SPENCER FREI

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RESEARCH INTERESTS

My research interests are in the foundations of deep learning and artificial intelligence. My goal is to understand the statistical and computational mechanisms underlying the success of deep learning and AI, and to develop methods which improve the performance of systems utilizing these technologies.

EMPLOYMENT

Tenure-track Assistant Professor, Department of Statistics, University of California, Davis *2023–present*
— Member of the Graduate Group in Computer Science
— Long-term participant at Simons Institute, Fall 2024, for program on Modern Paradigms in Generalization

Postdoctoral Fellow, Simons Institute for the Theory of Computing, UC Berkeley *2021–2023*
— Mentors: Peter Bartlett and Bin Yu.
— Part of the NSF/Simons Collaboration on the Theoretical Foundations of Deep Learning.
— Visitor at École polytechnique fédérale de Lausanne (EPFL), Sep. & Oct. 2022, hosted by Emmanuel Abbé.

EDUCATION

Ph.D, Statistics, UCLA *2015–2021*
— Co-advisors: Quanquan Gu and Ying Nian Wu; committee members: Arash Amini and Qing Zhou.

MSc., Mathematics, University of British Columbia, Vancouver *2013–2015*

BSc., Mathematics, McGill University, Montréal. *2009–2013*
— First class honours.

PUBLICATIONS AND PREPRINTS (see also Google Scholar)

1. Usman Anwar, Johannes von Oswald, Louis Kirsch, David Krueger, **S. Frei**. Adversarial robustness of in-context learning in transformers for linear regression. Preprint, arXiv:2411.05189.
2. **S. Frei** and G. Vardi. Trained transformer classifiers generalize and exhibit benign overfitting in-context. Preprint, arXiv:2410.01774.
3. Shuning Shang, Roey Magan, Zhiwei Xu, **S. Frei**, Gal Vardi, Wei Hu. Benign overfitting in single-head attention. Preprint, arXiv:2410.07746.
4. Nikhil Ghosh, **S. Frei**, Wooseok Ha, Bin Yu. The effect of SGD batch size on autoencoder learning: Sparsity, sharpness and feature learning. Accepted at *JMLR*.
5. Neil Mallinar*, Austin Zane*, **S. Frei**, Bin Yu. Minimum-norm interpolation under covariate shift. *ICML 2024*.
6. Ruiqi Zhang, **S. Frei**, Peter L. Bartlett. Trained transformers learn linear models in-context. *JMLR 2024*.
7. Zhiwei Xu, Yutong Wang, **S. Frei**, Gal Vardi, Wei Hu. Benign overfitting and grokking in ReLU networks for XOR cluster data. *ICLR 2024*.
8. **S. Frei***, Gal Vardi*, Peter L. Bartlett, Nati Srebro. The double-edged sword of implicit bias: Generalization vs. robustness in ReLU networks. *NeurIPS 2023*.
9. **S. Frei***, Gal Vardi*, Peter L. Bartlett, Nathan Srebro. Benign overfitting in linear classifiers and leaky ReLU networks from KKT conditions for margin maximization. *COLT 2023*.

10. **S. Frei***, Gal Vardi*, Peter L. Bartlett, Nati Srebro, Wei Hu. Implicit bias in leaky ReLU networks trained on high-dimensional data. *ICLR 2023* **(Spotlight)**.

11. **S. Frei**, Niladri Chatterji, Peter L. Bartlett. Random feature amplification: Feature learning and generalization in neural networks. *JMLR 2023.*

12. **S. Frei**, Niladri Chatterji, Peter L. Bartlett. Benign overfitting without linearity: Neural network classifiers trained by gradient descent for noisy linear data. *COLT 2022.*

13. **S. Frei***, Difan Zou*, Zixiang Chen*, Quanquan Gu. Self-training converts weak learners to strong learners in mixture models. *AISTATS 2022*.

14. **S. Frei** and Quanquan Gu. Proxy convexity: A unified framework for the analysis of neural networks trained by gradient descent. *NeurIPS 2021.*

15. Difan Zou*, **S. Frei***, Quanquan Gu. Provable robustness of adversarial training for learning halfspaces with noise. *ICML 2021*.

16. **S. Frei**, Yuan Cao, Quanquan Gu. Provable generalization of SGD-trained neural networks of any width in the presence of adversarial label noise. *ICML 2021.*

17. **S. Frei**, Yuan Cao, Quanquan Gu. Agnostic learning of halfspaces with gradient descent via soft margins. *ICML 2021* **(Long Talk)**.

18. Ariana E. Anderson, Mirella Diaz-Santos, **S. Frei** *et al.* Hemodynamic latency is associated with reduced intelligence across the lifespan: an fMRI DCM study of aging, cerebrovascular integrity, and cognitive ability. *Brain Structure and Function*, 2020.

19. **S. Frei**, Yuan Cao, Quanquan Gu. Algorithm-dependent generalization bounds for overparameterized deep residual networks. *NeurIPS 2019*.

