KAIQING ZHANG

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EDUCATION

University of Illinois at Urbana-Champaign Aug. 2017 — Present
Ph.D. Candidate in Electrical and Computer Engineering

University of Illinois at Urbana-Champaign Jan. 2016 — Dec. 2017
M.S. in Applied Mathematics

University of Illinois at Urbana-Champaign Aug. 2015 — Aug. 2017
M.S. in Electrical and Computer Engineering

Tsinghua University Sept. 2011 — Jul. 2015
B.S. in Automation (with honor) & **Dual Degree** in Economics

RESEARCH INTERESTS

My research interests lie in the intersection of *control theory*, *game theory*, and *machine/reinforcement learning*, especially in *multi-agent* and *safety-critical* systems; with applications in intelligent and distributed cyber-physical systems, e.g., robotics, smart grid, and transportation systems. I resort to mathematical tools from the areas of Control Theory, Game Theory, Operations Research, and Probability Theory to develop *provably convergent* and *efficient* algorithms. Broadly speaking, the primary goal of my research is to lay theoretical foundations for the learning algorithms and systems that address *(data-driven) sequential-decision-making* problems in game theory and control theory, particularly in the presence of multiple decision-makers, towards *large-scale* and *reliable* autonomy.

RESEARCH EXPERIENCES

Reinforcement learning (RL) in robust control
Department of ECE & CSL, UIUC *May 2019 — Present*

- Investigate the *landscape* of a class of robust control problems, including risk-sensitive control, $\mathcal{H}_\infty$-optimal control, and mixed $\mathcal{H}_2/\mathcal{H}_\infty$ control synthesis, from a *policy optimization* perspective
- Analyze the *global convergence* and *sample complexity* of policy optimization algorithms for these non-convex problems, with *robust-on-the-fly* guarantees
- The theory also places the popular scheme of *robust adversarial RL* (RARL) under a solid theoretical footing, through the lens of robust control theory

Non-cooperative multi-agent RL in dynamic/Markov games
Department of ECE & CSL, UIUC *Dec. 2018 — Present*

- Develop provably *convergent* and *efficient* algorithms for several fundamental non-cooperative multi-agent RL (MARL) settings
- Establish *minimax-optimal* sample complexity guarantees for model-based MARL approach in zero-sum Markov games; establish *global convergence* and sample complexity of policy optimization methods in zero-sum linear quadratic games
- Investigate the settings of *inverse RL* with asymmetric information, robust MARL with *model-uncertainty*, and *decentralized* self-interested agents

Cooperative multi-agent RL with networked agents
Department of ECE & CSL, UIUC *Sept. 2017 — Present*

· Develop *provably convergent* MARL algorithms for *decentralized* MARL with *networked* agents
· Investigate the extensions to *batch/offline RL* settings, large-population/*mean-field* regimes, and *partial-observable* settings

Distributed control and operation in cyber-physical systems
Department of ECE, UIUC *Sept. 2015 — Aug. 2017*

· Developed distributed algorithms for voltage-VAR control in smart grid distribution networks, under *limited communication links* using *game-theoretic* approaches
· Developed dynamic pricing algorithms for the charging of electrical unmanned aerial vehicles in transportation networks that are coupled with power networks
· Developed improved parameter estimation framework for load modeling in distribution networks

On the performance of map-aware cooperative localization
LIDS, MIT & Tsinghua University *June 2014 — May 2015*

· Characterizeed the fundamental limits of localization accuracy using the information-theoretic bounds, i.e., Ziv-Zakai and Weiss-Weinstein bounds, for map-aware cooperative localization

PUBLICATIONS

Book Chapter

· **Kaiqing Zhang**, Zhuoran Yang, and Tamer Başar, "Multi-Agent Reinforcement Learning: A Selective Overview of Theories and Algorithms", *Studies in Systems, Decision and Control Handbook on Reinforcement Learning and Control, Springer, 2020 (Invited Chapter).*

