SHAORU CHEN

Microsoft Research, NYC

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RESEARCH OVERVIEW

My research focuses on developing scalable and efficient verification, optimization, and learning tools for safe control of complex nonlinear and learning-enabled systems with formal guarantees. The long-term goal is to make AI-enabled autonomous systems work safely and reliably in the real world. My works span safe and reliable AI, robust model predictive control, and safe control of learning-enabled systems.

EDUCATION

University of Pennsylvania   *Philadelphia, PA*
Ph.D. in Electrical and Systems Engineering   *Aug. 2017 - Dec. 2022*
Advised by: Prof. Victor M. Preciado
Research interests: control, optimization, machine learning. GPA: 3.96/4.00.

Zhejiang University   *Hangzhou, China*
B.E. in Electrical Engineering   *Aug. 2013 - Jun. 2017*
Chu Kochen Honors College, Advisor: Prof. Jian Chen. GPA 90.8/100

EXPERIENCE

Microsoft Research, NYC   Jan. 2023 - Present
Postdoctoral Researcher   *New York City, NY*

· Safety-assured control of neural network systems through online convex optimization.

- Filtered unsafe control inputs for neural network systems using neural network verification bounds and robust model predictive control.

- Relaxed the complex, nonconvex predictive control problem of neural network systems into a convex quadratic program with interpretable numerical results.

· Discovering planable continuous latent states from high-dimensional observations.

- Learned a latent space representation to capture the dynamics of an agent from image observations while discarding the exogenous noises and maintaining the local neighborhood structure.

- Designed a hierarchical motion planning method in the latent space utilizing the high-level abstractions of the latent states and the low-level latent dynamics.

· Verification-aided learning for safe policies with convergence guarantees.

- Designed a fine-tuning method based on convex optimization for learning neural network certificate functions with formal guarantees.

- Utilized cutting-plane methods to provide finite-step termination guarantees for the fine-tuning iteration which boosted the learning success rate.

University of Pennsylvania   Aug. 2017 - Dec. 2022
Graduate Research Assistant   *Philadelphia, PA*

· Scalable neural network verification through operator splitting.

- Proposed DeepSplit, a neural network verification algorithm that is scalable, modular, amenable for GPU acceleration, and enjoys fast theoretical convergence guarantees.

- Demonstrated the acceleration of the proposed method on certifying robustness of deep neural network image classifiers and deep Q-network in reinforcement learning tasks.

· Boosting tightness of robust model predictive control.

- Proposed a novel robust MPC method that jointly searches for robust state-feedback controllers and uncertainty over-approximations through a convex quadratic program.

- Demonstrated that the proposed method consistently and significantly outperforms existing robust MPC approaches through comprehensive comparison.

· Certificate function synthesis for hybrid systems with convergence guarantees.

- Proposed a counterexample-guided Lyapunov function synthesis algorithm for linear hybrid systems with finite-step termination guarantees.

- Applied the proposed method to approximate the region of attraction of NN-controlled systems.

· Differentiable safe controller design through control barrier functions.

- Proposed a differentiable safety layer using control barrier functions and a set-theoretic parameterization to construct a safe-by-construction NN controller.

- Demonstrated that the proposed safety layer enjoys improved training and evaluation efficiency compared with the projection-based safety layers.

Harvard University   Nov. 2016 - May 2017
Research Intern   *Cambridge, MA*

· Brain-network reconstruction using molecular imaging. Mentor: Prof. Quanzheng Li.

- Applied graph theory and machine learning to integrate the analysis of different types of brain molecular images for brain-network reconstruction and diagnosis of Alzheimer's disease.

University of California, Davis   Jul. 2016 - Sept. 2016
Research Intern   *Davis, CA*

· Fault-tolerant control of distributed energy resources. Mentor: Prof. Nael El-Farra.

- Developed sensor fault accommodation methods for control systems subject to improper sensor reading and sensor sampling rate drift.

- Examined stability and performance of a multi-rate sampled-data solid oxide fuel cell system.

PUBLICATIONS

(* indicates equal contribution)

Preprints

1. **Shaoru Chen**, Lekan Molu, Mahyar Fazlyab. Learning Neural Network Barrier Functions with Termination Guarantees. Submitted to American Control Conference (ACC) 2024.

2. Anurag Koul, Shivakanth Sujit, **Shaoru Chen**, Ben Evans, Lili Wu, Byron Xu, Rajan Chari, Riashat Islam, Raihan Seraj, Yonathan Efroni, Lekan Molu, Miro Dudik, John Langford, Alex Lamb. PcLast: Discovering Plannable Continuous Latent States. Submitted to International Conference on Learning Representations (ICLR) 2024.

3. Lekan Molu, **Shaoru Chen**, and Audrey Sedal. Lagrangian Properties and Control of Soft Robots Modeled with Discrete Cosserat Rods. Submitted to the 2024 IEEE International Conference on Robotics and Automation (ICRA).

Journal Publications

1. **Shaoru Chen**, Victor M. Preciado, Manfred Morari, and Nikolai Matni. Robust model predictive control with polytopic model uncertainty through System Level Synthesis. Automatica, 2023.

2. Shuo Yang*, **Shaoru Chen***, Victor M. Preciado, and Rahul Mangharam. Differentiable Safe Controller Design through Control Barrier Functions. IEEE Control Systems Letters (L-CSS), 2022.

3. **Shaoru Chen***, Eric Wong*, J. Zico Kolter, and Mahyar Fazlyab. DeepSplit: Scalable Verification of Deep Neural Networks via Operator Splitting. IEEE Open Journal of Control Systems (OJCSYS), 2022.

