Kunal Garg

Assistant Professor

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Fields of 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

Arizona State University

2025-   *Assistant professor, School for Engineering of Matter, Transport & Energy*

Massachusetts Institute of Technology

2022-24   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 PDF] [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 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, IIT Bombay	2014, 2015, 2016
Merit-cum-Means Scholarship awarded by IIT Bombay	2012-16

Research Projects

2023-   **Conflict and Deadlock Resolution in Large-scale Multi-agent Systems**

Supervisor   Prof. Chuchu Fan

Objective   *Safe motion planning for large-scale multi-agent system in obstacle fields*

- Proposed a hierarchical control framework for deadlock resolution
- Utilized large language models as high-level planners for intervention in deadlock and failure cases
- Designed a distributed low-level controller using graph neural networks
- Illustrated efficacy of the method on multi-robot hardware systems and in simulations with 1000+ agents

2022-23   **Model-free Fault Detection and Identification**

Supervisor   Prof. Chuchu Fan

Objective   *Recovery of autonomous systems from actuator faults*

- Proposed a model-free output-based neural fault-detection framework
- Obtained better robustness to perturbations in system parameters than model-based methods
- Illustrated safe recovery from faults for quadrotor systems

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

Supervisors   Prof. Ricardo Sanfelice, Prof. Alvaro Cardenas

Objective   *Provably secure-by-design control for cyber-physical systems*

- Proposed a novel computationally effective method of computing a viability domain
- Designed a control barrier function-based attack detection mechanism
- Characterized temporal security for safety under adversarial attacks

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

Supervisor   Prof. Dimitra Panagou

Objective   *Provably safe robust control design*

- Proposed a quadratic program-based framework for constrained control design
- Designed a robust control scheme for multi-agent scenarios with guaranteed safety
- Characterized relation between time of convergence, input constraints, and domain of attraction

2019-21   **Accelerated Methods for Convex Optimization**

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

Objective   *Accelerated methods for solving optimization problems*

- Proposed a fixed-time converging gradient flow-based optimization scheme for convex optimization
- Illustrated its applications to distributed optimization for large-scale machine learning problems
- Extended it to nonsmooth optimization problems

Teaching

Graduate Teaching Certificate (Description)

Awarded by University of Michigan Center for Research on Learning & Teaching in Winter 2021

Teaching Assistant

MIT Course 16.30/31: Feedback Control Systems   Fall '23

Role   Substitute lectures, creating assignments and exams, introduction of a drone-based lab component, weekly recitations and office hours

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

Role   Creating weekly assignments and final project

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

Role   Substitute lectures, weekly office hours and recitations, creating assignments and exams

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

Role   Substitute lectures, weekly office hours, creating assignments

IIT-B AE 152: Introduction to Aerospace Engineering   Fall '13

Role	Creating weekly assignments

Mentorship Experience and DEI Activities

2022- **Massachusetts Institute of Technology**

DEI Committee, Department of Aeronautics and Astronautics, MIT

- Attended weekly DEI committee meetings and gave DEI presentations to various research labs
- Ideated a plan for creating a uniform onboarding of graduate students across department labs

Student Mentorship

- Organized communication and writing sessions for graduate students
- Mentored a first-year female undergraduate student, Sera Hamilton, on a year-long project
- Submitted a robotics conference paper with Sera Hamilton based on her summer project
- Supervised an international high-school student on camera-based navigation of a drone

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

MESA Engineering Program, University of California, Santa Cruz

- Organized workshop on "How to write an effective SOP for grad-school applications"
- 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
- Mentored undergraduate students from diverse backgrounds with their career-related questions

Student Mentorship

- Guided 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**

President, Indian Student Association

- Arranged help sessions for international students to navigate the visa application process
- Organized cultural events to build the campus student community

Student Mentorship

- Guided new Ph.D. students in getting started with research and technical paper writing
- Guided several undergraduate and Master's students on projects related to motion planning

Grant-writing Experience

Full proposal

ARL - Scalable, Adaptive, and Resilient Autonomy (SARA) Collaborative Research Program

"Robust multi-agent cooperative agent planning and control using MARL equipped with neural barrier certificates", co-authored with Prof. Chuchu Fan

ARL - Tactical Behaviors for Autonomous Maneuver (TBAM) Collaborative Research Program

"Agile and risk-averse tactile maneuvering using adversarial sampling and neural control barrier functions", co-authored with Prof. Chuchu Fan

"Resilient Tactical Maneuvers for Autonomous Robotic Vehicles" co-authored with Prof. Ricardo Sanfelice and Prof. Alvaro Cardenas

White paper

"Robust Distributed Control and Mission Planning of Heterogeneous Robots in Dynamic and Partially Unknown Environments" with Prof. Chuchu Fan for ONR CAST program.

"In-Situ AI-based Safety Filtering and Self-Healing for Smallsat" with Prof. Chuchu Fan for NASA STMD University Smallsat Technology Partnerships solicitation.

"Secure by Design: Provable Security for Cyber-Physical Systems" with Prof. Ricardo Sanfelice and Prof. Alvaro Cardenas for ORN and AFOSR solicitations.

Talks and Seminars

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

Journal publications

Zhang, S., So, O., **Garg, K.**, Fan, C., "GCBF+: A Neural Graph Control Barrier Function Framework for Distributed Safe Multi-Agent Control", IEEE Transactions on Robotics, 2024, to appear.