Journal Papers and Preprints

· **Kaiqing Zhang**†, Xiangyuan Zhang†, Bin Hu, and Tamer Başar, "Derivative-free policy optimization for risk-sensitive and robust control design: Implicit regularization and sample complexity" († equal contribution), *Intl. Conf. on Machine Learning (ICML), 2021, under review.*
· Weichao Mao, **Kaiqing Zhang**, Ruihao Zhu, David Simchi-Levi, and Tamer Başar, "Is model-free learning nearly optimal for non-stationary RL?", *Intl. Conf. on Machine Learning (ICML), 2021, under review.*
· **Kaiqing Zhang**, Sham M. Kakade, Tamer Başar, and Lin F. Yang, "Model-based multi-agent RL in zero-sum Markov games with near-optimal sample complexity", *Journal of Machine Learning Research (JMLR), under review, preliminary version appeared in NeurIPS 2020 (**Spotlight**).*
· **Kaiqing Zhang**, Bin Hu, and Tamer Başar, "Policy optimization for $\mathcal{H}_2$ linear control with $\mathcal{H}_\infty$ robustness guarantee: Implicit regularization and global convergence", *SIAM Journal on Control and Optim. (SICON), under review, preliminary version appeared in L4DC 2020 (**Oral**).*
· **Kaiqing Zhang**, Zhuoran Yang, Han Liu, Tong Zhang, and Tamer Başar, "Finite-sample analysis for decentralized batch multi-agent reinforcement learning with networked agents", *IEEE Trans. on Automatic Control (TAC), 2021.*
· Tianyi Chen, **Kaiqing Zhang**, Georgios B. Giannakis, and Tamer Başar, "Communication-efficient distributed reinforcement learning", *IEEE Trans. on Control of Network Systems (TCNS), under review.*
· **Kaiqing Zhang**, Alec Koppel, Hao Zhu, and Tamer Başar, "Global convergence of policy gradient methods to (almost) locally optimal policies", *SIAM Journal on Control and Optim. (SICON)*, 2020.
· Alec Koppel†, **Kaiqing Zhang**†, Hao Zhu, and Tamer Başar, "Projected stochastic primal-dual method for constrained online learning with kernels" († equal contribution), *IEEE Trans. on Signal Process. (TSP)*, vol. 67 , no. 10 , pp. 2528-2542, May, 2019.
· **Kaiqing Zhang**, Yang Liu, Ji Liu, Mingyan Liu, and Tamer Başar, "Distributed learning of average belief over networks using sequential observations," *Automatica*, vol. 115, May 2020.

- **Kaiqing Zhang**, Liqun Lu, Chao Lei, Hao Zhu, and Yanfeng Ouyang, "Dynamic operations and pricing of electric unmanned aerial vehicle systems and power networks," *Journal of Transportation Research Part C: Emerging Technologies*, vol. 92, pp. 472-485, July 2018.
- **Kaiqing Zhang**, Wei Shi, Hao Zhu, Emiliano Dall'Anese, and Tamer Başar, "Dynamic power distribution system management with a locally connected communication network," *IEEE Journal of Selected Topics in Signal Process. (JSTSP)*, vol. 12, no. 4, pp. 673-687, May 2018.
- Hanchen Xu, **Kaiqing Zhang**, and Junbo Zhang, "Optimal joint bidding and pricing of profit-seeking load serving entity," *IEEE Trans. on Power Systems (TPS)*, vol. 33, no. 5, pp. 5427-5436, March 2018.
- **Kaiqing Zhang**, Siming Guo, and Hao Zhu, "Dependency analysis and improved parameter estimation for complex dynamic load modeling," *IEEE Trans. on Power Systems (TPS)*, vol. 32, no. 4, pp. 3287-3297, Nov. 2016.

Conference Papers

- Zengyi Qin, **Kaiqing Zhang**, Yuxiao Chen, Jingkai Chen, and Chuchu Fan, "Learning safe multi-agent control with decentralized neural barrier certificates," *Intl. Conf. on Learning Representations (ICLR), 2021*.
- **Kaiqing Zhang**, Sham M. Kakade, Tamer Başar, and Lin F. Yang, "Model-based multi-agent RL in zero-sum Markov games with near-optimal sample complexity", *Neural Info. Process. Systems (NeurIPS), 2020 (**Spotlight, top 2.96%**, 280 out of 9454 submissions)*.
- **Kaiqing Zhang**, Bin Hu, and Tamer Başar, "On the stability and convergence of robust adversarial reinforcement learning: A case study on linear quadratic systems," *Neural Info. Process. Systems (NeurIPS), 2020*.
- **Kaiqing Zhang**†, Tao Sun†, Yunzhe Tao, Sahika Genc, Sunil Mallya, and Tamer Başar, "Robust multi-agent reinforcement learning with model uncertainty" († equal contribution), *Neural Info. Process. Systems (NeurIPS), 2020*.
- Dongsheng Ding, **Kaiqing Zhang**, Tamer Başar, and Mihailo R. Jovanovic, "Natural policy gradient primal-dual method for constrained Markov decision processes," *Neural Info. Process. Systems (NeurIPS), 2020*.
- Weichao Mao, **Kaiqing Zhang**, Qiaomin Xie, and Tamer Başar, "POLY-HOOT: Monte-Carlo planning in continuous space MDPs with non-asymptotic analysis", *Neural Info. Process. Systems (NeurIPS), 2020*.
- Yanli Liu, **Kaiqing Zhang**, Tamer Başar, and Wotao Yin, "An improved analysis of (variance-reduced) policy gradient and natural policy gradient methods", *Neural Info. Process. Systems (NeurIPS), 2020*.
- Weichao Mao, **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, "Information state embedding in partially observable cooperative multi-agent reinforcement learning," *IEEE Conf. on Decision and Control (CDC), 2020*.
- Muhammad Aneeq uz Zaman, **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, "Reinforcement learning in non-stationary discrete-time linear-quadratic mean-field games," *IEEE Conf. on Decision and Control (CDC), 2020*.
- **Kaiqing Zhang**, Bin Hu, and Tamer Başar, "Policy optimization for $\mathcal{H}_2$ linear control with $\mathcal{H}_\infty$ robustness guarantee: Implicit regularization and global convergence," *Learning for Dynamics & Control (L4DC) Conference (**Oral, top 10%**, 14 out of all submissions), 2020*.
- **Kaiqing Zhang**, Zhuoran Yang, and Tamer Başar, "Policy optimization provably converges to Nash equilibria in zero-sum linear quadratic games", *Neural Info. Process. Systems (NeurIPS), 2019*.
- Xiangyuan Zhang, **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, "Non-Cooperative Inverse Reinforcement Learning", *Neural Info. Process. Systems (NeurIPS), 2019*.
- **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, "Online planning for decentralized stochastic control with partial history sharing," *IEEE American Control Conf. (ACC), 2019*.
- **Kaiqing Zhang**, Zhuoran Yang, and Tamer Başar, "Networked multi-agent reinforcement learning in continuous spaces", *IEEE Conf. on Decision and Control (CDC), 2018*.