20. **S. Frei** and Edwin Perkins. A lower bound for p_c in range-R bond percolation in two and three dimensions. *Electronic Journal of Probability* 21(56), 2016.

* indicates equal contribution.

INDUSTRY EXPERIENCE

Applied Scientist Intern, Amazon Alexa AI, Cambridge, MA *Summer 2020*

— Worked on natural language understanding using Transformer-based multilingual language models.

Student Researcher, Chatterbaby/UCLA School of Medicine, Los Angeles, CA *2018–2020*

— Developed deep learning models for audio analysis of infant cries that were deployed in Chatterbaby app (100k+ downloads on Android). Employed 20 hr/week when not teaching.

Biostatistical Consultant, Ritter Pharmaceuticals, Los Angeles, CA *2017–2019*

— Consulted on the analysis of clinical trial data using linear regression and mixed effects models.

Student Researcher, Blackthorn Therapeutics/UCLA School of Medicine, Los Angeles, CA *2016–2018*

— Analyzed MRI and neuropsychiatric data using generalized linear models for a biotech company-sponsored project. Employed 20 hr/week when not teaching.

HONORS

- Selected for NeurIPS 2023 Tutorial, "Reconsidering Overfitting in the Age of Overparameterized Models"
- Rising Star in Machine Learning, University of Maryland, 2022.
- Best Reviewer Award: ICML 2020, ICML 2021, NeurIPS 2021, ICLR 2022.
- Dissertation Year Fellowship, UCLA, 2020–2021.

• Most Promising Computational Statistician, UCLA, 2016.
• Research Fellowship, Montréal Institut des sciences mathématiques, 2012.

TALKS $^{\vee}$ **indicates virtual presentation**

• "Reconsidering Overfitting in the Age of Overparameterized Models" (three hour tutorial)
— NeurIPS 2023 Tutorial, presented with Vidya Muthukumar and Fanny Yang *December 2023*

• "Learning Linear Models In-Context with Transformers"
— University of Southern California, Department of Data Sciences and Operations Seminar *October 2024*
— UCLA, Department of Statistics and Data Science Seminar *May 2024*
— École normale supérieure, INRIA SIERRA Seminar *April 2024*
— Sorbonne Université and Paris Diderot University, Statistics Seminar *April 2024*
— Apple Machine Learning Research, Cupertino *November 2023*
— University of Basel, Department of Mathematics and Computer Science Seminar *November 2023*
— University of Oxford, Computational Statistics and Machine Learning Seminar *October 2023*
— University of Cambridge, Machine Learning Group *October 2023*
— Google DeepMind, London *October 2023*
— Imperial College London, Imperial + AI Seminar *October 2023*
— The Alan Turing Institute, London, Rough Paths Interest Group$^{\vee}$ *October 2023*
— Stanford University, Tengyu Ma group meeting *September 2023*
— Google Research, In-Context Learning Reading Group$^{\vee}$ *August 2023*

• "Benign Overfitting from KKT Conditions for Margin Maximization"
— Conference on Learning Theory, Bangalore *July 2023*

• "Implicit Regularization and Benign Overfitting for Neural Networks in High Dimensions"
— Youth in High Dimensions Workshop, International Center for Theoretical Physics, Trieste *May 2023*
— UC Berkeley, Department of Biostatistics Seminar *April 2023*
— University of British Columbia, Mathematics of Information, Learning, and Data Seminar *January 2023*
— University of Alberta, Dept. of Mathematical and Statistical Sciences, Statistics Seminar *October 2022*
— EPFL, Fundamentals of Learning and Artificial Intelligence Seminar *September 2022*

• "Statistical Learning Theory, Optimization, and Neural Networks" (two hour tutorial)
— Simons Institute, Deep Learning Theory Workshop & Summer School *August 2022*

• "Benign Overfitting without Linearity"
— University of Southern California, Symposium on Frontiers of Machine Learning and AI *November 2022*
— Joint Statistical Meetings, Washington, D.C. *August 2022*
— Conference on Learning Theory, London *July 2022*
— ETH Zürich, Data, Algorithms, Combinatorics, & Optimization Seminar *June 2022*
— Harvard University, Probabilitas Seminar$^{\vee}$ *May 2022*
— University of Toronto, Statistics Research Day$^{\vee}$ *May 2022*
— University of British Columbia, Christos Thrampoulidis group meeting$^{\vee}$ *April 2022*
— Theory of Overparameterized Machine Learning Workshop$^{\vee}$ *April 2022*
— Google Research, Algorithms Seminar$^{\vee}$ *March 2022*
— Oxford University, Yee Whye Teh group meeting$^{\vee}$ *March 2022*
— NSF/Simons Mathematics of Deep Learning Seminar$^{\vee}$ *March 2022*

• "Random Feature Amplification: Feature Learning and Generalization in Neural Networks"
— EPFL, Nicolas Flammarion group meeting *October 2022*
— Microsoft Research, Machine Learning Foundations Seminar$^{\vee}$ *April 2022*
— Columbia University, Daniel Hsu group meeting$^{\vee}$ *April 2022*
— Theory of Overparameterized Machine Learning Workshop$^{\vee}$ *April 2022*

