Saber Jafarpour

Information

Research Assistant Professor
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Research Experience

University of Colorado Boulder 2023–present
Department of Electrical and Computer Engineering
Research Assistant Professor

Georgia Institute of Technology 2021–2023
Institute for Robotics and Intelligent Machines
Postdoctoral Research Fellow (Advisor: Samuel Coogan)

University of California, Santa Barbara 2016–2021
Center of Control, Dynamical Systems, and Computation
Postdoctoral Research Fellow (Advisor: Francesco Bullo)

Education

Queen's University, Canada 2011–2016
Department of Mathematics and Statistics
Ph.D. in Applied Mathematics (Advisor: Andrew D. Lewis)
Dissertation: On the Role of Regularity in Mathematical Control Theory

Shiraz University, Iran 2008–2011
Department of Mechanical Engineering
M.Sc. in Applied Mechanics (Advisor: Mojtaba Mahzoon)

Shiraz University, Iran 2004–2008
Department of Mechanical Engineering
B.Sc. in Mechanical Engineering

Research Interests

My research is the borad 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:

- Safety assurance of learning-enabled systems
- Performance of optimization and learning algorithms
- Robustness of large-scale autonomous systems
- Geometric control of nonlinear systems

Journal Papers

[J1] **S. Jafarpour***, A. Harapanahalli*, and S. Coogan. Efficient interaction-aware interval analysis of neural network feedback loops. *IEEE Transactions on Automatic Control*, 2024a. URL https://arxiv.org/abs/2307.14938. To appear

[J2] **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

* equal contribution

[J3] **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

[J4] **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

[J5] 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

[J6] **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

[J7] **S. Jafarpour** and S. Coogan. Monotonicity and contraction on polyhedral cones. *IEEE Transactions on Automatic Control*, 2024. URL http://arxiv.org/abs/2210.11576. To appear

[J8] **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)**

[J9] **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

[J10] **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

[J11] **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

[J12] **S. Jafarpour**. On small-time local controllability. *SIAM Journal on Control and Optimization*, 58(1):425–446, 2020. DOI: 10.1137/16M1068797

[J13] **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

[J14] 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*, 11(2):573–585, 2024. DOI: 10.1109/TCNS.2023.3332730

[J15] 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

[J16] 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

[J17] 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

[J18] 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

[J19] 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

[J20] 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

[J21] 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

[J22] 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*, pages 2918–2924, Marina Bay Sands, Singapore, Dec. 2023. DOI: 10.1109/CDC49753.2023.10383575

[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*, pages 6044–6051, Marina Bay Sands, Singapore, Dec. 2023b. DOI: 10.1109/CDC49753.2023.10383360

[C3] **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

[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. URL https://arxiv.org/abs/2306.15340

[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, Atlanta, USA, June 2022. 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*, Austin, USA, 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, Los Angeles, USA, Dec. 2014a. DOI: 10.1109/CDC.2014.7040268

Under review Papers

[U1] **S. Jafarpour***, Z. Liu*, and Y. Chen. Probabilistic reachability analysis of stochastic control systems. *IEEE Transactions on Automatic Control*, 2024b. URL https://arxiv.org/abs/2407.12225. Submitted

[U2] Z. Liu, **S. Jafarpour**, and Y. Chen. Probabilistic reachability of discrete-time nonlinear stochastic system. *Automatica*, 2024. 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] Mixed-monotone Theory for Verification of Autonomous System, *Guest Lecturer in UIUC Verification of Embedded & Cyber-physical systems*, Apr. 2024 (Host: Huan Zhang) [Slides]

[T2] Safety Assurance in Learning-enabled Autonomous Systems, *Waterloo Data and Artificial Intelligence Institute*, Mar. 2024. [Slides]

[T3] Safety of Autonomous Systems with Learning-enabled Feedbacks, *Reliable Autonomous System Lab, Massachusetts Institute of Technology (MIT)*, Nov. 2023, (Host: Chuchu Fan) [Slides]

[T4] Reachability Analysis of Control Systems: A Mixed Monotone Approach, *ECEE Department Seminar, University of Colorado Boulder*, Oct. 2023, [Slides]

[T5] Interaction-aware interval reachability of neural network controlled systems, *2023 Allerton Conference on Communication, Control, and Computing*, Oct. 2023. [Slides] [Link]

[T6] 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]

[T7] Weak and Semi-Contraction for Large-Scale Network Systems, *LANS Seminar Talk, Argonne National Laboratory*, Apr. 2023. (Host: Adrian Maldonado) [Slides]

[T8] 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]

[T10] Robustness Certificates for Implicit Neural Networks: A Mixed Monotone Contractive Approach, *Learning for Dynamics and Control (L4DC), Stanford University*, Jun. 2022. [Slides]

[T11] Robustness of Neural Networks via Non-Euclidean Contraction Theory, *Indian Institute of Technology Delhi (virtual)*, Control Colloquium, Jun. 2022. [Slides]

[T12] Safety and Resilience of Large-scale Networks via Contraction Theory, *University of California, Riverside, Mechanical Engineering Department*, Mar. 2022. [Slides]

[T13] Frequency synchronization and multistability in power grids, *RSRG Virtual Seminar, California Institute of Technology*, May 2021. (Host: Steven Low) [Slides]

[T14] Non-Euclidean Contraction and its Extensions with Applications to Network Systems, *Georgia Institute of Technology*, May 2021. (Host: Samuel Coogan) [Slides]

[T15] Weak and Semi-Contraction for Network Systems, *Mathematical Biology Seminar, Department of Mathematics, University of Iowa,* Apr. 2021. (Host: Zahra Aminzare) [Slides]

[T16] Stability and Control of Large-scale Nonlinear Networks, *Queen's University Control Seminar, Department of Mathematics, Queen's University*, Apr. [Slides] 2021.

[T17] Synchronization and Multistability in Complex Networks and Power Grids, *Control Theory Seminar, Peking University*, May 2020. [Slides]

Teaching Experience

CU Boulder

Fall	2024	Instructor, Advanced Linear Systems (ECEN 5448)
Spring	2024	Instructor, Control System Analysis (ECEN 5138)
Fall	2023	Instructor, Advanced Linear Systems (ECEN 5448)

UCSB

Aug.	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

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)

Grants Submitted

2024 **NSF-Cyber Physical Systems**

Title: *Toward A Principled Framework for Verification and Control of Dynamical Systems under Stochastic Uncertainty* (Role: co-PI)

2023 **NSF-Safe Learning-Enabled Systems**

Title: *Safety in the Learned Feedback Loop via Conflict Recognition, Uncertainty Adaptation, and Performant Resolution* (Role: co-PI)

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 Collaboration 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

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

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 1st in the M.Sc. Mechanical Engineering program, Shiraz University
2003	Awarded Silver Medal in the 23th Iranian Student Mathematical Olympiad

Profesional Service

2023-2024	Finance Chair for the 8th IFAC Conference on Analysis and Design of Hybrid Systems (ADHS 2024)
2024	Associate Editor for 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
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