Hannah Lawrence

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EDUCATION

Yale University, New Haven CT, May 2019, GPA 3.998

B.S. Applied Math, B.S. Computer Science, summa cum laude

Thesis in Computer Science**:** *Ill-Conditioned Laplacian Systems in Theory and Practice,* advised by Professor Daniel Spielman

Thesis in Applied Math: *Consistent Online Learning*, advised by Professor Amin Karbasi

HONORS

Russell Henry Chittenden Prize

Awarded to the senior at Yale majoring in the natural science or mathematics who ranks highest in scholarship, 2019

Emerson Tuttle Cup

Presented to the residential college senior most distinguished for scholastic attainments, 2019

Computing Research Association Research Scholar

Grace Hopper conference fellowship with research focus and exclusive programming, 2018

Phi Beta Kappa

Elected junior year (< 1% of class), 2018

D.E. Shaw Discovery Fellowship

Competitive financial fellowship for women in STEM, 2017

Science, Technology, and Research Scholar

Selective STEM program for freshmen, 2016

RESEARCH INTERESTS

My research interests include sparse recovery, theoretical machine learning, signal processing, numerical linear algebra, and spectral graph theory, and especially the applications in which some subset of these paradigms intersect. I like developing provably robust, scalable, and accurate algorithms for inverse problems, often in imaging applications. More broadly, I enjoy mathematical algorithms for data science.

PUBLICATIONS

Minimax Regret of Switching-Constrained Online Convex Optimization: No Phase Transition. Lin Chen, Qian Yu, Hannah Lawrence, and Amin Karbasi. *In submission; arXiv:1910.10873*

Low-Rank Toeplitz Matrix Estimation via Random Ultra-Sparse Rulers. Hannah Lawrence, Jerry Li, Cameron Musco, and Christopher Musco. *In submission.*

RELEVANT COURSEWORK

Statistics and Data Science:
- Optimization Techniques
- Statistical Learning Theory
- Stochastic Processes
- Dynamic and Discrete Optimization
- Theoretical Network Science
- Machine Learning and Data Mining
- Information Theory
- Neural Nets

Computer Science:
- Advanced NLP
- Natural Language Processing
- Computational Complexity
- Design and Analysis of Algorithms
- Systems Programming
- Data Structures

Mathematics:
- Spectral Graph Theory
- Extremal Combinatorics
- Functional Analysis
- Algebraic Geometry
- Complex and Real Analysis
- Linear Algebra/Vector Calc.
- Abstract Algebra
- Discrete Mathematics
- Differential Equations

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RESEARCH EXPERIENCE

Center for Computational Mathematics, Flatiron Institute, *Research Analyst*, September 2019 - Present

- Studying the use of equivariant neural network architectures for imaging inverse problems in cryogenic electron microscopy and holographic phase retrieval.
- Collaborating with postdoctoral associates and research scientists to design both supervised and unsupervised architectures, taking into account rotational and translational invariances in the imaging data. Work combines existing Fourier-based approaches with novel paradigms in deep learning.

Microsoft Research New England, *Intern*, Summer 2019

- Developed Fourier-based algorithms for sample-optimal low-rank Toeplitz covariance estimation, mentored by Cameron Musco. Contributed rigorous error bounds for the case of exact sparsity.
- Contributed new ideas for finding asymptotically optimal rulers, a decades-old problem in combinatorics, and used a computational approach to slightly improve known upper bound.
- Devised new generalizations of leverage score sampling, a common technique in numerical linear algebra, and proved a restricted isometry property for off-grid Fourier matrices. Techniques have possible applications in active sampling, kernel learning, and sparse recovery.

Yale Institute for Network Science, *Student Researcher*, January 2019 – May 2019

- Developed novel algorithms for provably optimal switching-constrained optimization in online learning, extending to both online and bandit convex optimization, under guidance of Professor Amin Karbasi and in collaboration with his graduate student, Lin Chen.
- Computed minimax rate of switching-constrained online optimization in arbitrary dimension, solving an open problem in the field, in the spirit of existing seminal results in the discrete analogues (multi-armed bandit and prediction from experts). Write-up is in revision.

