

Xiangxiang Xu

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RESEARCH INTERESTS

My research interests span **information theory**, **machine learning theory**, and **statistical learning**, with a particular focus on learning algorithm design. My research develops principled learning approaches to tackle challenges in real-world engineering applications.

EMPLOYMENT

Postdoctoral Associate, EECS, MIT Aug. 2021 – present
• Advisor: Prof. Lizhong Zheng
Research Assistant, Tsinghua–Berkeley Shenzhen Institute Aug. 2020 – Jul. 2021

EDUCATION

Tsinghua Univ., Beijing, China Sept. 2014 – Aug. 2020
• Ph.D., Electronic Engineering
• Advisors: Prof. Lin Zhang and Prof. Shao-Lun Huang
• Thesis: *A Local Information Geometric Study on Machine Learning Algorithms*
Tsinghua Univ., Beijing, China Aug. 2010 – Jul. 2014
• B.Eng., Electronic Engineering

HONORS & AWARDS

Best Poster Runner-up, ACM Sensys 2016 & 2018
IEEE PES Student Prize Paper Award in Honor of T. Burke Hayes 2016
First Prize Winner of Tsinghua–DEK Scholarship (*one* awarded per year) 2012
Excellence Award of EDA (Electronic Design Automation) Practice 2011

RESEARCH EXPERIENCE

Research Laboratory of Electronics, MIT Aug. 2021 – present
Advisor: Prof. Lizhong Zheng
• Multivariate Information Decomposition and Learning
<https://gilearning.github.io/>

- Established feature geometry, a unified learning framework that converts learning problems to geometric operations in function space. Proposed nesting technique, an approach to systematically construct learning objectives for implementing such geometric operations.
- Developed learning algorithms for computing multivariate information decomposition, demonstrated applications in conditional inference, multimodal learning with missing modalities, and sequential dependence decomposition.
- Applied feature geometry to wireless physical layer communication, provided learning solutions to (1) multi-user detection with channel state information and (2) coherent detection with non-uniform digital modulation.

Tsinghua–Berkeley Shenzhen Institute, Tsinghua May. 2017 – Jul. 2021
Advisors: Prof. Lin Zhang and Prof. Shao-Lun Huang
• *Information-theoretic Learning Algorithm Analysis and Design*

- Provided an information-theoretic characterization and interpretation of feature extraction in deep neural networks.
- Based on information-theoretic characterizations, designed learning algorithms for classification, unsupervised learning, and distributed learning.
- *Distributed Hypothesis Testing With Communication Constraints*
 - Characterized error exponent regions of distributed hypothesis testing (DHT) with constant communication bits. Proved the optimality of type-based encoders for general DHT problems under constant-bit constraints.
 - Provided error exponent region for DHT with ternary communication constraints, the first extension over the 1-bit constraint results established by [Han-Kobayashi 1989].

Dept. of Electronic Engineering, Tsinghua

Sep. 2014 – Apr. 2017

Advisor: Prof. Lin Zhang

- *Vehicle-based Environmental Sensing System*

- Designed and implemented *Gotcha*, a mobile environmental sensing system, deployed on a fleet of 100 electric vehicles (EVs) in Shenzhen, China, and developed algorithms for pollution map reconstruction. The collected data have supported studies analyzing air quality, GPS trajectory, and EV charging behaviors.

TEACHING EXPERIENCE

Recitation Instructor at MIT

- Signals, Systems and Inference 6.3010 (6.011) Spring 2023

Mentorship at MIT

- Undergraduate Research Program Feb. 2023 – Nov. 2023
 - UROP (MIT Undergraduate Research Opportunities Program):
Ishank Agrawal, *Deep Learning Approach to Multi-user Detection*
- High School Research Program Summer 2023
 - RSI (Research Science Institute):
Timothy Mathew, *Coherent Detection With Non-uniform Digital Modulation*
 - RISE (research internship in science engineering)
Christina Lee (admitted to MIT), *Empirical Analysis for Reservoir Computing*

Teaching Assistant at Tsinghua

- Information Theory and Statistical Learning Fall 2019
- Learning from Data Fall 2018, Spring 2019
- Inference and Information Fall 2017
- Probability Theory Spring 2017
- Fundamentals of Applied Information Theory (MOOC) Fall 2016
- Calculus A Fall 2015, Spring 2016, Fall 2016

PREPRINTS

- [P1] **Xiangxiang Xu** and Lizhong Zheng. “A geometric framework for neural feature learning”. *Submitted to Journal of Machine Learning Research (JMLR)*, under major revision. *Also available as arXiv preprint arXiv:2309.10140. 2023.*

