**Wenhan (Winston) Cao**

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**RESEARCH INTERESTS**

My research focuses on bridging the theory of learning and control, with the goal of

building trustworthy autonomous systems. In simple terms, I explore how AI can

enhance control systems to provide greater efficiency, while using control theory to

ensure that AI systems are guaranteed to perform reliably.

**EDUCATION**

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| **Tsinghua University** | September 2019-Present |
| *Ph.D student in Intelligent Vehicle Engineering* | *Beijing, China* |

Supervisor: Dr. [Shengbo Eben Li](https://scholar.google.com/citations?user=Dxiw1K8AAAAJ&hl=en), Professor of [Intelligent Driving Laboratory](http://www.idlab-tsinghua.com/thulab/labweb/index.html)

Co-supervisor: Dr. [Chang Liu](http://www2.coe.pku.edu.cn/FACULTY/LIUCHANG/author/chang-liu-%E5%88%98%E7%95%85/index.html), Assistant Professor of [Autonomous Robots Lab](http://www2.coe.pku.edu.cn/FACULTY/LIUCHANG/index.html)

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| **University of Manchester** | *January 2023-June 2024* |
| *Visiting Ph.D. Student in Computer Science* | *Manchester, UK* |

Supervisor: Dr. [Wei Pan](https://panweihit.github.io/), Senior Lecturer of [Robotics and Embodied AI Lab](https://panweihit.github.io/people/)

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| **Technical University of Munich** | *September 2023-December 2023* |
| *Visiting Ph.D. Student in Control and Optimization* | *Munich, Germany* |

Supervisor: Dr. [Sandra Hirche](https://www.ce.cit.tum.de/en/itr/home/), Professor of [Chair of Information-Oriented Control](https://www.ce.cit.tum.de/en/itr/home/)

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| **Beijing Jiaotong University** | *September 2015-June 2019* |
| *Bachelor of Electrical Engineering* | *Beijing, China* |

GPA ranking: 1/305

**SELECTED PUBLISHED PAPERS**

**Wenhan Cao**, Chang Liu, Zhiqian Lan, Shengbo Eben Li, Wei Pan & Angelo Alessandri. *Robust Bayesian Inference for Moving Horizon Estimation.* To Appear in Automatica. [[Paper](https://arxiv.org/abs/2210.02166)] [[Code](https://github.com/wenhancao/robust-Bayesian-inference-for-MHE.git)]

**Wenhan Cao** & Wei Pan (2024). *Impact of Computation in Integral Reinforcement Learning for Continuous-Time Control.* In 2024 International Conference on Learning Representations (ICLR). **(Spotlight)** [[Paper](https://openreview.net/forum?id=xJEd8PkdNz)] [[Poster](https://drive.google.com/file/d/16z45LOEU8xaPaEoFFIc2hfIneyXCCio_/view?usp=sharing)] [[Code](https://github.com/anonymity678/Computation-Impacts-Control)]

**Wenhan Cao**, Alexandre Capone, Rishabh Yadav, Sandra Hirche & Wei Pan. *Computation-Aware Learning for Stable Control with Gaussian Process.* In 2024 Robotics: Science and Systems (RSS). [[Paper](https://roboticsconference.org/program/papers/4/)] [[Poster](https://drive.google.com/file/d/1rSKLy-SEqgMR7Z8Ius9dhHuqOROflWe0/view?usp=sharing)] [[Recording](https://www.youtube.com/watch?v=AE0iPGlVM30)]

Jingliang Duan, **Wenhan Cao**, Yang Zheng & Lin Zhao. *On the Optimization Landscape of Dynamic Output Feedback Linear Quadratic Control.* IEEE Transactions on Automatic Control (TAC), 69(2):920–935, 2024. **(Regular Paper)** [[Paper](https://ieeexplore.ieee.org/abstract/document/10124022)] [[Code](https://github.com/soc-ucsd/LQG_gradient/tree/master/dLQR)]

Shiqi Liu, **Wenhan Cao**, Chang Liu, Tianyi Zhang & Shengbo Eben Li. *Convolutional Unscented Kalman Filter for Multi-Object Tracking with Outliers.* IEEE Transactions on Intelligent Vehicles (TIV), pp. 1–12, 2024. [[Paper](https://ieeexplore.ieee.org/document/10643343)]

**Wenhan Cao**, Chang Liu, Zhiqian Lan, Yingxi Piao & Shengbo Eben Li. *Generalized Moving Horizon Estimation for Nonlinear Systems with Robustness to Measurement Outliers.* In 2023 American Control Conference (ACC). [[Paper](https://ieeexplore.ieee.org/document/10156391)] [[Code](https://github.com/wenhancao/robust-Bayesian-inference-for-MHE.git)] [[Slides](https://drive.google.com/file/d/1I4Ihmdwlf3kf3sYs4YXGwT6WWOHkr-Pd/view?usp=sharing)]