4. James T. Allen, **Shaoru Chen**, and Nael H. El-Farra. Model-based Strategies for Sensor Fault Accommodation in Uncertain Dynamic Processes with Multi-rate Sampled Measurements. Chemical Engineering Research and Design, 2019.

Conference Publications

1. **Shaoru Chen***, Kong Yao Chee*, Nikolai Matni, M. Ani Hsieh, George J. Pappas. Safety Filter Design for Neural Network Systems via Convex Optimization. In 2023 IEEE 62nd Conference on Decision and Control (CDC), 2023.

2. **Shaoru Chen**, Victor M. Preciado, and Mahyar Fazlyab. One-shot reachability analysis of neural network dynamical systems. In 2023 IEEE 40th International Conference on Robotics and Automation (ICRA), 2023.

3. **Shaoru Chen**, Ning-Yuan Li, Victor M. Preciado, and Nikolai Matni. Robust Model Predictive Control of Time-Delay Systems through System Level Synthesis. In 2022 IEEE 61st Conference on Decision and Control (CDC), 2022.

4. **Shaoru Chen**, Mahyar Fazlyab, Manfred Morari, George J. Pappas, and Victor M. Preciado. Learning Rregion of Attraction for Nonlinear Systems. In 2021 60th IEEE Conference on Decision and Control (CDC), 2021.

5. **Shaoru Chen**, Mahyar Fazlyab, Manfred Morari, George J. Pappas, and Victor M. Preciado. Learning Lyapunov Functions for Hybrid Systems. In Proceedings of the 24th International Conference on Hybrid Systems: Computation and Control (HSCC), 2021.

6. **Shaoru Chen**, Han Wang, Manfred Morari, Victor M. Preciado, and Nikolai Matni. Robust Closed-loop Model Predictive Control via System Level Synthesis. In 2020 59th IEEE Conference on Decision and Control (CDC), 2020.

7. Ximing Chen, **Shaoru Chen**, and Victor M. Preciado. Safety Verification of Nonlinear Polynomial System via Occupation Measures. In 2019 IEEE 58th Conference on Decision and Control (CDC), 2019.

8. Han Wang, Mahyar Fazlyab, **Shaoru Chen**, and Victor M. Preciado. Robust Convergence Analysis of Three-Operator Splitting. In 2019 57th Annual Allerton Conference on Communication, Control, and Computing (Allerton), 2019.

9. **Shaoru Chen**, James T. Allen, and Nael H. El-Farra. Stability and Performance-Based Strategies for Sensor Fault Accommodation in Multi-rate Sampled-data Processes. IFAC-PapersOnLine, 2017.

10. Zhiyang Liu, Jian Chen, **Shaoru Chen**, Lianghui Huang, and Zhigang Shao. Modeling and Control of Cathode Air Humidity for PEM Fuel Cell Systems. IFAC-PapersOnLine, 2017.

HONORS AND AWARDS

Chu Kochen Honors College Research Fellowship, Zhejiang University	2017
Chunhui Scholarship (highest honor in College of Control Science and Engineering, ZJU)	2017
First-Class Scholarship for Outstanding Students of Zhejiang University (top 3%)	2014, 2015
Outstanding Student Leader Awards, Zhejiang University	2014
First Prize of Chinese Physics Olympiad (Top 55 in Jiangsu Province, China)	2012

INVITED TALKS

Learning Lyapunov Functions for Hybrid Systems
- Spotlight talk in the 55th Annual Conference on Information Sciences and Systems (CISS), 2021.

PROFESSIONAL SERVICE

Journal Reviewer IEEE Transactions on Automatic Control (TAC), Automatica, IEEE Open Journal of Control Systems (OJCSYS), IEEE Control Systems Letters (L-CSS), IEEE Transactions on Vehicular Technology (TVT).

Conference Reviewer IEEE Conference on Decision and Control (CDC), IEEE International Conference on Robotics and Automation (ICRA), American Control Conference (ACC), IFAC World Congress, Annual Learning for Dynamics and Control Conference (L4DC), ACM International Conference on Hybrid Systems: Computation and Control (HSCC), IFAC Symposium on System Identification (SYSID).

TEACHING EXPERIENCE

Graduate Teaching Assistant at the University of Pennsylvania	Philadelphia, PA
- ESE 618-001 Learning for Dynamics and Control	Fall 2021
- ESE 619 Model Predictive control	Spring 2021
- ESE 605 Modern Convex Optimization	Spring 2020
- ESE 504 Introduction to Optimization Theory	Fall 2018

TECHNICAL SKILLS

| **Programming Languages** | Python, Matlab, C |
| **Tools** | PyTorch, Gurobi, Yalmip, CVX, MPT, LaTeX |

REFERENCES

George J. Pappas (email: pappasg@seas.upenn.edu)
UPS Foundation Professor, Chair
Department of Electrical and Systems Engineering, University of Pennsylvania

Manfred Morari (email: morari@seas.upenn.edu)
Practice Professor, Peter and Susanne Armstrong Faculty Fellow
Department of Electrical and Systems Engineering, University of Pennsylvania

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Assistant Professor
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Victor M. Preciado (email: preciado @seas.upenn.edu)
Associate Professor
Department of Electrical and Systems Engineering, University of Pennsylvania

Mahyar Fazlyab (email: mahyarfazlyab@jhu.edu)
Assistant Professor
Department of Electrical and Computer Engineering, Johns Hopkins University

John Langford (email: jcl@microsoft.com)
Partner Researcher Manager
Microsoft Research, NYC