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Sheng Cheng

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EDUCATION

Ph.D. in Electrical Engineering, Control — 08/2021
University of Maryland, College Park, MD — Advisor: Dr. Derek Paley

M.S. in Electrical Engineering, Control — 08/2018
University of Maryland, College Park, MD — Advisor: Dr. Nuno Martins

B.Eng. in Control Science and Engineering, Automation — 07/2014
Harbin Institute of Technology, Harbin, China — Advisor: Dr. Yong'an Zhang

ACADEMIC POSITIONS

Postdoctoral Research Associate — 08/2021—present
University of Illinois Urbana-Champaign, Urbana, IL — Advisor: Dr. Naira Hovakimyan

RESEARCH INTERESTS

Safe learning for control; aerial robotics; optimization; adaptive control; distributed parameter systems

SELECTED PUBLICATIONS

Under review and in-preparation articles (* equal contributions, † mentored students)

UR1. R. Tao[†], **S. Cheng**, X. Wang, S. Wang, N Hovakimyan, "DiffTune-MPC: Closed-Loop Learning for Model Predictive Control", under review, 2023.

UR2. Y. Gu[†], **S. Cheng**, N. Hovakimyan, "Proto-MPC: An Encoder-Prototype-Decoder Approach for Quadrotor Control in Challenging Winds", under review, 2023.

UR3. **S. Cheng**, M. Kim*, L. Song*, C. Yang, Y. Jin, S. Wang, N. Hovakimyan, "DiffTune: Auto-Tuning through Auto-Differentiation," under revision for IEEE Transactions on Robotics, 2023 (preprint: https://arxiv.org/abs/2209.10021).

UR4. Z. Wu*[†], **S. Cheng***, P. Zhao, A. Gahlawat, K. A. Ackerman, A. Lakshmanan, C. Yang, J. Wu, N. Hovakimyan "$\mathcal{L}_1$Quad: $\mathcal{L}_1$ Adaptive Augmentation of Geometric Control for Agile Quadrotors with Performance Guarantees," under review by IEEE Transactions on Control Systems Technology, 2023 (preprint: https://arxiv.org/abs/2302.07208).

UR5. H. Lee[†], **S. Cheng**, Z. Wu, N. Hovakimyan, "Geometric Tracking Control of Omnidirectional Multirotors in the Presence of Rotor Dynamics," under review (preprint: https://arxiv.org/abs/2209.10024), 2023.

UR6. J. L. Bullock[†], **S. Cheng**, N. Hovakimyan, "L_1 Adaptive Augmentation of an NDI Controller for Safer Flight through Microbursts," in preparation, 2023.

UR7. C. Tao[†], **S. Cheng**, N. Hovakimyan, "Control-oriented Trajectory Planning using B-Splines with Feasibility Guarantees," in preparation, 2023

Journal articles

J1. Q. Chen[†], **S. Cheng**, N. Hovakimyan, "Simultaneous Spatial and Temporal Assignment for Fast UAV Trajectory Optimization using Bilevel Optimization," IEEE Robotics and Automation Letters, vol. 8, no. 6, pp. 3860-3867, June 2023.

J2. **S. Cheng** and D. A. Paley, "Cooperative estimation and control of a diffusion-based spatiotemporal process using mobile sensors and actuators," Autonomous Robot, May 2023.

J3. **S. Cheng** and D. A. Paley, "Optimal guidance and estimation of a 2D diffusion-advection process by a team of mobile sensors," Automatica, vol. 137, p. 110112, March 2022.

J4. **S. Cheng** and D. A. Paley, "Optimal control of a 2D diffusion-advection process with a team of mobile actuators under jointly optimal guidance," Automatica, vol. 133, p. 109866, August 2021.

J5. **S. Cheng** and N. C. Martins, "An optimality gap test for a semidefinite relaxation of a quadratic program with two quadratic constraints," SIAM Journal on Optimization, vol. 31, no. 1, pp. 866-886, March 2021.

J6. A. Wolek, **S. Cheng**, D. Goswami, and D. A. Paley, "Cooperative mapping and target search over an unknown occupancy graph using mutual information," IEEE Robotics and Automation Letters, vol. 5, no. 2, pp. 1071-1078, 2020.