**Wenhan Cao,** Jingliang Duan, Shengbo Eben Li, Chen Chen, Chang Liu, & Yu Wang. *Primal-Dual Estimator Learning Method with Feasibility and Near-Optimality Guarantees*. In 2022 IEEE Conference on Decision and Control (CDC). [[Paper](https://ieeexplore.ieee.org/document/9992814)] [[Slides](https://drive.google.com/file/d/1Nueg0BkHXsr6s7BwFkDdz3MGJXMRvt9i/view?usp=sharing)]

**Wenhan Cao**, Jianyu Chen, Jingliang Duan, Shengbo Eben Li & Yao Lyu. *Reinforced Optimal Estimator*. In 2021 Modeling, Estimation and Control Conference (MECC). **(Student Best Paper Finalist)** [[Paper](https://www.sciencedirect.com/science/article/pii/S240589632102245X)] [[Slides](https://drive.google.com/file/d/1ZXlsONIwnuPpb4IFkeCRYL7clDx7hTor/view?usp=sharing)]

**SELECTED PREPRINTS (\* denotes equal contribution)**

**Wenhan Cao**, Shiqi Liu, Chang Liu, Zeyu He, Stephen S.-T. Yau & Shengbo Eben Li. *Convolutional Bayesian Filtering.* Submitted to IEEE Transactions on Automatic Control. [[Paper](https://arxiv.org/abs/2404.00481)] [[Slides](https://drive.google.com/file/d/1vuGl7mLdf4Muuaur2buQaIbgiV8pHmTu/view?usp=sharing)]

**Wenhan Cao**, Tianyi Zhang, Zeju Sun, Chang Liu, Stephen S.-T. Yau & Shengbo Eben Li. *Nonlinear Bayesian Filtering with Natural Gradient Gaussian Approximation.* Submitted to IEEE Transactions on Pattern Analysis and Machine Intelligence. [[Paper]](https://arxiv.org/abs/2410.15832) [[Code]](https://github.com/TianyiMehdi/NANO-filter) [[Slides]](https://drive.google.com/file/d/1O8qNHLxzhbikJ_4Ae-LQPQEzaFJre81U/view?usp=sharing)

Shiqi Liu\*, **Wenhan Cao\***, Zeyu He, Chang Liu, Tianyi Zhang & Shengbo Eben Li. *One Filters All: A Generalist Filter For State Estimation*. Submitted to ICML 2025.

Tianyi Zhang, **Wenhan Cao**, Chang Liu, Tao Zhang, Jiangtao Li & Shengbo Eben Li. *Robust State Estimation for Legged Robots with Dual Beta Kalman Filter.* Submitted to IEEE Robotics and Automation Letters. [[Paper]](https://arxiv.org/abs/2411.11483)

**HONORS & AWARDS**

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| Study Abroad Fund from Tsinghua University | 2022 |

Student Best Paper Finalist of Modeling, Estimation and Control Conference 2021

China National Scholarship 2016

The First Prize Scholarship from Beijing Jiaotong University 2016, 2017 & 2018

**SOFTWARE**

I contributed to the General Optimal Control Problem Solver (GOPS), an easy-to-use reinforcement learning (RL) solver package designed to build real-time, high-performance controllers for industrial applications. I was primarily responsible for the core design and implementation of the trainer, sampler, and buffer modules. [[Docs](https://gops.readthedocs.io/en/latest/introduction.html)] [[Paper](https://www.sciencedirect.com/science/article/pii/S2772424723000070)]

**INVITED TALKS & CONFERENCES PRESENTATIONS**

*NANO filter: Bayesian Filtering with Natural Gradient Gaussian Approximation* at the Department of Astronomy, Tsinghua University, Beijing, China, hosted by Prof. [Zheng Cai](https://i.astro.tsinghua.edu.cn/~zcai/index.html), August 2024.

*Convolutional Bayesian Filtering* at the Department of Mathematical Sciences, Tsinghua University, Beijing, China, hosted by Prof. [Stephen Shing-Toung Yau](https://homepages.math.uic.edu/~yau/), February 2024.

*Generalized Moving Horizon Estimation for Nonlinear Systems with Robustness to Measurement Outliers* in 2023 American Control Conference, San Diego, CA, USA (Oral Presentation), May 2023.

*Learning-based state estimation methods* at the Technical University of Munich, Munich, Germany (Online Presentation), hosted by Prof. [Sandra Hirche](https://www.ce.cit.tum.de/en/itr/home/), February 2023.

*Primal-Dual Estimator Learning Method with Feasibility and Near-Optimality Guarantees* in 2022 IEEE 61st Conference on Decision and Control, Cancún, Mexico (Oral Presentation), December 2022.

*Reinforced Optimal Estimator* in 2021 IFAC Modeling, Estimation and Control Conference, Texas, USA (Oral Presentation), October 2021.

*Accelerated Inverse Reinforcement Learning with Randomly Pre-sampled Policies for Autonomous Driving Reward Design* in 2019 IEEE Intelligent Transportation Systems Conference, Auckland, New Zealand (Oral Presentation), October 2019.

**PROFESSIONAL SERVICES**

**Conference Reviewer:** CDC, ACC, L4DC, ICLR, AAMAS & IFAC NMPC

**Journal Reviewer:** TASE, TITS, TNNLS & RA-L