JOURNAL
PUBLICATIONS
(SELECTED)

- JSAIT **Xiangxiang Xu** and Shao-Lun Huang. “On Distributed Learning with Constant Communication Bits”. In: *IEEE Journal on Selected Areas in Information Theory* 3.1 (2022), pp. 125–134.
- Entropy **Xiangxiang Xu**, Shao-Lun Huang, Lizhong Zheng, and Gregory W. Wornell. “An Information Theoretic Interpretation to Deep Neural Networks”. In: *Entropy* 24.1 (2022), p. 135.
- TIT Shao-Lun Huang and **Xiangxiang Xu**. “On the Sample Complexity of HGR Maximal Correlation Functions for Large Datasets”. In: *IEEE Transactions on Information Theory* 67.3 (2021), pp. 1951–1980. DOI: 10.1109/TIT.2020.3044622.
- JSAIT Shao-Lun Huang, **Xiangxiang Xu**, and Lizhong Zheng. “An information-theoretic approach to unsupervised feature selection for high-dimensional data”. In: *IEEE Journal on Selected Areas in Information Theory* (2020).

CONFERENCE
PUBLICATIONS
(SELECTED)

- Allerton **Xiangxiang Xu** and Lizhong Zheng. “Sequential Dependence Decomposition and Feature Learning”. In: *2023 59th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*. IEEE. Sept. 2023, pp. 1–8.
- Allerton **Xiangxiang Xu**, Lizhong Zheng, and Ishank Agrawal. “Neural Feature Learning for Engineering Problems”. In: *2023 59th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*. IEEE. Sept. 2023, pp. 1–8.
- ISIT **Xiangxiang Xu** and Lizhong Zheng. “Kernel Subspace and Feature Extraction”. In: *2023 IEEE International Symposium on Information Theory (ISIT) (ISIT’2023)*. Taipei, Taiwan, June 2023, pp. 1032–1037.
- Neurips Xinyi Tong, **Xiangxiang Xu**, Shao-Lun Huang, and Lizhong Zheng. “A Mathematical Framework for Quantifying Transferability in Multi-source Transfer Learning”. In: *Advances in Neural Information Processing Systems*. Vol. 34. 2021, pp. 26103–26116.
- ISIT **Xiangxiang Xu** and Shao-Lun Huang. “An information theoretic framework for distributed learning algorithms”. In: *2021 IEEE International Symposium on Information Theory (ISIT)*. IEEE. 2021, pp. 314–319.

INVITED TALKS

- Feature Geometry and Multivariate Dependence Learning*
- NLP Reading Group, University College London Jan. 2024
 - Wireless@VT Seminar, Virginia Tech [Video] Dec. 2023
 - Computer Vision Seminar, Univ. of Michigan Nov. 2023
 - MLTea, MIT Oct. 2023
- Sequential Dependence Decomposition and Feature Learning*
- Signals, Information, and Algorithms Laboratory, MIT Oct. 2023
- Learning With Feature Geometry*
- Boston Univ. Mar. 2023
 - Northeastern Univ. Feb. 2023
- Multivariate Feature Extraction*
- Signals, Information, and Algorithms Laboratory, MIT Oct. 2022
- On Distributed Hypothesis Testing with Constant Communication Bits*
- Comm/InfoTheory Seminar, MIT Apr. 2022

PROFESSIONAL
ACTIVITIES

Reviewer for

- IEEE Transactions on Information Theory (TIT)
- IEEE International Symposium on Information Theory (ISIT)
- IEEE Information Theory Workshop (ITW)
- IEEE International Conference on Sensing, Communication and Networking (SECON)

Session Chair for

- IEEE International Symposium on Information Theory (ISIT)