Garg, K., Zhang, S., So, O., Dawson, C., Fan, C., "Learning Safe Control for Multi-Robot Systems: Methods, Verification, and Open Challenges ", Annual Reviews in Control, Vol. 57, 2024, 100948.

Garg, K., Usevitch, J., Breeded, J., Black, M., Agrawal, D., Parwana, H., Panagou, D., " Advances in the Theory of Control Barrier Functions: Addressing Practical Challenges in Safe Control Synthesis for Autonomous and Robotic Systems.", Annual Reviews in Control, Vol. 57, 2024, 100945.

Garg, K., Dawson, C., Xu, K., Ornik, M., Fan, C., "Model-free Neural Fault Detection and Isolation for Safe Control", IEEE Control Systems Letters, Vol. 7, pp. 3169-3174, 2023.

Burbano, L., **Garg, K.**, Leudo, S., Cardenas, A. A., Sanfelice, R. G., "Online Attack Recovery in Cyber-Physical Systems", IEEE Security and Privacy, Vol. 21, no. 4, pp. 20-28, Aug. 2023.

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, Vol. 68, no. 8, pp. 5029-5036, Aug. 2023.

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. Presentation video

Breeden, J., **Garg, K.**, and Panagou, D., "Control Barrier Functions in Sampled-Data Systems", IEEE Control Systems Letters, Vol. 6, pp 367-372, 2022. Presentation video

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., "CAPPA: 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 publications

[**CDC'24**] **Garg, K.**, Hamilton, S., Fan, C., "Deadlock Resolution in Multi-Agent Systems using Hierarchical Control", IEEE Conference on Decision and Control, 2024

[**CoRL'23**] Zhang, S., **Garg, K.**, Fan, C., "Neural Graph Control Barrier Functions Guided Distributed Collision-avoidance Multi-agent Control", Conference on Robot Learning, 2023.

[**Allerton'23**] **Garg, K.**, Fan, C., "Neural Network-based Fault Detection and Identification for Quadrotors using Dynamic Symmetry", Allerton Conference on Communication, Controls and Computing, 2023.

[**IFAC'23**] **Garg, K.**, Baranwal, M. "Accelerating Distributed Optimization via Fixed-Time Convergent Flows", 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," IEEE Conference on Decision and Control, 2021. **CDC Talk**

[**ACC'21**] **Garg, K.**, and Panagou, D., "Robust Control Barrier and Control Lyapunov Functions with Fixed-Time Convergence Guarantees," American Control Conference, 2021. **ACC Talk**

[**ACC'21**] **Garg, K.**, and Panagou, D., "Characterization of Domain of Fixed-time Stability under Control Input Constraints," American Control Conference, 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," IEEE Conference on Decision and Control, 2020. **CDC Talk**

[**CDC'20**] Usevitch, J., **Garg, K.**, and Panagou, D., "Strong Invariance Using Control Barrier Functions: A Clarke Tangent Cone Approach," IEEE Conference on Decision and Control, 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," IEEE Conference on Decision and Control, 2020. **CDC Talk**

[**ACC'20**] **Garg, K.**, Arabi E., and Panagou, D., "Prescribed-time convergence with input constraints: A control Lyapunov function based approach," American Control Conference, 2020. **ACC Talk**

[**ACC'20**] Arabi E., **Garg, K.**, and Panagou, D., "Safety-Critical Adaptive Control with Nonlinear Reference Model Systems," American Control Conference, 2020.

[**CDC'19**] **Garg, K.**, and Panagou, D., "Control-Lyapunov and Control-Barrier Functions based Quadratic Program for Spatio-temporal Specifications," IEEE Conference on Decision and Control, 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, 2019.

[**CDC'18**] Usevitch, J., **Garg, K.**, and Panagou, D., "Finite-Time Resilient Formation Control with Bounded Inputs," IEEE Conference on Decision and Control, 2018.

[**ACC'18**] **Garg, K.**, and Panagou, D., "New Results on Finite-Time Stability: Geometric Conditions and Finite-Time Controllers," American Control Conference, 2018.

[**SciTech'18**] **Garg, K.**, and Panagou, D., "A Robust Coordination Protocol for Safe Multi-Agent Motion Planning," AIAA Science and Technology (SciTech) Forum, 2018.

[**CDC'17**] **Garg, K.**, Han, D., and Panagou, D., "Robust Semi-Cooperative Multi-Agent Coordination in the Presence of Stochastic Disturbances," IEEE Conference on Decision and Control, 2017.

Other publications

Reports

Brat, G.P., Yu, H., Atkins, E., Sharma, P., Cofer, D., Durling, M., Meng, B., Alexander, C., Borgyos, S., Fan, C., **Garg, K.**, Topcu, U., Bakirtzis, G., 2023. Autonomy Verification & Validation Roadmap and Vision 2045 (No. NASA/TM-20230003734).

Poster

[**IROS'23**] **Garg, K.,** Fan, C., "Hierarchical Control Framework for Deadlock-free Multi-Agent Motion Planning", late breaking result poster, International Conference on Intelligent Robots and Systems (IROS) 2023.

[**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.

Conference workshop

[**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.

Submitted manuscripts

Garg, K., Arkin, J., Zhang, S., Roy, N., Fan, C., "Large Language Models to the Rescue: Deadlock Resolution in Multi-Robot Systems", IEEE Conference on Robotics and Automation, 2025.