Conference papers

C1. J. L. Bullock[†], **S. Cheng**, A. Patterson, M. Acheson, N. Hovakimyan, I. Gregory, "Reference Command Optimization for the Transition Flight Mode of a Lift Plus Cruise Vehicle," to appear at 2024 AIAA SciTech Forum, 2023.

C2. L. Song[†], **S. Cheng**, N. Hovakimyan, S. Mitra, "Automatic Formal Verification of L_1 Adaptive Control Systems," to appear at 2024 AIAA SciTech Forum, 2023.

C3. A. Bansal, Y. Zhao, J. Zhu, S. Cheng, Y. Gu, H. Yoon, H. Kim, N. Hovakimyan, L. Sha, "Synergistic Perception and Control Simplex for Verifiable Safe Vertical Landing," to appear at 2024 AIAA SciTech Forum, 2023. (preprint: https://arxiv.org/abs/2312.02937)

C4. L. Song[†], Y. Li, **S. Cheng**, P. Zhao, S. Mitra, N. Hovakimyan, "Verification of $\mathcal{L}_1$ Adaptive Control using Verse Library: A Case Study of Quadrotors," In Proceedings of the ACM/IEEE 14th International Conference on Cyber-Physical Systems (with CPS-IoT Week 2023), pp.245–246, San Antonio, TX, 2023.

C5. **S. Cheng**, L. Song[†], M. Kim, S. Wang, N. Hovakimyan, "DiffTune+: Hyperparameter-Free Auto-Tuning using Auto-Differentiation," In Proceedings of 5th Learning for Dynamics and Control Conference, pp. 170-183, PMLR, *Selected for oral presentation (**9.5% acceptance rate**)*, 2023.

C6. Z. Wu[†], **S. Cheng**, K. A. Ackerman, A. Gahlawat, A. Lakshmanan, P. Zhao, and N. Hovakimyan, "$\mathcal{L}_1$ Adaptive Augmentation for Geometric Tracking Control of Quadrotors," 2022 International Conference on Robotics and Automation, pp. 1329–1336, Philadelphia, PA, 2022.

C7. **S. Cheng** and D. A. Paley, "Optimal guidance of a team of mobile actuators for controlling a 1D diffusion process with unknown initial conditions," 2021 American Control Conference, pp. 1497-1502, New Orleans, LA, 2021.

C8. **S. Cheng** and D. A. Paley, "Optimal guidance and estimation of a 1D diffusion process by a team of mobile sensors," 2020 IEEE Conference on Decision and Control, pp. 1222–1228, Jeju Island, South Korea, 2020.

C9. **S. Cheng** and D. A. Paley, "Optimal control of a 1D diffusion process with a team of mobile actuators under jointly optimal guidance," American Control Conference, pp. 3449-3454, Denver, CO, 2020.

C10. **S. Cheng** and N. C. Martins, "Reaching a target in a time-costly area using a two-stage optimal control method," American Control Conference, pp. 4903-4910, Philadelphia, PA, 2019.

Posters, Demos, and Workshop Papers

MISC1. L. Song[†], **S. Cheng**, N. Hovakimyan, "Meta-Learning-Inspired Control Auto-Tuning with Verified Robustness," presented as a poster at the *Formal methods techniques in robotics systems: Design and control Workshop* at IEEE/RSJ International Conference on Intelligent Robots and Systems, 2023

MISC2. C. Ray[†], **S. Cheng**, N. Hovakimyan, "An Educational Quadrotor Testbed for $\mathcal{L}_1$ Adaptive Control," demonstrated on-site at IEEE/RSJ International Conference on Intelligent Robots and Systems, 2023

MISC3. **S. Cheng**, M. Kim, L. Song, Z. Wu, S. Wang, N. Hovakimyan, "DiffTune: Auto-Tuning through Auto-Differentiation," presented as an invited poster at 2023 Hyundai Vision Conference, 2023

MISC4. **S. Cheng**, M. Kim, L. Song, Z. Wu, S. Wang, N. Hovakimyan, "DiffTune: Auto-Tuning through Auto-Differentiation," presented as a late breaking poster at the American Control Conference, 2023

