Andrew J. Taylor

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Education

Ph.D.	Control & Dynamical Systems	Caltech	2017-Present
M.S.	Aerospace Engineering	University of Michigan	2016-2016
B.S.	Aerospace Engineering	University of Michigan	2012-2015

Research Projects

Machine Learning for Nonlinear Control

Developed a novel episodic framework for integrating general supervised learning models into quadratic-program based nonlinear controllers for achieving stability [C1] and safety [C4], with experimental demonstrations on a robotic Segway platform and a planar bipedal robot [C9]. Evaluated the impact of error in learning models on resulting system behavior through projection-based methods [C2, J2], with experimental demonstration. Proposed an approach for robust data-driven nonlinear control via convex optimization that exploits underlying system structure to achieve improvements in data-efficiency [C11]. Explored the use of preference-based learning in simultaneously tuning robustness parameters of a safety-critical controller [C12]. Composed an overview of different approaches to data-driven safety-critical control comparing computational requirements and theoretical safety properties [U2].

Model Predictive Nonlinear Control

Explored the unification of nonlinear guarantee-based control for stability and safety with optimality-based model predictive control. Demonstrated long-standing theoretical results for optimal stabilization experimentally on a robotic system with consideration of computational requirements and improvements in performance [C5]. Proposed a novel formulation of safety-critical control for legged robotics on difficult terrain with experimental demonstration on a quadruped, highlighting improvements in safety over existing approaches [C8]. Deployed whole-body motion planning paired with an inverse-dynamics controller on a biped robot [C16] to achieve robust dynamic walking. Proposed a novel multi-rate nonlinear control architecture for unifying mid-level planning algorithms with low-level control design to satisfy safety and actuation constraints [C14].

Discrete-Event Control

Proposed an approach for efficiently using control resources via event-triggered safety-critical control and performed an analysis highlighting similarities and differences with event-triggered stabilization [J1]. Explored the impact of periodic sampling on existing convex optimization-based approaches for stabilization and proposed modifications to allow low-frequency sampled-data based control [J3]. Developed a framework for addressing safety-critical control in the context of periodic sampling by exploring theoretical safety guarantees and structural properties that ensure convex control synthesis [C13].

Disturbance Robust Safety-Critical Control
Proposed an approach for balancing robustness to disturbances with system performance in safety-critical control using a novel type of robust Control Barrier Function [J4]. Controllers synthesized using these functions are deployed on an automated semi-truck, demonstrating the ability to provide robustness to complex braking dynamics while respecting safety requirements [U1].

Adaptive Control for Safety-Critical Systems
Integrated classical results in adaptive nonlinear control with modern approaches for safety-critical control synthesis. Proposed the novel definition of adaptive Control Barrier Functions to accommodate parametric uncertainty in nonlinear systems and demonstrated their efficacy on an adaptive cruise control system [C3]. Extended these results to the hybrid systems setting while reducing strict limitations on the behavior of the system [C7].

Robust Perception-Based Control
Formulated an approach for robustly performing safety-critical control with general uncertain measurement models via Control Barrier Functions and convex optimization [C6]. Demonstrated ability of method to successfully robustify a perception-based control system in a high-fidelity simulation environment and experimentally using a black-box perception system [C10].

Safety-Critical Control for Higher-Order Systems
Extended classical notion of backstepping control used for higher-order nonlinear systems to the safety-critical context using Control Barrier Functions. Demonstrate the ability to constructively synthesize Control Barrier Functions, and the ability to safely regulate various systems in simulation [C15].

Industrial Experience

Flight Sciences Intern **2017**
Blue Origin, Advisor: Darin Brekke
Researched applications and limitations of vision-based navigation using LiDAR. Evaluated methods for point cloud registration to enable marker detection in sparse point clouds. Designed and constructed a mobile testbed for vision navigation using the Robotic Operating System (ROS) and developed post-processing software for inertial navigator assisted registration of point clouds.

Michigan eXploration Laboratory (MXL) Research Assistant **2013-2016**
University of Michigan, Advisor: James Cutler
Designed a 3-axis reaction wheel assembly prototype for CubeSat missions and conducted simulations and trade studies for the attitude control subsystem for the TBEx CubeSat mission.