OTHER
PUBLICATIONS

INFORMATION THEORY & LEARNING APPLICATIONS

- [L1] Xinyi Tong, **Xiangxiang Xu**, and Shao-Lun Huang. “On the Optimal Error Exponent of Type-Based Distributed Hypothesis Testing”. In: *Entropy* 25.10 (2023), p. 1434.
- [L2] Xinyi Tong, **Xiangxiang Xu**, and Shao-Lun Huang. “On Sample Complexity of Learning Shared Representations: The Asymptotic Regime”. In: *2022 58th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*. IEEE. 2022.
- [L3] **Xiangxiang Xu** and Lizhong Zheng. “Multivariate Feature Extraction”. In: *2022 58th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*. 2022.
- [L4] Ziyang Zheng, Xinyi Tong, Xinchun Yu, **Xiangxiang Xu**, and Shao-Lun Huang. “Multi-source Transfer Learning for Signal Detection over a Fading Channel with Co-channel Interference”. In: *ICC 2022-IEEE International Conference on Communications*. IEEE. 2022, pp. 2609–2614.
- [L5] Mingyang Li, **Xiangxiang Xu**, Shao-Lun Huang, and Lin Zhang. “Dual Feature Distributional Regularization for Defending Against Adversarial Attacks”. In: *Neural Information Processing: 28th International Conference, ICONIP 2021, Sanur, Bali, Indonesia, December 8–12, 2021, Proceedings, Part VI 28*. Springer. 2021, pp. 377–386.
- [L6] **Xiangxiang Xu** and Shao-Lun Huang. “On distributed hypothesis testing with constant-bit communication constraints”. In: *2021 IEEE Information Theory Workshop (ITW)*. IEEE. 2021.
- [L7] Shao-Lun Huang, **Xiangxiang Xu**, Lizhong Zheng, and Gregory W. Wornell. “A local characterization for Wyner common information”. In: *2020 IEEE International Symposium on Information Theory (ISIT)*. IEEE. 2020, pp. 2252–2257.
- [L8] **Xiangxiang Xu** and Shao-Lun Huang. “Maximal Correlation Regression”. In: *IEEE Access* 8 (2020), pp. 26591–26601.
- [L9] **Xiangxiang Xu** and Shao-Lun Huang. “On the Optimal Tradeoff Between Computational Efficiency and Generalizability of Oja’s Algorithm”. In: *IEEE Access* 8 (2020), pp. 102616–102628.
- [L10] **Xiangxiang Xu**, Weida Wang, and Shao-Lun Huang. “On the sample complexity of estimating small singular modes”. In: *2020 IEEE International Symposium on Information Theory (ISIT)*. IEEE. 2020, pp. 1189–1194.
- [L11] Shao-Lun Huang and **Xiangxiang Xu**. “On the robustness of noisy ACE algorithm and multi-layer residual learning”. In: *2019 IEEE International Symposium on Information Theory (ISIT)*. IEEE. 2019, pp. 2474–2478.

- [L12] Lu Li, Yang Li, **Xiangxiang Xu**, Shao-Lun Huang, and Lin Zhang. “Maximal Correlation Embedding Network for Multilabel Learning with Missing Labels”. In: *2019 IEEE International Conference on Multimedia and Expo (ICME)*. IEEE. 2019, pp. 393–398.
- [L13] Lichen Wang, Jiaxiang Wu, Shao-Lun Huang, Lizhong Zheng, **Xiangxiang Xu**, Lin Zhang, and Junzhou Huang. “An efficient approach to informative feature extraction from multimodal data”. In: *Proceedings of the AAAI Conference on Artificial Intelligence*. Vol. 33. 2019, pp. 5281–5288.
- [L14] **Xiangxiang Xu** and Shao-Lun Huang. “On the Asymptotic Sample Complexity of HGR Maximal Correlation Functions in Semi-supervised Learning”. In: *2019 57th Annual Allerton Conference on Communication, Control, and Computing (Allerton)*. IEEE. 2019, pp. 879–886.
- [L15] Shao-Lun Huang and **Xiangxiang Xu**. “On the Sample Complexity of HGR Maximal Correlation Functions”. In: *2019 IEEE Information Theory Workshop (ITW)*. Aug. 2019, pp. 1–5. DOI: 10.1109/ITW44776.2019.8989373.
- [L16] **Xiangxiang Xu**, Shao-Lun Huang, Lizhong Zheng, and Lin Zhang. “The Geometric Structure of Generalized Softmax Learning”. In: *2018 IEEE Information Theory Workshop (ITW)*. IEEE. 2018, pp. 1–5.

