Saber Jafarpour

CONTACT INFORMATION

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RESEARCH EXPERIENCE

Department of Electrical, Computer, and Energy Engineering University of Colorado Boulder	Aug. 2023–present
Research Associate	
School of Electrical and Computer Engineering Georgia Institute of Technology	Sept. 2021–Aug. 2023
Postdoctoral Research Fellow (Advisor: Samuel Coogan)	
Center of Control, Dynamical Systems, and Computation University of California, Santa Barbara	Aug. 2016–Aug. 2021
Postdoctoral Research Fellow (Advisor: Francesco Bullo)	

EDUCATION

Department of Mathematics and Statistics, Queen's University	Aug. 2011–July 2016
Ph.D. in Applied Mathematics (Advisor: Andrew D. Lewis) Dissertation: On the Role of Regularity in Mathematical Control Theory	
Department of Mechanical Engineering, Shiraz University	Aug. 2008–May 2011
M.Sc. in Applied Mechanics (Advisor: Mojtaba Mahzoon)	
Department of Mechanical Engineering, Shiraz University	Aug. 2004–Aug. 2008
B.Sc. in Mechanical Engineering	

RESEARCH INTERESTS

My research interests are in safety, learning, and control of autonomous systems with applications to robotic systems and multi-agent cyber-physical networks. More specifically, I am interested in:

- Safety and robustness of learning-based autonomous systems
- Contraction theory for optimization and learning algorithms
- Resilience of nonlinear dynamic networks
- Geometric control and controllability of systems

JOURNAL/ CS-CONFERENCE PAPERS

[J1] **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

[J2] **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

[J3] **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

[J4] 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

[J5] **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

[J6] **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)**

[J7] **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

[J8] **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

[J9] **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

[J10] **S. Jafarpour**. On small-time local controllability. *SIAM Journal on Control and Optimization*, 58(1):425–446, 2020. DOI: 10.1137/16M1068797

[J11] **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

[J12] M. Pirani and **S. Jafarpour**. Network critical slowing down: Data-driven detection of critical transitions in nonlinear networks. *IEEE Transactions on Control of Network Systems*, 2022. URL https://arxiv.org/abs/2208.03881. To appear

[J13] 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=l0V53bErniB

[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

[J15] 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

[J16] 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

[J17] 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

[J18] 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

[J19] 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

[J20] 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

REFEREED CONFERENCE PAPERS

[C1] **S. Jafarpour** and S. Coogan. A contracting dynamical system perspective toward interval markov decision processes. In *IEEE Conf. on Decision and Control*, Marina Bay Sands, Singapore, 2023. to appear

[C2] 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*, Marina Bay Sands, Singapore, Dec. 2023b. URL https://arxiv.org/abs/2304.03671. to appear

[C3] **Jafarpour, S.**, A. Harapanahalli, and S. Coogan. Interval reachability of nonlinear dynamical systems with neural network controllers. In *Learning for Dynamics and Control Conference*, pages 12–25. PMLR, 2023

[C4] 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

[C5] **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

[C6] 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

[C7] 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*, Cancún, México, Dec. 2022. DOI: 10.1109/CDC51059.2022.9993197

[C8] **S. Jafarpour** and S. Coogan. Resilience of input metering in dynamic flow networks. In *American Control Conference*, pages 126–131, June 2022a. DOI: 10.23919/ACC53348.2022.9867237

[C9] 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*, Dec. 2021. DOI: 10.1109/CDC45484.2021.9682883. Invited Tutorial Session

[C10] 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

[C11] **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

[C12] **S. Jafarpour** and A. D. Lewis. Real analytic control systems. In *IEEE Conf. on Decision and Control*, pages 5618–5623, Dec. 2014a. DOI: 10.1109/CDC.2014.7040268

UNDER REVIEW PAPERS

[U1] **S. Jafarpour***, A. Harapanahalli*, and S. Coogan. Efficient interaction-aware interval analysis of neural network feedback loops. *IEEE Transactions on Automatic Control*, 2023. Submitted

[U2] **S. Jafarpour** and S. Coogan. Monotonicity and contraction on polyhedral cones. *IEEE Transactions on Automatic Control*, 2022b. URL http://arxiv.org/abs/2210.11576. Submitted

[U3] A. Davydov*, **S. Jafarpour***, A. V. Proskurnikov, and F. Bullo. Non-Euclidean monotone operator theory and applications. *Journal of Machine Learning Research*, June 2023. URL https://arxiv.org/abs/2303.11273. Submitted

BOOKS

[B1] **S. Jafarpour** and A. D. Lewis. *Time-Varying Vector Fields and Their Flows*. SpringerBriefs in Mathematics. Springer International Publishing, 2014b. DOI: 10.1007/978-3-319-10139-2

INVITED TALKS

[T1] Interaction-aware interval reachability of neural network controlled systems, *2023 Allerton Conference on Communication, Control, and Computing*, October 2023. [Slides] [Link]

[T2] 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]

[T3] Weak and Semi-Contraction for Large-Scale Network Systems, *LANS Seminar Talk, Argonne National Laboratory*, Apr. 2023. (Host: Dr. Adrian Maldonado) [Slides]

[T4] Exploiting Structure in Feedback Systems with Learning-based Components, *ECEE Seminar Talk, University of Colorado Boulder*, Feb. 2023. [Slides]

