

Saber Jafarpour

INFORMATION	Research Assistant Professor Department of Electrical and Computer Engineering University of Colorado Boulder, Room ECOT 241	Email: saber.jafarpour@colorado.edu Google Scholar: Saber Jafarpour Orcid ID: 0000-0002-7614-2940 Webpage: saberjafarpour.github.io
RESEARCH EXPERIENCE	University of Colorado Boulder Department of Electrical and Computer Engineering <i>Research Assistant Professor</i> Georgia Institute of Technology Institute for Robotics and Intelligent Machines <i>Postdoctoral Research Fellow (Advisor: Samuel Coogan)</i> University of California, Santa Barbara Center of Control, Dynamical Systems, and Computation <i>Postdoctoral Research Fellow (Advisor: Francesco Bullo)</i>	2023–present 2021–2023 2016–2021
EDUCATION	Queen’s University, Canada Department of Mathematics and Statistics <i>Ph.D. in Applied Mathematics (Advisor: Andrew D. Lewis)</i> Dissertation: On the Role of Regularity in Mathematical Control Theory Shiraz University, Iran Department of Mechanical Engineering <i>M.Sc. in Applied Mechanics (Advisor: Mojtaba Mahzoon)</i> Dissertation: Investigating Nonholonomic Constraints in Robotic Systems Shiraz University, Iran Department of Mechanical Engineering <i>B.Sc. in Mechanical Engineering</i>	2011–2016 2008–2011 2004–2008
RESEARCH INTERESTS	My research is the broad intersection of control theory and autonomy. I develop mathematically rigorous and computationally efficient tools for safety, learning, and control of autonomous systems with applications to robotics and multi-agent cyber-physical networks. More specifically, I have been conducting research in the following areas: <ul style="list-style-type: none">• Safety assurance of learning-enabled robotic systems• Uncertainty quantification in autonomous systems• Resilience of large-scale multi-agent systems• Geometric control of nonlinear systems	
JOURNAL PAPERS	<p>[J21] S. Jafarpour*, A. Harapanahalli*, and S. Coogan. Efficient interaction-aware interval analysis of neural network feedback loops. <i>IEEE Transactions on Automatic Control</i>, 2024a. URL https://arxiv.org/abs/2307.14938. To appear</p> <p>[J20] S. Jafarpour and S. Coogan. Monotonicity and contraction on polyhedral cones. <i>IEEE Transactions on Automatic Control</i>, 2024. URL http://arxiv.org/abs/2210.11576. To appear</p> <p>[J19] M. Pirani* and S. Jafarpour*. Network critical slowing down: Data-driven detection of critical transitions in nonlinear networks. <i>IEEE Transactions on Control of Network Systems</i>, 11(2):573–585, 2024. DOI: 10.1109/TCNS.2023.3332730</p>	

- [J18] **S. Jafarpour**, A. Davydov, and F. Bullo. Non-Euclidean contraction theory for monotone and positive systems. *IEEE Transactions on Automatic Control*, 68(9):5653–5660, 2023. DOI: [10.1109/TAC.2022.3224094](https://doi.org/10.1109/TAC.2022.3224094)
- [J17] A. Davydov, **S. Jafarpour**, and F. Bullo. Non-Euclidean contraction theory for robust nonlinear stability. *IEEE Transactions on Automatic Control*, 67(12):6667–6681, 2022. DOI: [10.1109/TAC.2022.3183966](https://doi.org/10.1109/TAC.2022.3183966)
- [J16] **S. Jafarpour**, P. Cisneros-Velarde, and F. Bullo. Weak and semi-contraction for network systems and diffusively-coupled oscillators. *IEEE Transactions on Automatic Control*, 67(3):1285–1300, 2022a. DOI: [10.1109/TAC.2021.3073096](https://doi.org/10.1109/TAC.2021.3073096)
- [J15] **S. Jafarpour**, V. Purba, S. V. Dhople, B. Johnson, and F. Bullo. Singular perturbation and small-signal stability for inverter networks. *IEEE Transactions on Control of Network Systems*, 9(2):979–992, 2022c. DOI: [10.1109/TCNS.2021.3084444](https://doi.org/10.1109/TCNS.2021.3084444)