SENSING SYSTEM & DATA ANALYSIS

- [S1] Xinlei Chen, Susu Xu, Xinyu Liu, **Xiangxiang Xu**, Hae Young Noh, Lin Zhang, and Pei Zhang. “Adaptive Hybrid Model-enabled Sensing System (HMSS) for Mobile Fine-Grained Air Pollution Estimation”. In: *IEEE Transactions on Mobile Computing* (2020).
- [S2] Rui Ma, Ning Liu, **Xiangxiang Xu**, Yue Wang, Hae Young Noh, Pei Zhang, and Lin Zhang. “Enhancing the Data Learning With Physical Knowledge in Fine-Grained Air Pollution Inference”. In: *IEEE Access* 8 (2020), pp. 88372–88384.
- [S3] Rui Ma, Ning Liu, **Xiangxiang Xu**, Yue Wang, Hae Young Noh, Pei Zhang, and Lin Zhang. “Fine-Grained Air Pollution Inference with Mobile Sensing Systems: A Weather-Related Deep Autoencoder Model”. In: *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4.2 (2020), pp. 1–21.
- [S4] Lu Li, Yang Li, **Xiangxiang Xu**, and Lin Zhang. “A maximal correlation embedding method for multilabel human context recognition”. In: *Proceedings of the 18th International Conference on Information Processing in Sensor Networks*. ACM. 2019, pp. 305–306.
- [S5] Rui Ma, Ning Liu, **Xiangxiang Xu**, Yue Wang, Hae Young Noh, Pei Zhang, and Lin Zhang. “A deep autoencoder model for pollution map recovery with mobile sensing networks”. In: *Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers*. ACM. 2019, pp. 577–583.

- [S6] Xinlei Chen, **Xiangxiang Xu**, Xinyu Liu, Shijia Pan, Jiayou He, Hae Young Noh, Lin Zhang, and Pei Zhang. “PGA: Physics Guided and Adaptive Approach for Mobile Fine-Grained Air Pollution Estimation”. In: *Proceedings of the 2018 ACM International Joint Conference and 2018 International Symposium on Pervasive and Ubiquitous Computing and Wearable Computers*. ACM. 2018, pp. 1321–1330.
- [S7] Rui Ma, **Xiangxiang Xu**, Hae Young Noh, Pei Zhang, and Lin Zhang. “Generative Model Based Fine-Grained Air Pollution Inference for Mobile Sensing Systems”. In: *Proceedings of the 16th ACM Conference on Embedded Networked Sensor Systems*. ACM. 2018, pp. 426–427.
- [S8] Rui Ma, **Xiangxiang Xu**, Yue Wang, Hae Young Noh, Pei Zhang, and Lin Zhang. “Guiding the Data Learning Process with Physical Model in Air Pollution Inference”. In: *2018 IEEE International Conference on Big Data (Big Data)*. IEEE. 2018, pp. 4475–4483.
- [S9] Xinyu Liu, Xinlei Chen, **Xiangxiang Xu**, Enhao Mai, Hae Young Noh, Pei Zhang, and Lin Zhang. “Delay Effect in Mobile Sensing System for Urban Air Pollution Monitoring”. In: *Proceedings of the 15th ACM Conference on Embedded Network Sensor Systems*. ACM. 2017, p. 73.
- [S10] Xinyu Liu, **Xiangxiang Xu**, Xinlei Chen, Enhao Mai, Hae Young Noh, Pei Zhang, and Lin Zhang. “Individualized Calibration of Industrial-Grade Gas Sensors in Air Quality Sensing System”. In: *Proceedings of the 15th ACM Conference on Embedded Network Sensor Systems*. ACM. 2017, p. 74.
- [S11] Tianyu Yang, **Xiangxiang Xu**, Qinglai Guo, Lin Zhang, and Hongbin Sun. “EV charging behaviour analysis and modelling based on mobile crowdsensing data”. In: *IET Generation, Transmission & Distribution* 11.7 (2017), pp. 1683–1691.
- [S12] Xinlei Chen, **Xiangxiang Xu**, Xinyu Liu, Hae Young Noh, Lin Zhang, and Pei Zhang. “HAP: Fine-Grained Dynamic Air Pollution Map Reconstruction by Hybrid Adaptive Particle Filter”. In: *Proceedings of the 14th ACM Conference on Embedded Network Sensor Systems CD-ROM*. ACM. 2016, pp. 336–337.
- [S13] **Xiangxiang Xu**, Xinlei Chen, Xinyu Liu, Hae Young Noh, Pei Zhang, and Lin Zhang. “Gotcha II: Deployment of a Vehicle-based Environmental Sensing System”. In: *Proceedings of the 14th ACM Conference on Embedded Network Sensor Systems CD-ROM*. ACM. 2016, pp. 376–377.
- [S14] **Xiangxiang Xu**, Pei Zhang, and Lin Zhang. “Gotcha: a mobile urban sensing system”. In: *Proceedings of the 12th ACM Conference on Embedded Network Sensor Systems*. ACM. 2014, pp. 316–317.