

AMIT K. SANYAL

Office

216 Link Hall
Mechanical and Aerospace Engineering
Syracuse University
Syracuse, NY 13104
315-443-0466

Home

101 Turning Leaf Dr.
Manlius
NY 13104
315-692-2480
dr.asanyal@gmail.com

<http://eng-cs.syr.edu/our-departments/mechanical-and-aerospace-engineering/people/?peopleid=3261>

Research Interests and Applications

Navigation and Control of Spacecraft, Unmanned Vehicles and their Formations; Geometric Mechanics, Nonlinear and Geometric Control; Discrete Variational Mechanics; Optimal Control and Estimation; Robotics; Adaptive Control; Geometric/Algebraic methods in Nonlinear Systems; Dynamics of Multi-Body Systems; Nonlinearly Stable Data-driven Control.

Education

2001-2004 Ph.D. in Aerospace Engineering, University of Michigan, Ann Arbor, MI. Date of completion: August 2004.

Dissertation title: *Dynamics and Control of Multibody Systems in the Presence of Gravity*.

Co-Chairs: N. Harris McClamroch (Aerospace Engineering), Anthony M. Bloch (Mathematics).

2001-2004 Master of Science in Mathematics, University of Michigan, Ann Arbor, MI. Date of completion: December 2004.

Advisor: Anthony M. Bloch, Mathematics.

1999-2001 Master of Science in Aerospace Engineering, Texas A & M University, College Station, TX. Date of completion: May 2001.

Thesis title: *Geometrical Transformations in Higher Dimensional Euclidean Spaces*.

Chair: John L. Junkins, Aerospace Engineering.

1995-1999 Bachelor of Technology in Aerospace Engineering, Indian Institute of Technology, Kanpur, India. Project title: *Input Shaping Control of Flexible Spacecraft*, supervised by: Ashish Tewari.

Research and Teaching Experience

2015- *Associate Professor, Mechanical and Aerospace Engineering, Syracuse University, Syracuse, NY.* Adjunct appointment with Electrical Engineering and Computer Science.

Nonlinear control and estimation of unmanned vehicles and aerospace systems, geometric mechanics, geometric control, optimal control and estimation, robust data-driven control of uncertain autonomous systems.

Courses taught: *AEE 577, Spaceflight mechanics; MEE 725, Advanced Engineering Dynamics; MAE 700/728, Geometric and Optimal Control; MAE 600/AEE 630, Spacecraft Dynamics and Control; MAE 628, Linear Systems Theory.*

2010-2015 *Assistant Professor, Mechanical and Aerospace Engineering, New Mexico State University, Las Cruces, NM.*

Nonlinear control and estimation of spacecraft and unmanned vehicles, spacecraft rendezvous and proximity operations, coupled translational and rotational motion control for asteroid/comet proximity operations.

Courses taught: *AE 362, Orbital Mechanics; ME 452, Control System Design; AE 561/ME 405, Spacecraft Dynamics and Control; AE/ME 527, Control of Mechanical Systems; AE/ME 529, Non-linear and Optimal Control; ME 580 Numerical Analysis II.*

2007-2010 *Assistant Professor, Mechanical Engineering, University of Hawaii, Honolulu, HI.*

Nonlinear and optimal control and estimation of spacecraft, underwater vehicles, aircraft and mobile robots. Designed spacecraft attitude determination and control subsystem (ADCS) in the Hawaii Space Flight Laboratory.

Courses taught: *ME 451, Feedback Control Systems; ME 691, Graduate Seminar; ME 402, Dynamical Systems Laboratory; ME 651, Automatic Control; ME 696, Rigid Body Dynamics and Control.*

2004-2006 *Post-doctoral research associate, Arizona State University, Tempe, AZ.*

Discrete and continuous variational problems, optimal control and estimation for mechanical systems. Co-organizer of *Geometry, Control and Dynamical Systems Seminar*. Taught courses in control systems, linear algebra, and attitude determination and control.

2003-2004 *Research Assistant, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Control, dynamics, and numerical integration of nonlinear under-actuated mechanical systems, applying ideas from modern geometry and algebra. Emphasis on applications to the control of underactuated multibody spacecraft.

2002-2003 *Teaching Assistant, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Held some classes and office hours (6 hours/week) for junior year flight dynamics and control course. Developed solutions and formulated some problems for graded assignments.

2001-2002 *Research Fellow, Aerospace Engineering, University of Michigan, Ann Arbor, MI.*

Adaptive control and identification techniques applied to a tri-axial attitude control testbed. Used MATLAB/Simulink Real-time Workshop and WinCon control software (Quanser Consulting, Inc.), to interface between remote terminal and onboard PC104.

1999-2001 *Research Assistant, Aerospace Engineering, Texas A & M University, College Station, TX.*

Star pattern recognition for attitude determination using a CCD camera as star tracker, as part of StarNav experiment on space shuttle mission STS-107.

Honors and Awards

2001 Distinguished Graduate Student Masters Research Award, Texas A & M University.

2002 College of Engineering Fellowship, University of Michigan.

2003 Engineering Academic Scholar Certificate, College of Engineering, University of Michigan.

2012 Summer Faculty Fellow, Air Force Research Laboratory.

2015 Senior Member, AIAA and IEEE.

2021 Associate Fellow, AIAA.

2024 Visiting Faculty Research Fellow, Air Force Research Laboratory.

Professional Service

2004 Chair of session on Spacecraft Control, American Control Conference.

2008-2011 Member of AIAA Technical Committee on Guidance, Navigation and Control (GNC TC).

- 2009-** Member of IEEE technical committees on Aerospace Control and Nonlinear Systems.
- 2009** AIAA Guidance, Navigation and Control Conference: Chair of session titled “Spacecraft GN&C: Rendezvous and Proximity Operations.”
- 2010** AIAA Guidance, Navigation and Control Conference: Technical area co-chair for Sensor Systems; chair of session titled “Sensor Systems 1.”
- 2012** Co-chair of session on Estimation and Fault Detection, ASME Dynamic Systems and Control Conference.
- 2012** Organizer and co-chair of session on Geometric Control, IEEE Conference on Decision and Control.
- 2014** Organizer and chair of industry/applications tutorial session on Rendezvous, Proximity Operations and Capture of Space Objects, American Control Conference.
- 2014, 2015, 2018** International Program Committee, Indian Control Conference.
- 2015** Organizer and chair of session on Attitude and Pose Estimation, IEEE Conference on Decision and Control.
- 2010, 2016** Program Committee, IEEE Conference on Decision and Control.
- 2017** Co-chair of session “Control Applications II”, American Control Conference.
- 2020** Co-chair of session “Cooperative Control I”, American Control Conference.
- 2022** Chair of sessions “Learning in Nonlinear Systems” and “Robotics IV”, co-chair of session “Security and Estimation”, American Control Conference.