Designed and developed a dual-microprocessor system and sensor peripherals that collect attitude data for a high-altitude balloon-based CubeSat and developed attitude determination algorithms and a motor controller interface to allow torque-based command of a reaction wheel for 1-axis pointing of a high-altitude balloon payload. Also designed a nichrome wire flight termination unit for high-altitude balloons and conducted the successful launch and recovery of 20 high-altitude balloon system missions.

Flight Sciences Intern **2016**

Blue Origin, Advisor: Darin Brekke

Researched and determined parameters for characterizing performance of prototype GPS receivers. Developed testing scenarios for a GNSS signal simulator to provide various RF environments to receivers. Developed high-level and receiver-specific testing plans to assess receiver performance parameters, and conducted data-reduction, analysis, and comparison of receiver performance.

Payload Systems Engineering Intern **2015**

NASA Jet Propulsion Laboratory (JPL), Advisor: Bogdan Oaida

Developed an architecture for the Science Merit Function, a high-fidelity modeling tool for assessing sensitivity in the performance of science instruments with respect to engineering design variables. Evaluated mathematical uses for the SMF including constrained optimization and graceful degradation. Worked with the Europa Project's instrument design and science requirements to locate critical design trade-offs, and constructed payload requirements documents in MagicDraw/XML.

Mechanical Subsystems Lead **2012-2013**

Student Space Systems Fabrication Laboratory (S3FL) 2012 CanSat Team, Advisor: Brian Gilchrist

Successfully designed and fabricated a structure and aero-braking descent control system to protect an egg released from a rocket at 1600 m. Contributed significantly to the development and testing of electrical power, command \& data handling, flight software, and ground station subsystems in build up to launch. Authored a detailed pre-flight preparation document, and competed in NASA sponsored CanSat challenge, placing 13th out of 40 international teams.

Teaching Experience

CDS 233: Nonlinear Control Teaching Assistant **2019-2021**

Caltech, Professor: Aaron Ames

Covered topics in nonlinear control including feedback linearization, zero dynamics, control Lyapunov Functions, backstepping, Control Barrier Functions, nonlinear robust control, nonlinear adaptive control, and hybrid systems control. Composed and graded homework assignments, held biweekly office hours, provided guidance on course projects, held make-up lectures on topics in nonlinear control, updated lecture notes, and proctored and graded exams.

CDS 232: Nonlinear Dynamics Teaching Assistant **2019-2021**
Caltech, Professor: Aaron Ames
Covered topics in nonlinear dynamics included existence and uniqueness of solutions, Hartman-Grobman theory, linearizations, Lyapunov stability, invariance principles, input-to-state stability, barrier functions, periodic orbits, and Poincaré sections. Composed and graded homework assignments, held biweekly office hours, provided guidance on course projects, held make-up lectures on topics in nonlinear dynamics, updated lecture notes, and proctored and graded exams.

AERO 205: Introduction to Aerospace Engineering Systems Teaching Assistant **2016**
University of Michigan, Professor: Peter Washabaugh
Taught 3 technical labs (10 students each) a week focused on CAD packages, fluid dynamics, structural mechanics, and control algorithm design. Provided guidance on and design and fabrication of course hovercraft project, including use of tools such as laser cutters and 3D printers.

AERO 483: Space Systems Design Teaching Assistant **2016**
University of Michigan, Professor: JP Sheehan
Help two teams (30 students each) develop conceptual space mission such as a Titan lander or Space Tug by providing system level and technical insight. Provided personalized feedback on weekly updates from each student, answering questions and offering new directions for their work.

Honors & Awards

Conference on Robotics Learning (CoRL) Best Paper Nominee [C6]	2020
Thomas A. Tisch Prize for Graduate Teaching in CMS	2020
George M. Landes Prize for Technical Communication	2016
Frank Sheehan Scholarship for Aeronautics (2 years)	2014-2015
University of Michigan Dean's List (6 terms)	2012-2015
University of Michigan University Honors (6 terms)	2012-2015
University of Michigan James B. Angell Scholar (2 terms)	2012-2015
S3FL CanSat Team Most Valuable Member	2012

Professional Experience & Service

Professional Societies

Institute of Electrical and Electronics Engineers (IEEE)	2019-Present
Sigma Gamma Tau Aerospace Honors Society	2013-2016
American Institute of Aeronautics & Astronautics (AIAA)	2013-2016

