

# Willow M. Ahrens

ASSISTANT PROFESSOR AT GEORGIA TECH · COMPILERS, DATA STRUCTURES, ALGORITHMS

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## Education

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### Georgia Institute of Technology

Atlanta, GA

ASSISTANT PROFESSOR

Aug. 2025 - Present

### Massachusetts Institute of Technology

Cambridge, MA

POSTDOCTORAL RESEARCHER. COMPUTER SCIENCE, PI: SAMAN AMARASINGHE

Sep. 2024 - Jul 2025

- Productionized Ph.D. research for deployment in real-world python ecosystems, integrating research to eventually include as a backend for pydata/sparse, in the default conda installation.
- Research conducted under a DARPA SBIR grant.
- Published 5 papers in top-tier conferences and journals, including OOPSLA, CGO, SIGMOD, and ASPLOS.
- Developed Finch.jl programming language and compiler for sparse and structured arrays.

### Massachusetts Institute of Technology

Cambridge, MA

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

Sep. 2016 - Sep 2024

- 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 and another in CGO.
- 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

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### Finch: Sparse and Structured Tensor Programming with Control Flow

OOPSLA 2025

Apr. 2025

W. AHRENS, T. F. COLLIN, R. PATEL, K. DEEDS, C. HONG, AND S. AMARASINGHE.

- Built the Finch array programming language and compiler.
- Finch is the first compiler to automatically specialize flexible control flow to diverse array data structures.
- Supports a familiar programming language of loops, statements, ifs, breaks, etc., over a wide variety of array structures, such as sparsity, run-length-encoding, symmetry, triangles, padding, or blocks. Finch reliably utilizes the key properties of structure, such as structural zeros, repeated values, or clustered non-zeros.
- The first compiler to support convolution over sparse arrays, as well as worst-case optimal joins and variable-width blocks.
- Demonstrated dramatic speedups in operations such as SpMV and SpGEMM, image processing, and graph analytics.

### Looplets: A Language for Structured Coiteration.

CGO 2023

Feb. 2023

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

- Published in Proceedings of the 21st ACM/IEEE International Symposium on Code Generation and Optimization, in CGO 2023.
- Proposed the Looplets language, the key IR behind the Finch tensor compiler. Allows flexible iteration over a wide variety of sparse and structured arrays.

### Galley: Modern Query Optimization for Sparse Tensor Programs.

SIGMOD 2025

Jun. 2025

K. DEEDS, W. AHRENS, M. BALAZINSKA, AND D. SUCIU.

- Published in Proceedings of the ACM on Management of Data, Volume 3, Issue 3.

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

PLDI 2022

Jun. 2022

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

- 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.

### Tensor Algebra Compilation with Workspaces.

CGO 2019

2019

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

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

# Teaching

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## Georgia Tech Course CS8803-DSL (Domain Specific Languages for HPC)

Atlanta, GA

### INSTRUCTOR

- Designed CS8803-DSL, a graduate-level seminar course on domain-specific languages for high-performance computing.
- Taught the basics of compiler construction and language design as it relates to the challenges of HPC and performance engineering.
- Covered topics such as architectural modelling, optimization techniques, and program analysis, through the context of contemporary DSLs and research in the field.

## MIT Course 6.1200 (Mathematics For Computer Science)

Boston, MA

### TEACHING ASSISTANT

- 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

Cambridge, MA

### GLASSBLOWING INSTRUCTOR

Feb 2019 – Present

- 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.

## Center for Access to Engineering Excellence

Berkeley, CA

### TUTOR

Jan 2014 – May 2014

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

# 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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2026	<b>Program Committee</b> , OOPSLA 2026: 47th ACM SIGPLAN Conference on Programming Language Design and Implementation	Oakland, CA
2025	<b>Organizer</b> , JuliaCon Global 2025: Sparse and Graph Computing in Julia Minisymposium	Pittsburgh, PA
2025	<b>Program Committee</b> , PLDI 2025: 46th ACM SIGPLAN Conference on Programming Language Design and Implementation	Seoul, South Korea
2025	<b>Program Committee</b> , CC25: ACM SIGPLAN 2025 International Conference on Compiler Construction (CC'25) co-located with CGO, PPoPP and HPCA	Las Vegas, NV
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

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## 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.

<b>Sandia National Laboratory</b>	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.	
<b>MIT Julia Lab</b>	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.	
<b>Los Alamos National Laboratory</b>	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.	
<b>NVIDIA</b>	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.	