- [J14] P. Cisneros-Velarde, **S. Jafarpour**, and F. Bullo. A contraction analysis of primal-dual dynamics in distributed and time-varying implementations. *IEEE Transactions on Automatic Control*, 67(7):3560–3566, 2022. DOI: [10.1109/TAC.2021.3103865](https://doi.org/10.1109/TAC.2021.3103865)
- [J13] K. D. Smith, **S. Jafarpour**, and F. Bullo. Transient stability of droop-controlled inverter networks with operating constraints. *IEEE Transactions on Automatic Control*, 67(2):633–645, 2022a. DOI: [10.1109/TAC.2021.3053552](https://doi.org/10.1109/TAC.2021.3053552)
- [J12] K. D. Smith, **S. Jafarpour**, A. Swami, and F. Bullo. Topology inference with multivariate cumulants: The Möbius inference algorithm. *IEEE/ACM Transactions on Networking*, 30(5):2102–2116, 2022b. DOI: [10.1109/TNET.2022.3164336](https://doi.org/10.1109/TNET.2022.3164336)
- [J11] **S. Jafarpour***, A. Davydov*, A. V. Proskurnikov, and F. Bullo. Robust implicit networks via non-Euclidean contractions. In *Advances in Neural Information Processing Systems (NeurIPS)*, volume 34, pages 9857–9868, Dec. 2021. URL <https://openreview.net/forum?id=SwfsoPuGYku>
- [J10] **S. Jafarpour**, E. Y. Huang, K. D. Smith, and F. Bullo. Flow and elastic networks on the n -torus: Geometry, analysis and computation. *SIAM Review (Research Spotlight)*, 64(1):59–104, 2021. DOI: [10.1137/18M1242056](https://doi.org/10.1137/18M1242056)
- [J9] A. Silva, F. Kocayusufoglu, **S. Jafarpour**, A. Swami, F. Bullo, and A. K. Singh. Combining physics and machine learning for network flow estimation. In *International Conference on Learning Representations*, Online, May 2021. URL <https://openreview.net/forum?id=10V53bErniB>
- [J8] X. Duan, **S. Jafarpour**, and F. Bullo. Graph-theoretic stability conditions for Metzler matrices and monotone systems. *SIAM Journal on Control and Optimization*, 59(5):3447–3471, 2021. DOI: [10.1137/20M131802X](https://doi.org/10.1137/20M131802X)
- [J7] **S. Jafarpour**. On small-time local controllability. *SIAM Journal on Control and Optimization*, 58(1):425–446, 2020. DOI: [10.1137/16M1068797](https://doi.org/10.1137/16M1068797)
- [J6] V. Purba, B. Johnson, **S. Jafarpour**, F. Bullo, and S. V. Dhople. Dynamic aggregation of grid-tied three-phase inverters. *IEEE Transactions on Power Systems*, 35(2):1520–1530, 2020. DOI: [10.1109/TPWRS.2019.2942292](https://doi.org/10.1109/TPWRS.2019.2942292)
- [J5] V. Purba, B. Johnson, M. Rodriguez, **S. Jafarpour**, F. Bullo, and S. V. Dhople. Reduced-order aggregate model for parallel-connected single-phase inverters. *IEEE Transactions on Energy Conversion*, 34(2):824–837, 2019. DOI: [10.1109/TEC.2018.2881710](https://doi.org/10.1109/TEC.2018.2881710)
- [J4] **S. Jafarpour**, E. Y. Huang, and F. Bullo. Synchronization of Kuramoto oscillators: Inverse Taylor expansions. *SIAM Journal on Control and Optimization*, 57(5):3388–3412, 2019. DOI: [10.1137/18M1216262](https://doi.org/10.1137/18M1216262)
- [J3] **S. Jafarpour** and F. Bullo. Synchronization of Kuramoto oscillators via cutset projections. *IEEE Transactions on Automatic Control*, 64(7):2830–2844, 2019. DOI: [10.1109/TAC.2018.2876786](https://doi.org/10.1109/TAC.2018.2876786)
- [J2] M. George, **S. Jafarpour**, and F. Bullo. Markov chains with maximum entropy for robotic surveillance. *IEEE Transactions on Automatic Control*, 64(4):1566–1580, 2019. DOI: [10.1109/TAC.2018.2844120](https://doi.org/10.1109/TAC.2018.2844120)