· Zhuoran Yang, **Kaiqing Zhang**, Mingyi Hong, and Tamer Başar, "A finite sample analysis of the actor-critic algorithm", *IEEE Conf. on Decision and Control (CDC), 2018.*

· **Kaiqing Zhang**, Zhuoran Yang, Han Liu, Tong Zhang, and Tamer Başar, "Fully decentralized multi-agent reinforcement learning with networked agents", *Intl. Conf. on Machine Learning (ICML), 2018.*

· **Kaiqing Zhang**, Zhuoran Yang, and Zhaoran Wang, "Nonlinear structured signal estimation in high dimensions via iterative hard thresholding," *Intl. Conf. on Artificial Intelligence and Statistics (AISTATS), 2018.*

· **Kaiqing Zhang**, Yuan Shen, and Moe Z. Win, "On the performance of map-aware cooperative localization," *IEEE Intl. Conf. on Commun. (ICC)*, 2016.

OTHER RESEARCH EXPERIENCES

Visiting Graduate Student	Simons Institute, UC Berkeley (virtual)	Aug. 2020 — Dec. 2020
Research Scientist Intern	Amazon AWS AI Labs, Seattle, WA	May 2019 — Aug. 2019
Visiting Fellowship	Army Research Lab. (ARL), Adelphi, MD	Jun. 2018 — Aug. 2018
Research Scientist Intern	Nation. Renew. Energy Lab. (NREL), CO	Jun. 2016 — Sept. 2016

TEACHING EXPERIENCES

Teaching Assistant	ECE 543 Statistical Learning Theory by Prof. R. Srikant	Spring 2020

PATENTS

U.S. Patent No. 908486	Robust Actor/Critic Multi-Agent RL for Mobile Robotics Applications

AWARDS & HONORS

· Simons-Berkeley Research Fellowship, Simons Institute & UC Berkeley 2022

· Linde + CAST Postdoctoral Scholar Fellowship, Caltech CMS & CSIS (declined) 2021

· Kuck Computational Science & Engineering Scholarship, UIUC 2020

· Hong, McCully, and Allen Fellowship (**$12000**), UIUC 2018 & 2019 & 2020

· YEE Fellowship Award, College of Engineering, UIUC 2020

· NeurIPS Travel Award 2019

· CDC Student Travel Award 2019 & 2020

· Mavis Future Faculty Fellows (MF3), UIUC 2019

· ICML Travel Award 2018

· James M. Henderson Fellowship, UIUC 2016

· Beijing Outstanding Undergraduate Thesis 2015

· National Scholarship (**top 3%**), Tsinghua University 2014

· **Meritorious Winner** 2014 Mathematical Contest in Modeling 2014

· **First Prize** in 34th Challenge Cup of Tsinghua University 2014

· **Third place** in competition of Adult-Size Group in RoboCup 2013

· Comprehensive First-Class Scholarship of Tsinghua University (**top 5%**) 2012 & 2013

· **First Prize** of National Physics Olympiad, with Pre-Admission to Tsinghua University 2011

PROFESSIONAL SERVICES & ACTIVITIES

· Co-organizer of the online seminar series *Games, Decisions & Networks*

· Reviewer for *ICML*, *NeurIPS*, *AAAI*, *Mathematical Programming, IEEE Trans. Automatic Control (TAC), Automatica, IEEE Journal of Selected Topics in Signal Processing (JSTSP), IEEE Trans. Smart Grid (TSG), IEEE Trans. Power Systems (TPS), IEEE Control Systems Letters (L-CSS), IEEE Communications Letters (CL), System & Control Letters, IEEE American Control Conf. (ACC), IEEE Control and Decision Conf. (CDC), IEEE Intl. Conf. on Communications (ICC)*

· Organizer of the invited sessions *Machine Learning in Complex Networks* at *IEEE Control and Decision Conf. (CDC)*, 2018, 2019

· President of *Tsinghua University Alumni Association (THU-AA)* in UIUC Sept. 2019 — Present

· Committee of the 8th *IEEE Power and Energy Conf. at Illinois (PECI)* April 2016 — Feb. 2017

· Vice-President of the *Student Union* of the Dept. of Automation Aug. 2013 — Aug. 2014