Professional Society Memberships

AIAA, ASME, IEEE, SIAM.

Funded Research Projects (Current and Past)

- *CPS: Small: NSF-DST: Autonomous Operations of Multi-UAV Uncrewed Aerial Systems using Onboard Sensing to Monitor and Track Natural Disaster Events*, NSF, 3/1/2024 to 2/28/2027, PI, \$453,372.
- *Collaborative Research: NRI: Integration of Autonomous UAS in Wildland Fire Management*, NSF (with Ohio State), 1/1/2022 to 12/31/2025, PI at Syracuse University, \$536,983.
- *A Platform-Independent Flight Management Unit for Small UAS*, Akrobotix LLC (flow through from NSF SBIR Phase 1), 2/1/2020 to 04/30/2021, PI, \$31,981.
- *Reliable Perception and Control for UAV Navigation in 3D Space*, Semiconductor Research Corporation, 2/1/2019 to 1/31/2022, Co-PI, \$299,638.
- *Enabling Multimodal Sensing, Real-time Onboard Detection and Adaptive Control for Fully Autonomous Unmanned Aerial Systems*, NSF Cyber-Physical Systems, 8/15/2017 to 8/14/2020, Co-PI, \$600,000.
- *Spacecraft Autonomous Rendezvous and Proximity Operations*, AFRL Summer Faculty Fellowship Program, July-August 2012 (8 weeks), \$12,400.
- *Reliable Perception and Control for UAV Navigation in 3D Space*, Semiconductor Research Corporation, 05/2019-04/2022, Co-PI, \$93,333.

- *CPS: Medium: Enabling Multimodal Sensing, Real-Time Onboard Detection and Adaptive Control for Fully Autonomous Unmanned Aerial Systems*, National Science Foundation, 10/2017-09/2021, Co-PI, \$533,000.
- *Towards Full Onboard Autonomy for Unmanned Vehicles in GPS-denied Environments*, Gryphon Sensors SRC Inc., 11/2016-12/2017, PI, \$74,826.
- *Guidance and Control of Low-Altitude Small Unmanned Aerial Vehicles in GPS-Denied Environments*, Syracuse University Center for Advanced Systems and Engineering, 02/2016-07/2017, PI, \$50,000.
- *Adaptive Singularity-Free Control Moment Gyroscope Cluster*, NMSU Arrowhead Launch program, 02/2015-01/2016, PI, \$30,000.
- *High Control Authority Variable Speed Control Moment Gyroscope*, Young Entrepreneurs Program, Air Force Research Laboratory, 03/2015-12/2015, PI, \$50,000.
- *Robust State and Uncertainty Estimation for Unmanned Systems in the Presence of External Uncertainties*, National Science Foundation, 09/2011-08/2014, PI, \$278,158.
- *Proximity Operations for Near-Earth Asteroid Exploration*, National Aeronautics and Space Administration, 09/2011-08/2015, Co-PI, \$749,980 (multi-institution, \$459,318 to NMSU).
- *Inclusion of Spacecraft Dynamics and Control in Aerospace Engineering Curriculum at NMSU*, NASA NM Space Grant Consortium, 09/2010-07/2012, PI, \$24,481.
- *Robust Estimation and Control of Small Spacecraft with Reconfigurable Sensors and Actuators*, NASA NM Space Grant Consortium, 09/2010-07/2012, PI, \$24,902.
- *Enhanced Advanced Intelligent Reconnaissance System (E-AIRS): Identification and tracking of targets from a UAV platform using visible range COTS cameras*, Hawaii Technology Development Venture, PI, 01/2010-12/2010, PI, \$35,000.

Research Papers

Research articles in journals or books

1. A. Dongare, R. Hamrah and A. K. Sanyal, “Finite-time Stable Pose Estimation on $SE(3)$ using Onboard Optical Sensors,” under revision for *Automatica*, an IFAC journal.
2. N. Wang, R. Hamrah, A. K. Sanyal and M. Glauser, “Geometric Extended State Observer on $TSE(3)$ with Fast Finite-Time Stability: Theory and Validation on a Rotorcraft Aerial Vehicle,” *Aerospace Engineering Science and Technology*, <https://doi.org/10.1016/j.ast.2024.109596>.
3. M. Bhatt, A. Sanyal, and S. Sukumar, “Asymptotically Stable Optimal Multi-rate Rigid Body Attitude Estimation based on Lagrange-d’Alembert Principle,” *Journal of Geometric Mechanics*, vol. 15(1), pp. 73-97, 2023.
4. H. Eslamiat, N. Wang, R. Hamrah, and A. K. Sanyal, “Geometric Integral Attitude Control on $SO(3)$,” *Electronics*, vol. 11(18), pn. 2821, 2022.
5. P. Cruz, P. Batista, and A. Sanyal, “Design and analysis of attitude observers based on the Lagrange-d’Alembert principle applied to constrained three-vehicle formations,” *Advances in Space Research*, vol. 69 (11), pp. 4001-4012, 2022.
6. M. Bhatt, S. Sukumar, and A. K. Sanyal, “Discrete-Time Rigid Body Pose Estimation Based on Lagrange-d’Alembert Principle,” *Journal of Nonlinear Science*, vol. 32, pn. 86, 2022.