- [J1] **S. Jafarpour** and A. D. Lewis. Locally convex topologies and control theory. *Mathematics of Control, Signals and Systems*, 28(4):1–29, 2016b. DOI: [10.1007/s00498-016-0179-0](https://doi.org/10.1007/s00498-016-0179-0)

- [C14] A. Harapanahalli, **Jafarpour, S.**, and S. Coogan. **immrax**: A parallelizable and differentiable toolbox for interval analysis and mixed monotone reachability in JAX. *IFAC-PapersOnLine*, 58 (11):75–80, 2024. DOI: [10.1016/j.ifacol.2024.07.428](https://doi.org/10.1016/j.ifacol.2024.07.428). 8th IFAC Conference on Analysis and Design of Hybrid Systems ADHS 2024
- [C13] **S. Jafarpour** and S. Coogan. A contracting dynamical system perspective toward interval markov decision processes. In *IEEE Conf. on Decision and Control*, pages 2918–2924, Marina Bay Sands, Singapore, Dec. 2023. DOI: [10.1109/CDC49753.2023.10383575](https://doi.org/10.1109/CDC49753.2023.10383575)
- [C12] A. Harapanahalli, **S. Jafarpour**, and S. Coogan. Contraction-guided adaptive partitioning for reachability analysis of neural network controlled systems. In *IEEE Conf. on Decision and Control*, pages 6044–6051, Marina Bay Sands, Singapore, Dec. 2023b. DOI: [10.1109/CDC49753.2023.10383360](https://doi.org/10.1109/CDC49753.2023.10383360)
- [C11] **Jafarpour, S.**, A. Harapanahalli, and S. Coogan. Interval reachability of nonlinear dynamical systems with neural network controllers. In *Proceedings of The 5th Annual Learning for Dynamics and Control Conference*, volume 211 of *Proceedings of Machine Learning Research*, pages 12–25. PMLR, 2023. URL <https://proceedings.mlr.press/v211/jafarpour23a.html>
- [C10] A. Harapanahalli, **Jafarpour, S.**, and S. Coogan. A toolbox for fast interval arithmetic in **numpy** with an application to formal verification of neural network controlled system. In *ICML workshop on Formal Verification of Machine Learning (WFVML 2023)*, 2023a. URL <https://arxiv.org/abs/2306.15340>
- [C9] **S. Jafarpour**, A. Davydov, M. Abate, F. Bullo, and S. Coogan. Robust training and verification of implicit neural networks: A non-Euclidean contractive approach. In *ICML Workshop on Formal Verification of Machine Learning*, July 2022b. DOI: [10.48550/arXiv.2208.03889](https://doi.org/10.48550/arXiv.2208.03889)
- [C8] **S. Jafarpour***, M. Abate*, A. Davydov*, F. Bullo, and S. Coogan. Robustness certificates for implicit neural networks: A mixed monotone contractive approach. In *Learning for Dynamics and Control Conf.*, volume 168, pages 917–930, June 2022. URL <https://proceedings.mlr.press/v168/jafarpour22a>. (Oral Presentation: Top 10 percent of submitted papers)
- [C7] A. Davydov*, **S. Jafarpour***, M. Abate, F. Bullo, and S. Coogan. Comparative analysis of interval reachability for robust implicit and feedforward neural networks. In *IEEE Conf. on Decision and Control*, Cancun, Mexico, Dec. 2022. URL <https://arxiv.org/abs/2204.00187>. To appear
- [C6] A. Davydov*, **S. Jafarpour***, A. V. Proskurnikov, and F. Bullo. Non-Euclidean monotone operator theory with applications to recurrent neural networks. In *IEEE Conf. on Decision and Control*, Cancun, México, Dec. 2022. DOI: [10.1109/CDC51059.2022.9993197](https://doi.org/10.1109/CDC51059.2022.9993197)
- [C5] **S. Jafarpour** and S. Coogan. Resilience of input metering in dynamic flow networks. In *American Control Conference*, pages 126–131, Atlanta, USA, June 2022. DOI: [10.23919/ACC53348.2022.9867237](https://doi.org/10.23919/ACC53348.2022.9867237)