Reservoir Labs, *Research Intern,* Summer 2018

- Developed theoretical underpinnings for a novel, randomized, sparse, multidimensional Fast Fourier Transform (FFT) algorithm, extending the existing theory to treat general complex vectors.
- Contributed to rigorous proofs of correctness and runtime, using tools from Fourier analysis, number theory, and probabilistic bounds; identified and corrected errors in previous implementation.
- Implemented and tested algorithm in end-to-end simulations, with particular attention to cases of low SNR and approximate sparsity; obtained several orders of magnitude speedup over existing methods.
- Researched new interpolation method to perform sublinear compressed sensing using the sparse FFT, requiring literature review of both the theoretical foundations of compressed sensing and recent classes of algorithms.
- Presented research to senior researchers and CEO, and compiled two white papers with the new ideas.

Yale Institute for Network Science, *Student Researcher*, Spring 2018

- Created a fast Laplacian solver for ill-conditioned matrices under guidance of Professor Daniel Spielman
- Refined analysis of highly theoretical contraction algorithm from a recent paper (Cohen et al, 2016*)* for the case of undirected graphs, including tighter bounds for more general parameter choice.
- Adapted algorithm for practical implementation in Julia, and empirically identified parameter selection criteria
- Tested precision and runtime on numerous weighting schemes for constructing ill-conditioned graphs; algorithm successfully solved cases on which algorithms in the current Laplacian solver library failed.

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Center for Computational Biology (Numerical Algorithms Group), Flatiron Institute, *Research Assistant,* Summer 2017

- Created software package in Matlab and C++ to efficiently compute the multidimensional "sinc transform" using the non-uniform Fourier transform, and to calculate the (proven) optimal quadrature weights for MRI image reconstruction. Algorithm achieves asymptotic speedup over naive method, confirmed by empirical tests.
- Updated quadrature scheme from Gauss-Legendre to corrected trapezoidal rule, achieving additional 8x speedup. Library available at github.com/hannahlawrence/sinctransform.
- Investigated other reconstruction techniques, including preconditioned conjugate gradient methods, under conditions such as non-uniform and missing data.
- Conducted research on the phase retrieval problem in x-ray diffraction microscopy by studying the difference-map algorithm, as well as the use of a known reference object for improved data recovery.
- Simulated realistic phase retrieval conditions and efficiently tested iterative method's performance in response to different variables on computing cluster, ultimately identifying new and crucial parameters affecting reconstruction accuracy.

Gerstein Laboratory (Yale), *Research Assistant,* Summer 2016

- Applied principles of network analysis and spectral community detection to investigate the relationship between 3D conformation of chromatin in humans and functional organization of genes, chromosomes, and pathways.
- Self-taught Matlab, wrote scripts to address the analysis of large matrices on Yale's computing cluster, parsed genetic information databases, and selected visualization software for dense networks.
- Created novel metrics to evaluate the proximity of biological units, including randomized, modularity-based, and enrichment analysis methods; identified units with unexpected expression-proximity relation in cancer cells.

SKILLS

Proficient: Matlab • C • Python • Unix • Racket *Intermediate*: Pytorch • C++ • R • Julia • Spanish

WORK EXPERIENCE

Yale Computer Science Department, *Undergraduate Learning Assistant*, Jan. 2017 – May 2018

- Provided teaching assistance for CS 365, "Algorithms," CS 223, "Data Structures and Programming Techniques," and CS 201, "Introduction to Computer Science."
- Held weekly tutoring hours to aid students with assignments and graded proofs of correctness, requiring expertise in course content and debugging techniques.

Yale Student Technology Collaborative, *Student Technician and Coordinator*, Jan. 2017 – Jan. 2019

- Offered personal technology (hardware and software) support for members of the Yale community.
- Promoted to queue coordinator: allocate work requests, ensure timely responses, and train new hires.

PROJECTS

Deletion-Resilient Permutations

Final project for Extremal Combinatorics (group), May 2019

- Investigated a particular class of error-correcting codes, in which a message is sent through a deletion channel.
- Extended recent results (Alon et al 2018), including developing algorithms to efficiently compute error-resilient permutations, analyzing the case of repeated symbols, and quantitatively comparing different encoding methods in terms of runtime, compression rate, and success probability.

