Clayton H. Sanford

claytonsanford.com ⋄ clayton@cs.columbia.edu ⋄ (831) 332-0431
LinkedIn: in/claytonsanford ⋄ Github: chsanford

EDUCATION

Columbia University September 2019 - May 2024
Ph.D. in Computer Science
M.S. (Feb. 2021), M.Phil. (Feb 2023) *New York, NY*

· Thesis: "Representational Capabilities of Feed-forward and Sequential Neural Architectures."
· Advisors: Rocco Servedio and Daniel Hsu

Brown University September 2014 - May 2018
Sc.B. with Honors in Applied Mathematics - Computer Science *Providence, RI*

· Thesis: "Applying Rademacher-Like Bounds to Combinatorial Samples and Function Selection."
· Thesis Advisor: Eli Upfal; Concentration Advisor: Caroline Klivans
· Magna Cum Laude

EXPERIENCE

Research Scientist August 2024 - present
Google Research *New York, NY*

Student Researcher January 2024 - May 2024
Google Research *New York, NY*

· Contrasted the capabilities of transformers and graph neural networks to solve graph reasoning tasks.

Applied Sciences Intern May 2023 - August 2023
Microsoft Research *New York, NY*

· Trained transformer models with up to 500 million parameters to learn combinatorial search tasks with behavioral cloning and chain-of-thought reasoning.
· Proved theoretical results about the advantages of transformers over graph neural networks (GNNs) for identifying isomorphisms between different combinatorial problems, to support positive empirical results. (Manuscript in progress.)

Research Intern (PhD) May 2022 - August 2022
Allen Institute for AI *Seattle, WA*

· Improved year-long temperature and humidity predictions of ML-corrected coarse-grid climate models by using novelty detection techniques.
· Work presented at NeurIPS 2022 climate ML workshop and American Meteorological Society conference, and under review of the *Journal of Advances in Modeling Earth Systems*.
· Recognized with the Outstanding Internship award, a cash prize awarded to four AI2 interns.

Software Engineering Intern April 2019 - August 2019
Lumi Labs *Palo Alto, CA*

· Designed and built front-end (Objective C) and back-end (Java and Scala) features as at 15-person startup.
· Implemented clustering algorithms on geographic data in Java.

Associate Data Scientist August 2018 - April 2019
LinkedIn *San Francisco, CA*

· Used Hive and SQL to create stable and frequently-used datasets that repopulate daily.
· Performed deep-dive analyses on open questions for the LinkedIn Learning product.
· Co-coordinated a bi-weekly machine learning reading group.

Data Analytics Intern June 2017 - August 2017
LinkedIn *San Francisco, CA*

· Analyzed subscription patterns with LinkedIn Learning team using Pig, HDFS, SQL, and Python.
· Contextualized findings in the Learning business and presented to stakeholders.

PUBLICATIONS

Neural networks

· C. Sanford, B. Fatemi, E. Hall, A. Tsitsulin, M. Kazemi, J. Halcrow, B. Perozzi, V. Mirrokni. "Understanding Transformer Reasoning Capabilities via Graph Algorithms." *Preprint.*
· C. Sanford, D. Hsu, M. Telgarsky. "Transformers perform parallel computation in log-depth." *International Conference on Machine Learning (ICML) 2024.*
· C. Sanford, D. Hsu, M. Telgarsky. "Representational strengths and limitations of transformers." *Neural Informational Processing Systems (NeurIPS) 2023.*
· N. Ardeshir*, D Hsu*, C. Sanford*. "Intrinsic dimensionality and generalization properties of the R-norm inductive bias." *Conference on Learning Theory (COLT) 2023.*
· A. Bietta*, J. Bruna*, C. Sanford*, M. Song*. "Learning single-index models with shallow neural networks." *NeurIPS 2022.*
· V. Chatziafratis*, I. Panageas*, C. Sanford*, S. Stavroulakis*. "On scrambling phenomena for randomly initialized recurrent networks." *NeurIPS 2022.*
· D. Hsu*, C. Sanford*, R. Servedio*, E.-V. Vlatakis-Gkaragkounis*. "Near-Optimal Statistical Query Lower Bounds for Agnostically Learning Intersections of Halfspaces with Gaussian Marginals." *COLT 2022.*
· C. Sanford, V. Chatziafratis. "Expressivity of Neural Networks via Chaotic Itineraries beyond Sharkovsky's Theorem." *AISTATS 2022.*
· N. Ardeshir*, C. Sanford*, D. Hsu. "Support vector machines and linear regression coincide with very high-dimensional features." *NeurIPS 2021.*
· D. Hsu*, C. Sanford*, R. Servedio*, E.-V. Vlatakis-Gkaragkounis*. "On the Approximation Power of Two-Layer Networks of Random ReLUs." *COLT 2021.*