- [C4] F. Bullo, P. Cisneros-Velarde, A. Davydov, and **S. Jafarpour**. From contraction theory to fixed point algorithms on Riemannian and non-Euclidean spaces. In *IEEE Conf. on Decision and Control*, Austin, USA, Dec. 2021. DOI: [10.1109/CDC45484.2021.9682883](https://doi.org/10.1109/CDC45484.2021.9682883). Invited Tutorial Session
- [C3] E. Y. Huang, **S. Jafarpour**, and F. Bullo. Synchronization of coupled oscillators: The Taylor expansion of the inverse Kuramoto map. In *IEEE Conf. on Decision and Control*, pages 5340–5345, Miami, USA, Dec. 2018. DOI: [10.1109/CDC.2018.8619559](https://doi.org/10.1109/CDC.2018.8619559)
- [C2] **S. Jafarpour** and A. D. Lewis. The classical and tautological orbit theorems. In *22nd International Symposium on Mathematical Theory of Networks and Systems*, July 2016a
- [C1] **S. Jafarpour** and A. D. Lewis. Real analytic control systems. In *IEEE Conf. on Decision and Control*, pages 5618–5623, Los Angeles, USA, Dec. 2014a. DOI: [10.1109/CDC.2014.7040268](https://doi.org/10.1109/CDC.2014.7040268)

- [U4] Z. Liu, S. Jafarpour, and Y. Chen. Safety verification of stochastic systems: A set-erosion approach. *IEEE Control Systems Letters*, 2024a. URL <https://arxiv.org/abs/2410.02107>. Submitted
- [U3] Z. Liu, **S. Jafarpour**, and Y. Chen. Probabilistic reachability of discrete-time nonlinear stochastic system. *Automatica*, 2024b. URL <https://www.arxiv.org/abs/2409.09334>. Submitted

	[U2]	S. Jafarpour*, Z. Liu*, and Y. Chen. Probabilistic reachability analysis of stochastic control systems. <i>IEEE Transactions on Automatic Control</i> , 2024b. URL https://arxiv.org/abs/2407.12225 . Submitted		
	[U1]	A. Davydov*, S. Jafarpour*, A. V. Proskurnikov, and F. Bullo. Non-Euclidean monotone operator theory and applications. <i>Journal of Machine Learning Research</i> , June 2023. URL https://arxiv.org/abs/2303.11273 . Submitted		
BOOKS	[B1]	S. Jafarpour and A. D. Lewis. <i>Time-Varying Vector Fields and Their Flows</i> . SpringerBriefs in Mathematics. Springer International Publishing, 2014b. DOI: 10.1007/978-3-319-10139-2		
GRANTS SUBMITTED	2024	NSF-Cyber Physical Systems (total amount: \$600K, my share: \$300K) Title: <i>Collaborative Research: Toward A Principled Framework for Verification and Control of Dynamical Systems under Stochastic Uncertainty</i> (Role: PI) Other PI: Yongxin Chen (Georgia Tech)		
	2024	NSF-Software and Hardware Foundations (total amount: \$1.2M, my share: \$210K) Title: <i>Collaborative Research: Certifiable Correctness in Neural Network Feedback Loops</i> (Role: PI) Other PIs: Samuel Coogan (Georgia Tech), Lillian Ratliff (University of Washington), Shreyas Kousik (Georgia Tech)		
GRANT WRITING EXPERIENCE	2021	Collaboration in writing the proposal for grant AFOSR FA9550-22-1-0059 (2021-2024) Title: <i>Contraction Theory for Network Systems: Stability, Control and Optimization</i> PI: Francesco Bullo		
	2018	Collaboration in writing the proposal for grant HDTRA1-19-1-0017 (2019-2022). Title: <i>Inferring Network Structure and Flows Using Partial Observations</i> PIs: Ambuj K. Singh, Francesco Bullo, and Ananthram Swami		
TEACHING EXPERIENCE	<u>CU Boulder</u>			
	Fall	2024	Advanced Linear Systems (ECEN 5448)	Course Lecturer
	Spring	2024	Control System Analysis (ECEN 5138)	Course Lecturer
	Fall	2023	Advanced Linear Systems (ECEN 5448)	Course Lecturer
	<u>UCSB</u>			
	Aug.	2018	Engineering Mechanics: Dynamics (ME 16)	Course Lecturer
	Fall	2018	Nonlinear Network Systems	Guest Lecturer
	<u>Queen’s University</u>			
	Winter	2015	Introduction to Control Theory (MATH 332)	Course Lecturer
	Winter	2014	Lagrangian Mechanics, Dynamics, and Control (MATH 439/836)	Course Lecturer
MENTORING	2024 - present	SeyedAmirreza Alavi (Ph.D. student, CS, CU Boulder)		