7. C.-H. Chang, J. Casas, A. K. Sanyal, and V. Duenas, "Motorized FES-cycling and closed-loop non-linear control for power tracking using a finite-time stable torque algorithm," *Frontiers in Control Engineering*, vol. 3, 2022, doi: 10.3389/fcteg.2022.910126.
8. A. K. Sanyal, "Data-Driven Discrete-time Control with Hölder-Continuous Real-time Learning," *International Journal of Control*, vol. 95(8), pp. 2175-2187, 2022, doi: 10.1080/00207179.2021.1901993; arXiv version available at: <https://arxiv.org/abs/2006.05288>.
9. R. Hamrah and A. K. Sanyal, "Finite-time stable tracking control for an underactuated system in SE(3) in discrete time," *International Journal of Control*, vol. 95 (4), pp. 1106-1121, 2022, doi: 10.1080/00207179.2020.1841299.
10. R. Hamrah, R. R. Warier, and A. K. Sanyal, "Finite-time stable estimator for attitude motion in the presence of bias in angular velocity measurements," *Automatica*, vol. 132(10), 2021, doi: 10.1016/j.automatica.2021.109815.
11. X. Li, A. K. Sanyal, R. R. Warier, and D. Qiao, "Landing of hopping rovers on Irregularly-shaped small bodies using attitude control," *Advances in Space Research*, vol. 65(11), pp. 2674-2691, 2020, doi: 10.1016/j.asr.2020.02.029.
12. R. R. Warier, A. K. Sanyal, and S. P. Viswanathan, "Finite Time Stable Attitude Estimation of Rigid Bodies With Unknown Dynamics," *Asian Journal of Control*, vol. 21(4), pp. 1522-1530, 2019, doi: 10.1002/asjc.2089.
13. X. Li, R. R. Warier, A. K. Sanyal, and D. Qiao, "Trajectory Tracking Near Small Bodies Using Only Attitude Control and Orbit-Attitude Coupling," *AIAA Journal of Guidance, Control and Dynamics*, vol. 42(1), 2019, doi: 10.2514/1.G003653.
14. E. Samiei, M. Nazari, E. A. Butcher, and A. K. Sanyal, "Robust Stochastic Stabilization of Attitude Motion," *International Journal of Dynamics and Control*, vol. 7, pp. 619-635, 2019, doi: 10.1007/s40435-018-0465-5.
15. S. P. Viswanathan and A. K. Sanyal, "Adaptive Singularity-Free Control Moment Gyroscopes," *AIAA Journal of Guidance, Control and Dynamics*, vol. 41(11), 2018, doi: 10.2514/1.G003545.
16. M. Nazari, E. A. Butcher, and A. K. Sanyal, "Spacecraft Attitude Fractional Feedback Control Using Rotation Matrices and Exponential Coordinates," *AIAA Journal of Guidance, Control and Dynamics*, vol. 41(10), 2018, doi: 10.2514/1.G002956.
17. S. P. Viswanathan, A. K. Sanyal and E. Samiei, "Integrated Guidance and Feedback Control of Underactuated Robotics System in SE(3)," *Journal of Intelligent & Robotic Systems*, vol. 89, pp. 251-263, 2018, doi: 10.1007/s10846-017-0547-0.
18. A. Siravuru, S. P. Viswanathan, K. Sreenath and A. K. Sanyal, "The Reaction Mass Biped: Geometric Mechanics and Control," *Journal of Intelligent & Robotic Systems*, vol. 89, pp. 155-173, 2018.
19. E. Samiei, A. K. Sanyal and E. A. Butcher, "Stabilization of rigid body attitude motion with time-delayed feedback," *Aerospace Science and Technology*, vol. 68, pp. 509-517, 2017.
20. A. K. Sanyal and M. Izadi, "Stable Estimation of Rigid Body Motion Based on the Lagrange-d'Alembert Principle," in *Multisensor Attitude Estimation: Fundamental Concepts and Applications*, pp. 57-76, 2016, ed.: H. Fourati, CRC Press (Taylor and Francis), FL.
21. M. Izadi and A. K. Sanyal, "Rigid Body Pose Estimation based on the Lagrange-d'Alembert Principle," *Automatica*, vol. 71(9), pp. 78-88, 2016, doi: 10.1016/j.automatica.2016.04.028.

22. S. Brás, M. Izadi, C. Silvestre, A. Sanyal and P. Oliveira, “Nonlinear Observer for 3D Rigid Body Motion Estimation using Doppler Measurements”, *IEEE Transactions on Automatic Control*, vol. 61(11), pp. 3580-3585, 2016, doi: 10.1109/TAC.2016.2526671.
23. M. Nazari, E. Butcher, T. Yucelen and A. K. Sanyal, “Decentralized Consensus Control of a Rigid Body Spacecraft Formation in Orbit with Communication Delay,” *AIAA Journal of Guidance, Control and Dynamics*, vol. 39, pp. 838-851, 2016, doi: 10.2514/1.G001396.
24. G. Misra, M. Izadi, A. Sanyal and D. Scheeres, “Coupled Orbit-Attitude Dynamics of Spacecraft and Relative State Estimation During Exploration of Small Solar System Bodies,” *Advances in Space Research*, vol. 57(8), pp. 1747-1761, 2016, doi: 10.1016/j.asr.2015.05.023.
25. J. Bohn and A. K. Sanyal, “Almost global finite-time stabilization of rigid body attitude dynamics using rotation matrices,” *International Journal of Robust and Nonlinear Control*, 2016, vol. 26(9), pp. 2008-2022, doi: 10.1002/rnc.3399.
26. E. Samiei, E. A. Butcher, A. K. Sanyal and R. Paz, “Attitude Stabilization of Rigid Spacecraft with Minimal Attitude Coordinates and Unknown Time-varying Delay,” *Aerospace Science and Technology*, vol. 46, pp. 412-421, 2015, doi: 10.1016/j.ast.2015.08.007.
27. S. P. Viswanathan, A. K. Sanyal, F. Leve and N. H. McClamroch, “Dynamics and Control of Spacecraft with a Generalized Model of Variable Speed Control Moment Gyroscopes,” *ASME Journal of Dynamic Systems, Measurement and Control*, vol. 137(7), paper 071003, 2015, doi: 10.1115/1.4029626.
28. A. K. Sanyal and J. Bohn, “Finite Time Stabilization of Simple Mechanical Systems using Continuous Feedback,” *International Journal of Control*, vol. 88(4), pp. 783-791, 2015.
29. D. Lee, A. Sanyal, E. Butcher and D. Scheeres, “Finite-Time Control for Spacecraft Body-Fixed Hovering over an Asteroid”, *IEEE Transactions in Aerospace and Electronic Systems*, vol. 51(1), pp. 506-520, 2015, doi: 10.1109/TAES.2014.140197.
30. D. Lee, A. Sanyal and E. Butcher, “Asymptotic Tracking Control for Spacecraft Formation Flying with Decentralized Collision Avoidance,” *AIAA Journal of Guidance, Control and Dynamics*, vol. 38(4), pp. 587-600, 2015.
31. D. Lee, H. Bang, E. A. Butcher and A. K. Sanyal, “Kinematically Coupled Relative Spacecraft Motion Control using the State-Dependent Riccati Equation Method,” *ASCE Journal of Aerospace Engineering*, vol. 28(4), 2015, doi: 10.1061/(ASCE)AS.1943-5525.0000436.
32. D. Lee, E. A. Butcher and A. K. Sanyal, “Optimal interior Earth-Moon Lagrange point transfer trajectories using mixed impulsive and continuous thrust,” *Aerospace Science and Technology*, vol. 39, pp. 281-292, 2014.
33. D. Lee, A. Sanyal, E. Butcher and D. Scheeres, “Almost Global Asymptotic Tracking Control for Spacecraft Body-Fixed Hovering near an Asteroid,” *Aerospace Science and Technology*, vol. 38, pp. 105-115, 2014.
34. M. Izadi and A. K. Sanyal, “Rigid Body Attitude Estimation Based on the Lagrange-d’Alembert Principle,” *Automatica*, vol. 50(10), pp. 2570-2577, 2014.
35. D. Lee, H. Bang, A. Sanyal and E. Butcher, “Nonlinear Output Tracking and Disturbance Rejection for Autonomous Close Range Rendezvous and Docking of Spacecraft,” *Transactions of Japan Society for Aeronautical and Space Sciences*, vol. 57(4), pp. 225-237, 2014.

