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 [P3]
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

Reach-Avoid Reinforcement Learning [C4] [J1]

PU, NJ, USA

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

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]

NTU, Taiwan

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

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] Haimin Hu, Kensuke Nakamura, **K.-C. Hsu**, Naomi Ehrich Leonard, Jaime F. Fisac, Emergent Coordination through Game-Induced Nonlinear Opinion Dynamics, submitted to *IEEE Conference on Decision and Control (CDC),* Mar 2023.

[P2] Athindran Ramesh Kumar, **K.-C. Hsu**, Peter J. 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.

[P3] **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 — Sept. 2022
- For the new *Intelligent Robotic Systems* course

3rd Prize in Integrated Circuit Design Contest — Ministry of Education, Taiwan — July 2018
- Out of about 300 teams

2nd Prize in Taiwan Creative Electromagnetic Implementation Competition — High-speed RF and mm-Wave Tech. Center, Taiwan — Aug. 2017
- Under the supervision of Prof. Tzong-Lin Wu |

8th place in Data Structure and Programming Contest — Cadence, Taiwan — Mar. 2017
- Out of about 250 students

Graduate Representative in NTUEE graduate ceremony — Dept. of EE, NTU, Taiwan — June 2018
- Given to top ten students of four years

Professor Chun-Hsiung Chen Scholarship — Electromagnetic Industry-Academia Consortium, Taiwan — Jan. 2018
- Rewarded outstanding performances in electromagnetic fields

Presidential Awards — Dept. of EE, NTU, Taiwan — second semester of 2014 and 2016
- Given to top ten students of that semester

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