is investigated.
 - Receding Horizon Model Predictive Control (RHMP) with constraints is used to do constrained optimization of the cost function.
 - Inequality constraint on state and equality constraint on path is applied to implement object avoidance from space debris during docking.
 - Simulated the docking system for both 15-3 meters and 3 meters-80mm docking with derived control law in MATLAB for verifying terminal docking performance.

Research Projects

- **Predefined-Time Nonlinear Sliding Mode Attitude Tracking of Spacecraft** [Report]
Prof. Somya Ranjan Sahoo, Nonlinear Systems (EE651) Jan. 2022 – Apr. 2022
 - We consider the attitude tracking control problem for rigid spacecraft with bounded external disturbances. We implement and analyze a predefined-time predefined-bounded attitude tracking control scheme based on sliding mode control.
 - Two mathematical formulations are discussed which can be used to derive control law and their proof of stability is given. Finally, numerical simulations are carried out to evaluate the performance of both the control law and compare them.
- **Energy Efficient time table scheduling to improve the utilization of Regenerative energy** Funded by DMRC [Report]
Prof. Faiz Hamid (IIT Kanpur) Jan. 2022 – Apr. 2022
 - As part of a team of three, coordinated the arrivals and departures of all trains located within the same electricity supply interval to utilize the energy generated by braking trains to accelerate trains.
 - Implemented NSGA-II algorithm with real-world speed profiles to minimize the trains' energy consumption with the dwell time obtained from the machine learning model.
- **Trajectory Tracking Control Algorithm for a Wheeled Mobile Robot** [Report]
Prof. Dipak Giri, Aircraft Systems (AE322) Jan. 2022 – Apr. 2022
 - A recently developed trajectory tracking control system for a wheeled mobile robot is presented in this study, which includes hierarchical sliding mode and backstepping control algorithms.
 - The closed-loop stability and zero tracking error are guaranteed by the backstepping hierarchical sliding mode tracking control. The method's usefulness and aptitude for practical applications are demonstrated by numerical simulation results.
- **Optimality of Error Dynamics in Flight Guidance** [Report]
Prof. Mangal Kothari, Optimal Control and Reinforcement Learning (AE691) Aug. 2021 – Dec. 2021
 - The optimal convergence of the tracking error and an optimal error dynamics that achieves this optimal pattern as well as guarantees the finite-time convergence for guidance law design is proposed.
 - Developed laws will be compared with proportional navigation and guidance (PNG) and sliding motion control (SMC) to compare results and illustrate performance.
- **Improved Linear Quadratic Regulator for Spacecraft Docking using Krotov Conditions** [Report]
Prof. Dipak Giri Dec. 2019 – May. 2020
 - Designed control algorithm using Krotov conditions, overcoming issue of non-differentiability constraint for cost function in Hamilton-Jacobi-Bellman (HJB) equation solution.
 - Improved robustness of existing algorithm by developing global optimum solutions for mission scenarios under various parametric constraints in terminal docking phase.

Technical Projects

- **PetCAT** [Github]
Robotics Club, IIT Kanpur Apr. 2020 – Dec. 2020
 - Developed biologically inspired robot that mimics structure and behaviour of Cats under obstacle-avoidance team.
 - Implemented and tested a new method of Advanced Fuzzy Potential Field Method (AFPMPF) which solved the problem of local minimum field disturbances at low computation.

- **Autonomous Navigation in Rough Mars Terrain Environment** [Report] [Github]
Robotics Club, IIT Kanpur May. 2020 – Jul. 2020
 - Implemented and tested GPS and ArUco-marker based navigation on Mars environment in Gazebo using OpenCV and ROS.
 - Developed a new and efficient algorithm of combining Depth maps and A* algorithm for obstacle avoidance.
- **3D Shape Completion for Autonomous Vehicles** [Report]
Robotics Club, IIT Kanpur Sept. 2020 – Dec. 2020
 - Implemented Semantic Segmentation on KITTI data set using UNet for pixel segmentation to recognise objects.
 - Developed algorithms for completing and classifying the shape of 3D objects using point cloud.

Coursework

Core Aerospace Engineering: Space Dynamics^g, Flight Mechanics, Incompressible Aerodynamics*, Compressible Aerodynamics, Aerospace Structures, Air Breathing Propulsion, Solar System Mechanics^g, Introduction to Robotics

Control Systems: Classical Control System, Basics of Modern Control Systems^g, Non-linear Systems ^{*g}, Optimal Control and Reinforcement Learning^g

Mathematics: Partial Differential Equations*, Linear Algebra & ODE, Real Analysis & Multivariate Calculus, Complex Analysis

: Awarded A grade for exceptional performance, ^g: Graduate level Course

Technical Skills

Programming Skills: C/C++, Python, Bash

Robotics : ROS, basilisk, OpenCV, Gazebo, Rviz

Utilities: MATLAB, Simulink LabView, Linux, Git, Autocad, Arduino IDE, L^AT_EX

Framework: PyTorch, NumPy, Matplotlib

Language Skills

English: Full Professional Proficiency

Hindi: Native Proficiency

Achievements and Accolades

- Rank 3rd, Undergraduate Department position
- National top 1% in JEE Advanced (2019) among the 2.3 lakhs shortlisted candidates
- Recieved scholarship from MHRD, Government of India for being in top 5 percentile in Grade XII all over India.
- First position in National Science Congress'17 conducted by DST, GoV of India.
- National Rank 84 in National Science Talent Search Examination (NSTSE) conducted by Unified Council.

Management and Leadership Skills

Career Department Mentor – AnC Wing: Working in collaboration with the research wing and career development wings of the AnC council to assist them in organizing the sessions/workshops aimed at career prospects available in the department.

Coordinator – Anime Club: Manged the club and organized Anime quiz, Discussions and OST challenges in online mode.

Secretary – Research Wing: Organized Students' Research Convention (SRC'21) with participation from 50+ researchers across the nation.