[T5] 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: Dr. Ali Belabbas) [Slides]

[T6] 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]

[T8] Safety and Resilience of Large-scale Networks via Contraction Theory, *University of California, Riverside, Mechanical Engineering Department*, Mar. 2022. [Slides]

[T9] Frequency synchronization and multistability in power grids, *RSRG Virtual Seminar, Department of Electrical Engineering, California Institute of Technology*, May 2021. [Slides]

[T10] Non-Euclidean contraction and its extensions with applications to network systems, *School of Electrical and Computer Engineering, Georgia Institute of Technology*, May 2021. [Slides]

[T11] Weak and Semi-Contraction for Network Systems, *Mathematical Biology Seminar, Department of Mathematics, University of Iowa*, Apr. 2021. [Slides]

[T12] Stability and Control of Large-scale Nonlinear Networks, *Queen's University Control Seminar, Department of Mathematics, Queen's University*, Apr. [Slides] 2021.

[T13] Synchronization and Multistability in Complex Networks and Power Grids, *Control Theory Seminar, Peking University*, May 2020. [Slides]

TEACHING EXPERIENCE	**CU Boulder**		
	Fall	2023	Instructor, Advanced Linear Systems (ECEN-MCEN 5448)
	UCSB		
	Summer	2018	Instructor, Engineering Mechanics: Dynamics (ME 16)
	Fall	2018	Guest Lecturer, Nonlinear Network Systems
	Queen's University		
	Winter	2015	Instructor, Introduction to Control Theory (MATH 332)
	Winter	2014	Instructor, Lagrangian Mechanics, Dynamics, and Control (MATH 439/836)

MENTORING		
	Sept. 2023 - present	Yiting Chen (Ph.D. student, ECEE CU Boulder)
	Sept. 2022 - present	Akash Harapanahalli (Ph.D. student, ECE Georgia Tech)
	Sept. 2021 - Jun 2022	Matthew Abate (Ph.D. student, ME Georgia Tech)
	Sept. 2020 - Mar 2022	Alexander Davydov (Ph.D. student, ME UCSB)
	Sept. 2018 - Aug. 2021	Kevin D. Smith (Ph.D. student, ECE, UCSB)
	Sept. 2019 - Jul. 2021	Pedro Cisneros-Velarde (Ph.D. student, ECE, UCSB)
	May 2017 - Sept. 2018	Elizabeth Y. Huang (Ph.D. student, ME, UCSB)

GRANTS SUBMITTED	2023	NSF-Safe Learning-Enabled Systems (NSF 23-562) Title: *Safety in the Learned Feedback Loop via Conflict Recognition, Uncertainty Adaptation, and Performant Resolution* Role: co-PI other PIs: Samuel Coogan, Shreyas Kousik, Lillian J. Ratliff

GRANT WRITING EXPERIENCE	2021	Collaboration in writing the proposal for grant AFOSR FA9550-22-1-0059 (2021-2024) Title: *Contraction Theory for Network Systems: Stability, Control and Optimization* PI: Francesco Bullo
	2018	Assistant in writing the proposal for grant HDTRA1-19-1-0017 (2019-2022). Title: *Inferring Network Structure and Flows Using Partial Observations* PIs: Ambuj K. Singh, Francesco Bullo, and Ananthram Swami

CONFERENCE ORGANIZER	Summer 2022	Organizer of the **Whiteboard Seminars** for Decision and Control Lab at Georgia Institute of Technology.
	July 2017	Session Chair for **Controlled Networks and System Controllability** at the 14th SIAM Conference on Control & its Applications, Pittsburgh

INVITED WORKSHOPS	July 2023	Geometry, Topology and Control System Design, Banff Research Station, Canada
	Sept. 2021	Autonomous Energy Systems, NREL (Virtual workshop)
	Aug. 2020	Autonomous Energy Systems, NREL (Virtual workshop)
	Apr. 2019	Innovative Optimization and Control Methods for Autonomous Systems, NREL
	July 2012	Focus Program on Geometry, Mechanics and Dynamics, Fields Institute, Toronto

HONORS AND AWARDS	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 1st in the M.Sc. Mechanical Engineering program, Shiraz University
	2008	Ranked 26th in M.Sc. Entrance Exam for Iranian Universities
	2004	Ranked 288th in B.Sc. Entrance Exam for Iranian Universities
	2003	Awarded Silver Medal in the 23rd Iranian Student Mathematical Olympiad

OUTREACH ACTIVITY	2023	Mentor for Georgia Intern-Fellowships for Teachers (GIFT)

REVIEW ACTIVITY	Grants	❑ Panelist for NSF-Energy, Power, Control, and Networks (EPCN)
	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)

PROFESIONAL SERVICE	Fall 2023	Finance Chair for the 8th IFAC Conference on Analysis and Design of Hybrid Systems

UNIVERSITY SERVICE	Fall 2023	Diversity, Equity, and Inclusion (DEI) Committee, CU Boulder Department of Electrical, Computer, and Energy Engineering
	Fall 2023	Faculty and Staff Recruitment, Retention, and Retirement (FSR³) committee, CU Boulder Department of Electrical, Computer, and Energy Engineering

REFERENCES

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