

Fredrik Kjolstad

Research Vision and Interests

I aim to make it possible to develop optimized and portable **sparse computing applications** with ease. Towards this vision I develop **programming systems**, including compilers and languages, for making it easy to specify sparse computing applications without sacrificing performance or portability. I have developed the **taco compiler** for sparse tensor algebra that allows users to separately specify tensor operations and irregular data structures, relying on the compiler to produce fast sparse code. I have also developed the **Simit programming language** for computing on sparse systems as graphs using linear and tensor algebra.

Education

- Summer 2019 **Ph.D., Computer Science, Massachusetts Institute of Technology.**
(Expected) Thesis: Code Generation for Sparse Computation
Adviser: Saman Amarasinghe
- August 2011 **M.S. Computer Science, University of Illinois at Urbana-Champaign.**
Thesis: Refactoring Transformations for Maintainable, Scalable and Efficient Parallelism
Award: Best Poster Award at the UIUC Grad Expo (M.S. and Ph.D.).
Adviser: Marc Snir
- June 2005 **B.E., Computer Science, Norwegian University of Science and Technology in Gjøvik.**
Bachelor project: Stopmotion
Awards: Rosing award from the Norwegian Computer Society for best IT-related student work in Norway (2005 and 2006) and Eureka award from the Norwegian University of Science and Technology in Gjøvik for best bachelor project (2005).

Research Experience

Massachusetts Institute of Technology

- Research Assistant **The Taco Sparse Tensor Algebra Compiler.** (2015-present)
Design and implementation of a compiler for tensor algebra on sparse and dense tensors [3, 8]. Development of a plugin framework for adding new tensor data structures, such as hash maps, without changing the code generator [2]. Design of a new IR for sparse tensor algebra optimization and an optimization to insert workspaces into tensor algebra expressions [1].
- The Simit Language for Computing on Sparse Systems.** (2013-present)
Design and implementation of a programming language for computing on sparse systems, represented as hierarchical hypergraphs, with linear and tensor algebra [4, 9]. The key concept is a tensor assembly construct and type system that lets the programmer efficiently transition between graph and algebra abstractions.

University of Illinois at Urbana-Champaign

Research Assistant **Automatic Datatype Generation, Optimization, and Compilation.** (2011-2013)
Design and implementation of a compiler for MPI datatypes to be used in MPI libraries to compile datatypes to custom specialized code [5]. Design and implementation of an intermediate representation and code generation algorithm to convert C code that packs data into buffers to declarative MPI datatypes that can target zero-copy hardware [10].

Refactoring for Parallel Programming. (2009-2010)

Design and implementation of the Immutator refactoring system for converting mutable Java classes to immutable classes [6]. Exploration of potential refactoring tools for high-performance computing applications [11].

Parallel Programming Patterns. (2009-2010)

Exploration, classification, and definition of parallel programming patterns, including the ghost cell pattern [12].

Awards

- 2017 Distinguished Paper Award at the Object-Oriented Programming, Systems, Languages & Applications Conference (OOPSLA).
- 2016 Adobe Fellowship.
- 2013 Best Paper Award at the 20th European MPI Users' Group Meeting (EuroMPI).
- 2011 Best Poster Award from the University of Illinois at Urbana-Champaign Spring Grad Expo.
- 2006 Rosing Award for best national IT-related student work in 2005 and 2006 from the Norwegian Computer Society.
- 2005 Eureka Award for best bachelor project from the Norwegian University of Science and Technology in Gjøvik.

Publications

Published 12 peer-reviewed papers, 6 conference/journal papers (2 best paper awards) and 6 short/workshop papers, in the venues OOPSLA, TOG, ICSE, CGO, ASE, EuroMPI, PPOPP, CAP, and ParaPLOP.

Conference and Journal Publications

1. Fredrik Kjolstad, Peter Ahrens, Shoaib Kamil, and Saman Amarasinghe. Sparse Tensor Algebra Optimization with Workspaces. *International Symposium on Code Generation and Optimization (CGO)*, 2019.
2. Stephen Chou, Fredrik Kjolstad, and Saman Amarasinghe. Format Abstraction for Sparse Tensor Algebra Compilers. *Object-Oriented Programming, Systems, Languages & Applications (OOPSLA)*, 2018.
3. Fredrik Kjolstad, Shoaib Kamil, Stephen Chou, David Lugato, and Saman Amarasinghe. The Tensor Algebra Compiler. *Object-Oriented Programming, Systems, Languages & Applications (OOPSLA)* [**Distinguished Paper Award**], 2017.
4. Fredrik Kjolstad, Shoaib Kamil Jonathan Ragan-Kelley, David I.W. Levin, Shinjiro Sueda, Desai Chen, Etienne Vouga, Danny M. Kaufman, Gurtej Kanwar, Wojciech Matusik, and Saman Amarasinghe. Simit: A Language for Physical Simulation. *ACM Transactions on Graphics (TOG, presented at SIGGRAPH)*, 2016.