36. A. K. Sanyal and A. Goswami, "Dynamics and Balance Control of the Reaction Mass Pendulum (RMP): A 3D Multibody Pendulum with Variable Body Inertia," *ASME Journal of Dynamic Systems, Measurement and Control*, vol. 136(2), paper 021002, 2014.
37. D. Lee, E. Butcher and A. Sanyal, "Optimal mixed impulsive and continuous thrust trajectories to the interior Earth-Moon L1 Lagrange point," *Advances in the Astronautical Sciences*, vol. 148, pp. 3963-3982, 2013.
38. A. Weiss, I. Kolmanovsky, D. S. Bernstein, and A. Sanyal, "Inertia-Free Spacecraft Attitude Control Using Reaction Wheels," *AIAA Journal of Guidance, Control and Dynamics*, vol. 36(5), pp. 1425-1439, 2013.
39. M. C. Sorgenfrei, S. S. Joshi, and A. K. Sanyal, "Controller Gain-Tuning for a Small Spacecraft Attitude Tracking Maneuver Using a Genetic Algorithm," *Journal of Small Satellites*, vol. 2(1), pp. 105-118, 2013.
40. A. K. Sanyal and N. Nordkvist, "Attitude State Estimation with Multi-Rate Measurements for Almost Global Attitude Feedback Tracking," *AIAA Journal of Guidance, Control and Dynamics*, vol. 35(3), pp. 868-880, 2012.
41. A. M. Bloch, P. E. Crouch, N. Nordkvist and A. K. Sanyal, "Embedded geodesic problems and optimal control for matrix Lie groups," *Journal of Geometric Mechanics*, vol. 3(2), pp. 197-223, 2011.
42. N. A. Chaturvedi, A. K. Sanyal, and N. H. McClamroch, "Rigid Body Attitude Control: Using rotation matrices for continuous, singularity-free control laws", *IEEE Control Systems Magazine*, vol. 31(3), pp. 30-51, 2011.
43. A. K. Sanyal, *Dynamics and Control of Multibody Systems in Central Gravity: Using Internal Motion to Control Attitude and Orbit*, Lambert Academic Publishing, 2011.
44. A. K. Sanyal, N. Nordkvist and M. Chyba, "An Almost Global Tracking Control Scheme for Maneuverable Autonomous Vehicles and its Discretization," *IEEE Transactions on Automatic Control*, vol. 56(2), pp. 457-462, 2011.
45. I. Kolmanovsky, T. Lee, A. Sanyal and J. Shen, "HarrisFest [Conference Reports]," *IEEE Control Systems Magazine*, vol. 30(5), pp. 81-83, 2010, doi: 10.1109/MCS.2010.937816.
46. A. K. Sanyal, A. Fosbury, N. A. Chaturvedi, and D. S. Bernstein, "Inertia-Free Spacecraft Attitude Tracking with Disturbance Rejection and Almost Global Stabilization," *AIAA Journal of Guidance, Control and Dynamics*, vol 32(4), pp. 1167-1178, 2009.
47. A. K. Sanyal, C. Moseley, and A. M. Bloch, "Analytical and Numerical Solution of a Sub-Riemannian Optimal Control Problem with Applications to Quantum Spin Systems," *Comm. Information and Systems*, special issue dedicated to Roger Brockett on his 70th birthday, vol 9(1), pp. 59-76, 2009.
48. A. M. Bloch, I. I. Hussein, M. Leok, and A. K. Sanyal, "Geometric structure-preserving Optimal Control of the Rigid Body," *Journal of Dynamical and Control Systems*, vol. 15, no. 3, pp. 307-330, 2009.
49. A. K. Sanyal, A. M. Bloch, P. E. Crouch, and J. E. Marsden, "Optimal Control and Geodesics on Quadratic Matrix Lie Groups," *Foundations of Computational Mathematics*, vol 8(4), pp. 469-500, 2008.
50. A. K. Sanyal, T. Lee, M. Leok, and N. H. McClamroch, "Global Optimal Attitude Estimation using Uncertainty Ellipsoids," *Systems and Control Letters*, vol 57(3), pp. 236-245, 2008.