Interdisciplinary ML and data science

· C. Sanford, A. Kwa, O. Watt-Meyer, S. Clark, N. Brenowitz, J. McGibbon, C. Bretherton. "Improving the predictions of ML-corrected climate models with novelty detection." *Journal of Advances in Modeling Earth Systems.*
· T. Chin*, J. Ruth*, C. Sanford*, R. Santorella*, P. Carter, B. Sandstede. "Enabling equation-free modeling via diffusion maps." *Journal of Dynamics and Differential Equations,* 2022.
· K. Cygan*, C. Sanford*, W. Fairbrother. "Spliceman2 - A Computational Web Server That Predicts Sequence Variations in Pre-mRNA Splicing." *Bioinformatics* 33 (18), 2017.

FELLOWSHIPS AND AWARDS

NSF GRFP Fellowship March 2021
National Science Foundation

· Competitive fellowship that provides three years of full funding for graduate research.

Paul Charles Michelman Memorial Award May 2023
Columbia Computer Science

· Given to a PhD student in Computer Science who has performed exemplary service to the department, devoting time and effort beyond the call to further the department's goals (cash prize).

Department Service Award May 2020, 2022, 2023
Columbia Computer Science

· Awarded up to 10% of PhD students for their service to the department.

Outstanding Intern Award December 2022
Allen Institute for AI

· Awarded to four summer interns who went above and beyond as researchers and as colleagues (cash prize).

Computer Science Senior Prize May 2018
Brown Computer Science

· Awarded to the top students in the computer science department based on academic achievement and department service (cash prize).

Outstanding Winner April 2016
Interdisciplinary Contest in Modeling *Consortium for Mathematics and its Applications*

· Designation given to five out of over 3000 teams for mathematical modeling of water scarcity in the ICM contest.

LEADERSHIP AND MENTORSHIP EXPERIENCE

Community Board Member May 2023 - present
Manhattan Community Board 9 *New York, New York*

· Appointed by the borough president to represent community needs of a district on the west side of Manhattan between 110th and 155th St.
· Serves on the the Economic Development/West Harlem Piers Committee and the LGBTQ Task Force.

PhD Representative May 2022 - May 2024
Department of Computer Science *Columbia University*

· Coordinated a well-attended PhD student welcome event to help new students visit.
· Attends faculty meetings to represent student concerns and communicate faculty decisions to student body.
· Personally assisted students ensure that the department is paying them adequately and assisted international students with CPT approval issues.

President September 2022 - September 2023
qSTEM (LGBTQ affinity for School of Engineering) *Columbia University*

· Organized coffee hours, happy hours, movie showings, and board game nights to build community among LGBTQ grad students.

President February 2015 - May 2018
Applied Math Department of Undergraduates (APMA DUG) *Brown University*

· Hosted well-attended advising panels for students interested in Applied Math courses and research.
· Created problems for and managed a casual math competition every semester.

· Coordinated lectures by Applied Math faculty members for undergrads every semester.
· Welcomed prospective students and new concentrators by planning department-sponsored celebrations.

President November 2014 - May 2018
Outing Club *Brown University*

· Led an executive board of forty members that ran trips every weekend of the academic year.
· Managed and apportioned a $27000 annual budget.
· Recruited, interviewed, and trained new trip leaders.