	2022 - 2024	Akash Harapanahalli (Ph.D. student, ECE, Georgia Tech)		
	2021 - 2022	Matthew Abate (Ph.D. student, ME, Georgia Tech)		
	2020 - 2022	Alexander Davydov (Ph.D. student, ME UCSB)		
	2018 - 2021	Kevin D. Smith (Ph.D. student, ECE, UCSB)		
	2019 - 2021	Pedro Cisneros-Velarde (Ph.D. student, ECE, UCSB)		
	2017 - 2018	Elizabeth Y. Huang (Ph.D. student, ME, UCSB)		
INVITED TALKS	[T18]	Reachability Analysis of Dynamical Systems: A Mixed Monotone Contracting Approach, <i>Allerton Conference on Communication, Control, and Computing</i> , Sep. 2024 (Host: Daniel Liberzon)		

- [T17] Mixed-monotone Theory for Verification of Autonomous System, *Guest Lecturer in UIUC Verification of Embedded & Cyber-physical systems*, Apr. 2024 (Host: Huan Zhang) [\[Slides\]](#)
- [T16] Safety Assurance in Learning-enabled Autonomous Systems, *Waterloo Data and Artificial Intelligence Institute*, Mar. 2024. [\[Slides\]](#)
- [T15] Safety of Autonomous Systems with Learning-enabled Feedbacks, *Reliable Autonomous System Lab, Massachusetts Institute of Technology (MIT)*, Nov. 2023, (Host: Chuchu Fan) [\[Slides\]](#)
- [T14] Reachability Analysis of Control Systems: A Mixed Monotone Approach, *ECEE Department Seminar, University of Colorado Boulder*, Oct. 2023, [\[Slides\]](#)
- [T13] Interaction-aware interval reachability of neural network controlled systems, *2023 Allerton Conference on Communication, Control, and Computing*, Oct. 2023. [\[Slides\]](#) [\[Link\]](#)
- [T12] Reachability Analysis of Neural Network Controlled Systems: A Mixed Monotone Contracting Approach, *Workshop on Geometry, Topology and Control System Design, Banff Centre for Arts and Creativity, Canada*, June 2023. [\[Slides\]](#) [\[Video\]](#)
- [T11] Weak and Semi-Contraction for Large-Scale Network Systems, *LANS Seminar Talk, Argonne National Laboratory*, Apr. 2023. (Host: Adrian Maldonado) [\[Slides\]](#)
- [T10] Exploiting Structure in Feedback Systems with Learning-based Components, *ECEE Seminar Talk, University of Colorado Boulder*, Feb. 2023. [\[Slides\]](#)
- [T9] Exploiting Structure in Analysis and Design of Feedback Systems with Learning-Based Components, *Coordinated Science Laboratory, University of Illinois, Urbana Champaign (UIUC)*, Jan. 2023. (Host: Mohamed-Ali Belabbas) [\[Slides\]](#)
- [T8] Robustness Certificates for Implicit Neural Networks: A Mixed Monotone Contractive Approach, *Learning for Dynamics and Control (L4DC), Stanford University*, Jun. 2022. [\[Slides\]](#)
- [T7] Robustness of Neural Networks via Non-Euclidean Contraction Theory, *Indian Institute of Technology Delhi (virtual)*, Control Colloquium, Jun. 2022. [\[Slides\]](#)
- [T6] Safety and Resilience of Large-scale Networks via Contraction Theory, *University of California, Riverside, Mechanical Engineering Department*, Mar. 2022. [\[Slides\]](#)
- [T5] Frequency synchronization and multistability in power grids, *RSRG Virtual Seminar, California Institute of Technology*, May 2021. (Host: Steven Low) [\[Slides\]](#)
- [T4] Non-Euclidean Contraction and its Extensions with Applications to Network Systems, *Georgia Institute of Technology*, May 2021. (Host: Samuel Coogan) [\[Slides\]](#)
- [T3] Weak and Semi-Contraction for Network Systems, *Mathematical Biology Seminar, Department of Mathematics, University of Iowa*, Apr. 2021. (Host: Zahra Aminzare) [\[Slides\]](#)
- [T2] Stability and Control of Large-scale Nonlinear Networks, *Queen's University Control Seminar, Department of Mathematics, Queen's University*, Apr. [\[Slides\]](#) 2021.
