James R. Ferlez

CONTACT INFORMATION

James Ferlez
3426 Engineering Hall
Irvine, CA 92697-2700 USA

Cell: +1-814-206-6702
E-mail: jferlez@uci.edu
Web: jferlez.github.io; Google Scholar; GitHub

RESEARCH INTERESTS

Machine Learning and AI: Neural network architectures; Neural Network verification; learning algorithms; assured autonomy; reinforcement learning.
Computer Science and Formal Methods: Concurrency theory; modal logic; process algebra; model checking; hybrid systems.
Stochastic Control: reinforcement learning; dynamic programming; simulation-based methods.

EDUCATION

Ph.D., Electrical Engineering **August 2019**
University of Maryland, College Park, MD.

- Thesis Topic: *Generalized Synchronization Trees*
- Advisors: Professor Steven I. Marcus and Professor W. Rance Cleaveland
- Area of Study: Control Engineering
- Future Faculty Fellow.
- Thesis defended successfully on December 5, 2018

M.S., Electrical Engineering **August 2009**
Pennsylvania State University, University Park, PA.

- Paper Title: *An Algorithm for Complex-Valued ICA Based on an Isomorphism for the Multiplicative Group of Complex Matrices.*
- Advisors: Professor Robert M. Nickel and Professor W. Kenneth Jenkins
- Area of Study: Signal Processing.
- Joint Undergraduate/Graduate Program.

B.S., Electrical Engineering **December 2008**
Pennsylvania State University, University Park, PA.

- With Distinction and Honors.
- Thesis Title: *Acoustic Source Separation in Multi-speaker Environments.*
- Advisors: Professor Robert M. Nickel and Professor W. Kenneth Jenkins
- Joint Undergraduate/Graduate Program.

AWARDS AND HONORS

Winner of 2022 Verification of Neural Networks Competition (VNN-COMP 2022) in the TLL Verification Category

- FastBATLLNN, a TLL verification tool I developed and implemented, won in the TLL verification category.

Future Faculty Fellow (2014)

- Awarded by the University of Maryland Department of Electrical and Computer Engineering to excellent students with aspirations toward an academic career.

IN PREPARATION/ UNDER REVIEW PUBLICATIONS

[1] Odema, M., **Ferlez, J.**, Shoukry, Y. and Al Faruque, M. *SEO: Safety-Aware Energy Optimization Framework for Multi-Sensor Neural Controllers at the Edge*. Under double-blind review, *Design Automation Conference (DAC) 2023*.

[2] Odema, M.*, **Ferlez, J.***, Shoukry, Y. and Al Faruque, M. *EnergyShield: Provably-Safe Offloading of Neural Network Controllers for Energy Efficiency*. Under double-blind review, *International Conference on Cyber-Physical Systems (ICCPS) 2023*.
* **Equally contributing authors**

[3] **Ferlez, J.** and Shoukry, Y. *Assured Neural Network Architectures for Control and Identification of Nonlinear Systems.* https://arxiv.org/abs/2109.10298.

[4] **Ferlez, J.**, Elnaggar, M., Shoukry, Y and Fleming, C. *ShieldNN: A Provably Safe NN Filter for Unsafe NN Controllers.* https://arxiv.org/abs/2006.09564.

[5] **Ferlez, J.**, R. Cleaveland, and S. Marcus. *Hennessy-Milner Classes and Linear Time-Invariant Systems under Weak Bisimulation Semantics.* In preparation; draft available upon request.

JOURNAL AND SELECTIVE SINGLE-TRACK CONFERENCE PUBLICATIONS

[6] **Ferlez, J.**, and Shoukry, Y. *Polynomial-Time Reachability for LTI Systems with Two-Level Lattice Neural Network Controllers. IEEE Control Systems Letters (L-CSS)*, to appear, 2023. (To be presented at the *American Control Conference*, 2023.)