• "Self-Training Converts Weak Learners to Strong Learners in Mixture Models"
— Simons Institute for the Theory of Computing, Deep Learning Theory Symposium *December 2021*

• "Proxy Convexity: A Unified Optimization Framework For Neural Networks Trained by Gradient Descent"
— Simons Institute for the Theory of Computing, Meet the Fellows Welcome Event *September 2021*

• "Generalization of SGD-Trained Neural Networks in the Presence of Adversarial Label Noise"
— ETH Zürich, Young Data Science Researchers Seminar$^{\vee}$ *April 2021*
— Johns Hopkins University, Machine Learning Seminar$^{\vee}$ *April 2021*
— Max-Planck-Institute MiS, Machine Learning Seminar$^{\vee}$ *March 2021*
— NSF/Simons Mathematics of Deep Learning Seminar$^{\vee}$ *February 2021*

PROFESSIONAL SERVICE

• Workshop co-organizer: Deep Learning Theory Workshop & Summer School, Simons Institute for the Theory of Computing, Berkeley, 2022.
• Area Chair/Senior PC for conferences: NeurIPS 2023, ALT 2024, NeurIPS 2024, ALT 2025, ICML 2025.
• Area Chair for workshops: Theoretical Foundations of Foundation Models @ ICML 2024.
• Reviewer for journals: *Annals of Statistics*, *Journal of Machine Learning Research*, *SIAM Journal on Mathematics of Data Science*, *Neural Computation*, *Mathematics of Operations Research*, *Transactions on Machine Learning Research*.
• Reviewer for conferences: ICML 2020, NeurIPS 2020, AISTATS 2021, ICML 2021, NeurIPS 2021, ICLR 2022, AISTATS 2022, ICML 2022, ICLR 2023, COLT 2023, ICLR 2025.
• Reviewer for workshops: Theory of Overparameterized Machine Learning (TOPML) 2021, ICML Workshop on Overparameterization: Pitfalls & Opportunities (ICMLOPPO) 2021, TOPML 2022, NeurIPS Workshop on Mathematics of Modern Machine Learning (M3L) 2023, NeurIPS Workshop on Robustness of Few-Shot Learning in Foundation Models (R0-FoMo) 2023.
• Reviewer, ENVISION Research Competition for Women in STEM, 2022.
• Volunteer for Queer in AI.

UNIVERSITY SERVICE

• UC Davis
— Department of Statistics, Publicity and Event Planning committee, 2023-2024
— Department of Statistics, Seminar organizer, Winter 2024

CONFERENCE, WORKSHOP, AND PROGRAM PARTICIPATION

• Modern Paradigms in Generalization Program (Long-term Participant), Simons Institute, Berkeley, 2024.
• International Conference on Learning Representations. Vienna, 2024.
• Neural Information Processing Systems. New Orleans, 2023.
• Conference on Learning Theory. Bangalore, 2023.
• Youth in High Dimensions. Trieste, 2023.
• Joint Statistical Meetings. Washington, DC, 2022.
• Deep Learning Theory Summer Cluster. Simons Institute for the Theory of Computing, Berkeley, 2022.
• Conference on Learning Theory. London, 2022.
• Deep Learning Theory Symposium. Simons Institute for the Theory of Computing, Berkeley, 2021.
• Mathematical/Scientific Foundations of Deep Learning Annual Meeting. Simons Foundation, New York, 2021.
• ICML Workshop on Overparameterization: Pitfalls and Opportunities. Online, 2021.
• Theory of Overparameterized Machine Learning (TOPML) Workshop. Rice University (online), 2021; 2022.
• Theory of Deep Learning Special Quarter. TTIC/Northwestern Institute for Data, Econometrics, Algorithms, and Learning (online) 2020.
• Neural Information Processing Systems. Vancouver, BC, 2019.

• Emerging Challenges in Deep Learning Workshop. Simons Institute, Berkeley, 2019.
• Summer School in Probability. Pacific Institute for the Mathematical Sciences, Vancouver, BC, 2014.

TEACHING EXPERIENCE

• UC Davis, Department of Statistics
— Instructor, Stats 35B: Statistical Data Science II, Winter 2024.
— Instructor, Stats 250: Theoretical Foundations of Modern AI, Winter 2024.
— Organizer, Stats 290: Seminar in Statistics. Winter 2024.

• UCLA, Department of Statistics
— TA, Stats 100C: Linear Models, Spring 2020.
— TA, Stats 102C: Monte Carlo Methods, Fall 2019.
— TA, Stats 100B: Mathematical Statistics, Winter 2016.
— TA, Stats 100A: Probability Theory, Fall 2016.
— TA, Stats 10: Intro to Statistics, Summer 2016.

PROGRAMMING LANGUAGES AND SKILLS

Significant experience with Python and PyTorch. Regularly run multi-node, multi-GPU LLM training runs on a Slurm cluster, monitoring jobs on wandb. Experience with AWS. Other languages: R, Matlab.