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## Presentations

2025	<b>"PyData/Sparse and Finch: extending sparse computing in the Python ecosystem"</b> , Pydata Global 2025	Online
2025	<b>"Finch: Sparse and Structured Tensor Programming with Control Flow"</b> , Dependently Typed, PL Club at Georgia Tech	Atlanta, GA
2025	<b>"Sparsity-Aware Autoscheduling for Numpy with Finch and Galley"</b> , Sparse Workshop, PLDI	Seoul, South Korea
2025	<b>"Finch.jl: Flexible and Efficient Sparse Tensor Programming!"</b> , JuliaCon 2025	Pittsburgh, PA
2025	<b>"Sparse and Structured Tensor Programming"</b> , Oak Ridge National Laboratory, Computer Science and Mathematics Division	Oak Ridge, TN
2024	<b>Panelist</b> , Working Toward an Interface for Sparse BLAS, Supercomputing 2024	Atlanta, GA
2024	<b>"binsparse: A Binary Sparse Tensor File Format"</b> , HPC Graph Toolkits and the GraphBLAS Forum, Supercomputing 2024	Atlanta, GA
2024	<b>"Sparse and Structured Array Programming"</b> , BU Principles of Programming and Verification (POPV), BU	Boston, MA
2024	<b>"Sparse and Structured Array Programming"</b> , Google	Virtual
2024	<b>"Finch: Sparse and Structured Array Programming"</b> , Ph.D. Defense, MIT	Cambridge, MA
2024	<b>"Finch: Sparse and Structured Array Programming"</b> , Sammaniversary, MIT	Cambridge, MA
2024	<b>"Compiling Control Flow in Sparse and Structured Array Programs"</b> , Sparse Workshop, PLDI	Copenhagen, Denmark
2024	<b>"Compilers for Sparse and Structured Array Programming"</b> , International Workshop on Efficient Generative AI, University of Edinburgh	Edinburgh, UK
2024	<b>"Finch: A Sparse and Structured Array Compiler in Julia"</b> , Cambridge Area Julia Users Network	Cambridge, MA
2024	<b>"Supporting the Sparse BLAS: File Formats and Benchmarks"</b> , Sparse BLAS Workshop 2, University of Tennessee	Knoxville, TN
2023	<b>"Sparse Compilers, Sparse Benchmarks"</b> , Sparse BLAS Workshop, University of Tennessee	Knoxville, TN
2023	<b>"Exploring the Design Space of Sparsity Through Compilers"</b> , The Sparse Rooflines Group	Virtual
2023	<b>"Exploring the Design Space of Sparsity Through Compilers"</b> , RelationalAI Virtual Talk	Virtual
2023	<b>"Finch: A Compiler for Sparse and Structured Data"</b> , Stanford University	Stanford, CA
2023	<b>"Finch: A Compiler for Sparse and Structured Data"</b> , Lawrence Berkeley National Lab	Berkeley, CA
2023	<b>"Finch: A Compiler for Sparse and Structured Data"</b> , University of Washington PLSE Group	Seattle, WA
2022	<b>"An Asymptotic Cost Model for Autoscheduling Sparse Tensor Programs"</b> , ADA Symposium	Ann Arbor, Michigan
2021	<b>"Contiguous Partitioning: Registers, Caches, and Distributed Memories"</b> , DOE CSGF Review	Washington, D.C.
2021	<b>"On Optimal Partitioning for Variable Block Row Format"</b> , MIT CRIBB Seminar	Cambridge, MA
2018	<b>"The Tensor Algebra Compiler (taco)"</b> , CSAIL Alliances Annual Meeting	Cambridge, MA
2018	<b>"For-Loops 2.0: Index Notation And The Future Of Array Compilers"</b> , JuliaCon 2018	London, UK

## Complete Publications

**Insum: Sparse GPU Kernels Simplified and Optimized with Indirect Einsums.**

ASPLOS 2026

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

Mar. 2026

- To be published in ASPLOS '26: Proceedings of the 31st ACM International Conference on Architectural Support for Programming Languages and Operating Systems.

**Binsparse: A Specification for Cross-Platform Storage of Sparse Matrices and Tensors**

arXiv:2506.19175 [cs]

B. BROCK, W. AHRENS, H. ABBASI, T. DAVIS, J. KIM, J. KITCHEN, S. PATTY, I. VIRSHUP, E. WELCH

Jun. 2025

- Published in arXiv:2506.19175 [cs].
- Ongoing Specification: <https://github.com/GraphBLAS/binsparse-specification>

**The Continuous Tensor Abstraction: Where Indices Are Real**

OOPSLA 2025

J. WON, W. AHRENS, T. F. COLLIN, J. S. EMER, AND S. AMARASINGHE.

Apr. 2025

- Published in Proceedings of the ACM on Programming Languages, Volume 9, Issue OOPSLA2.

**Finch: Sparse and Structured Tensor Programming with Control Flow**

OOPSLA 2025

W. AHRENS, T. F. COLLIN, R. PATEL, K. DEEDS, C. HONG, AND S. AMARASINGHE.

Apr. 2025

- Published in Proceedings of the ACM on Programming Languages, Volume 9, Issue OOPSLA1.

**SySTeC: A Symmetric Sparse Tensor Compiler**

CGO 2025

R. PATEL, W. AHRENS, AND S. AMARASINGHE.

Mar. 2025

- Published in Proceedings of the 23rd ACM/IEEE International Symposium on Code Generation and Optimization.

**Interface for Sparse Linear Algebra Operations.**

arXiv:2411.13259 [cs]

A. ABDELFATTAH, W. AHRENS, H. ANZT, ET AL.

Nov. 2024

- Published in arXiv:2411.13259 [cs].

**Galley: Modern Query Optimization for Sparse Tensor Programs.**

SIGMOD 2025

K. DEEDS, W. AHRENS, M. BALAZINSKA, AND D. SUCIU.

Jun. 2025

- Published in Proceedings of the ACM on Management of Data, Volume 3, Issue 3.

**SySTeC: A Symmetric Sparse Tensor Compiler**

CGO 2025

R. PATEL, W. AHRENS, AND S. AMARASINGHE.

Mar. 2025

- Published in Proceedings of the 23rd ACM/IEEE International Symposium on Code Generation and Optimization, in CGO 25.

**Mechanised Hypersafety Proofs about Structured Data**

PLDI 2024

V. GLADSHTEIN, Q. ZHAO, W. AHRENS, S. AMARASINGHE, AND I. SERGEY.

Jun. 2024

- Published in Proceedings of the ACM on Programming Languages, Volume 8, Issue PLDI, p. 173:647-173:670. Jun. 2024

**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.