

# Willow M. Ahrens

PH.D. COMPUTER SCIENCE AT CSAIL, MIT · COMPILERS, DATA STRUCTURES, ALGORITHMS

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## Education

### Massachusetts Institute of Technology

Cambridge, MA

PH.D. COMPUTER SCIENCE, GPA: 4.9 / 5.0, ADVISOR: SAMAN AMARASINGHE

Sep. 2016 - Present

- Collaborated on intermediate languages, cost models, compiler passes, and algorithms for state-of-the-art research projects.
- Published 6 papers in top-tier conferences and journals, including PLDI, CGO, TOMS, and IPDPS.
- Presented at 15+ conferences, workshops, and research groups in academia and industry.
- Advised 4 undergraduates and 3 masters students. Proposed projects and provided weekly feedback. One student published in SPAA.
- Developed Finch.jl programming language and compiler for sparse and structured arrays.
- Discovered compiler algorithms to automatically adapt programs to input properties.

### University of California, Berkeley

Berkeley, CA

BS IN EECS, MINOR IN MATH, GPA: 3.8 / 4.0, ADVISOR: JAMES DEMMEL

Sep. 2012 - May 2016

- Berkeley Benchmarking and Optimization Group
- Developed a reproducible linear algebra library in C, ReproBLAS.

## Selected Publications

### Looplets: A Language for Structured Coiteration.

CGO 2023

W. AHRENS, D. DONENFELD, F. KJOLSTAD, AND S. AMARASINGHE.

Feb. 2023

- Published in Proceedings of the 21st ACM/IEEE International Symposium on Code Generation and Optimization, in CGO 2023.
- Built the core language and compiler behind Finch tensor tensor compiler. Finch is the first compiler to support convolution over sparse arrays, as well as worst-case optimal joins and variable-width block formats.

### Autoscheduling For Sparse Tensor Algebra With An Asymptotic Cost Model.

PLDI 2022

W. AHRENS, F. KJOLSTAD, AND S. AMARASINGHE.

Jun. 2022

- Published in Proceedings of the 43rd ACM SIGPLAN International Conference on Programming Language Design and Implementation.
- Discovered an asymptotic notation for the runtime of sparse tensor programs.
- Built the first asymptotic autoscheduler for sparse tensor compilers.

### Algorithms for Efficient Reproducible Floating Point Summation.

ACM Trans. Math. Softw.

W. AHRENS, J. DEMMEL, AND H. D. NGUYEN.

Jul. 2020

- Published in ACM Transactions on Mathematical Software, vol. 46, no. 3, p. 22:1-22:49, Jul. 2020.
- Discovered algorithms for bitwise identical sums of floating point numbers under reassociation, using only 6 words of memory.
- Implemented ReproBLAS library to implement performant versions of these algorithms for common linear algebra routines.

### Tensor Algebra Compilation with Workspaces.

CGO 2019

F. KJOLSTAD, W. AHRENS, S. KAMIL, AND S. AMARASINGHE.

2019

- Published in 2019 IEEE/ACM International Symposium on Code Generation and Optimization (CGO), 2019, pp. 180-192.

### A Fill Estimation Algorithm for Sparse Matrices and Tensors in Blocked Formats.

IPDPS 2018

W. AHRENS, H. XU, AND N. SCHIEFER.

2018

- Published in 2018 IEEE International Parallel and Distributed Processing Symposium (IPDPS), 2018, pp. 546-556.

## Teaching

### MIT Course 6.1200 (Mathematics For Computer Science)

Boston, MA

TEACHING ASSISTANT

Sep 2022 - Dec 2022

- Taught 6.1200 (formally 6.042), a proof-based course designed to teach the fundamentals of algorithmic thinking in computer science, with attention given to concepts such as induction, asymptotic analysis, graphs, and probability.
- Led two discussion sections with 30 students each, covering example problems and their solutions.
- With 2 other TAs, staffed the last in-person office hours before homework was due each week, with attendance regularly exceeding 40 students requesting individual attention.

## MIT Glass Lab

GLASSBLOWING INSTRUCTOR

- Supervised pairs of beginner students one at a time for weekly two-hour sessions.
- Ensured student safety in their first experiences with handling 2400 °F glass in a crowded hot shop.
- Explained critical techniques in glassblowing, including gathering, marvering, blocking, and blowing.

Cambridge, MA

Feb 2019 – Present

## Center for Access to Engineering Excellence

TUTOR

- Tutored groups of around 2-5 students at a time in lower-division Computer Science, Math, and Physics courses.

Berkeley, CA

Jan 2014 – May 2014

# Mentorship Experience

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## Radha Patel

MASTERS STUDENT

Ongoing

- Investigated symmetric tensor processing in the Finch Programming Language.
- Implemented new symmetric tensor datastructures.
- Discovered new program transformations to optimize symmetric tensor kernels.