MISC5. **S. Cheng**, M. Kim, L. Song, Z. Wu, S. Wang, N. Hovakimyan, "An Auto-Tuning Framework for Controllers using Auto-Differentiation," orally presented at the *Learning to Adapt and Improve in the Real World Workshop* at the Conference on Robot Learning, 2022

RESEARCH EXPERIENCE

University of Illinois Urbana-Champaign

Robust and Resilient Autonomy for Advanced Air Mobility   11/2022—present

Role: Lead Postdoctoral Research Associate   Advisor: Dr. Naira Hovakimyan

- Proposing to use parametric trajectory optimization and differential flatness of vertical takeoff and landing (VTOL) vehicles to address the control ambiguity issue of VTOL vehicles at transition phase.
- Advising Ph.D. students to develop an $\mathcal{L}_1$ adaptive controller for rejecting the wind disturbances of a microburst and safely recovering an aircraft from the subsequent loss in altitude.
- Integrating $\mathcal{L}_1$ adaptive control with verifiable obstacle detection algorithm for synergistic perception and control simplex on AAM vehicles in an autonomous landing scenario.
- Leading Ph.D. students to demonstrate the proposed algorithms on the Generic UAM (GUAM) simulator developed by NASA.
- Advising a student team to build quadrotor platforms that can perform learning onboard with real-time data.
- Advised undergraduate students to develop a differentiable UAV trajectory planning algorithm that achieves simultaneous spatial and temporal optimization.

DiffTune: Auto-Tuning Through Auto-Differentiation   05/2022—present

Role: Postdoctoral Research Associate   Collaborator: Dr. Naira Hovakimyan, Dr. Shenlong Wang

- Proposed a novel auto-tuning scheme using auto-differentiation (DiffTune) that connects conventional non-machine-learning controllers to machine learning and applies auto-differentiation for efficient and safe controller tuning.
- Proposed hyperparameter-free DiffTune that promotes faster controller tuning without hyperparameter-tuning.
- Experimentally verified the efficacy of DiffTune in tuning a challenging nonlinear controller for quadrotor and systematically evaluated its tuning performance, generalization, and handling of uncertainties.
- Developed and open-sourced the DiffTune toolset which facilitates custom tuning applications of other users.
- Advising Ph.D. students on the development of DiffTune to closed-loop learning for model predictive control.
- Investigating the theoretical foundations for gradient estimation subject to uncertainties and noise in systems.
- Extending capabilities of DiffTune to handle controller tuning with non-differentiable dynamics/controllers/costs.
- Proposing meta-DiffTune that enables parameter-level generalization and robustness to unseen tasks and environments.
- Leading the collaboration with a research team from USC to develop applications of DiffTune for quadrupedal robots.

Autonomous Quadrotor with Safety Guarantees   09/2021—09/2022

Role: Postdoctoral Research Associate   Advisor: Dr. Naira Hovakimyan

- Lead the theoretical development and experimentation of a safe and agile quadrotor control framework ($\mathcal{L}_1$Quad) that applies the $\mathcal{L}_1$ adaptive augmentation to a geometric controller.
- Developed the experimental quadrotor testbed by customizing Ardupilot firmware for efficient onboard computation (400 Hz).
- Lead the open sourcing of $\mathcal{L}_1$Quad implementation in Matlab/Simulink (Parrot Mambo) and C++ (Ardupilot and Crazyflie).
- Collaborating with a research team from JAIST to deploy $\mathcal{L}_1$Quad to a resilient quadrotor platform with soft propellers.

University of Maryland, College Park

Distributed Estimation and Control of a Spatiotemporal Process with Multiple Aerial Vehicles   02/2019–08/2021

Role: Graduate Research Assistant   Advisor: Dr. Derek Paley

- Proposed a jointly optimal guidance and actuation/sensing strategy for a team of mobile actuators/sensors to efficiently control/estimate a 2D diffusion-advection process.
- Validated the jointly optimal guidance and actuation/sensing strategies in hardware-in-the-loop simulations with an outdoor quadrotor swarm testbed.
- Built and maintained the outdoor quadrotor swarm testbed with six quadrotors.

