

# 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 reinforcement learning and optimization in multi-agent and safety-critical systems, with applications in cyber-physical systems including robotics, autonomous driving systems, and the smart grid. I resort to mathematical tools from the areas of Control Theory, Game Theory, Operations Research, and Probability to develop provably convergent and efficient algorithms. Broadly speaking, my research belongs to the area of *Learning for Control*, aiming to lay theoretical foundations for the learning algorithms that address sequential-decision-making problems in control systems.

## RESEARCH EXPERIENCES

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<b>Learning for robust control</b> <i>Department of ECE, UIUC</i>	Sept. 2019 — Present <i>Advisor: Prof. Tamer Başar</i>
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- Investigate the landscape of robust control problems, e.g., risk-sensitive control, linear quadratic games, and mixed  $\mathcal{H}_2/\mathcal{H}_\infty$  control synthesis, from an optimization perspective
- Develop and analyze the global convergence property of policy gradient algorithms for these problems

<b>Multiagent reinforcement learning with theoretical analysis</b> <i>Department of ECE, UIUC</i>	Sept. 2017 — Present <i>Advisor: Prof. Tamer Başar</i>
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- Develop reinforcement learning algorithms for multi-agent systems, that are networked, and/or self-interested, and/or have a large-population of agents, and/or with partial observability
- Establish convergence for these multi-agent RL algorithms, under several benchmark problem settings

<b>On the value of communication links for distribution network operation: A game theoretic perspective</b> <i>Department of ECE, UIUC</i>	Aug. 2016 — Aug. 2017 <i>Advisor: Prof. Hao Zhu</i>
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- Analyze and develop distributed algorithms for voltage-VAR control under limited communication links using game theoretic approaches
- Quantify the value of communication links for infrastructure deployment

<b>On the performance of map-aware cooperative localization</b> <i>Department of EECS, MIT</i>	Oct. 2014 — May 2015 <i>Advisor: Prof. Moe Z. Win &amp; Prof. Yuan Shen</i>
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- Characterize the fundamental limits of localization accuracy by the information-theoretic bounds, i.e., Ziv-Zakai and Weiss-Weinstein bounds, for map-aware cooperative localization

## PUBLICATIONS

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### Book Chapters

- **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.

### Journals and Preprints

- **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”, *arXiv:2007.07461*, 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”, *SIAM Journal on Control and Optim. (SICON)*, 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, to appear.
- **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)*, under review.
- Tianyi Chen, **Kaiqing Zhang**, Georgios B. Giannakis, and Tamer Başar, “Communication-efficient distributed reinforcement learning”, *IEEE Trans. on Automatic Control (TAC)*, under review.
- **Kaiqing Zhang**<sup>†</sup>, Alec Koppel<sup>†</sup>, Hao Zhu, and Tamer Başar, “Projected stochastic primal-dual method for constrained online learning with kernels” (The authors <sup>†</sup> contributed equally), *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.
- Yingchen Zhang, Rui Yang, **Kaiqing Zhang**, Huaiguang Jiang, and Jun Jason Zhang, “Consumption behavior analytics-aided energy forecasting and dispatch,” *IEEE Intelligent Systems*, vol. 32, no. 4, pp. 59-63, Aug. 2017.
- **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.
- Feifei Gao and **Kaiqing Zhang**, “Enhanced multi-parameter cognitive architecture for future wireless communications,” *IEEE Commun. Magazine*, vol. 53, no. 7, pp. 86-92, Jul. 2015.

