

Kunal Garg

Postdoctoral Associate

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Research Interests

Distributed multi-agent motion planning and control, Provably safe control design using machine learning-based certificates, Constrained control synthesis using optimization methods, Finite-time stability theory for safe and robust control, Security of cyber-physical systems using control theory

Academic Positions

Massachusetts Institute of Technology

2022- Postdoctoral Associate in Department of Aeronautics and Astronautics

Advisor: [Prof. Chuchu Fan](#)

University of California, Santa Cruz

2021-22 Postdoctoral Scholar in Electrical and Computer Engineering department

Advisors: [Prof. Ricardo Sanfelice](#) and [Prof. Alvaro Cardenas](#)

Education

University of Michigan, Ann Arbor

2021 **Ph.D.**, Aerospace Engineering

Advisor: [Prof. Dimitra Panagou](#), Aerospace Engineering

Thesis: Advances in the Theory of Fixed-time Stability with Applications in Constrained Control and Optimization [[Thesis](#)] [[Defense video](#)]

2019 **M.S.E.**, Aerospace Engineering

Indian Institute of Technology, Bombay

2016 **Bachelor of Technology** with Honors

Major: Aerospace Engineering

Minor: Computer Science and Engineering

Advisor: Prof. Aditya Paranjape

Thesis: Flutter Mitigation using Active Feedback Control

Awards and Honors

DAAD AInet Fellow for the Postdoc-NeT-AI - AI and Robotics	2022
Richard and Eleanor Towner Prize for Distinguished Academic Achievement (UMich)	2021
Professor Pierre T. Kabamba Award for Excellence in control systems (UMich)	2021
Student Travel Grant for IEEE Conference on Decision and Control	2020, 2021
Student Travel Grant for Annual American Control Conference	2020, 2021
Best Student Paper Finalist, AIAA Guidance, Navigation and Controls Conference	2019
Tau Beta Pi member: Initiated at TBP-Michigan Gamma chapter	2017
Institute Silver Medal, Department Rank 1, IIT Bombay	2016
Institute Academic Prize for the years 2013-14 and 2014-15, IIT Bombay	
Merit-cum-Means Scholarship awarded by IIT Bombay	2012-16

Talks and Seminars

- Jan 2023 **DASC Lab Controls Conversations Seminar Series, Robotics Institute, University of Michigan, Ann Arbor**
Safe recovery of dynamical systems from actuator faults
- Sept 2022 **Mechanical Department Seminar Series, University of Maryland Baltimore County**
Robust safety and fixed-time stability for multiagent systems under spatiotemporal specifications
- June 2022 **Controls Talk, Mechanical Engineering, University of Texas at Dallas**
Fixed-time stability in constrained optimization and control with provable guarantees
- Apr 2022 **Postdoctoral Research Symposium, University of California, Irvine**
Provable security of cyber-physical systems under adversarial attacks
- Feb 2022 **William Maxwell Reed Seminar, University of Kentucky**
Constrained control for spatiotemporal requirements with provable guarantees
- Feb 2022 **AFOSR Center of Excellence in Assuring Autonomy in Contested Environments**
Sampling-based computation of viability domain to prevent safety violations by attackers
- Dec 2021 **MESA Engineering Program, University of California, Santa Cruz**
How to prepare an effective Statement of Purpose for grad-school applications
- Feb 2021 **Institute for Robotics and Intelligent Machines, Georgia Institute of Technology**
Fixed-time stability in multiagent control under input constraints
- Jan 2020 **Department of Systems and Control Engineering, IIT Bombay**
Prescribed-time control under spatiotemporal and input constraints: A QP-based approach

Mentorship Experience and DEI activities

2022- **Massachusetts Institute of Technology**

DEI Committee, Department of Aeronautics and Astronautics, MIT

- Served on the department committee, with duties including attending weekly meetings for bringing diverse voices and giving DEI presentations to various research labs
- Ideated a plan for creating a uniform onboarding of graduate students across department labs so that students can have a smooth transition to graduate school

Student Mentorship

- Organized communication and writing sessions for the new graduate student to help them learn the process of paper writing
- Mentored a first-year female undergraduate student on a year-long project, educating her on advanced control techniques and implementation of a novel safe distributed control algorithm on multiple ground rovers
- Guided five undergraduate students for Undergraduate Research Opportunities Program (UROP) in setting up multi-agent drone simulation and experimental framework
- Co-supervised an international high-school student on a project involving camera-based navigation of a drone to follow a target

2021-22 **University of California, Santa Cruz**

MESA Engineering Program, University of California, Santa Cruz

- Co-organized a workshop on “To Phd or not to PhD” with Prof. Pascale Garaud for scholars of applied math (SAM) students at USCS
- Panelist on STEM Hub Grad Student Panel and MEP Grad-school Panel
- Organized workshop on “How to write an effective SOP for grad-school applications”
- Mentored undergraduate students from diverse background for their career related questions

Graduate School Committee, Cal-Bridge

Objective: Increase the representation of historically underserved groups and first generation students in STEM Ph.D. programs.

