Shengtai Yao

syao31@jh.edu yaoshengtai01@163.com yaoshengtai.github.io Shengtai Yao

Research Interests

My research interests lie broadly in ***Optimization*** and ***Machine Learning Theory***, with a current focus on ***Geometric Machine Learning*** and ***Distributionally Robust Optimization***.

Education

Johns Hopkins University, Baltimore, MD, United States *Aug 2024 – Dec 2025*
M.S.E. Applied Mathematics and Statistics

- **GPA:** 4.0/4.0
- **Selected Coursework:** Introduction to Convexity (A+), Computing for Applied Mathematics (A), Bayesian Statistics (A), Nonlinear Optimization II* (A+), Control Theory and Optimal Control* (A), Probability Theory I* . (* *indicates Ph.D. level courses*)
- **Master's Thesis:** *Any-Dimensional Invariant Universality*
  Advised by *Prof. Mateo Díaz*

Tsinghua University, Beijing, China *Sep 2019 – Jun 2024*
B.E. Mechanical Engineering (Elite Program)

- **GPA:** 3.56/4.0
- **Selected Coursework:** Calculus A1, Calculus A2, Linear Algebra, Advanced Topics in Linear Algebra, Probability and Statistics, Discrete Mathematics I, Complex Analysis, Introduction to Data Science, Deep Learning, Advanced Python Programming, Numerical Computation.
- **Undergraduate's thesis:** *Physics-Informed Neural Networks (PINNs) for Multi-Physics Coupling Computation and Inverse Analysis*
  Advised by *Prof. Qiang He*
- **Honors & Awards:**
  - Outstanding Graduation Thesis (Top 5%) *Jun 2024*
  - Scholarship for Technological Innovation *Nov 2023*
  - Mechanical '87 Student Innovation Scholarship *Nov 2023*
  - Scholarship for Academic Performance *Dec 2020*

Publications

- **S. Yao**, E. Levin, M. Díaz, *Any-Dimensional Invariant Universality*, Johns Hopkins University, 2025.
- **S. Yao**, Y. Wu, R.H. Taylor, E.M. Boctor, *Boost Calibration for Dual-Arm Co-Robotic Ultrasound System.* 2025 IEEE International Ultrasonics Symposium (IUS). *Poster Presented*
- **S. Yao**, W. Huang, Y. Hu, Q. He, *Boundary Region Reinforcement Physics-Informed Neural Networks for solving Partial Differential Equations.* Journal of Engineering Applications of Artificial Intelligence (EAAI), *Under 2nd round review.*
- **S. Yao**, H. Li, X. Hu, K. Hermann, K. Zhang, Y. Li, M. Li, *Identifying Traffic Risk Hotspots Using Spatial-temporal Network Kernel Density Estimation: A Novel Optimal Parameter Selection Method with Dual Dataset Validation.* Transportation Research Board (TRB) 103th Annual Meeting. *Poster Presented.*

Patents

- Y. Liu, J. Yang, Z. Guo, **S. Yao**, J. Xiang, B. Luo, S. Ruan, *Science Popularization Device for Demonstrating Vibration Phenomena and Their Influencing Factors* CN Patent 2023235678170, Jul 23, 2024.
- J. Yang, Q. Wu, Z Xu, Z. Ning, F. Meng, **S. Yao**, Y. Liu, S. Pan, *Science Popularization Device for the Principle of Space Station Robotic Arm.* CN Patent 202222928298.5. Mar 24, 2023.

Research in Johns Hopkins University

Any-dimensional Invariant Universality (Master's Thesis) *Apr 2025 - Current*
Advisor: Prof. Mateo Díaz Department of Applied Mathematics and Statistics

- Conducted literature review on equivariant machine learning and neural network universality
- Strengthened theoretical foundations in abstract algebra (Artin) and functional analysis (Rudin)
- Proved the universal approximation capability of DeepSet architecture for any-dimensional sets
- Proposed a new graph model "Tensor Contraction Graphon Network" and proved its universality
- Proposed models for point clouds based on graphon networks and proved the universality

Finite-Sample Guarantees for Causal Distributionally Robust Optimization *Apr 2025 - Current*
Advisor: Prof. Luhao Zhang Department of Applied Mathematics and Statistics

- Reviewed key literature on Distributionally Robust Optimization (DRO)
- Strengthened the theoretical background in probability theory and statistical learning
- Established generalization bounds for Wasserstein DRO using a causal-aware distance for each policy
- Derived uniform bounds for policy classes via covering numbers and local Rademacher complexity

Boost Calibration for Dual-Arm Co-Robotic Ultrasound System *Oct 2024 - Feb 2025*
Advisor: Prof. Emad M. Boctor, Russell H. Taylor, Postdoc Yixuan Wu Department of Computer Science

- Proposed a new method "Boost Calibration" for accurately calibrating dual-arm robotic systems by solving the nonlinear equation $AXt_1 = YCZt_2$ in SE(3).
- Developed a robust and efficient error estimation method for dual-arm robot simulation
- Performed simulations to demonstrate its applicability to ultrasound tomography

Bayesian Hierarchical Spatial Modeling for Photoacoustic Spectral Unmixing *Apr 2025*
Bayesian Statistics Coursework Project

- Developed a Bayesian hierarchical spatial model based on the Conditional Autoregressive (CAR) to incorporate spatial smoothness into photoacoustic spectral unmixing.
- Derived full conditional distributions and implemented Gibbs sampling with KDE for posterior inference.
- Achieved smooth and biologically consistent concentration maps while preserving model interpretability.

Research in Tsinghua University

Physics-Informed Neural Networks (PINNs) for Multi-Physics Coupling Computation and Inverse Analysis (*Undergraduate Thesis*) *Oct 2023 – Jul 2024*
github.com/Yaoshengtai/BRR-PINNs
Advisor: Prof. Qiang He Department of Mechanical Engineering

- Proposed a novel method, "BRR-PINNs", that more accurately enforces boundary conditions and achieves higher solution precision
- Compared BRR-PINNs with conventional PINNs, the "hard" method, and g-PINNs in terms of computational complexity and accuracy
- Validated BRR-PINNs in the thermo-elastic coupling problem, obtaining relative L_2 error of $\mathcal{O}\left(10^{-5}\right)$ for heat transfer and $\mathcal{O}\left(10^{-4}\right)$ for deformation
- Conducted inverse analysis to predict the physical state of a seal faceplate, reaching an accuracy of $\mathcal{O}\left(10^{-2}\right)$
- Developed an open-source PINNs computing software based on PyTorch.

Data-Driven Urban Traffic Risk Analysis *Sep 2022 - Aug 2023*
github.com/HuXiao-THU/Traffic-risk-detection
Advisor: Prof. Meng Li Department of Civil Engineering and Tsinghua-Benz Institute

- Utilized Spatial-temporal Network Kernel Density Estimation (ST-NKDE) method to estimate risk distribution on road networks, visualizing results
- Proposed novel method based on Kullback-Leibler (KL) divergence for calculating optimal bandwidth in kernel density estimation, enhancing result reliability
- Collaborated with Mercedes to develop visualization website to showcase results

Extracurricular Activities

Trainee *Jul 2022*
Algorithm Training Program, Tsinghua University

Group Head *Feb 2020 - Jun 2021*
Study Group of Technology Association, Tsinghua University

Member *Jul 2019*
Chinese Calligraphers Association, China

Technologies

Languages: C, C++, Python, R, SQL, MATLAB, LaTeX

Software: SolidWorks, AutoCAD, COMSOL, ROS2