Kai-Chieh Hsu

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I work on combining game-theoretic reasoning and machine learning techniques for safe human-centered robotic systems.

Research Interests

Machine Learning	Safe reinforcement learning (RL), adversarial RL and safe Sim2Real transfer
Human-Robot Interaction	Generative models and inverse RL for strategy and intent inference
Multi-Agent Planning	Game-theoretic counterfactual reasoning and iterative linear quadratic game

Education

Princeton University (PU)
Princeton, NJ, USA

Ph.D. Candidate in Electrical and Computer Engineering (ECE) — Sept. 2021 - June 2024 (EXPECTED)

M.A. in Electrical and Computer Engineering — Sept. 2019 - May 2021

- Concentration: Machine learning and Robotics
- Achieved 4.0/4.0 GPA
- Thesis Advisor: Prof. Jaime Fernández Fisac

National Taiwan University (NTU)
Taipei, Taiwan

B.S. in Electrical Engineering (EE) — Sept. 2014 - Jan. 2019

- Concentration: Signal processing and Digital IC design
- Achieved 4.19/4.30 overall GPA and ranked in **top 5**%
- Research Advisors: Prof. An-Yeu (Andy) Wu and Prof. Jean-Fu Kiang

Work Experiences

Research Scientist Intern [P2]
Remote

NVIDIA Corporation (Manager: Prof. Marco Pavone, Mentor: Prof. Karen Leung, Yuxiao Chen) — May 2022 - Dec. 2022

- Formalize **responsibility** by safety margin decrease and policy shift with **counterfactual reasoning**
- Estimate the responsibility level online with **hidden Markov model**
- Incorporate the estimated responsibility into the **trajectory prediction** models

Research Projects

Adversarial Safety Game [C1]
PU, NJ, USA

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac, Duy Phuong Nguyen — Feb. 2022 - PRESENT

- Robustify the **reachability-based RL** by jointly training an adversarial agent under the self-play spirit
- Construct an online shielding scheme combining the model-based **contingent rollout** and model-free best-effort policies.

Inverse Specification [C2]
PU, NJ, USA

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac — July 2020 - PRESENT

- Use Bayesian optimization to infer constraints **interactively with humans** by asking for ranking feedback
- **Select queries actively** to speed up the convergence to the true preference based on information-theoretic metrics
- Survey in **inverse optimal control** and **behavior cloning**

Safe Sim2Real Transfer (Sim-to-Lab-to-Real) [J1]
PU, NJ, USA

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac, Duy Phuong Nguyen

Intelligent Robot Motion Lab, Prof. Anirudha Majumdar, Allen Z. Ren — May 2021 - Jan. 2022

- Use **Reachability-Based RL** and a **supervisory control** scheme to allow the least-restrictive safe exploration
- Combine with **PAC-Bayes control** to provide a tight performance lower bound to unseen environments

March 27, 2023

Reach-Avoid Reinforcement Learning [C4] [J1]

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac
Hybrid Systems Laboratory, Prof. Claire J. Tomlin, Vicenç Rubies-Royo

PU, NJ, USA

July 2020 - Mar. 2021

- Derive a time-discounted formulation of the reach-avoid optimal control problem that lends itself to **(deep) RL**
- Deploy our reach-avoid Q-Learning in a range of nonlinear systems, including an **attack-defense game**
- Reach-avoid reinforcement learning allows learning from near defeat and fits in **safe reinforcement learning**

ECG Real-Time Telemonitoring [J2] [C5]

Access IC Lab, Prof. An-Yeu (Andy) Wu

NTU, Taiwan

Aug. 2017 - Mar. 2019

- **Edge Classification**: Incorporate **compressed sensing**, task-driven dictionary learning (predictive sparse coding) and PCA to render light-weighted classifier and overcome limited labeled data challenge
- **On-Demand Recovery**: Design a two-stage algorithm that classifies and reconstructs only problematic signals. This algorithm utilizes the information from classification stage to speed up the reconstruction algorithm
- **Hardware Design and Chip Implementation**: Propose a hardware architecture for on-demand recovery to allow hardware sharing between classification and reconstruction algorithms

Publications

Preprint

[P1] Athindran Ramesh Kumar, **K.-C. Hsu**, Peter Ramadge, Jaime F. Fisac, Fast, Smooth, and Safe: Implicit Control Barrier Functions through Reach-Avoid Differential Dynamic Programming, submitted to *IEEE Control Systems Letters,* Mar 2023.

[P2] **K.-C. Hsu**, Karen Leung, Yuxiao Chen, Jaime F. Fisac, Marco Pavone, Interpretable Trajectory Prediction for Autonomous Vehicles via Counterfactual Responsibility, submitted to *IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS),* Feb 2023.