Cooperative Mapping, Searching, and Tracking in an Uncertain Urban Environment 09/2018–06/2019

Role: Graduate Research Assistant   Advisor: Dr. Derek Paley

- Proposed an efficient mapping strategy that drives agents to follow waypoints generated from frontier nodes and unexplored regions.
- Proposed a path planning method that generates conflict-free and locally optimal paths over a graph-based map.
- Built quadrotors with Pixhawk flight controllers and engaged in the development of the coordination software OpenMACE led by Heron Systems, Inc (acquired by Shield AI in 2021).
- Validated a cooperative mapping and search algorithm on the outdoor quadrotor swarm testbed.

Reaching a Target within a GPS-denied or Costly Area: a Two-stage Optimal Control Approach 08/2016–08/2018

Role: Graduate Research Assistant   Advisor: Dr. Nuno Martins

- Formulated a two-stage optimization problem and transformed it into a quadratic program with two quadratic constraints (QC2QP).
- Proposed a necessary and sufficient test to determine whether a globally optimal solution for a general QC2QP can be computed from that of a specific convex semidefinite relaxation.
- Implemented a controller that steers a quadrotor to reach a target within a denied area in experiments.
- Analyzed data from bat experiments (conducted by Comparative Neural Systems and Behavior Lab at JHU) and investigated bat's strategy on reaching a target within a man-made denied area.

PROPOSAL EXPERIENCE

NSF SLES: Guaranteed Tubes for Safe Learning across Autonomy Architectures 05/2023

PI: Dr. Naira Hovakimyan   **[Funded, $1.5M]**   University of Illinois Urbana-Champaign

- Led the discussions to form the scope and plans for the proposal by coordinating the PI and co-PIs from different institutions.
- Wrote 40% of the proposal (one technical thrust using DiffTune).

AFOSR DURIP: A Training-Testing-Benchmarking Environment for Learning-Enabled Control Frameworks 05/2022

PI: Dr. Naira Hovakimyan   **[Funded]**   University of Illinois Urbana-Champaign

- Devised the scope and components of the proposed facility based on the needs from various projects in the lab.
- Wrote 100% of the proposal.

Safe UAV Flight in Challenging Environments with Uncertainty-Aware Perception, Planning, and Control 09/2022

PI: Dr. Naira Hovakimyan   Submitted to Sony Research Award Program   University of Illinois Urbana-Champaign

- Led the discussions to form the scope and plans for the proposal.
- Wrote 50% of the proposal (background, research objectives, and thrusts).

Safe and Robust Autonomous Flight in Challenging Environments with Uncertainty-aware Perception, Planning, and Control   Submitted to Smart Transportation Infrastructure Initiative   04/2022

PI: Dr. Shenlong Wang   University of Illinois Urbana-Champaign

- Led the discussions to form the scope and plans for the proposal.
- Wrote 50% of the proposal (background, research objectives, and thrusts).

NASA ULI: Robust and Resilient Autonomy for Advanced Air Mobility 10/2021

PI: Dr. Naira Hovakimyan   **[Funded, $6M]**   University of Illinois Urbana-Champaign

・Participated in the discussion with collaborators from multi-disciplinary backgrounds to develop the proposal.

・Wrote 5% of the proposal (outreach section, project management, and data management plan).

Distributed Estimation and Control of a Spatiotemporal Process with Multiple Underwater Vehicles   06/2020

PI: Dr. Derek Paley   **[Funded, $56K]**   University of Maryland, College Park

・Developed the proposal to Northrop Grumman-UMD seed grant on my Ph.D. work of optimal estimation and control of a spatiotemporal process, with applications to multiple underwater vehicles.

・Wrote 100% of the proposal.

Distributed Estimation and Control of a Spatiotemporal Process with Multiple Aerial Vehicles   02/2020

PI: Dr. Derek Paley   [Whitepaper to Isarel Minister of Defense]   University of Maryland, College Park

・Developed the proposal to Isarel Minister of Defense on my Ph.D. work of optimal estimation and control of a spatiotemporal process, with applications to multiple aerial vehicles.