[7] **Ferlez, J.**, Khedr, H. and Shoukry, Y. *Fast BATLLNN: Fast Box Analysis of Two-Level Lattice Neural Networks. ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, April 2022, pp 1 - 11. 10.1145/3501710.3519533. **(25% Acceptance Rate.)**

[8] Khedr, H., **Ferlez, J.** and Shoukry, Y.. *PEREGRiNN: Penalized- Relaxation Greedy Neural Network Verifier* in *Computer Aided Verification (CAV)*, (A. Silva and K. R. M. Leino, eds.), pp. 287–300, 2021. 978-3-030-81685-8_13. **(32% Acceptance Rate.)**

[9] **Ferlez, J.** and Y. Shoukry. *AReN: Assured ReLU NN Architecture for Model Predictive Control of LTI Systems. ACM International Conference on Hybrid Systems: Computation and Control (HSCC)*, April 2020, pp. 1-11. https://dl.acm.org/doi/abs/10.1145/3365365.3382213. **(25% Acceptance Rate.)**

[10] **Ferlez, J.**, R. Cleaveland, and S. Marcus. *Generalized Synchronization Trees.* In *Foundations of Software Science and Computation Structures (FoSSaCS)*, Pages 304–319. Springer Berlin Heidelberg, 2014. doi: 10.1007/978-3-642-54830-7_20. ISBN 978-3-642-54830-7. **(29.2% Acceptance Rate.)**

CONFERENCE PUBLICATIONS

[11] Cruz, U. S., **Ferlez, J.** and Shoukry, Y. *Safe-by-Repair: A Convex Optimization Approach for Repairing Unsafe Two-Level Lattice Neural Network Controllers*. To appear: *2022 61st IEEE Conference on Decision and Control (CDC).*

[12] **Ferlez, J.** and Shoukry, Y. *Bounding the Complexity of Formally Verifying Neural Networks: A Geometric Approach. 2021 60th IEEE Conference on Decision and Control (CDC)*, pp. 5104–5109, 2021. CDC45484.2021.9683375

[13] **Ferlez, J.**, X. Sun, and Y. Shoukry. *Two-Level Lattice Neural Network Architectures for Control of Nonlinear Systems. 59th IEEE Conference on Decision and Control (CDC)*, 2020, pp. 2198-2203. CDC42340.2020.9304079

[14] **Ferlez, J.**, R. Cleaveland, and S. Marcus. *Bisimulation in Behavioral Dynamical Systems and Generalized Synchronization Trees. IEEE Conference on Decision and Control (CDC)*, 2018, pp. 751–758. https://ieeexplore.ieee.org/document/8619607

WORKSHOP PUBLICATIONS

[15] **Ferlez, J.**, R. Cleaveland, and S. Marcus. *Bisimulation and Hennessy-Milner Logic for Generalized Synchronization Trees.* In *Proceedings EXPRESS/SOS 2017*, volume 255, pages 35–50, 2017. doi: 10.4204/EPTCS.255.3. http://arxiv.org/abs/1709.00827.

GRANTS

CPS Small: AIDE: Formally Verified AI Deployment on the Edge
Sponsor: National Science Foundation (NSF)
Lead PIs: Yasser Shoukry and Mohammad Al Faruque
Senior Personnel: James Ferlez

Dates: 2023-2025 (expected)
Award Amount: $600,000
Status: Under review
Contributions: Helped develop a research program to extend results on energy efficient implementation of neural networks without compromising system safety.

CPS Breakthrough: Compositional Modeling of Cyber-Physical Systems (CNS-1446665)
Sponsor: National Science Foundation (NSF)
Lead PIs: W. Rance Cleaveland and Steven I. Marcus
Dates: September 2014 - August 2018
Award Amount: $500,000
Status: Funded
Contributions: Helped develop a research program to extend results from my early PhD research; **directly wrote ≈60% of the submitted grant proposal text.**

Research Experience

University of California, Irvine, Irvine, CA

Postdoctoral Researcher **October 2019 - Present**

- Carried out research on the verification of machine learning algorithms (particularly deep neural networks) in control applications, with focus on the development of correct-by-design architectures for safe deep ReLU neural networks.
  - Extended previous results on correct-by-design ReLU neural network architectures to nonlinear control systems.
  - Helped develop new algorithms for verifying the safety of deep ReLU neural networks by verifying their adherence to joint input-output constraints.
  - Developed new algorithms to more efficiently verify safety of special ReLU neural network architectures, both
  - Developed new algorithms to perform repair on unsafe neural networks, while maintaining existing safety properties.
  - Helped develop new algorithms to reduce energy usage of closed-loop neural network controllers without compromising system safety.
- Supported by grants:
  - C3.AI Digital Transformation Institute (DTI) 2022 Award: Semantic Adversarial Analysis for Secure Critical Infrastructure.
  - NSF Grant 1845194 (CAREER): Decision Procedures for High-Assurance, AI-Controlled, Cyber-Physical Systems (PI: Yasser Shoukry.)