51. A. M. Bloch, P. E. Crouch, and A. K. Sanyal, “A Variational Problem on Stiefel Manifolds,” *Nonlinearity*, vol 19(10), pp. 2247-2276, 2006.
52. N. A. Chaturvedi, A. K. Sanyal, M. Chellapa, Jean L. Valk, N. H. McClamroch, and D. Bernstein, “Adaptive Tracking of Angular Velocity for a Planar Rigid Body with Unknown Models for Inertia and Input Nonlinearity,” *IEEE Transactions on Control Systems Technology*, vol 14(4), pp. 613-627, 2006.
53. A. K. Sanyal, J. Shen, A. M. Bloch, and N. H. McClamroch, “Stability and Stabilization of Relative Equilibria of Dumbbell Bodies in Central Gravity,” *AIAA Journal of Guidance, Control and Dynamics*, vol 28(5), pp. 833-842, 2005.
54. A. K. Sanyal, A. M. Bloch, and N. H. McClamroch, “Dynamics of multibody systems in planar motion in a central gravitational field,” *Dynamical Systems*, vol. 19(4), pp. 303-343, 2004.
55. J. Shen, A. K. Sanyal, and N. H. McClamroch, “Asymptotic Stability of Multibody Attitude Systems,” *Stability and Control of Dynamical Systems with Applications*, D. Liu and P. J. Antsaklis, Eds., Birkhäuser, Boston, 2003.
56. A. K. Sanyal, A. Verma, and J. L. Junkins, “Adaptation and Cooperation in Control of Multiple Robot Manipulators,” *Journal of Astronautical Sciences*, Vol. 48(2,3), pp. 305-336, 2000.

Refereed conference papers

1. N. Srinivasu, A. Dongare and A. K. Sanyal, “Variational Observer Designs on Lie Groups, with Applications to Rigid Body Motion Estimation,” to appear in *IEEE Conference on Decision and Control*, Milan, Italy, December 2024.
2. N. Wang and A. K. Sanyal, “Robust and finite-time stable model-free control for second order systems without velocity measurements,” to appear in *IEEE Conference on Decision and Control*, Milan, Italy, December 2024.
3. N. Srinivasu, Z. He and A. K. Sanyal, “A Variational Observer on Spheres and its Application to Pointing Direction Motion Estimation,” to appear in *IEEE Conference on Decision and Control*, Milan, Italy, December 2024.
4. N. Wang, R. Hamrah and A. K. Sanyal, “Robust and Hölder-continuous finite-time stabilization of rigid body attitude dynamics using rotation matrices,” *American Control Conference*, Toronto, ON, Canada, pp. 3999-4004, July 2024.
5. A. K. Sanyal, “Variational Estimation for Mechanical Systems on Lie Groups Based on Geometric Mechanics,” *IFAC Workshop on Lagrangian and Hamiltonian Methods for Nonlinear Control*, Besançon, France, June 2024.
6. A. Dongare, R. Hamrah, and A. K. Sanyal, “Finite-time Stable Pose Estimation on SE(3) using Onboard Optical Sensors,” *AIAA SCITECH 2024 Forum*, Orlando, FL, Jan 2024.
7. A. Dongare, A. K. Sanyal, and R. Hamrah, “Discrete-time Control of Nonlinear Control-Affine Systems with Uncertain Dynamics,” *9th Indian Control Conference*, Visakhapatnam, India, Dec 2023.
8. D. Hadley, A. Hoff, A. Tricarico, and A. K. Sanyal, “A Case Study on Gravitational Orbit-Attitude Coupling of Spacecraft near Small Bodies,” *AAS/AIAA Astrodynamics Specialist Conference*, Big Sky, MT, Aug 2023.

9. A. Dongare, R. Hamrah, I. Kolmanovsky and A. K. Sanyal, "Reference Governor for Constrained Data-Driven Control of Aerospace Systems with Unknown Input-Output Dynamics," *7th IEEE Conference on Control Technology and Applications*, Barbados, Aug 2023.
10. J. Cheng, Y. G. Alqaham, A. Sanyal and Z. Gan, "Practice Makes Perfect: An Iterative Approach to Achieve Precise Tracking for Legged Robots," *American Control Conference*, San Diego, CA, May-June 2023.
11. N. Wang, M. Glauser, and A. K. Sanyal, "Turbulent flows and UAV flight test with fan array wind tunnel," *75th Annual Meeting of the Division of Fluid Dynamics*, American Physical Society, Indianapolis, IN, November 2022.
12. N. Wang and A. K. Sanyal, "A Hölder-continuous Extended State Observer for Rigid Body Attitude Dynamics," *22nd IFAC Symposium on Automatic Control in Aerospace ACA 2022*, Mumbai, India, pp. 340-345, October 2022.
13. P. Bhale, M. Kumar, and A. K. Sanyal, "Finite-time stable disturbance observer for unmanned aerial vehicles," *American Control Conference*, Atlanta, GA, pp. 5010-5015, June 2022.
14. A. Dongare, A. K. Sanyal, I. Kolmanovsky, and S. P. Viswanathan, "Integrated Guidance and Control of Driftless Control-affine Systems with Control Constraints and State Exclusion Zones," *American Control Conference*, Atlanta, GA, pp. 3893-3898, June 2022.
15. S. Teng, A. K. Sanyal, R. Vasudevan, A. Bloch, and M. Ghaffari, "Input Influence Matrix Design for MIMO Discrete-Time Ultra-Local Model," *American Control Conference*, Atlanta, GA, pp. 2730-2735, June 2022.
16. G. Catry, A. Thurling, N. Bosson, A. Dzodic, P. Le Porin, N. Wang, A. K. Sanyal, F. Noca, M. N. Glauser, "Development of a Free-Flight Wind Test Facility Featuring a GNSS Simulator to Achieve Immersive Drone Testing," *AIAA SCITECH 2022 Forum*, San Diego, CA, Jan 2022.
17. N. Wang, C. W. R. Kjellberg, G. Catry, N. Bosson, A. K. Sanyal and M. Glauser, "Turbulent flows generated by fan array wind tunnel," *74th Annual Meeting of the Division of Fluid Dynamics*, American Physical Society, Phoenix, AZ, November 2021.
18. H. Eslamiat, A. K. Sanyal, and C. Lindsay, "Discrete Time Optimal Trajectory Generation and Transversality Condition with Free Final Time," *2021 Int. Conference on Unmanned Aircraft Systems*, Athens, Greece, July 2021.
19. P. Cruz, P. Batista, and A. K. Sanyal, "Attitude observers for three-vehicle heterogeneous formations based on the Lagrange-d'Alembert principle," *European Control Conference*, Rotterdam, Netherlands, June-July 2021.
20. A. Dongare, R. Hamrah, and A. K. Sanyal, "Attitude Pointing Control using Artificial Potentials with Control Input Constraints," *American Control Conference*, New Orleans, LA, pp. 1-6, May 2021.
21. N. Wang, and A. K. Sanyal, "A Hölder-continuous Extended State Observer for Model-free Position Tracking Control," *American Control Conference*, New Orleans, LA, pp. 2133-2138, May 2021.
22. M. Bhatt, S. Sukumar, and A. K. Sanyal, "Rigid Body Geometric Attitude Estimator using Multi-rate Sensors," *IEEE Conference on Decision and Control*, Jeju Island, Korea, pp. 1511-1516, Dec 2020, doi: 10.1109/CDC42340.2020.9304059.
23. N. Wang, J. E. van der Elst, A. Sanyal, M. Glauser, "Multirotor Unmanned Aerial Vehicle (UAV) Flight Performances under Shear Flow Turbulence with Different Control Schemes," *73rd Annual Meeting of the Division of Fluid Dynamics*, American Physical Society, virtual (online), Nov 2020.