Peer Advisor September 2017 - May 2018
Matched Advising Program for Sophomores (MAPS) *Brown University*

· Advised two sophomore Applied Math students as they declared their concentrations and decided on coursework and internships.

Peer Advisor September 2015 - May 2017
Meiklejohn Peer Advisory Program *Brown University*

· Advised eleven first year students on adjusting to college life, selecting courses, building connections, and finding their academic paths.

RELEVANT COURSEWORK

Algorithms and Theory: Models of Computation, Analysis and Design of Algorithms, Advanced Algorithms Seminar, Computational Linear Algebra, Intro to Cryptography, Randomized Algorithms, Computation and the Brain

Artificial Intelligence: Machine Learning, Artificial Intelligence, Foundations of Prescriptive Analytics, Independent Study for ML research, Optimization Methods for ML, ML Theory, Algorithmic Game Theory

Probability and Statistics: Probability and Computation, Information Theory, Recent Applications in Probability and Statistics, Probabilistic Methods in Computer Science

Dynamical Systems: Applied Ordinary Differential Equations, Applied Partial Differential Equations I, Topics in Chaotic Dynamics, Independent Study for Dynamical Systems Research

Pure Mathematics: Linear Algebra, Abstract Algebra, Analysis: Functions of One Variable

Non-Technical: Persuasive Communication, Classrooms in Context: Public Education in Providence

TEACHING EXPERIENCE

Graduate Teaching Assistant September 2023 - December 2023
Columbia University Department of Computer Science

· Provided readings for course syllabus, graded assignments, and mentored student final projects for the Machine Learning and Climate graduate seminar, taught by Alp Kucukelbir.

Graduate Instructor January 2022 - May 2022
Columbia University Department of Computer Science

· Developed and taught a lab on basics of data science and ML for non-CS students to accompany a then-new class on Natural and Artificial Neural Networks by Christos Papaidimitriou.
· Created a series of Colab notebooks and short lectures to accompany each topic for a lab with fifteen students.

Graduate Teaching Assistant January 2021 - April 2021
Columbia University Department of Computer Science

· Held office hours, graded assignments, and prepared course materials for Introduction to Computational Learning Theory, taught by Rocco Servedio.

Head Teaching Assistant April 2017 - December 2017
Brown University Department of Computer Science

· Led a staff of 14 UTAs through grading assignments, running review sessions, and holding office hours.
· Hired UTAs after interviewing 35 candidates for the job.
· Managed an Algorithms class with 170 students and coordinated interactive grading sessions and exams.
· Taught an supplemental section on NP-hardness to a group of forty students for 90 minutes.
· Brainstormed, wrote-up, and edited problems for homework assignments and exams.

Undergraduate Teaching Assistant September 2015 - May 2017
Brown University Departments of CS and Applied Math

· Served on the course staffs of four courses: Accelerated Intro to CS, Discrete Structures and Probability, Theory of Computation, Topics in Chaotic Dynamics.
· Created problems for and graded homework assignments and exams.
· Hosted office hours for helping students understand course material and solve homework problems.

Tutor and Volunteer Representative January 2015 - May 2016
Swearer Tutoring Enrichment in Math and Science (STEMS)

· Tutored math and science in class and after school at a nearby public school in Providence.
· Interviewed potential volunteers and planned meetings to help train tutors.

Tutor September 2011 - June 2014
Soquel High School

· Tutored math at homework club after school twice a week for three years.