University of Maryland, College Park, MD

Postdoctoral Researcher **June 2019 - September 2019**

- Carried out research on the verification of machine learning algorithms (particularly deep neural networks) in control applications, with focus on the development of correct-by-design architectures for safe deep ReLU neural networks.
  - Used barrier certificates to develop safety ReLU layers that can be appended to an arbitrary data-trained ReLU neural network to obtain an overall safe controller for the kinematic bicycle model.
  - Developed bounds on the size/depth of a ReLU architecture necessary to implement an optimal MPC controller for a linear system with quadratic cost.
- Supported by grants:
  - NSF Grant 1845194 (CAREER): Decision Procedures for High-Assurance, AI-Controlled, Cyber-Physical Systems (PI: Yasser Shoukry.)

University of Maryland, College Park, MD

Research Assistant **January 2010 - May 2019**

- Carried out basic research on the mathematical foundations of cyber-physical systems modeling, resulting in the development of a novel modeling framework, Generalized Synchronization Trees.
  - Developed a generalization version of Synchronization Trees, the process algebra modeling primitives, to continuous and hybrid systems;
  - Developed and compared notions of bisimulation for Generalized Synchronization Trees; and
  - Studied the interaction of modal logic with the semantics of these notions of bisimulation, especially for Linear Time-Invariant Systems.
- Supported research on topics of interest to the larger research group, such as:
  - Reinforcement learning and multi-armed bandits;
  - Dynamic programming and stochastic optimal control;
  - Stochastic approximation and global optimization;
  - Deep neural networks; and
  - Cumulative prospect theory.
- Supported by grants:
  - NSF Expeditions in Computing Grant: Next-Generation Model Checking and Abstract Interpretation with a Focus on Embedded Control and Systems Biology (NSF Grant: CCF-0926194).
  - NSF CPS Breakthrough: Compositional Modeling of Cyber-Physical Systems (NSF Grant: CNS-1446665).

TEACHING EXPERIENCE

University of California, Irvine, Irvine, CA

Guest Lecturer **Spring 2022**

- Delivered two lectures for *EECS 195: Autonomous Systems*
- Independently developed one lecture on training Neural Networks; audio and slides available upon request.

University of Maryland, College Park, MD

Teaching Assistant **Spring 2018**

- Discussion TA for two sections of *ENEE 222: Elements of Discrete Signal Analysis*

University of Maryland, College Park, MD

Co-Instructor **Fall 2016**

- Co-taught two sections of *ENEE 222: Elements of Discrete Signal Analysis*

Pennsylvania State University, University Park, PA

Teaching Assistant **Spring 2005, Fall 2005 and Fall 2006**

- Teaching Assistant for *EE 453: Fundamentals of Digital Signal Processing*

Teaching Assistant **Fall 2004**

- Teaching Assistant for *EE 350: Continuous-Time Linear Systems*

TALKS/ SEMINARS/ PROJECTS

Efficient Verification of Two-Level Lattice Neural Networks.
- **Talk**: Southern California Control Workshop, Fall 2021.

AReN: Assured ReLU Networks for MPC Control of LTI Systems.
- **Poster**: Southern California Machine Learning Symposium 2021 (rescheduled from 2020).

AReN: Assured ReLU Networks for MPC Control of LTI Systems.
- **Talk**: Information Theory and Applications 2020.

A Proposed Adaptive Structure for Hierarchical Sensorimotor Control.
- **Project**: Adaptive Control.
- Proposed and implemented an adaptive, MPC-based "high-level" sensorimotor controller of the kind suggested by Todorov et.al. to control a two-link manipulator with unknown task mass.

Some Notes on "Elementary Proof of a Theorem of Helson".
- **Project**: Harmonic Analysis.
- Presented the following paper – including noting some (small) errors:
  Raouf Doss. *Elementary Proof of a Theorem of Helson.* In Proceedings of the American Mathematical Society, pages 418–420, 1971.

A Review of the Stochastic Maximum Principle with an Application to Stochastic Hybrid Systems.
- **Project**: Stochastic Control.
- Reviewed relevant results for the Stochastic (Pontryagin's) Maximum Principle, and demonstrated that it can be applied to a certain specific problem for stochastic hybrid systems.