- Assisted with students' questions regarding Ph.D. program, and reviewed their graduate school essays and NSF GRFP proposals.

Student Mentorship

- Guided and supervised Ph.D. students from Hispanic backgrounds in getting them started with research
- Supervised a Master's student with their thesis, helped them with design-of-experiment for a switched control design for performance improvement of a low-end quadrotor

2018-21 **University of Michigan, Ann Arbor**

Student Mentorship

- Guided and supervised new Ph.D. students on getting started with research and technical paper writing in the beginning of their doctoral studies
- Guided Master's students on projects such as development of RRT based motion planning algorithm for non-holonomic system and fixed-wing multi-agent motion planning
- Supervised three undergraduate students for Summer Undergraduate Research Program (SURP) on development of Gazebo simulation environment for visualization of motion planning algorithms

Research Experience

2022- **Conflict and Deadlock Resolution in Large-scale Multi-agent Systems**

Supervisor Prof. Chuchu Fan

- Key results
- Distributed hierarchical control framework for deadlock resolution, safe motion planning with connectivity maintenance in a large-scale multi-agent system in obstacle fields
 - RL-based high-level planner integrated with a GNN-CBF-based low-level controller for safe coordination in a distributed manner for scalability
 - Mid-level monitor for connectivity maintenance using CNN-based distributed connectivity predictor for making and breaking edges to efficiently achieve the team objective

2022- **Model-free Fault Detection and Identification**

Supervisor Prof. Chuchu Fan

- Key results
- Model-free output-based neural fault-detection and identification (FDI) framework
 - Better robustness to perturbations in system parameters as compared to model-based FDI
 - Safe recovery from faults using neural network FDI and control barrier functions-QP controller

2021-22 **Secure and Resilient Design of Internet of Battlefield Things**

Supervisors Prof. Alvaro Cardenas, Prof. Ricardo Sanfelice

- Key results
- Computationally effective method of computing a viability domain for safety under cyber-attacks
 - Control barrier function based effective attack detection mechanism for attack recovery
 - Temporal security for safety and convergence properties under finite-interval attacks

2017-21 **From High-Level Task Specifications to Geometric Control via Lyapunov Abstractions**

Supervisor Prof. Dimitra Panagou

- Key results
- QP based control design for constrained non-linear dynamical system using for complex missions involving STL based specification such as safety and fixed-time convergence
 - Robust control scheme for a multi-agent scenario involving safety and convergence requirements under additive disturbances and estimation uncertainties
 - Multiple-Lyapunov function based conditions for Finite-time stability of Switched and Hybrid systems under arbitrary switching and unstable subsystems

2019-21 **Fixed-time Optimization**

Collaborators Prof. Dimitra Panagou, Prof. Alfred Hero, Dr. Mayank Baranwal, Dr. Rohit Gupta

- Key results
- Fixed-time converging gradient flow-based optimization schemes for constrained and unconstrained convex optimization, and min-max problems
 - Novel fixed-time scheme for distributed optimization under relaxed assumptions on the objective functions; applications include large-scale SVM, economic dispatch
 - Fixed-time stable proximal dynamical systems for nonsmooth optimization problems

2016-18 **Trajectory Prediction of Multiagent Systems in Obstacle Environment**

Supervisor Prof. Dimitra Panagou

- Key results
- Distributed multi-agent collision avoidance algorithm under system uncertainties and partial information for quadrotors; implementation on Gazebo
 - Switched system based multi-agent motion planning algorithm for fixed-wing aircraft

Grant-writing Experience

Full proposal

ARL - Tactical Behaviors for Autonomous Maneuver Collaborative Research Program

Wrote a full proposal, titled “Resilient Tactical Maneuvers for Autonomous Robotic Vehicles” with Prof. Ricardo Sanfelice and Prof. Alvaro Cardenas

White paper

Co-authored a Mandatory Preliminary Proposal (MPP) for NASA STMD University Smallsat Technology Partnerships solicitation titled "In-Situ AI-based Safety Filtering and Self-Healing for Smallsat".

