Rachel Lawrence

Researcher, AI and Mathematics

Overview

Researcher specializing in the **mathematical and computational foundations of machine intelligence**. My work combines tools from graph theory, optimization, and dynamical systems with modern AI methods to study **abstraction** and **reasoning** in learning systems. I develop theoretical frameworks and empirical tools that advance **efficient, trustworthy** and **generalizable** intelligence.

Education

Ph.D., Electrical Engineering and Computer Science, *University of California, Berkeley*.
Ph.D. Thesis: Simplicial Reaction Networks and Dynamics on Graphs *GPA 4.0*
Major Field: Theory of Computing *Minor Fields:* Machine Learning, Mathematics

Bachelor of Science, Applied Mathematics, *Yale University*.
Senior Thesis: Constructive Counting of Hamiltonian Cycles in Dense and Regular Directed Graphs

Research

2024 – present **Microsoft Research Cambridge**, *Research Scientist, Machine Intelligence.*

Logical reasoning capabilities for next-generation language models; abstraction, tool-use, and fine-tuning for algorithmic reasoning; and inductive bias in diffusion and language models.

Selected work:

RE-IMAGINE: Symbolic Benchmark Synthesis for Reasoning Evaluation. Developed a benchmark mutation pipeline differentiating statistical recall of training sets from correct abstraction on reasoning tasks, revealing a "reasoning gap" in all leading foundation models. *ICML 2025, ICLR 2025, US Patent 504387-US01*

A Fourier Space Perspective on Diffusion Models. Introduced a Fourier-domain forward process, improving performance for high-frequency-rich data and exposing inductive biases in diffusion dynamics.

Better Think Thrice: Learning to Reason Causally with Double Counterfactual Consistency. Improved causal reasoning abilities in foundation models by introducing a double counterfactual consistency metric.

Process Validity: A Rule-Based North Star for Trustworthy Reasoning. A validity-oriented framework for research and communication around trustworthy reasoning models, including a formal mathematical standard for AI reasoning.

Abstraction and Generalization for Reasoning Models. Ongoing research exploring new methods to improve generalization in foundation models via abstraction, symbolic reasoning, and neuro-symbolic architectures, for applications in mathematical reasoning and code generation.

2017 – 2023 **University of California, Berkeley**, *Ph.D., Electrical Engineering and Computer Science.*

Developed theoretical results linking graph dynamical systems, combinatorial optimization, and algorithmic convergence; with applications to robust machine learning, matrix completion, and constraint propagation.

Selected work:

Simplicial Reaction Networks and the Global Attractor Conjecture. Resolved the Global Attractor and Persistence Conjectures for matroid quadratic dynamical systems. Linked chemical reaction systems to combinatorial optimization, with implications for chemical computing and sampling algorithms.

Structural Conditions for Persistence in Quadratic Dynamical Systems. Developed structural conditions beyond prior state of the art for convergence of quadratic dynamical systems in detailed-balanced settings.

Hardness of Minimum Rank on Graphs. Proved that determining whether a graph has minimum rank three is complete for the existential theory of the reals; and no finite forbidden subgraph characterization exists.

Zero Forcing with Random Sets. Established new bounds for random zero forcing, with implications for the inverse eigenvalue problem and approximation of minimum rank on graphs.

Differentially Private GANs. Implemented privacy-preserving GANs robust to adversarial manipulation.

2020 **Microsoft Research Redmond**, *Ph.D. Research Intern.*
Dynamic Graph Analysis for the Organoid Connectome. Used theoretical results on sampling and community detection on random graph models to identify time-varying community structures in the cortical organoid connectome, a stem-cell model for early brain development.

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2016 – 2017 **Reservoir Labs, Inc.**, *Software Engineer.*
Compiler Optimization: Built a compiler for fast parallel computation on SIMD architectures.
ENSIGN Hypergraph Analysis: Developed a high-performance tool for unsupervised hypergraph analysis via tensor decomposition, and led its application to medical resource optimization at Mount Sinai hospital.

2016 **Pixar Animation Studios**, *Research and Development Intern.*
Developed a production tool for art-directable cloth simulation *SIGGRAPH 2016*

2015 – 2016 **Yale Department of Mathematics**, *SUMRY Fellow.*
Developed algebraic and combinatorial methods to determine incidence of arcs in the projective plane and proved that the number of 10-arcs in a finite projective plane is not quasipolynomial. *(Journal of Geometry 2016, MathFest 2015, Ohio State Young Mathematicians' Conference).*

2013 – 2014 **Yale University**, *Research Intern.*
Department of Mathematics: Designed a method to use driven iterated function systems to perform pattern recognition in time-series data. *Center for Statistical Genomics and Proteomics:* Implemented statistical methods to study pleiotropy in genetic pathways implicated in Bipolar Disorder and Schizophrenia.

Teaching

2018, 2021 **U.C. Berkeley**, *Graduate Student Instructor.*
Taught and designed course materials for *Discrete Mathematics and Probability Theory.*
Received the 2022 Berkeley EECS Outstanding Graduate Student Instructor Award, and the University Certificate in Teaching and Learning in Higher Education.

2018 **Stanford Pre-Collegiate Studies**, *Lead Instructor.*
Artificial Intelligence (Instructor). Designed and taught an original, intensive summer course in AI, with a focus on mathematical foundations, hands-on coding, ethical decision-making, and social impact.

2013 – present **Yale Splash and Learning Unlimited**, *Executive Director (2015-16), Nonprofit Board (present).*
Directed a 501(c) educational outreach organization providing accessible learning opportunities to students. Brought the Splash at Yale organization to financial sustainability, achieving its first revenue-positive year. Scaled outreach programs to more than 50 universities and 20,000 students, designed and taught 20 original courses, and chaired the national SplashCon conference. Continuing advisory role on the nonprofit board.

2015, 2016 **Yale University**, *Undergraduate Teaching Assistant*, *Design and Analysis of Algorithms.*

Academic Honors

2023 – 2024 **MOST Fellowship for Mathematics Outreach**.
2017 – 2022 **National Physical Sciences Consortium Graduate Fellowship**.
2022 **Berkeley EECS Outstanding TA Award**.
2021 **D.E. Shaw Zenith Fellowship**.
2024, 2020 **AMS Mathematics Research Communities**, *Artificial Intelligence (2024) and Inverse Eigenvalue Problems on Graphs (2020).*
2013 – 2015 **Yale Department of Mathematics SUMRY Fellowship**.
Yale College Dean's Research Fellowship.
Davenport Richter Fellowship.

Service and Community

Nonprofit board, *Splash at Yale; Learning Unlimited.*

Executive board, *Berkeley CS GSA; Berkeley Theory Group; HackYale.*

Algorithms research consultant; Ph.D. peer mentor, *Berkeley EECS.*

Outreach coordinator, *Berkeley Women in Computer Science and Engineering.*

Invited speaker, *National Museum of Mathematics.*

Training certificates, *MoMath Mathematics Outreach Seminar and Training Program; Harvard GSAS: Algorithmic Fairness, Accountability, and Ethics; UC Berkeley: Communication for Engineering Leaders; UC Berkeley: Teaching and Learning in Higher Education.*