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CACooN: Clustering Augmented Co-occurrence Networks for Unsupervised Word Embeddings *Final project for Advanced Natural Language Processing (group)*, Dec. 2018

- Developed a novel, graph-based approach for unsupervised word sense induction, embedding, and disambiguation by creation of an augmented co-occurrence graph, and neural vertex embedding methods.
- Evaluated task on SemEval 2010 Task 14 as proof of concept, and present promising avenues for further research.

Low-Rank Matrix Factorization via Nonconvex Optimization: Frank-Wolfe and Mirror Descent Algorithms *Final project for Optimization Techniques (individual)*, Dec. 2018

- Proposed, analyzed, implemented, and evaluated the novel application of the Frank-Wolfe and mirror descent algorithms for nonconvex optimization in the matrix completion and phase retrieval problems.
- Tested performance with respect to spectral and random initialization, step size, noise, and sampling rate.
- Compile recent theoretical results from nonconvex optimization and matrix factorization to understand empirical behavior.

Algorithmic Discrepancy Directed Reading, *Yale Math Department*, Sep. 2018 – Dec. 2018

- Weekly independent study in algorithmic discrepancy, including canonical algorithms and complexity results; present summary of key theorems and algorithms at department-wide symposium.

PRESENTATIONS

Efficient Covariance Estimation, research talk presented to the machine learning lunch at Microsoft Research New England and to the Undergraduate Intern Program at Microsoft Research Redmond, 2019.

Mathematics of Gerrymandering, survey talk presented to the graduate intern lunch at Microsoft Research New England, 2019.

Consistent Online Learning, research talk given at the Applied Mathematics department's senior thesis colloquium, 2019.

Efficient Reconstruction of Sparse Data, concluding research talk presented to the CEO and senior researchers at Reservoir Labs, 2019.

Spectral Learning, survey lecture given for CPSC 677 (advanced natural language processing, a graduate course), 2018.

Hitchhiker's Guide to Algorithmic Discrepancy, presented at the Yale Math Department's directed reading program colloquium, 2018.

EXTRACURRICULAR ACTIVITIES

MathCounts, *President*, Jan. 2018 – May 2019; *Vice President*, Jan. 2017; *Curriculum Coordinator*, Jan. 2016

- Organized competitions and recruitment events attended by hundreds of middle school students and educators.
- Recruited and trained new coaches, and communicated with teacher liaisons throughout New Haven.
- Led undergraduate board toward strategic organization growth, including new event proposals and outreach.

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- Coached twenty middle school students weekly, producing new and engaging organization-wide curriculum.

Applied Math Departmental Student Advisory Committee, *Founder*, Jan. 2019 – May 2019

- Founded the first such applied math committee in Yale's history to enact infrastructural improvement and support undergraduates in applied math.
- Led committee to establish the department's first peer mentorship program and first senior thesis presentations.
- Curated extensive online resources about the applied math major, and hosted social and course selection events open to all students.
- Advised underclassmen one-on-one, and served as the departmental representative at the annual academic fair for prospective students.

Dean's Committee on Science and Quantitative Reasoning, *Member*, Sept. 2018 – May 2019

- Drafted and disseminated a large-scale survey for all STEM majors in the undergraduate population at Yale.
- Performed subsequent analyses of STEM retention, diversity statistics, and personal testimonies.
- Published findings and actionable suggestions into a report, presented in-person to the Dean of Yale.
- Promoted the establishment of new student departmental advisories and peer mentorship programs.

Musical Ensembles, *Member,* Sept. 2015 – May 2019

- Performed in the Yale Symphony Orchestra (*violin*), Berkeley College Orchestra (*concertmaster*), Yale Precision Marching Band (*flute)*, and Davenport Pops Orchestra (*violin*).
- As music arranger for the Davenport Pops Orchestra, self-taught the Sibelius composition software, and collaborated with other students to produce orchestra-wide arrangements performed at campus-wide concerts.