・Wrote 100% of the proposal.

Autonomous Resource Allocation for Distributed Estimation and Control of Dynamical Systems   05/2019

PI: Dr. Derek Paley   [Whitepaper to AFOSR]   University of Maryland, College Park

・Proposed to use partial differential equations to model the spatiotemporal dynamical system.

・Wrote 30% of the proposal (prior work, advancements to the state-of-the-art, technical thrust).

SEMINARS and PRESENTATIONS

Invited seminar, Robotics and Perception Group at the University of Zurich	07/2023
Oral presentation, 5th Learning for Dynamics and Control (9.5% acceptance rate)	06/2023
Invited seminar, Robotics Seminars @ Illinois, University of Illinois Urbana-Champaign	03/2023
Invited seminar, Secure Learning Lab, University of Illinois Urbana-Champaign	02/2023
Invited seminar, Robotics and Controls Seminar, University of North Carolina at Charlotte	02/2023
Organized a one-day lab workshop for hosting Dr. Kevin Wise *(Vice President and Distinguished Senior Technical Fellow at Boeing)*, Advanced Controls Research Laboratory, University of Illinois Urbana-Champaign	09/2022
Job talk, Advanced Controls Research Laboratory, University of Illinois Urbana-Champaign	05/2021
Oral presentation, SIAM Conference on Applications of Dynamical Systems	05/2021
Oral presentation, American Control Conference	05/2021
Oral presentation, IEEE Conference on Decision and Control	12/2020
Oral presentation, American Control Conference	07/2020
Oral presentation, American Control Conference	07/2019

SELECTED HONORS AND AWARDS

Excellent Reviewer, AIAA Journal of Guidance, Control, and Dynamics.	12/2022
Student Travel Support Award, 2020 IEEE Conference on Decision and Control.	12/2020
Student Travel Award, 2020 American Control Conference.	06/2020
Future Faculty Fellow, A. James Clark School of Engineering, University of Maryland.	12/2018
George Corcoran Award, Department of Electrical and Computer Engineering, University of Maryland.	09/2016
International Teaching Fellowship, University of Maryland.	10/2015
Distinguished Teaching Assistant Award, ECE Department, University of Maryland.	05/2015
Outstanding Undergraduate Thesis Award, Harbin Institute of Technology.	07/2014

TEACHING EXPERIENCE

Lecturer, "Advanced Dynamics of Aerospace Systems" (co-teaching with Dr. Derek Paley)	01/2021–05/2021
Teaching Assistant Training & Development Fellow, ECE Department, University of Maryland.	08/2015–05/2016
International Teaching Fellow Mentor, University of Maryland.	10/2015–05/2016
Teaching Assistant, ECE Department, University of Maryland.	08/2014–05/2016

PROFESSIONAL SERVICES

Session Chair, Control Techniques for AAM Autonomy (GNC-28), AIAA SciTech 2024   01/2024

Session Chair, Motion and Path Planning I, 2023 IROS   10/2023

Co-organizer, Workshop on Robust and Resilient Autonomy: Progress and Challenges, IFAC World Congress   07/2023

Co-organizer, the GN&C Workshop, 2023 AIAA SciTech Forum   01/2023

Coordinator, AVIATE Seminar, University of Illinois Urbana-Champaign   10/2022–present

Co-organizer, one-day lab workshop for hosting Dr. Kevin Wise *(Vice President and Distinguished Senior Technical Fellow at Boeing)*, Advanced Controls Research Laboratory, University of Illinois Urbana-Champaign   09/2022

PROFESSIONAL ACTIVITIES AND AFFILIATIONS

Journal Reviewer: IEEE Transactions on Control Systems Technology; Automatica; Journal of Guidance, Control, and Dynamics; IEEE Control Systems Letters; IEEE Transactions on Aerospace and Electronic Systems; IEEE Transactions on Industrial Informatics; Robotics; Sensors.

Conference Reviewer: CoRL; ICRA; IROS; IFAC WC; CDC; ACC; and DARS-SWARM.

Member: IEEE CSS Technical Committee on Intelligent Control.