Journal Reviewer

Artificial Intelligence	1 Paper
ASME Journal of Dynamic Systems, Measurement, and Control	1 Paper
ASME Journal of Mechanisms & Robotics	1 Paper

IEEE Transactions on Automatic Control (TAC)	2 Papers
IEEE Transactions on Control Systems Technology (TCST)	1 Paper
IEEE Control Systems Letters (L-CSS)	4 Papers
IEEE Robotics and Automation Letters (RA-L)	3 Papers
IFAC Automatica	3 Papers

Conference Reviewer

Conference on Robotics Learning (CoRL)	1 Paper
IEEE American Control Conference (ACC)	3 Papers
IEEE Conference on Decision and Control (CDC)	6 Papers
IEEE International Conference on Robotics & Automation (ICRA)	1 Paper
Learning for Dynamics and Control (L4DC)	2 Papers

Publications & Presentations

Journal Publications

[J4] A. Alan, **A. J. Taylor**, C. R. He, G. Orosz, and A. D. Ames, "Safe Controller Synthesis with Tunable Input-to-State Safe Control Barrier Functions", *IEEE Control Systems Letters*, vol. 6, pp. 908-913, 2021.

[J3] **A. J. Taylor**, V. D. Dorobantu, Y. Yue, P. Tabuada, and A. D. Ames, "Sampled-Data Stabilization with Control Lyapunov Functions via Quadratically Constrained Quadratic Programs", *IEEE Control Systems Letters*, 2021, vol. 6, pp. 680-685, 2021.

[J2] **A. J. Taylor**, A. Singletary, Y. Yue and A. D. Ames, "A Control Barrier Perspective on Episodic Learning via Projection-to-State Safety", *IEEE Control Systems Letters*, vol. 5, no. 3, pp. 1019-1024, 2021.

[J1] **A. J. Taylor**, P. Ong, J. Cortés and A. D. Ames, "Safety-Critical Event Triggered Control via Input-to-State Safe Barrier Functions", *IEEE Control Systems Letters*, vol. 5, no. 3, pp. 749-754, 2021.

Conference Publications

[C16] M. Y. Galliker, N. Csomay-Shanklin, R. Grandia, **A. J. Taylor**, F. Farshidian, M. Hutter, A. D. Ames, "Bipedal Locomotion with Nonlinear Model Predictive Control: Online Gait Generation using Whole-Body Dynamics", in *Proceedings of the IEEE-RAS Conference on Humanoid Robots (Humanoids)*, 2022.

[C15] **A. J. Taylor**, P. Ong, T. G. Molnár, A. D. Ames, "Safe Backstepping with Control Barrier Functions", in *Proceedings of the 61st Conference on Decision and Control (CDC)*, 2022.

[C14] N. Csomay-Shanklin, **A. J. Taylor**, U. Rosolia, A. D. Ames, "Multi-Rate Planning and Control of Uncertain Nonlinear Systems: Model Predictive Control and Control Lyapunov Functions", in *Proceedings of the 61st Conference on Decision and Control (CDC)*, 2022.

[C13] **A. J. Taylor**, V. D. Dorobantu, R. K. Cosner, Y. Yue, A. D. Ames, "Safety of Sampled-Data Systems with Control Barrier Functions via Approximate Discrete Time Models", in *Proceedings of the 61st Conference on Decision and Control (CDC)*, 2022.

[C12] R. K. Cosner, M. Tucker, **A. J. Taylor**, K. Li, T. G. Molnár, W. Ubellacker, A. Alan, G. Orosz, Y. Yue, A. D. Ames, "Safety-Aware Preference-Based Learning for Safety-Critical Control", in *Proceedings of the 4th Conference on Learning for Dynamics and Control (L4DC)*, Palo Alto, CA, USA, 2022, pp. 1020-1033.

[C11] **A. J. Taylor**, V. D. Dorobantu, S. Dean, B. Recht, Y. Yue, and A. D. Ames, "Towards Robust Data-Driven Control Synthesis for Nonlinear Systems with Actuation Uncertainty", in *Proceedings of the IEEE 60th Conference on Decision and Control (CDC)*, 2021, pp. 6469-6476.