Wrote a white-paper for ONR and AFOSR, titled “Secure by Design: Provable Security for Cyber-Physical Systems”

Assistance with Proposal writing

Assisted Prof. Ricardo Sanfelice with an AFOSR proposal, wrote a few sections of the proposal and helped with proof reading

Teaching Experience

Guest lectures

California State Summer School for Mathematics & Science (COSMOS) (Jul 2021)

Took guest lectures for COSMOS Cluster 11 on “Feedback Control with Applications to Robotics”.

Graduate Teaching Certificate

Awarded by University of Michigan Center for Research on Learning & Teaching in Winter 2021 ([Description](#))

Graduate Student Instructor

[Fall '17] AEROSP 584: Navigation and Guidance of Aerospace Vehicles

[Winter '18, '19] EECS 562: Nonlinear Systems and Control

[Winter '20] AEROSP 740: Special Topics on Multi-agent Control

Undergraduate Student Assistant

[Fall '13] AE 152: Introduction to Aerospace Engineering

Publications

Journal

Burbano, L., **Garg, K.**, Leudo, S., Cardenas, A. A., Sanfelice, R. G., "[Online Attack Recovery in Cyber-Physical Systems](#)", IEEE Security and Privacy, 2023 (available in Early Access).

Garg, K., Baranwal, M., Gupta, R., and Benosman, M. "[Fixed-Time Stable Proximal Dynamical System for Solving Mixed Variational Inequality Problems](#)", IEEE Transactions on Automatic Control, 2023 (available in Early Access).

- Garg, K.**, Arabi, E., and Panagou, D., “[Fixed-time Control Under Spatiotemporal and Input Constraints: A Quadratic Programming Based Approach](#)”, *Automatica*, Vol 141, July 2022, 110314.
- Garg, K.**, Cosner, R. K., Rosoliya, U., Ames, A. D., and Panagou, D., “[Multi-rate Control Design under Input Constraints using Fixed-Time Barrier Functions](#)”, *IEEE Control Systems Letters*, Vol. 6, pp 608-613, 2022. [CDC Talk](#)
- Breeden, J., **Garg, K.**, and Panagou, D., “[Control Barrier Functions in Sampled-Data Systems](#)”, *IEEE Control Systems Letters*, Vol. 6, pp 367-372, 2022. [CDC Talk](#)
- Baranwal, M., **Garg, K.**, Panagou, D., and Hero, A. “[Distributed Fixed-Time Economic Dispatch under Time-Varying Topology and Uncertain Information](#)”, *IEEE Control Systems Letters*, Vol. 5, No. 4, pp 1183-1188, October 2021.
- Garg, K.**, and Panagou, D., “[Fixed-Time Stable Gradient Flows: Applications to Continuous-Time Optimization](#)”, *IEEE Transactions on Automatic Control*, Vol. 66, No. 5, pp 2002-2015, May 2021.
- Garg, K.**, and Panagou, D., “[Finite-Time Stability of Hybrid Systems with Unstable Modes](#)”, *Frontiers in Control Engineering*, 2:707729 , August 2021.
- Garg, K.**, and Baranwal, M., “[CAPP: Continuous-time Accelerated Proximal Point Algorithm for Sparse Recovery](#)”, *IEEE Signal Processing Letters*, Vol. 27, pp 1760-1764, September 2020.
- Garg, K.**, and Panagou, D., “[Finite-Time Estimation and Control for Multi-Aircraft Systems under Wind and Dynamic Obstacles](#),” *AIAA Journal of Guidance, Control, and Dynamics*, Vol. 42, No. 7, pp 1489-1505, July 2019.