SKILLS

Proficient in LaTeX, C/C++, Python, ROS, shell scripting, and simulation software, including MATLAB and Simulink.

Proficient in commercial autopilot system ArduPilot, both software usage and customization and hardware configuration.

Proficient in video filming and processing using Adobe Premiere Pro and Sony Vegas Pro.

MENTORED STUDENTS

Ph.D. students

Ran Tao (Mechanical Engineering, University of Illinois Urbana-Champaign)	09/2023–present
Ziyin Han (Mechanical Engineering, University of Illinois Urbana-Champaign)	08/2023–present
John Bullock (Electrical and Computer Engineering, University of Illinois Urbana-Champaign)	09/2022–present
Yuliang Gu (Mechanical Engineering, University of Illinois Urbana-Champaign)	09/2022–present
Chengyu Yang (Mechanical Engineering, University of Illinois Urbana-Champaign)	05/2022–present
Lin Song (Mechanical Engineering, University of Illinois Urbana-Champaign)	07/2022–present
Chuyuan Tao (Mechanical Engineering, University of Illinois Urbana-Champaign)	03/2022–present
Minkyung Kim (Mechanical Engineering, University of Illinois Urbana-Champaign)	02/2022–present
Masamichi Kosuge (Visiting student from Keio University)	12/2021–03/2022
Hyungyu Lee (Mechanical Engineering, University of Illinois Urbana-Champaign)	12/2021– present
Michael Aramyan (Mechanical Engineering, University of Illinois Urbana-Champaign)	10/2021– present
Zhuohuan Wu (Mechanical Engineering, University of Illinois Urbana-Champaign)	09/2021–02/2023

Master students

Yang Zhao (Mechanical Engineering, University of Illinois Urbana-Champaign)	05/2023–present
Koushik Udayachandran (Aerospace Engineering, University of Illinois Urbana-Champaign)	03/2023–05/2023
Rong Wang (Mechanical Engineering, University of Illinois Urbana-Champaign)	09/2022–02/2023
Charlie Ray (Aerospace Engineering, University of Illinois Urbana-Champaign)	06/2022–05/2023
Jiahao Yu (Mechanical Engineering, University of Illinois Urbana-Champaign)	05/2022–12/2022

Undergraduate students

Shishir Bhatta (Computer Science, University of Illinois Urbana-Champaign	09/2023–present
Junjie Gao (Computer Engineering, University of Illinois Urbana-Champaign)	05/2023–present
Yiquan Jin (Mechanical Engineering, University of Illinois Urbana-Champaign)	03/2023–07/2023
Chenhao Xu (Computer Science, University of Illinois Urbana-Champaign)	10/2022–05/2023

Di Liang (Computer Science, University of Illinois Urbana-Champaign) 10/2022–present

Donggu Lee (Mechanical Engineering, University of Illinois Urbana-Champaign) 09/2022–present

Jae Lee (Mechanical Engineering, University of Illinois Urbana-Champaign) 08/2022–05/2023

Casey Li (Mechanical Engineering, University of Illinois Urbana-Champaign) 05/2022–05/2023

Zhongchun Yu (Mechanical Engineering, University of Illinois Urbana-Champaign) 05/2022–05/2023

Youyou Yu (Computer Engineering, University of Illinois Urbana-Champaign) 05/2022–05/2023

Qianzhong Chen (Mechanical Engineering, University of Illinois Urbana-Champaign) 01/2022–12/2022

Simon Ge (Computer Engineering, University of Illinois Urbana-Champaign) 01/2022–05/2023

Albert Kwan (Aerospace Engineering, University of Illinois Urbana-Champaign) 12/2021–05/2022

Clive Chung (Mechanical Engineering, University of Illinois Urbana-Champaign) 09/2021–05/2023

Ezra Bregin (Aerospace Engineering, University of Maryland) 09/2020–05/2021

Charles Flanagan (Aerospace Engineering, University of Maryland) 09/2019–05/2020

Joshua Yuan (Summer Research Student, University of Maryland) 05/2019–08/2019

Aniket Goel (Aerospace Engineering, University of Maryland) 09/2018–05/2019