### Conferences

- 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**, Zhuoran Yang, Han Liu, Tong Zhang, and Tamer Başar, “Finite-sample analyses for decentralized cooperative multi-agent reinforcement learning from batch data,” *IFAC World Congress*, 2020.
- Wesley Suttle, Zhuoran Yang, **Kaiqing Zhang**, Zhaoran Wang, Tamer Başar, Ji Liu, “A multi-agent off-policy actor-critic algorithm for distributed reinforcement learning,” *IFAC World Congress*, 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, 14 out of all submissions)*, 2020.
- Muhammad A. Zaman, **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, “Approximate equilibrium computation for discrete-time linear-quadratic mean-field games,” *IEEE American Control Conf. (ACC)*, pp. 333-339, 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)*, pp. 9482-9493, 2019.
- **Kaiqing Zhang**, Alec Koppel, Hao Zhu, and Tamer Başar, “Convergence and iteration complexity of policy gradient method for infinite-horizon reinforcement learning,” *IEEE Conf. on Decision and Control (CDC)*, pp. 7415-7422, 2019.
- Yixuan Lin, **Kaiqing Zhang**, Zhuoran Yang, Zhaoran Wang, Tamer Başar, Romeil Sandhu, and Ji Liu, “A communication-efficient multi-agent actor-critic algorithm for distributed reinforcement learning,” *IEEE Conf. on Decision and Control (CDC)*, pp. 5562-5567, 2019.
- **Kaiqing Zhang**, Alec Koppel, Hao Zhu, and Tamer Başar. “Policy search in infinite-horizon discounted reinforcement learning: Advances through connections to non-convex optimization,” *IEEE Annual Conf. on Info. Sci. and Syst. (CISS)*, 2019.
- **Kaiqing Zhang**, Erik Miehling, and Tamer Başar, “Online planning for decentralized stochastic control with partial history sharing,” *IEEE American Control Conf. (ACC)*, pp. 3544-3550, 2019.
- **Kaiqing Zhang**, Hao Zhu, Tamer Başar, and Alec Koppel, “Projected stochastic primal-dual method for constrained online learning with kernels,” *IEEE Conf. on Decision and Control (CDC)*, pp. 4224-4231, 2018.
- **Kaiqing Zhang**, Zhuoran Yang, and Tamer Başar, “Networked multi-agent reinforcement learning in continuous spaces,” *IEEE Conf. on Decision and Control (CDC)*, pp. 2771-2776, 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)*, pp. 2759-2764, 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**, Wei Shi, Hao Zhu, and Tamer Başar, “Distributed equilibrium-learning for power network voltage control with a locally connected communication network,” *IEEE American Control Conf. (ACC)*, pp. 3092-3097, 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** and Hao Zhu, “A game theoretic approach for communication-free distribution system management,” *IEEE Global Conf. on Signal and Info. Process. (GlobalSIP)*, 2017.

- **Kaiqing Zhang**, Siming Guo, and Hao Zhu, “Parameter sensitivity and dependency analysis for the WECC dynamic composite load model,” *Hawaii Intl. Conf. System Sciences (HICSS)*, 2017.
- **Kaiqing Zhang**, Yuan Shen, and Moe Z. Win, “On the performance of map-aware cooperative localization,” *IEEE Intl. Conf. on Commun. (ICC)*, 2016.
- **Kaiqing Zhang**, Hong Hu, Wenhan Dai, Yuan Shen, and Moe Z. Win, “An area state-aided indoor localization algorithm and its implementation,” *IEEE Intl. Conf. on Commun. (ICC)*, 2015.
- Zhao Zhang, **Kaiqing Zhang**, Feifei Gao, and Shun Zhang, “Spectrum prediction and channel selection for sensing-based spectrum sharing scheme using online learning techniques,” *IEEE Intl. Symp. on Personal, Indoor and Mobile Radio Commun. (PIMRC)*, 2015.
- **Kaiqing Zhang**, Jiachen Li, and Feifei Gao, “Machine learning techniques for spectrum sensing when primary user has multiple transmit powers,” *IEEE Intl. Conf. on Commun. Systems (ICCS)*, 2014.

## 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 Fellow</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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|---|--------------------|
| · 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               |
| · <b>Best poster award</b> of the PSERC IAB meeting   | 2015               |
| · 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 (Shaanxi), with Pre-Admission to Tsinghua | 2011               |

## PROFESSIONAL SERVICES & ACTIVITIES

- 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)*, *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