RESEARCH TALKS

· ICML expo talk. July 2024. "Giving your Graph a Voice: Graph Representations and Large Language Models."
· Simons Foundation Flatiron talk, July 2024. "Transformers and graph algorithms."
· Thesis defense, April 2024. "Representational Capabilities of Feed-forward and Sequential Neural Architectures."
· Google Research NYC talk, April 2024. "A distributed Computing Lens on Transformers."
· Simons Foundation Flatiron talk, January 2024. "Representational Strengths and Limitations of Transformers."
· Google Research Mountain View talk, January 2024. "Representational Strengths and Limitations of Transformers."
· Formal Languages and Neural Networks (FLANN) talk, virtual, November 2023. "Representational Strengths and Limitations of Transformers."
· Joan Bruna group meeting, NYU, October 2023. "Representational Strengths and Limitations of Transformers."
· "Theory and Practice of Foundation Models" invited speaker, Yale, October 2023. "Representational Strengths and Limitations of Transformers."
· Algorithms seminar, Google NYC, July 2023. "Representational Strengths and Limitations of Transformers."

- Data Science guest lecture, UC San Diego, May 2023. "Representational Strengths and Limitations of Transformers."
- Engaged Scholars Program Research Symposium, Columbia University, April 2023. "Machine Learning, Neural Networks, and CS Theory."
- Columbia StatisticalML Symposium, Columbia University, April 2023. "Transformers can learn pairwise—but not three-wise—functions."
- 22nd Conference on Artificial Intelligence for Environmental Science, 103rd American Meteorological Society Annual Meeting, January 2023. "Improving the Predictions of ML-Corrected Climate Models with Novelty Detection."
- Tackling Climate Change with Machine Learning workshop, NeurIPS 2022, December 2022. "Improving the Predictions of ML-Corrected Climate Models with Novelty Detection."
- Vaggos Chatziafratis group meeting, UC Santa Cruz, November 2022. "Why do over-parameterized neural networks work?"
- Kevin Jamieson, Jamie Morgenstern, and Ludwig Schmidt group meeting, University of Washington, July 2022. "Approximation Powers and Limitations of Neural Networks."
- COLT 2022, July 2022. "Near-Optimal Statistical Query Lower Bounds for Agnostically Learning Intersections of Halfspaces with Gaussian Marginals."
- Algorithms and Theory Seminar, Boston University, April 2022. "On the approximation power of two-layer networks of random ReLUs."
- Algorithms and Complexity seminar, MIT, April 2022. "On the approximation power of two-layer networks of random ReLUs."
- Eli Upfal group meeting, Brown University, April 2022. ""Benign overfitting" and the behavior of high-dimensional linear regression and classification models."
- AISTATS, March 2022. "Expressivity of Neural Networks via Chaotic Itineraries beyond Sharkovsky's Theorem."
- Joan Bruna group meeting, NYU, February 2022. "Near-Optimal Statistical Query Lower Bounds for Agnostically Learning Intersections of Halfspaces with Gaussian Marginals."
- Data Science Institute virtual poster session Columbia, February 2022. "On the approximation power of two-layer networks of random ReLUs."
- NeurIPS, December 2021. "Support vector machines and linear regression coincide with very high-dimensional features."
- COLT 2021, August 2021. "On the approximation power of two-layer networks of random ReLUs."
- Demystifying the dissertation, Columbia, December 2020. "Opening the Black Box: Mathematical Approaches to Understanding Deep Learning."
- Demystifying the PhD, Columbia, November 2020.

DEPARTMENT SERVICE

- Organized the CS theory student retreat in Fall 2021 and 2022.
- Ran events at and coordinated the Columbia Visit Day for admitted students in Spring 2020, 2022, and 2023.
- Started the Columbia Theory Student seminar, where students share their research on a weekly basis.
- Advised three cohorts of undergraduate theory seminars on ML and deep learning theory.

ACADEMIC SERVICE

Reviewer

- AAAI 2024, FOCS 2024, ICLR 2024, ALT 2024, JMLR 2023, NeurIPS 2023 (top reviewer), ICLR climate workshop 2023, SODA 2022, STOC 2022.

TECHNICAL SKILLS AND INTERESTS

Programming Languages	Python, Java, Scala, SQL
Technologies	Pytorch, Jax, Tensorflow, Docker, Hadoop, Spark, Git
Spoken Languages	English (native), Spanish (intermediate proficiency)
Other Interests	Backpacking, Running, Climbing, Cooking, New York, Public Transit