## Cecilia Chen

UNDERGRADUATE STUDENT

2023

- Investigated graph processing in the Finch Programming Language.
- Implemented several kernels from the GAP benchmark suite in Finch. (Link)
- Discovered new program transformations to optimize symmetric tensor kernels.

## Alexandra Dima

MASTERS STUDENT

2021-2023

- Built GSTACO graph processing framework, unifying tensor and graph interfaces.
- Compiled graph operations to Finch.
- Thesis: A. Dima, "GSTACO: A Generalized Sparse Tensor Algebra Compiler," Thesis, Massachusetts Institute of Technology, 2023. (Link)

## Emily Lu

UNDERGRADUATE STUDENT

2023

- Built basic tensor user interface functions (e.g. indexing, slicing, etc.) by compiling to Finch.

## Yiming Chen

UNDERGRADUATE STUDENT

2022

- Investigated distributional properties of recursive kronecker sparse matrix generators.

## Suzy Mueller

MASTERS STUDENT

2020

- Discovered algorithms for more efficient sparse tensor transpositions.
- Publication: S. Mueller, W. Ahrens, S. Chou, F. Kjolstad, and S. Amarasinghe, "Brief Announcement: Sparse Tensor Transpositions," in Proceedings of the 32nd ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), 2020, pp. 559–561. (Link)

## Tony Wang

UNDERGRADUATE STUDENT

2019

- Used term rewriting to recognize important kernels (such as matrix multiply) in Swizzles.jl array combinator language.

# Honors

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2017-2021 **CSGF Fellow**, DOE Computational Science Graduate Fellow

Washington, D.C.

2016 **Warren Y. Dere Design Award**, UC Berkeley

Berkeley, CA

# Service

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2022-2024	<b>Organizer</b> , Sparse Roofline Benchmark Working Group, a multi-university collaboration to standardize benchmarking of sparse linear algebra	Virtual
2022-2024	<b>Editor</b> , GraphBLAS BinSparse Binary Sparse File Format Standards Committee	Virtual
2023	<b>Program Committee</b> , DRAGSTERS (Distributions, Relational Algebra, Graphs, Semi-Rings, Tensors, and All That) workshop at PLDI conference	Orlando, FL
2022	<b>Reviewer</b> , Parallel Computing	N/A
2020	<b>Reviewer</b> , IEEE Transactions on Computers	N/A
2020	<b>Reviewer</b> , IEEE Transactions on Computers	N/A
2019	<b>Reviewer</b> , IEEE Transactions on Computers	N/A
2021	<b>Reviewer</b> , IEEE Transactions on Parallel and Distributed Systems	N/A
2020	<b>Reviewer</b> , IEEE Transactions on Parallel and Distributed Systems	N/A
2019	<b>Reviewer</b> , IEEE Transactions on Parallel and Distributed Systems	N/A

## Experience

### 2022 NSF I-Corps Fall Cohort #2 - South Regional Node Program

Virtual

ENTREPRENEURIAL LEAD

Aug. 2022 - Nov. 2022

- Interviewed 100 potential customers to validate the market for tensor algebra compilers.

### Sandia National Laboratory

Albuquerque, NM

CSGF PRACTICUM INTERN, SUPERVISOR: ERIK BOMAN

May 2019 - Aug 2019

- Discovered algorithms to reorganize sparse matrix nonzeros into dense blocks. Proposed the 1D-VBR sparse matrix format. Julia.

### MIT Julia Lab

Cambridge, MA

RESEARCH ASSISTANT

Sep 2016 - May 2019

- Worked with Professor Alan Edelman to develop Julia abstractions for scientific computing.
- Developed prototype Julia implementation for the CLIMA earth and atmosphere modeling project.
- Developed array programming infrastructure based on Julia base array interface.

### Los Alamos National Laboratory

Los Alamos, NM

RESEARCH INTERN, SUPERVISOR: HAI AH NAM

May 2016 - Aug 2016

- Parallelized a coupled cluster doubles nuclear quantum physics simulation to run on Wolf cluster. C++/MPI.

### NVIDIA

Santa Clara, CA

SOFTWARE ENGINEERING INTERN

June 2014 - Aug 2014

- Worked in a team to create a CPU profiler, intercepting dll calls and sampling using signal handlers. Created a small real-time system to handle stack traces and process them into various types of call graphs.
- Fixed bugs, conducted testing, and wrote a test for cuda-gdb.

