

# Lei Wu

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## Education

- 2012.9 - 2018.7 **Ph.D. in Computational Mathematics**, *Peking University*, Beijing, China.  
Advisor: Prof. Weinan E
- 2018.2 - 2018.5 **Visiting student**, *PACM, Princeton University*, NJ, USA.  
Mentor: Weinan E
- 2014.3 - 2014.9 **Visiting student**, *Pacific Northwest National Laboratory*, WA, USA.  
Mentor: Guang Lin
- 2008.9 - 2012.6 **B.S. in Pure Mathematics**, *Nankai University*, Tianjin, China.

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## Professional Experiences

- 2021.12 - **Assistant Professor**, School of Mathematical Sciences & Center for Machine Learning Research, Peking University, Beijing, China.
- 2021.8 - 2021.11 **Postdoctoral Researcher**, Department of Statistics and Data Science, University of Pennsylvania, Philadelphia, USA.
- 2018.11 - 2021.7 **Postdoctoral Research Associate**, PACM, Princeton University, Princeton, USA.
- 2018.7 - 2018.11 **Research Assistant**, Beijing Institute of Big Data Research, Beijing, China.

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## Research Interests

- Mathematical understanding of machine learning and deep learning.
- Applying machine learning and deep learning to solve scientific computing problems.

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## Publications & Preprints

\* indicates equal contribution or alphabetical author order.

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### Published

- [1] Zihao Wang\*, **Lei Wu\***. Theoretical Analysis of Inductive Biases in Deep Convolutional Networks. In *Advances in Neural Information Processing Systems (NeurIPS)*, 2023.
- [2] **Lei Wu**, Weijie Su. The Implicit Regularization of Dynamical Stability in Stochastic Gradient Descent. In *International Conference on Machine Learning (ICML)*, 2023.
- [3] **Lei Wu**, Mingze Wang, Weijie Su. The alignment property of SGD noise and how it helps select flat minima: A stability analysis. In *Advances in Neural Information Processing Systems (NeurIPS)*, 2022.
- [4] Chao Ma, Daniel Kunin, **Lei Wu**, Lexing Ying Beyond the quadratic approximation: the multiscale structure of neural network loss landscapes. *Journal of Machine Learning*, 2022.
- [5] **Lei Wu**, Jihao Long. A spectral-based analysis of the separation between two-layer neural networks and linear methods. *Journal of Machine Learning Research*, 2022.
- [6] **Lei Wu**. Learning a single neuron for non-monotonic activation functions. In AISTATS, 2022.

- [7] Chao Ma\*, **Lei Wu\***, Weinan E. A qualitative study of the dynamic behavior of adaptive gradient algorithms. In *Mathematical and Scientific Machine Learning (MSML)*, 2021.
- [8] Weinan E\*, Chao Ma\*, Stephan Wojtowytsch\*, **Lei Wu\***. Towards a mathematical understanding of neural network-based machine learning: what we know and what we don't. *SIAM Trans. Appl. Math.*, 2020.
- [9] Huan Lei, **Lei Wu**, Weinan E. Machine learning based non-Newtonian fluid model with molecular fidelity. *Physical Review E*, 2020.
- [10] Weinan E\*, Chao Ma\*, **Lei Wu\***. Machine Learning from a Continuous Viewpoint. *Science China Mathematics*, 2020.
- [11] Chao Ma, **Lei Wu**, Weinan E. The slow deterioration of the generalization error of the random feature model. In *Mathematical and Scientific Machine Learning (MSML)*, 2020.
- [12] Weinan E\*, Chao Ma\*, **Lei Wu\***. The generalization error of minimum-norm solutions for over-parameterized neural networks models. *Journal of Pure and Applied Functional Analysis*, 2020.
- [13] Weinan E\*, Chao Ma\*, **Lei Wu\***. A comparative analysis of the optimization and generalization property of two-layer neural network and random feature models under gradient descent dynamics. *Science China Mathematics*, 2020.
- [14] Weinan E\*, Chao Ma\*, and **Lei Wu\***. The Barron space and the flow-induced function spaces for neural network models. *Constructive Approximation*, 2022.
- [15] **Lei Wu\***, Qingcan Wang\*, and Chao Ma. Global convergence of gradient descent for deep linear residual networks. In *Advances in Neural Information Processing Systems (NeurIPS)*, 2019.
- [16] Weinan E\*, Chao Ma\*, and **Lei Wu\***. A priori estimates of the population risk for two-layer neural networks. *Communications in Mathematical Sciences*, 2019.
- [17] Zhanxing Zhu\*, Jingfeng Wu\*, Bing Yu, **Lei Wu**, and Jinwen Ma. *The anisotropic noise in stochastic gradient descent: Its behavior of escaping from sharp minima and regularization effects*. In *International Conference on Machine Learning (ICML)*, 2019.
- [18] **Lei Wu**, Chao Ma, Weinan E. How SGD selects the global minima in over-parameterized learning: A dynamical stability perspective. In *Advances in Neural Information Processing Systems (NeurIPS)*, 2018.
- [19] **Lei Wu**, Zhanxing Zhu. Towards understanding and improving the transferability of adversarial examples in deep neural networks. Asian Conference on Machine Learning, 2020; arXiv:1802.09707
- [20] **Lei Wu**, Zhanxing Zhu, Weinan E. Towards understanding the generalization of deep learning: perspective of loss landscape. *ICML2017 Workshop on Principled Approaches to Deep Learning*, 2017.
- [21] Yi-An Ma, Tianqi Chen, **Lei Wu**, Emily B. Fox. Irreversible samplers from jump and continuous Markov processes. *Statistics and Computing*, 2018.
- [22] Huan Lei, Nathan A. Baker, **Lei Wu**, Gregory K. Schenter, Christopher J. Mundy, and Alexandre M. Tartakovsky. Smoothed dissipative particle dynamics model for mesoscopic multiphase flows in the presence of thermal fluctuations. *Physical Review E*, 2016.