Option Pricing in Continuous-Time: The Black-Scholes Formula.
- **Project**: Stochastic Processes.
- Presented the standard Martingale derivation of the Black-Scholes formula for pricing European Options (when the price of the underlying asset is modeled by geometric Brownian motion).

Multistage Adaptive Sampling: Upper Confidence Bound Sampling.
- **Controls Seminar Presentation**: *Simulation-Based Methods for Markov Decision Processes, Multi-Armed Bandits, and Monte Carlo Tree Search*
- Presented a seminar on the Upper Confidence Bound Sampling algorithm for Q learning.

SOFTWARE ARTIFACTS

FastBATLLNN: A fast tool for verifying Two-Level Lattice Neural Networks.

L-TLLBox: A fast tool for computing reachable sets for Two-Level Lattice Neural Network Controllers.

COMPUTER SKILLS

Python (including Numpy), Mathematica, MATLAB, C/C++, OpenCL/CUDA, Amazon EC2, Microsoft Azure

PROFESSIONAL SERVICE

Program Committee Service
- *HSCC 2022 Repeatability Artifact Program Committee*

Referee Service
- *IEEE Control Systems Letters*
- *IEEE Conference on Decision and Control*
- *IEEE Transactions on Automatic Control*
- *Mathematics of Operations Research*

OUTREACH AND MENTORING

Outreach
- Reading All-Stars Volunteer (2011 - 2019)

- Weekly program at Tubman Elementary School, Washington D.C., where each volunteer works one-on-one with a student to improve their literacy through extra practice, feedback and inspiration.
- Website: https://826dc.org/program/reading-all-stars/. Media references: Washington Post; Issuu.com.

Mentoring

- Graduate students mentored:
  - Xiaowu Sun (UCI)
  - Goli Vaisi (UCI)
  - Ulices Santa Cruz (UCI)
  - Haitham Khedr (UCI)

Professional Experience

Pennsylvania State University Libraries, University Park, PA

Web/Database Programmer **August 2008 - December 2009**

- Developed a comprehensive JavaScript framework to enhance several web forms, while ensuring maintainability by non-programmers. Also responsible for HTML/CSS coding. (Links available upon request).
- Prompted and assisted with the migration of electronic reserves usage and copyright information from a Microsoft Excel spreadsheet to a Microsoft Access database. Responsible for both database design and database programming with Visual Basic for Applications (VBA). The final product provided many important new capabilities and improved usability for the end-user.

Applied Research Laboratory, University Park, PA

Student Research Employee **August 2003 - August 2004**

- Conducted independent research to develop a system for automated fiber detection in composite material micrographs, which were often of very poor quality.
- Programmed an easy to use MATLAB GUI application to facilitate use by non-experts.
- Presented at the 2004 AFOSR Polymer Matrix Composite Review in Long Beach, CA.

Student Employee **May 2002 - August 2002; May 2003 - August 2003**

- Independently designed several digital logic circuits on a Xilinx FPGA.
- Assisted in the performance benchmarking of a Texas Instruments Digital Signal Processor (DSP) and wrote various pieces of boot code in that processor's assembly language.

References

Professor Steven I. Marcus (e-mail: marcus@umd.edu; phone: +1-301-405-7589)
- Professor Emeritus, Electrical and Computer Engineering, University of Maryland, College Park

⋆ *Dr. Marcus was my PhD co-supervisor.*

Professor W. Rance Cleaveland (e-mail: wcleavel@umd.edu; phone: +1-301-405-8572)
- Professor, Computer Science, University of Maryland, College Park
- Division Director for Computing and Communication Foundations (CCF), National Science Foundation (2019-2022).

⋆ *Dr. Cleaveland was my PhD co-supervisor.*

Professor Yasser Shoukry (e-mail: yshoukry@uci.edu; phone: +1-949-824-8147)
- Assistant Professor, Department of Electrical Engineering and Computer Science, UCI Samueli School of Engineering, University of California, Irvine

⋆ *Dr. Shoukry is my current Postdoc supervisor.*

Professor Mohammad Al Faruque (e-mail: alfaruqu@uci.edu; phone: +1-949-824-1909)
- Professor, Department of Electrical Engineering and Computer Science, UCI Samueli School of Engineering, University of California, Irvine

⋆ *Dr. Al Faruque is a current research collaborator.*