24. A. Dongare, A. K. Sanyal, H. Eslamiat, S. P. Viswanathan, "Guidance and Tracking Control for Rigid Body Attitude using Time-varying Artificial Potentials," *AAS/AIAA Astrodynamics Specialist Conference*, Lake Tahoe, NV, pp. 617-629, August 2020.
25. C. Chang, V. H. Duenas, and A. Sanyal, "Model free nonlinear control with finite-time estimation applied to closed-loop electrical stimulation induced cycling," *American Control Conference*, Denver, CO, pp. 5182-5187, July 2020, doi: 10.23919/ACC45564.2020.9147327.
26. R. Hamrah, A. K. Sanyal, and S. P. Viswanathan, "Discrete finite-time stable attitude tracking control of unmanned vehicles on $SO(3)$," *American Control Conference*, Denver, CO, pp. 824-829, July 2020, doi: 10.23919/ACC45564.2020.9147657.
27. M. Maadani, E. A. Butcher, and A. K. Sanyal, "Finite-time attitude consensus control of a multi-agent rigid body system," *American Control Conference*, Denver, CO, pp. 877-882, July 2020.
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29. N. Wang, R. Hamrah, and A. K. Sanyal, "A Finite-Time Stable Observer for Relative Attitude Estimation," *IEEE Conference on Decision and Control*, Nice, France, pp. 7911-7916, Dec 2019.
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33. Y. Li, H. Li, Z. Li, H. Fang, A. K. Sanyal, Y. Wang, and Q. Qiu, "Fast and Accurate Trajectory Tracking for Unmanned Aerial Vehicles based on Deep Reinforcement Learning," *IEEE International Conference on Embedded and Real-Time Computing Systems and Applications*, Hangzhou, China, Aug 2019.
34. M. H. Dhullipalla, R. Hamrah, R. R. Warier, and A. K. Sanyal, "Trajectory Generation on $SE(3)$ for an Underactuated Vehicle with Pointing Direction Constraints," *American Control Conference*, Philadelphia, PA, pp. 1930-1935, July 2019.
35. A. K. Sanyal and H. Eslamiat, "Target Localization Using Mobile Sensors and a Decentralized and Distributed Variational Estimator," *22nd International Conference on Information Fusion (FUSION)*, Ottawa, Canada, pp. 1-7, July 2019.
36. A. K. Sanyal, R. R. Warier, and R. Hamrah, "Finite Time Stable Attitude and Angular Velocity Bias Estimation for Rigid Bodies With Unknown Dynamics," *European Control Conference*, Naples, Italy, pp. 4047-4052, June 2019.
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39. R. R. Warier, A. K. Sanyal and S. P. Viswanathan, "Discrete-Time Optimal Trajectory Generation Through Multiple Waypoints," *Indian Control Conference (ICC)*, Delhi, India, pp. 342-346, January 2019.
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41. M. Izadi, A. K. Sanyal and R. R. Warier, "Variational Attitude and Pose Estimation Using the Lagrange-d'Alembert Principle," *IEEE Conference on Decision and Control*, Miami Beach, FL, pp. 1270-1275, December 2018.
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43. R. R. Warier, A. K. Sanyal, M. H Dhullipalla, and S.P. Viswanathan, "Trajectory Tracking Control For Underactuated Thrust-Propelled Aerial Vehicles," *2nd IFAC Conference on Modelling, Identification and Control of Nonlinear Systems (MICNON), IFAC-PapersOnLine*, Guadalajara, Mexico, vol. 51(3), pp. 555-560, June 2018.
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45. R. R. Warier, A. K. Sanyal, M. H Dhullipalla, and S.P. Viswanathan, "Finite-Time Stable Trajectory Tracking And Pointing Control For A Class of Underactuated Vehicle in SE(3)," *Indian Control Conference*, Kanpur, India, pp. 190-195, January 2018.
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49. S. P. Viswanathan, A. K. Sanyal and M. Izadi, "Integrated Guidance and Nonlinear Feedback Control of Underactuated Vehicles in SE(3)", *AIAA Guidance, Navigation, and Control Conference, AIAA SciTech Forum*, AIAA 2017-1044, January 2017.
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51. E. A. Butcher, M. Nazar, A. Dabiri, A. K. Sanyal, "Fractional PID control of spacecraft attitude dynamics using rotation matrices," *Proc. of International Astronautical Congress (IAC)*, Guadalajara, Mexico, September 2016.