- [T1] Synchronization and Multistability in Complex Networks and Power Grids, *Control Theory Seminar, Peking University*, May 2020. [\[Slides\]](#)

CONFERENCE
ORGANIZER

- 2024 Finance Chair for the **8th IFAC Conference on Analysis and Design of Hybrid Systems** (ADHS 2024), Boulder, Colorado.
- 2024 Co-organizer of the workshop **From Formal Methods to Data-Driven Verification and Control** in 63rd IEEE Conference on Decision and Control, Milan, Italy (with Abolfazl Lavaei, Chuchu Fan, and Lars Lindemann).
- 2022 Organizer of the **Whiteboard Seminars** for Decision and Control Lab at Georgia Institute of Technology.
- 2017 Session Chair for **Controlled Networks and System Controllability** at the 14th SIAM Conference on Control & its Applications, Pittsburgh, Pennsylvania.

HONORS AND AWARDS	2024	Outstanding Reviewer, IEEE Control Systems Letters (L-CSS)
	2018	Outstanding Reviewer, IEEE Control Systems Letters (L-CSS)
	2011-2015	Queen's International Tuition Award, Queen's University
	2011-2012	Huntly Macdonald Sinclair Tuition Fellowship, Queen's University
	2011	Ranked 1 st in the M.Sc. Mechanical Engineering program, Shiraz University
	2003	Awarded Silver Medal in the 23 th Iranian Student Mathematical Olympiad
PROFESIONAL SERVICE	2024	Associate Editor handling 6 papers in 2024 IEEE International Conference on Intelligent Transportation Systems (ITS)
UNIVERSITY SERVICE	2024	Engagement & Community (EC) committee, CU Boulder Department of Electrical and Computer Engineering
	2023	Diversity, Equity, and Inclusion (DEI) Committee, CU Boulder Department of Electrical and Computer Engineering
	2023	Faculty and Staff Recruitment, Retention, and Retirement (FSR ³) committee, CU Boulder Department of Electrical and Computer Engineering
REVIEW ACTIVITY	Grants	❑ Panelist for two NSF programs
	Journals	❑ Nature Communications ❑ IEEE Transactions on Automatic Control ❑ Automatica ❑ SIAM Journal on Control and Optimization ❑ IEEE Transactions on Control of Network Systems ❑ IEEE Transactions on Power Systems ❑ IEEE Transactions on Circuits and Systems I: Regular Papers ❑ IEEE Control Systems Letters ❑ IEEE Transactions on Control Systems Technology ❑ IEEE Transactions on Network Science and Engineering ❑ Nonlinearity ❑ IEEE Transactions on Energy Conversion
	Conferences	❑ IEEE Conference on Decision and Control (CDC) ❑ American Control Conference(ACC) ❑ European Control Conference (ECC)
OUTREACH ACTIVITY	2023	Mentor for Georgia Intern-Fellowships for Teachers (GIFT)
REFERENCES	Francesco Bullo Department of Mechanical Engineering University of California, Santa Barbara bullo@engineering.ucsb.edu	
	Bahman Gharesifard Department of Mathematics and Statistics Queen's Univeristy, Canada bahman.gharesifard@queensu.ca	
	Majid Zamani Department of Computer Science University of Colorado Boulder majid.zamani@colorado.edu	
	Samuel Coogan School of Electrical and Computer Engineering Georgia Institute of Technology sam.coogan@gatech.edu	
	Andrew D. Lewis Department of Mathematics and Statistics Queen's University, Canada andrew@mast.queensu.ca	