## Presentations

2023	"Sparse Compilers, Sparse Benchmarks", Sparse BLAS Workshop 2023, University of Tennessee	Knoxville, TN
2023	"Exploring the Design Space of Sparsity Through Compilers", The Sparse Rooflines Group	Virtual
2023	"Exploring the Design Space of Sparsity Through Compilers", RelationalAI Virtual Talk	Virtual
2023	"Finch: A Compiler for Sparse and Structured Data", Stanford University	Stanford, CA
2023	"Finch: A Compiler for Sparse and Structured Data", Lawrence Berkeley National Lab	Berkeley, CA
2023	"Finch: A Compiler for Sparse and Structured Data", University of Washington PLSE Group	Seattle, WA
2022	"An Asymptotic Cost Model for Autoscheduling Sparse Tensor Programs", ADA Symposium	Ann Arbor, Michigan
2021	"Contiguous Partitioning: Registers, Caches, and Distributed Memories", DOE CSGF Review	Washington, D.C.
2021	"On Optimal Partitioning for Variable Block Row Format", MIT CRIBB Seminar	Cambridge, MA
2018	"The Tensor Algebra Compiler (taco)", CSAIL Alliances Annual Meeting	Cambridge, MA
2018	"For-Loops 2.0: Index Notation And The Future Of Array Compilers", JuliaCon 2018	London, UK

## Complete Publications

### Binary Sparse Format Specification Version 0.1

Online

B. BROCK, T. DAVIS, J. KITCHEN, E. WELCH, I. VIRSHUP, W. AHRENS

Nov. 2023

- Ongoing Specification: <https://github.com/GraphBLAS/binparse-specification>

## The Continuous Tensor Abstraction: Where Indices are Real

PLDI 2024 (submitted)

J. WON, W. AHRENS, J. EMER, AND S. AMARASINGHE.

Jun. 2024

- Submitted to the 44th ACM SIGPLAN International Conference on Programming Language Design and Implementation.

## Looplets: A Language for Structured Coiteration.

CGO 2023

W. AHRENS, D. DONENFELD, F. KJOLSTAD, AND S. AMARASINGHE.

Feb. 2023

- Published in Proceedings of the 21st ACM/IEEE International Symposium on Code Generation and Optimization, in CGO 2023.

## Autoscheduling For Sparse Tensor Algebra With An Asymptotic Cost Model.

PLDI 2022

W. AHRENS, F. KJOLSTAD, AND S. AMARASINGHE.

Jun. 2022

- Published in Proceedings of the 43rd ACM SIGPLAN International Conference on Programming Language Design and Implementation.

## Contiguous Graph Partitioning For Optimal Total Or Bottleneck Communication.

arXiv:2007.16192 [cs]

W. AHRENS.

Jun. 2021

- Published in arXiv:2007.16192 [cs].

## Algorithms for Efficient Reproducible Floating Point Summation.

ACM Trans. Math. Softw.

W. AHRENS, J. DEMMEL, AND H. D. NGUYEN.

Jul. 2020

- Published in ACM Transactions on Mathematical Software, vol. 46, no. 3, p. 22:1-22:49, Jul. 2020.

## Brief Announcement: Sparse Tensor Transpositions.

SPAA 2020

S. MUELLER, W. AHRENS, S. CHOU, F. KJOLSTAD, AND S. AMARASINGHE.

2020

- Published in Proceedings of the 32nd ACM Symposium on Parallelism in Algorithms and Architectures (SPAA), 2020, pp. 559-561.

## On Optimal Partitioning For Sparse Matrices In Variable Block Row Format.

arXiv:2005.12414 [cs]

W. AHRENS AND E. G. BOMAN.

May 2020

- Published in arXiv:2005.12414 [cs].

## A Parallel Fill Estimation Algorithm for Sparse Matrices and Tensors in Blocked Formats.

MIT Thesis

W. AHRENS.

2019

- Thesis submitted to the Massachusetts Institute of Technology in 2019.

## Tensor Algebra Compilation with Workspaces.

CGO 2019

F. KJOLSTAD, W. AHRENS, S. KAMIL, AND S. AMARASINGHE.

2019

- Published in 2019 IEEE/ACM International Symposium on Code Generation and Optimization (CGO), 2019, pp. 180-192.

## LATE Ain't Earley: A Faster Parallel Earley Parser.

arXiv:1807.05642 [cs]

W. AHRENS, J. FESER, AND R. HUI.

Jul. 2018

- Published in arXiv:1807.05642 [cs].

## A Fill Estimation Algorithm for Sparse Matrices and Tensors in Blocked Formats.

IPDPS 2018

W. AHRENS, H. XU, AND N. SCHIEFER.

2018

- Published in 2018 IEEE International Parallel and Distributed Processing Symposium (IPDPS), 2018, pp. 546-556.

## Parallel Compact Hash Algorithms for Computational Meshes.

SIAM J. Sci. Comput.

R. TUMBLIN, W. AHRENS, S. HARTSE, AND R. ROBEY.

Jan. 2015

- Published in SIAM Journal on Scientific Computing, vol. 37, no. 1, pp. C31-C53, Jan. 2015.