Journal Papers

[J1] **K.-C. Hsu**[*], Allen Z. Ren[*], Duy P. Nguyen, Anirudha Majumdar[+], and Jaime F. Fisac[+], Sim-to-Lab-to-Real: Safe Reinforcement Learning with Shielding and Generalization Guarantees, in *Artificial Intelligence,* Jan 2023. | Spotlight in ICLR Workshop and NeurIPS Workshop

[J2] C.-Y. Chou, **K.-C. Hsu**, B.-H. Cho, K.-C. Chen and A.-Y. (Andy) Wu, Low-Complexity On-demand Reconstruction for Compressively Sensed Problematic Signals, in *IEEE Trans. Signal Process.,* vol. 68, pp. 4094-4107, July 2020.

[J3] **K.-C. Hsu** and J.-F. Kiang, Joint Estimation of DOA and Frequency From A Mixture of Frequency Known and Unknown Sources with Orthogonal Coprime Arrays, in *Sensors, 19(2), 335,* Jan. 2019.

Conference Papers

[C1] **K.-C. Hsu**[*], Duy P. Nguyen[*], and Jaime F. Fisac, ISAACS: Iterative Soft Adversarial Actor-Critic for Safety, in *Learning for Dynamics and Control (L4DC),* Philadelphia, PA, USA, Jun 2023 (to appear).

[C2] S. Narain, D. Chee, P. Iyer, E. Mak, R. Valdez, M. Zhu, N. Jha, J. F. Fisac, **K.-C. Hsu**, P. Terway, K. Pochiraju, B. Englot, E. Pitz, S. Rooney, Y. Huang, AIMED: AI-Mediated Exploration of Design: An Experience Report, in *Proceedings of the IEEE Workshop on Design Automation for CPS and IoT (DESTION),* San Antonio, TX, USA, May 2023 (to appear).

[C3] H. Chen, **K.-C. Hsu**, W. Turner, P.-H. Wei, K. Zhu, D. Pan and H. Ren, Reinforcement Learning Guided Detailed Routing for FinFET Custom Circuits, in *International Symposium on Physical Design (ISPD),* Held Virtually, Mar 2023 (to appear).

[C4] **K.-C. Hsu**[*], V. Rubies-Royo[*], C. J. Tomlin and J. F. Fisac, Safety and Liveness Guarantees through Reach-Avoid Reinforcement Learning, in *Proceedings of Robotics: Science and Systems (RSS),* Held Virtually, July 2021.

[C5] **K.-C. Hsu**[*], B.-H. Cho[*], C.-Y. Chou and A.-Y. (Andy) Wu, Low-Complexity Compressed Analysis in Eigenspace with Limited Labeled Data for Real-Time Electrocardiography Telemonitoring, in *IEEE GlobalSIP,* Anaheim, USA, Nov 2018.

Honors & Awards

SEAS Travel Grant

SEAS, PU, NJ, USA
Nov. 2022

Teaching Assistant Award

Dept. of ECE, PU, NJ, USA

- For the new *Intelligent Robotic Systems* course

Sept. 2022

3rd Prize in Integrated Circuit Design Contest

Ministry of Education, Taiwan

- Out of about 300 teams

July 2018

2nd Prize in Taiwan Creative Electromagnetic Implementation Competition

High-speed RF and mm-Wave Tech. Center, Taiwan

- Under the supervision of Prof. Tzong-Lin Wu | 📄

Aug. 2017

8th place in Data Structure and Programming Contest

Cadence, Taiwan

- Out of about 250 students

Mar. 2017

Graduate Representative in NTUEE graduate ceremony

Dept. of EE, NTU, Taiwan

- Given to top ten students of four years

June 2018

Professor Chun-Hsiung Chen Scholarship

Electromagnetic Industry-Academia Consortium, Taiwan

- Rewarded outstanding performances in electromagnetic fields

Jan. 2018

Presidential Awards

Dept. of EE, NTU, Taiwan

- Given to top ten students of that semester

second semester of 2014 and 2016

Research & Teaching Experiences

Teaching Assistant

PU, NJ, USA

ECE346/566: Intelligent Robotic Systems, Prof. Jaime Fernández Fisac

Jan. 2022 - May 2022

ELE364: Machine Learning for Predictive Data Analytics, Prof. Niraj Jha

Sept. 2020 - Dec. 2020

Research Assistant

NTU, Taiwan

Access IC Lab, Prof. An-Yeu (Andy) Wu

Feb. 2018 - Mar. 2019

Group of Electromagnetic Applications, Prof. Jean-Fu Kiang

Feb. 2017 - Mar. 2019

Teaching Assistant

NTU, Taiwan

Digital System Design

Feb. 2018 - June 2018

Professional Activities

Reviewer	Artificial Intelligence, IEEE Open Journal of Control Systems, IEEE Trans. on Vehicular Technology, IETE Technical Review, IEEE Trans. on Signal Processing, ICRA, L4DC
Program Committee	NeurIPS Workshop on Human in the Loop Learning and Trustworthy Embodied AI

Skills

- **Program Languages**   Python, MATLAB, Verilog, C++
- **Others**   PyTorch, Jax, Git, SLURM, NumPyro, CVX, LaTeX