

# KAIQING ZHANG

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## EDUCATION

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<b>University of Illinois at Urbana-Champaign</b> <b>Ph.D. Candidate</b> in Electrical and Computer Engineering	Aug. 2017 — Present
<b>University of Illinois at Urbana-Champaign</b> <b>M.S.</b> in Applied Mathematics	Jan. 2016 — Dec. 2017
<b>University of Illinois at Urbana-Champaign</b> <b>M.S.</b> in Electrical and Computer Engineering	Aug. 2015 — Aug. 2017
<b>Tsinghua University</b> <b>B.S.</b> in Automation (with honor) & <b>Dual Degree</b> in Economics	Sept. 2011 — Jul. 2015

## RESEARCH INTERESTS

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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

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### 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

- Characterized 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

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### 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**<sup>†</sup>, Xiangyuan Zhang<sup>†</sup>, 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<sup>†</sup>, **Kaiqing Zhang**<sup>†</sup>, 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**, Liquan 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**<sup>†</sup>, Tao Sun<sup>†</sup>, Yunzhe Tao, Sahika Genc, Sunil Mallya, and Tamer Başar, “Robust multi-agent reinforcement learning with model uncertainty” (<sup>†</sup> 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 Miehl, 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 Miehl, 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 Miehl, and Tamer Başar, “Non-Cooperative Inverse Reinforcement Learning,” *Neural Info. Process. Systems (NeurIPS)*, 2019.
- **Kaiqing Zhang**, Erik Miehl, 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

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

## TEACHING EXPERIENCES

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<b>Teaching Assistant</b>	ECE 543 Statistical Learning Theory by Prof. R. Srikant	Spring 2020
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## PATENTS

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

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| · 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 ( <b>\$12000</b> ), 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 ( <b>top 3%</b> ), Tsinghua University                                | 2014               |
| · <b>Meritorious Winner</b> 2014 Mathematical Contest in Modeling                            | 2014               |
| · <b>First Prize</b> in 34th Challenge Cup of Tsinghua University                            | 2014               |
| · <b>Third place</b> in competition of Adult-Size Group in RoboCup                           | 2013               |
| · Comprehensive First-Class Scholarship of Tsinghua University ( <b>top 5%</b> )             | 2012 & 2013        |
| · <b>First Prize</b> of National Physics Olympiad, with Pre-Admission to Tsinghua University | 2011               |

## PROFESSIONAL SERVICES & ACTIVITIES

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- 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