Kai-Chieh Hsu

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I work on combining safety analysis and machine learning techniques to enable autonomous systems in safety-critical setting and human-robot interaction.

Research Interests

Machine Learning	Safe reinforcement learning and safe Sim2Real transfer
Human-Robot Interaction	Inverse reinforcement learning with active human feedback queries
Multi-Agent Planning	Game-theoretic approach in a zero-sum differential game

Education

Princeton University (PU)

Princeton, NJ, USA

Ph.D. Candidate in Electrical and Computer Engineering — 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 — 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

Research Projects

Inverse Specification

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 **imitation learning**

Safe Sim2Real Transfer (Sim-to-Lab-to-Real)

PU, NJ, USA

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac

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

PU, NJ, USA

Safe Robotics Laboratory, Prof. Jaime Fernández Fisac

Hybrid Systems Laboratory, Prof. Claire J. Tomlin, Vicenç Rubies-Royo — July 2020 - March 2021

- Derive a time-discounted formulation of the reach-avoid optimal control problem that lends itself to **(deep) reinforcement learning** methods by inducing contraction mapping property
- 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

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

Direction-of-Arrival (DOA) Estimation

NTU, Taiwan

Group of Electromagnetic Applications, Prof. Jean-Fu Kiang — Feb. 2017 - Mar. 2019

- **Antenna Uncertainty**: Utilized special matrix structure with Khatri-Rao subspace-based MUltiple SIgnal Classification (MUSIC) to improve immunity to uncertainties and detect DOAs with sensors half the number of sources
- **More Sources Than Sensors**: Proposed a new antenna array structure to increase the number of detectable sources based on fourth-order statistics and compressive sensing approach
- **Mixed Carrier Frequency (CF) Known and Unknown Sources**: Proposed a two-step algorithm to first estimate DOA of CF-known sources and then joint estimate the DOA and CF of CF-unknown sources

Publications

[1] **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. |

[2] 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. |

[3] **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. |

[4] **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 Global Conference on Signal and Information Processing (GlobalSIP)*, Anaheim, USA, Nov. 2018. |

[5] **K.-C. Hsu** and J.-F. Kiang, "DOA Estimation With Triply Primed Arrays Based on Fourth-Order Statistics," in *IEEE AP-S Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, Boston, USA, July 2018. |

[6] **K.-C. Hsu** and J.-F. Kiang, "DOA Estimation Using Triply Primed Arrays Based on Fourth-Order Statistics," in *Progress In Electromagnetics Research M*, Vol. 67, pp. 55-64, Mar. 2018. |

[7] **K.-C. Hsu** and J.-F. Kiang, "DOA Estimation of Quasi-Stationary Signals Using a Partly-Calibrated Uniform Linear Array with Fewer Sensors Than Sources," in *Progress In Electromagnetics Research M*, Vol. 63, pp. 185-193, Jan. 2018. |

Honors & Awards

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

Digital IC Design Certificate — National Chip Implementation Center, Taiwan
- Familiar with Verilog, logic synthesis, simulation and STA — Nov. 2018

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 IEEE Transactions on Vehicular Technology, IETE Technical Review, IEEE Transactions on Signal Processing, Conference on Information Sciences and Systems

Skills

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