Conference

- [**IFAC’23**] **Garg, K.**, Baranwal, M. “[Accelerating Distributed Optimization via Fixed-time Convergent Flows: Extensions to Non-convex Functions and Consistent Discretization](#)”, *IFAC World Congress*, 2023.
- [**ACC’23**] Leudo S. J., **Garg K.**, Sanfelice R. G. and Cardenas A. A., “[An Observer-based Switching Algorithm for Safety under Sensor Denial-of-Service Attacks](#)”, *American Control Conference* 2023.
- [**ICC’22**] **Garg, K.**, Baranwal, M., “[Fixed-Time Convergence For a Class of Nonconvex-Nonconcave Min-Max Problems.](#)”, *Indian Control Conference*, 2022.
- [**CDC’22**] **Garg, K.**, Sanfelice, R. G., Cardenas, A. A., “[Control barrier function based attack-recovery with provable guarantees](#)”, *IEEE Conference on Decision and Control*, 2022. [CDC Talk](#).
- [**CCTA’22**] **Garg, K.**, Cardenas, A. A., Sanfelice, R. G., “[Sampling based Computation of Viability Domain to Prevent Safety Violations by Attackers](#)”, *IEEE Conference on Control Technology and Applications* 2022. [CCTA Talk](#)
- [**AAAI’22**] Budhraja, P., Baranwal, M., **Garg, K.**, Hota, A., “[Breaking the Convergence Barrier: Optimization via Fixed-Time Convergent Flows](#),” *AAAI Conference on Artificial Intelligence* 2022.
- [**CDC’21**] **Garg, K.**, and Panagou, D., “[Finite-Time Stabilization of Switched Systems with Unstable Modes](#),” *60th IEEE Conference on Decision and Control*, December 2021. [CDC Talk](#)
- [**ACC’21**] **Garg, K.**, and Panagou, D., “[Robust Control Barrier and Control Lyapunov Functions with Fixed-Time Convergence Guarantees](#),” *Annual American Control Conference*, May 2021. [ACC Talk](#)
- [**ACC’21**] **Garg, K.**, and Panagou, D., “[Characterization of Domain of Fixed-time Stability under Control Input Constraints](#),” *Annual American Control Conference*, May 2021. [ACC Talk](#)
- [**CDC’20**] Black, M., **Garg, K.**, and Panagou, D., “[A Quadratic Program based Control Synthesis under Spatiotemporal Constraints and Non-vanishing Disturbances](#),” *59th IEEE Conference on Decision and Control*, December 2020. [CDC Talk](#)
- [**CDC’20**] Usevitch, J., **Garg, K.**, and Panagou, D., “[Strong Invariance Using Control Barrier Functions: A Clarke Tangent Cone Approach](#),” *59th IEEE Conference on Decision and Control*, December 2020 [CDC Talk](#).
- [**CDC’20**] **Garg, K.**, Baranwal, M., and Panagou, D., “[A Fixed-Time Convergent Distributed Algorithm for Strongly Convex Function in a Time-Varying Network](#),” *59th IEEE Conference on Decision and Control*, December 2020. [CDC Talk](#)

- [ACC'20] Garg, K., Arabi E., and Panagou, D., "[Prescribed-time convergence with input constraints: A control Lyapunov function based approach](#)," Annual American Control Conference, July 2020. **ACC Talk**
- [ACC'20] Arabi E., Garg, K., and Panagou, D., "[Safety-Critical Adaptive Control with Nonlinear Reference Model Systems](#)," Annual American Control Conference, July 2020.
- [CDC'19] Garg, K., and Panagou, D., "[Control-Lyapunov and Control-Barrier Functions based Quadratic Program for Spatio-temporal Specifications](#)," 58th IEEE Conference on Decision and Control, December 2019.
- [SciTech'19] Garg, K., and Panagou, D., "[Hybrid Planning and Control for Multiple Fixed-Wing Aircraft under Input Constraints](#)," **Best Student Paper Finalist**, AIAA Science and Technology (SciTech) Forum, January 2019.
- [CDC'18] Usevitch, J., Garg, K., and Panagou, D., "[Finite-Time Resilient Formation Control with Bounded Inputs](#)," 57th IEEE Conference on Decision and Control, December 2018.
- [ACC'18] Garg, K., and Panagou, D., "[New Results on Finite-Time Stability: Geometric Conditions and Finite-Time Controllers](#)," Annual American Control Conference, June 2018.
- [SciTech'18] Garg, K., and Panagou, D., "[A Robust Coordination Protocol for Safe Multi-Agent Motion Planning](#)," AIAA Science and Technology (SciTech) Forum, January 2018.
- [CDC'17] Garg, K., Han, D., and Panagou, D., "[Robust Semi-Cooperative Multi-Agent Coordination in the Presence of Stochastic Disturbances](#)," 56th IEEE Conference on Decision and Control, December 2017.

Poster/Workshop/other presentations

- [ACC '23] Leudo S. J., Garg K., Sanfelice R. G. and Cardenas A. A., "Hybrid Systems under Adversarial Scenarios", Poster presentation.
- [ICML'22] Garg, K., Baranwal, M. "Accelerating Distributed Optimization via Fixed-time Convergent Flows: Extensions to Non-convex Functions and Consistent Discretization", Workshop on Continuous Time Perspectives in Machine Learning in 2022 International Conference on Machine Learning.
- [CDC'22] Co-organizer and speaker: Workshop on "[Cyber-security in control of CPS: Recent developments and open challenges](#)" in IEEE Conference on Decision and Control 2022.

References

Available on request