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53. M. Izadi, S. P. Viswanathan, A. K. Sanyal, C. Silvestre and P. Oliveira, "The Variational Attitude Estimator in the Presence of Bias in Angular Velocity Measurements," *American Control Conference*, Boston, MA, pp. 4065-4070, July 2016.
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61. E. Samiei, M. Izadi, S. P. Viswanathan, A. K. Sanyal, and E. A. Butcher, "Robust Stabilization of Rigid Body Attitude Motion in the Presence of a Stochastic Input Torque," *IEEE International Conference on Robotics and Automation*, Seattle, WA, pp. 428-433, May 2015.
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63. E. Samiei, A. K. Sanyal, and E. A. Butcher, "Asymptotic Stabilization of Rigid Body Attitude Motion in the Presence of Unknown Time Delay in Feedback", *Indian Control Conference*, Chennai, India, pp. 209-214, January 2015.
64. S. P. Viswanathan, A. Sanyal and M. Izadi, "Mechatronics Architecture of Smartphone-Based Spacecraft ADCS using VSCMG Actuators", *Indian Control Conference*, Chennai, India, pp. 310-315, January 2015.
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66. A. K. Sanyal, M. Izadi and J. Bohn, "An Observer for Rigid Body Motion with Almost Global Finite-time Convergence", *ASME Dynamic Systems and Control Conference*, San Antonio, TX, October 2014.
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72. S. P. Viswanathan, A. K. Sanyal and F. Leve, "A General Dynamics Model for Spacecraft with Variable Speed Control Moment Gyroscopes," *AIAA/AAS Space Flight Mechanics Meeting*, Santa Fe, NM, Jan 2014.
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75. M. Izadi, J. Bohn, D. Lee, A. K. Sanyal, E. Butcher and D. J. Scheeres, "A Nonlinear Observer Design for a Rigid Body in the Proximity of a Spherical Asteroid," *ASME Dynamic Systems and Control Conference*, Stanford, CA, Oct 2013, DSCC2013-4085.
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83. M. Sorgenfrei, A. K. Sanyal and S. Joshi, "Preliminary Optimization Results for an Almost Globally Stable Control Law Using a Genetic Algorithm", *AIAA Guidance, Navigation and Control Conference*, Minneapolis, MN, Aug 2012, AIAA-2012-4558.
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87. N. Nordkvist and A. Sanyal, "A Lie Group Variational Integrator for Rigid Body Motion in SE(3) with Applications to Underwater Vehicle Dynamics," *IEEE Conference on Decision and Control*, Atlanta, GA, pp. 5414-5419, Dec 2010.
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91. A. K. Sanyal and M. Chyba, "Robust Feedback Tracking of Autonomous Underwater Vehicles with Disturbance Rejection," *Proc. of American Control Conference*, St. Louis, MO, pp. 3585-3590, Jun 2009.
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94. A. K. Sanyal, "Almost Global Robust Attitude Tracking Control of Rigid Bodies in Gravity," *18th International Symposium on Mathematical Theory of Networks and Systems*, July 27-30, Blacksburg, VA, 2008.
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96. T. Lee, M. Leok, N. H. McClamroch, and A. Sanyal, "Global Attitude Estimation using Single Direction Measurements," *Proc. of 2007 American Control Conference*, New York, NY, pp. 3659-3664, Jun 2007.

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99. A. K. Sanyal, "Optimal Attitude Estimation and Filtering Without Using Local Coordinates, Part I: Uncontrolled and Deterministic Attitude Dynamics," *Proc. of 2006 American Control Conference*, Minneapolis, MN, pp. 5734-5739, Jun 2006.
100. A. K. Sanyal, A. M. Bloch, and N. H. McClamroch, "Control of Mechanical Systems with Cyclic Coordinates using Higher Order Averaging," *Proc. of the 44th IEEE Conference on Decision and Control*, Seville, Spain, pp. 6835-6840, Dec 2005.
101. N. A. Chaturvedi, F. Bacconi, A. K. Sanyal, D. Bernstein and N. H. McClamroch, "Stabilization of a 3D Rigid Pendulum," *Proc. of 2005 American Control Conference*, Portland, OR, pp. 3030-3035, Jun 2005.
102. A. K. Sanyal, and A. M. Bloch, "Two Connected Bodies in a Central Gravitational Field," *Proc. of the 43rd IEEE Conference on Decision and Control*, Paradise Island, Bahamas, pp. 3968-3973, Dec 2004.
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105. A. K. Sanyal, J. Shen, and N. H. McClamroch, "Dynamics and Control of an Elastic dumbbell Spacecraft in a Central Gravitational Field," *Proc. of 42nd IEEE Conference on Decision and Control*, Maui, HI, pp. 2798-2803, Dec 2003.
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107. J. Shen, A. K. Sanyal, and N. H. McClamroch, "Asymptotic Stability of Rigid Body Attitude Systems," *Proc. of 42nd IEEE Conf. on Decision and Control*, Maui, HI, pp. 544-549, Dec 2003.
108. A. K. Sanyal, and D. S. Bernstein, "Globally Convergent Adaptive Tracking of Spacecraft Angular Velocity," *Proc. of the 13th IFAC Symposium on System Identification*, Rotterdam, The Netherlands, August 2003.
109. J. Shen, A. K. Sanyal, and N. H. McClamroch, "Controllability Analysis of a Two Degree of Freedom Nonlinear Attitude Control System," *15th International Symposium on Mathematical Theory of Networks and Systems*, South Bend, IN, August 2002.

Invited Talks, Conference and Workshop Presentations (without Proceedings)

1. A. K. Sanyal, "Orbit Determination for LEO Objects from Short Arc Measurements", research presentation at Air Force Research Laboratory, Griffiss Institute, Rome, NY, June 2024.

2. A. K. Sanyal, "Guidance, Navigation and Control for 3D Motion of Aerospace Vehicles," research presentation at Air Force Research Laboratory (AFRL) Workshop, College of Engineering and Computer Science, Syracuse University, NY, September 2022.
3. A. K. Sanyal, "Challenges and Directions in Guidance, Navigation and Control of Autonomous Aerospace Vehicles," research presentation at Ohio State University's Mechanical and Aerospace Engineering Department Seminar, Columbus, OH, March 2022.
4. A. K. Sanyal, "Autonomous Aerospace Vehicles: Challenges, Directions and Impacts," research presentation for Autonomous Systems Policy Institute at Syracuse University, Syracuse, NY, February 2022.
5. A. K. Sanyal, "The Quest for Greater Autonomy in Aerospace and Robotics: Putting Good Theory to Good Practice," research presentation for AIAA Syracuse University Chapter: Meet the Faculty Series, Syracuse, NY, October 2020.
6. A. K. Sanyal, "Finite-time Stability in Discrete Time and Its Uses," research presentation at Indian Institute of Technology, Bombay, India, July 2019.
7. A. K. Sanyal, "Control and Autonomy in the Age of Cyber-Physical Systems," research presentation at University of Michigan's College of Engineering Controls Seminar, Ann Arbor, MI, March 2018.
8. A. K. Sanyal, "Trajectory Generation and Control for a Class of Unmanned Vehicles in SE(3)," research presentation at Indian Institute of Technology, Bombay, India, July 2017.
9. A. K. Sanyal, "Guidance, Navigation and Control for Maneuverable Unmanned Vehicles," research presentation at Center for Advanced Systems and Engineering (CASE), Syracuse University, Syracuse, NY, February 2016.
10. A. K. Sanyal, "Reliable Operations with Collision Avoidance in Unmanned Vehicles," research presentation at George Washington University's Mechanical and Aerospace Engineering department seminar, Washington DC, October 2015.
11. A. K. Sanyal, "Reliable Operations with Collision Avoidance in Unmanned Vehicles," research presentation at Mechanical and Aerospace Engineering department seminar, Syracuse University, Syracuse, NY, October 2015.
12. A. K. Sanyal, "Dynamics, Control and Estimation of Robotic Spacecraft: How Good Theory Can Lead to Good Practice," research presentation at University of Arizona, Tucson, AZ, January 2015.
13. A. K. Sanyal, "Navigation and Control of Spacecraft in Proximity Operations: How Good Theory can Lead to Good Practice," research presentation at NASA Langley Research Center, Hampton, VA, July 2014.
14. A. K. Sanyal, "Robust State Estimation and Control for Small Spacecraft Using Geometric Mechanics," research presentation at NASA Ames Research Center, Mountain View, CA, May 2013.
15. A. K. Sanyal, "Physics, Mathematics and their Roles in Aerospace Control," research presentation at Air Force Research Laboratory, Space Vehicles Directorate, Kirtland AFB, NM, August 2012.
16. A. K. Sanyal, "Riccati Equation, Flexible Spacecraft and Variational Integrators: The trajectory of N. Harris McClamroch in Nonlinear Dynamics and Control," *HarrisFest: on the retirement occasion of N. Harris McClamroch*, University of Michigan, May 2010 (also reported on IEEE Control Systems Magazine, July 2010).