[C10] R. K. Cosner, A. W. Singletary, **A. J. Taylor**, T. G. Molnár, K. L. Bouman, and A. D. Ames, "Measurement-Robust Control Barrier Functions: Certainty in Safety with Uncertainty in State", in *Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)*, Prague, Czech Republic, 2021, pp. 6286-6291.

[C9] N. Csomay-Shanklin, R. K. Cosner, M. Dai, **A. J. Taylor**, and A. D. Ames, "Episodic Learning for Safe Bipedal Locomotion with Control Barrier Functions and Projection-to-State Safety", in *Proceedings of the 3rd Conference on Learning for Dynamics and Control (L4DC)*, Zürich, Switzerland, 2021, pp. 1041-1053.

[C8] R. Grandia, **A. J. Taylor**, A. D. Ames, and M. Hutter, "Multi-Layered Safety for Legged Robots via Control Barrier Functions and Model Predictive Control", in *Proceedings of the IEEE International Conference on Robotics and Automation (ICRA)*, Xi'an, China, 2021, pp. 8352-8358.

[C7] M. Maghenem, **A. J. Taylor**, A. D. Ames, and R. G. Sanfelice, "Adaptive Safety Using Control Barrier Functions and Hybrid Adaptation", in *Proceedings of the IEEE American Control Conference (ACC)*, New Orleans, LA, USA, 2021, pp. 2418-2423.

[C6] S. Dean, **A. J. Taylor**, R. K. Cosner, B. Recht, and A. D. Ames, "Guaranteeing Safety of Learned Perception Modules via Measurement-Robust Control Barrier Functions", in *Proceedings of the 4th Conference on Robotics Learning (CoRL)*, Boston, MA, USA, 2020.

[C5] R. Grandia, **A. J. Taylor**, A. Singletary, M. Hutter, A. D. Ames, "Nonlinear Model Predictive Control of Robotic Systems with Control Lyapunov Functions", in *Proceedings of Robotics: Science and Systems XVI (RSS)*, Bend, OR, USA, 2020.

[C4] **A. J. Taylor**, A. Singletary, Y. Yue, A. D. Ames, "Learning for Safety-Critical Control with Control Barrier Functions", in *Proceedings of the 2nd Conference on Learning for Dynamics and Control (L4DC)*, Berkeley, CA, USA, 2020, pp. 708-717.

[C3] **A. J. Taylor**, A. D. Ames, “Adaptive Safety with Control Barrier Functions”, in *Proceedings of the IEEE American Control Conference (ACC)*, Denver, CO, USA, 2020, pp. 1399-1405

[C2] **A. J. Taylor**, V. D. Dorobantu, M. Krishnamoorthy, H. M. Le, Y. Yue, A. D. Ames, “A Control Lyapunov Perspective on Episodic Learning via Projection to State Stability”, in *Proceedings of the IEEE 58th Conference on Decision and Control (CDC)*, Nice, France, 2019, pp. 1448-1455.

[C1] **A. J. Taylor**, V. D. Dorobantu, H. M. Le, Y. Yue, A. D. Ames, “Episodic Learning with Control Lyapunov Functions for Uncertain Robotic Systems”, in *Proceedings of the IEEE/RSJ International Conference on Intelligent Robotics and Systems (IROS)*, Macau, China, 2019, pp. 6878-6884.

Preprint Publications

[U2] K. P. Wabersich, **A. J. Taylor**, J. J. Choi, K. Sreenath, C. J. Tomlin, A. D. Ames, M. N. Zeilinger, “Data-Driven Safety Filters: Hamilton-Jacobi Reachability, Control Barrier Functions, and Predictive Methods for Uncertain Systems”, submitted to *IEEE Control Systems*, 2022.

[U1] A. Alan, **A. J. Taylor**, C. R. He, A. D. Ames, G. Orosz, “Control Barrier Functions and Input-to-State Safety with Application to Automated Vehicles”, submitted to *IEEE Transactions on Control Systems Technology (TCST)*, 2022.

Invited Presentations

[P1] “A Control Lyapunov Function Approach to Episodic Learning”, *1st Conference on Learning for Dynamics and Control (L4DC)*, Poster Presentation, 2019.

Computer Skills

Languages:	MATLAB, C, C++, Python
Platforms:	Windows, Linux
Software:	ROS, Keras, Tensorflow, CVX, Simulink, Altium, Solidworks, Autodesk Inventor, MultiSim, MagicDraw, Microsoft Office