5. Timo Schneider, Fredrik Kjolstad, and Torsten Hoefer. MPI Datatype Processing using Runtime Compilation. *The 20th European MPI Users' Group Meeting (EuroMPI) [Best Paper Award]*, 2013.
6. Fredrik Kjolstad, Danny Dig, Gabriel Acevedo, and Marc Snir. Transformation for Class Immutability. *33rd International Conference on Software Engineering*, 2011.

Peer-Reviewed Short and Workshop Publications

7. David Lugato, Fredrik Kjolstad, Stephen Chou, Saman Amarasinghe, and Shoaib Kamil. Taco: compilation et génération de code d'expressions tensorielles. *AVANCÉES No. 12*, 2018.
8. Fredrik Kjolstad, Stephen Chou, David Lugato, Shoaib Kamil, and Saman Amarasinghe. 32th IEEE/ACM International Conference on Automated Software Engineering (ASE tools paper). *taco: A Tool to Generate Tensor Algebra Kernels*, 2017.
9. Gilbert Bernstein, and Fredrik Kjolstad. Why New Programming Languages for Simulation? *ACM Transactions on Graphics (TOG perspective)*, 2016.
10. Fredrik Kjolstad, Torsten Hoefer, and Marc Snir. Automatic Datatype Generation and Optimization. *17th ACM SIGPLAN Symposium on Principles and Practice of Parallel Programming (PPoPP short paper)*, 2012.
11. Fredrik Kjolstad, Danny Dig, and Marc Snir. Bringing the HPC Programmer's IDE into the 21st Century through Refactoring. *SPLASH 2010 Workshop on Concurrency for the Application Programmer (CAP)*, 2010.
12. Fredrik Kjolstad and Marc Snir. Ghost Cell Pattern. *2nd Annual Workshop on Parallel Programming Patterns*, 2010.

Teaching and Mentorship

- 2011–present **Student Mentor.** Advised multiple undergraduate, master, and younger graduate students at MIT. Mentored three completed master theses with four more in progress:
1. Gurtej Kanwar, *Linear Algebra on Lattices: Simit Language Extensions with Applications to Lattice QCD* (June 2016).
 2. Parker Allen Tew, *An Investigation of Sparse Tensor Formats for Tensor Libraries* (June 2016).
 3. Stephen Chou, *Unified Sparse Formats for Tensor Algebra Compilers* (Feb. 2018).
 4. Sachin Shinde, *SuperTaco: A Distributed Backend for the Tensor Algebra Compiler* (expected January 2019)
 5. Patricio Noyola, *A Tensor Algebra Compiler Library Interface and Runtime* (expected Summer 2019)
 6. Suzanne A. Mueller, *Transpositions in the Tensor Algebra Compiler* (expected January 2020)
 7. Ryan Senanayake, *TAPAS: Tensor Algebra on Parallel Architectures Sparsely* (expected January 2020)
- Fall 2016 **Teaching Assistant, Performance Engineering of Software Systems, Massachusetts Institute of Technology.**
 Updated and administered one of the course projects and one of the homeworks, created one of the exam topics, graded, gave weekly recitations, and taught one lecture.

- Summer 2005 **Lecturer, five week course in mathematics and physics for incoming undergraduates, Norwegian University of Science and Technology in Gjøvik.**
Co-taught with one other lecture. Prepared course material, gave daily lectures and recitations, and jointly developed the final exam.
- Fall 2003/2004 **Teaching Assistant, Calculus 1, Norwegian University of Science and Technology in Gjøvik.**
Gave recitations and graded homework.
- Fall 2003 **Teaching Assistant, Introduction to Programming, Norwegian University of Science and Technology in Gjøvik.**
Gave recitations and graded homework.