17. A. K. Sanyal, S. B. Singh, and N. Nordkvist, “Numerical Simulation of an Almost Global Attitude Tracking Control Scheme Using a Lie Group Variational Integrator,” SIAM Conference on Control and Applications, Denver, CO, 2009.
18. A. K. Sanyal, T. Lee, M. Leok, and N. H. McClamroch, “A Geometric Method for Global Optimal Attitude Estimation,” 44th Annual Technical Meeting of the Society of Engineering Science, College Station, TX, 2007.
19. A. K. Sanyal, “Sub-Riemannian Optimal Control of a Three-Spin Quantum System,” 44th Annual Technical Meeting of the Society of Engineering Science, College Station, TX, 2007.
20. A. M. Bloch, P. E. Crouch, and A. K. Sanyal, “A Variational Problem on Stiefel Manifolds,” SIAM Conference on Applications of Dynamical Systems, Snowbird, UT, 2005.

Intellectual Property and Entrepreneurship

- *High Control Authority Variable Speed Control Moment Gyroscope*, patent application filed January 2015, patent granted February 2019, Patent No.: US 10,202,208 B1.
- *Robustly Stable Autonomous Vision-Inertial Navigation System (ROSAVINS) for Unmanned Vehicles*, patent application filed September 2017, patent granted March 2020, Patent No.: US 10,578,457 B2.
- *Co-founder and owner of Akrobotix LLC*, one of six winners of Genius NY business accelerator program, January 2017.

Reviewer for

- Several journals including: *AIAA Journal of Guidance, Control and Dynamics; Advances in Space Research; Aerospace Science and Technology; ASME Journal of Dynamic Systems, Measurement and Control; Automatica; IEEE Transactions on Automatic Control; IEEE Transactions on Control Systems Technology; IEEE Transactions on Aerospace and Electronic Systems; Journal of Geometric Mechanics; Journal of the Franklin Institute; Journal of Nonlinear Science; Journal of Small Satellites (online); SIAM Journal on Control and Optimization; Systems and Control Letters; Royal Society Proceedings-A.*
- Conference reviewer for: *AIAA Guidance Navigation and Control Conference, American Control Conference, IEEE Conference on Decision and Control, ASME Dynamic Systems and Control Conference, Int. Symp. on Mathematical Theory of Networks and Systems, International Conference on Robotics and Automation, IFAC conferences, Indian Control Conference*

Proposal Reviewer for NSF, AFOSR, NASA, ARO, DHS.

Editorial Board Memberships

- *Aerospace Science and Technology* (2009-2020)
- *ASME Journal of Dynamic Systems, Measurement and Control* (2019-current)
- *IEEE Transactions on Aerospace and Electronic Systems* (2020-2022)
- *IEEE Control Systems Society Conference Editorial Board* (2019-current)

Students Mentored in Research

- *Current:*
 - PhD students: N. Safaiei, N. Srinivasu, Z. Yu.

- MS students: Z. He, J. Zhao.
- BS students: C. Cline, D. F. Forschino.

- *Past:*

- PhD students: A. Dongare, N. Wang (co-advised with M. Glauser), R. Hamrah, H. Eslamiat, J. Bohn, S. P. Viswanathan, M. Izadi, and E. Samiei (co-advised with E. Butcher).
- MS students: B. A. Ratzlaff, H. Qian, N. Wang, S. Singh, A. Dongare, C. Hadjidimoulas, T. Hanrahan, V. McGovern, A. Butkus, G. Misra, S. P. Vishwanathan, J. Bohn, L. Holguin, E. Gregory, Z. Lee-Ho and S. B. Singh (co-advised with M. Chyba).
- BS students: T. Tang, A. Callo, M. Martin, N. Martel, R. Chiba, M. Roberts, N. Roslan, V. McGovern, J. Aamodt, L. Pham, J. Bohn (honors student), A. Duran, L. M. Alarcon, W. Jones, C.-S. Chan.

- *Past Visiting PhD students:* S. Bras and P. Cruz (Institute for Systems and Robotics, IST, Lisbon, Portugal); R. Warier (Indian Institute of Technology, Bombay, India); X. Li (Beijing Institute of Technology, Beijing, China).

Post-docs Mentored

- *2022-2023:* Reza Hamrah (PhD, Syracuse University, Syracuse, NY).
- *2017-2018:* Rakesh R. Warier (PhD, Indian Institute of Technology, Bombay, India).
- *2015-2016:* Sashi P. Viswanathan (PhD, New Mexico State University, Las Cruces, NM).
- *2012-2013:* Daero Lee (PhD, Missouri University of Science and Technology, Rolla, MO).
- *2008-2010:* Nikolaj Nordkvist (PhD, Technical University of Denmark, Kongens Lyngby, Denmark).