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## Preprints

- [1] Mingze Wang, **Lei Wu**. The Noise Geometry of Stochastic Gradient Descent: A Quantitative and Analytical Characterization. *arXiv preprint*, 2023.
- [2] Hongrui Chen\*, Jihao Long\*, **Lei Wu\***. The  $L^\infty$  Learnability of Reproducing Kernel Hilbert Spaces. *arXiv preprint*, 2023.
- [3] **Lei Wu**. Embedding Inequalities for Barron-type Spaces. *arXiv preprint*, 2023.
- [4] Hongrui Chen\*, Jihao Long\*, **Lei Wu\***. A duality framework for generalization analysis of random feature models and two-layer neural networks. *arXiv preprint*, 2023.
- [5] Chao Ma\*, **Lei Wu\***, Weinan E. The quenching-activation behavior of the gradient descent dynamics for two-layer neural network models. *arXiv preprint*, arxiv:2006.14450, 2020

- [6] Zhong Li\*, Chao Ma\*, **Lei Wu\***. Complexity measures for neural networks with general activation functions using path-based norms. *arXiv preprint arXiv:2009.06132*, 2020
- [7] Weinan E\*, Chao Ma\*, **Lei Wu\***. Analysis of the gradient descent algorithm for a deep neural network model with skip-connections. *arXiv preprint arXiv:1904.05263*, 2019

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## Teaching Experiences

- Fall 2023 **Instructor**, *Mathematical Introduction to Machine Learning*, Peking University.
- Spring 2023 **Instructor**, *Advanced Mathematics (B)*, Peking University.
- Fall 2022 **Instructor**, *Mathematical Introduction to Machine Learning*, Peking University.
- Spring 2022 **Instructor**, *Mathematical Introduction to Data Science*, Peking University.
- Summer 2021 **Instructor**, *Theoretical Deep Learning*, PKU Summer School on Applied Mathematics.
- Spring 2021 **Co-instructor**, *Mathematical Introduction to Machine Learning*, Princeton University.
- Summer 2020 **Co-instructor**, *Online Summer School of Deep Learning Theory*, Shanghai Jiao Tong University.
- Summer 2019 **Co-instructor**, *Mathematical Theory of Neural Network Models*, Peking University, (Summer Course).
- Summer 2018 **Co-instructor**, *Mathematical Introduction to Machine Learning*, Peking University, (Summer School).
- Spring 2015 **TA**, *Convex Optimization*, Peking University.
- Fall 2014 **TA**, *Applied Partial Differential Equations*, Peking University.
- Spring 2013 **TA**, *Calculus*, Peking University.
- Fall 2012 **TA**, *Linear Algebra*, Peking University.

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## Mentoring

### Graduate students

- Shan Jiang (21)

### Undergraduate students

- Kaizhao Liu (21), Zilin Wang (20), Liming Liu (20), Zihao Wang (20), Hongrui Chen (19), Zhanran Lin (19), Puheng Li (19), Zihan Wang (18).

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## Talks

- Joint Seminar of Machine Learning (virtual), June 2021
- One World Seminar Series on the Mathematics of Machine Learning (virtual), August 2020
- CCMA Deep Learning Seminar (virtual), PSU, May 2020
- Machine Learning Theory Workshop, Peking University, Beijing, June 2019
- Noah's Ark Lab, Huawei, Beijing, July 2019
- Machine Learning Theory Workshop, Peking University, Beijing, June 2018

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## Professional Services

Reviewer for:

- **Conference:** NeurIPS (2019-2022), ICML (2020-2021), ICLR(2020-2024), AISTATS(2022), MSML(2020-2022), AAAI(2019), IJCAI (2019).
- **Journal:** Journal of Machine Learning Research, SIAM Journal of Numerical Analysis, SIAM Journal on Mathematics of Data Science, SIAM Journal on Mathematical Analysis, European Journal of Applied Mathematics, Constructive Approximation, Machine Learning, Communications in Mathematical Sciences, Journal of Machine Learning, Journal of Scientific Computing, Annals of Applied Probability.