Service

- Organizer **Invited Workshop on Compiler Techniques for Sparse Tensor Algebra** (2019)
Invited workshop to bring together leading researchers on sparse tensor algebra compilation and computing from academia and industry. Tentative attendance by professors from 10 universities, industry researchers from 7 companies, and researchers from 2 government labs.
- Program Committee **ACM Symposium on Principles of Programming Languages Artifact Evaluation Committee** (POPL 2017)
- Journal Reviewer **ACM Transactions on Graphics** (TOG 2017)
IEEE Transactions on Parallel and Distributed Systems (TPDS 2017)
- Book Reviewer **Parallel Programming with Microsoft .NET – Design Patterns for Decomposition and Coordination on Multicore Architectures** (2010)
- Conference Reviewer **ASPLOS: Architectural Support for Programming Languages and Operating Systems** (2019)
CGO: Symposium on Code Generation and Optimization (2014, 2016, 2017, 2018)
PLDI: Programming Language Design and Implementation (2014)
LCPC: Parallel Architectures and Compilation Techniques (2014, 2018)
PPoPP: Principles and Practice of Parallel Programming (2011)
- Organizer **Third and fourth MIT Programming Languages Offsite Retreat** (2012 and 2013)
Attended by seven CSAIL professors and their research groups. Re-organized program around many short talks, hosted panels, invited external speakers, and gave opening remarks.

Panels

- Panelist **ADA Fall Symposium panel on Agile Systems Design** (Oct. 2018)
With Julian Shun, Baris Kasikci and Sharad Malik, moderated by Zachary Tatlock.

Talks

Given 31 talks at conferences/workshops (4 invited and 7 papers), universities (5), companies (7), guest lectures (2), offsites (2), and grant meetings (4).

The Sparse Tensor Algebra Compiler

- Feb. 2019 International Symposium on Code Generation and Optimization, Washington DC
Feb. 2019 Innovations in Software Engineering Conference, India, Invited Talk
Jan. 2019 UT Austin ECE, Invited Seminar
Nov. 2018 Key Presentation in DARPA Review

Nov. 2018 ADA Liaison Meeting Talk
 Sep. 2018 University of Texas, Austin
 Sep. 2018 Semiconductor Research Corporation TECHCON, Austin
 Jun. 2018 Adobe Research, Seattle
 Jun. 2018 NVIDIA, Redmond
 Jun. 2018 University of Washington
 Jun. 2018 Facebook AI, Menlo Park
 May 2018 Stanford
 May 2018 UC Berkeley
 May 2018 Google Brain, Mountain View
 Apr. 2018 Industry-Academia Partnership MIT Cloud Workshop, Invited Talk
 Mar. 2018 SIAM Parallel Processing for Scientific Computing, Tokyo, Invited Talk
 Jan. 2018 SciDAC4 Kickoff Meeting, Thomas Jefferson National Accelerator Facility
 Nov. 2017 University of Illinois, Urbana-Champaign
 Nov. 2017 Automated Software Engineering Tools Track (ASE)
 Oct. 2017 Object-Oriented Programming, Systems, Languages, and Analysis (OOPSLA)
 Oct. 2017 Microsoft Research, Redmond
 Apr. 2017 MIT, 6.S898 Guest Lecture

Simit: A Language for Computing on Sparse Systems

Sep. 2016 Intel Research, Hudson
 Aug. 2016 Microsoft Research, Redmond
 Jul. 2016 ACM Special Interest Group on Graphics (SIGGRAPH)
 Oct. 2015 MIT Computer Graphics Group Annual Retreat
 May 2015 MIT Programming Languages Offsite

Graphs, Matrices, and Compilers

Nov. 2014 Harvard, CS207 Guest Lecture

Transformation for Class Immutability

May 2011 33rd International Conference on Software Engineering
 Apr. 2011 UPCRC Illinois Summit

Refactoring for High-Performance Computing

Oct. 2010 SPLASH Workshop on Concurrency for the Application Programmer

Performance Optimization of Embedded 3D Graphics Applications

Oct. 2008 ARM Developer's Conference, Santa Clara, Invited Talk

Industry and Government Experience

2007-2009 **ARM Ltd.**, *Graphics Software Engineer*.
 Developed SDK Tools and OpenGL ES 1.1/2.0 3D Graphics Driver for the ARM Mali GPUs.

2006 **Accenture Technology Solutions**, *Programmer*.
 Designed parts of the pension web applications for the Norwegian government.

2005-2006 **Norwegian Army**, *Engineer*.
 Mandatory conscripted military service in the Norwegian Engineering Battalion.

References

Saman Amarasinghe

Department of Electrical Engineering and
Computer Science
Massachusetts Institute of Technology
saman@mit.edu
617-253-8879

P. Sadayappan

Department of Computer Science and
Engineering
Ohio State University
sadayappan.1@osu.edu
614-292-0053

Charles E. Leiserson

Department of Electrical Engineering and
Computer Science
Massachusetts Institute of Technology
cel@mit.edu
617-253-5833

Joel Emer

NVIDIA and Department of Electrical
Engineering and Computer Science
Massachusetts Institute of Technology
emer@csail.mit.edu
617-258-9190