Akshay Gopalakrishnan

Curriculum Vitae

"Silence is the best teacher"

Current- PhD Computer Science

Shared memory semantics, also known as memory consistency models, specify how a concurrent program behaves. While sequential interleaving is considered as the de-facto way of reasoning with such programs, current hardware as well as software drift away from it significantly. Semantics for them are termed as weak consistency models, allowing for more concurrent behaviors that result due to optimizations mainly understood as those done by hardware. While hardware models reflect desired optimizations, the same cannot be said for software models. Software (compiler) optimizations have historically been designed for sequential programs, and thus, optimization choices sometimes interact badly with concurrent software. This has resulted in software exhibiting unexpected concurrent behaviors, which makes software correctness a hard task to address. Existing solutions to this are too complex to be feasible in practice. They tend to either make code development difficult or limit the range of potential optimizations. This results in a trade-off between performance, as enabled by aggressive optimization, and the ability to ensure correctness of the optimized piece of software. The goal of this PhD is to unveil a precise and practically useful correlation between memory consistency models and compiler optimizations. In this endeavor, we propose a new design methodology of memory models for software, one that places emphasis on the compiler optimizations desired to be performed. We intend to establish a system of formally constructing models that allow compilers to also do much of the performance-giving optimizations, without sacrificing correct functioning of software.

Education

2021-Today **PhD Computer Science**, *McGill University*, Montreal, Canada.

2018–2021 **Masters of Computer Science - Thesis**, *McGill University*, Montreal, Canada.

2014–2018 **Bachelor of Information Technology**, *College of Engineering*, Pune, India.

2002-2014 **Miscellaneous Degree in Fun**, *Loyola High School and Junior College*, Pashan, Pune, India.

Masters Thesis

Title **Analysis of the ECMAscript memory model: a program transformation perspective**

Supervisors **Professor Clark Verbrugge**

Abstract Concurrent programs have been shown to give us tremendous performance benefits compared to their sequential counterparts. With the addition of several hardware features such as read/write buffers, speculation, etc., more efficient forms of concurrent memory accesses are introduced. Known as relaxed memory accesses, they are used to gain substantial improvement in the performance of concurrent programs. A relaxed memory consistency model specifically describes the semantics of such accesses for a particular programming language. Historically, such semantics are often ill-defined or misunderstood, and have been shown to conflict with common program transformations essential for the performance of programs. In this thesis, we give a formal declarative (axiomatic) style description of the ECMAScript relaxed memory consistency model. We analyze the impact of this model on two common program transformations, viz. instruction reordering and elimination. We give a conservative proof under which such an optimization is allowed for relaxed memory accesses. We use this result to reason about the validity of reordering accesses outside loops under the same model. We conclude this thesis by eliciting the limitations of our approach, critique on the semantics of the model, possible future work using our results, and pending foundational questions that we discovered while working on this thesis.

Link `https://escholarship.mcgill.ca/concern/theses/7p88cn613?locale=en`

Publications

2025 **Portability of Optimizations from SC to TSO.**, *9th International Symposium on Theoretical Aspects of Software Engineering (TASE) 2025*, Limassol, Cyprus, Conference.
`https://doi.org/10.1007/978-3-031-98208-8_8`

2025 **Memory Consistency and Program Transformations**, *Formal Aspects of Computing 2025*, Journal.
`https://dl.acm.org/doi/10.1145/3721143`

2023 **Memory Consistency Models for Program Transformations: An Intellectual Abstract**, *International Symposium on Memory Management (ISMM) 2023*, Orlando, Florida, USA, Conference.
`https://dl.acm.org/doi/10.1145/3591195.3595274`

2022 **Reordering Under the ECMAScript Memory Consistency Model**, *Languages and Compilers for Parallel Computing (LCPC) 2020*, New York, USA, Conference.
`https://link.springer.com/chapter/10.1007/978-3-030-95953-1_14`

Talks

Nov 2024 **Sequential Reasoning for Designing Safe Optimizations under TSO**, *Compiler Driven Performance (CDP) 2024 Workshop*, York University, Toronto, Ontario, Canada.

Jan 2024 **What Compilers Desire from Weak Memory**, *Future of Weak Memory 2024 Workshop*, Institution of Engineering and Technology, London, United Kingdom.

Dec 2023 (invited) **Memory Consistency and Program Transformations**, *Cisco Crimson Team : Tech Talk*, Cisco Systems Canada Co, Montreal, Canada.

Feb 2023 (invited) **Memory Consistency and Program Transformations**, *Programming Languages and Systems (PLAS) Seminar*, University of Kent, Canterbury, United Kingdom.

Nov 2022 **Memory Consistency and Program Transformations**, *Compiler Driven Performance (CDP) 2022 Workshop*, Toronto, Canada.

Oct 2022 **Memory Consistency and Program Transformations**, *Strategic Research Network: Computing Hardware for Emerging Intelligent Sensing Applications (COHESA) NSERC 2022*, Virtual.

Aug 2020 **Analysis of the ECMAScript Memory Model**, *Strategic Research Network: Computing Hardware for Emerging Intelligent Sensing Applications (COHESA) NSERC 2020*, Virtual.

Research Internships

Jan 2023 - April 2023 **Research Assistant**, *University of Kent*, Canterbury, Supervisor: **Professor Mark Batty**.
Transformational Specification of Out-of-Thin-Air memory models.

July 2020 - Oct 2020 **Research Fellow**, *Max Planck Institute for Software Systems (MPI-SWS)*, Virtual, Supervisor: **Dr. Viktor Vafeiadis**.
Symmetry Reduction for Model Checking Relaxed Memory programs.

Teaching Experience

Winter 2019, 2020, 2021, 2022, 2024, 2025 **Teaching Assistant: Concurrent Programming**, *McGill University*.
Duties: Discussions, Office hours, Grading, Assignment solutions, Invigilation.

Fall 2018, 2021, 2022, 2023, 2024 **Teaching Assistant: Operating Systems**, *McGill University*.
Duties: Office hours, Tutorials, Grading, Assignment solutions, Admin, Invigilation.

Fall 2019 **Teaching Assistant: Foundations of Programming**, *McGill University*.
Duties: Office hours, Tutorials, Grading.

Fall 2020 **Teaching Assistant: Advanced Algorithms**, *McGill University*.
Duties: Office hours, Grading, Assignment solutions.

Awards Received

Research funding (merit-based)

Fall 2023 **Mitacs Globalink Research Award (GRA) - UK Research and Innovation (UKRI) 2023**, *Mitacs*.
To undertake research in UK.

2021-2025 **Graduate Excellence Award**, *PhD*, McGill University.

2021-2022 **Murata Family Fellowship**, *PhD*, McGill University.
Awarded by the Faculty of Science to outstanding students.

Conference Travel Awards

June 2023 **ISMM/PLDI 2023 SIGPLAN PAC**, *ACM SIGPLAN*.

Jan 2020 **VMCAI 2020 Winter School**, *VMCAI*.

Jan 2020 **PLanQC 2020**, *ACM SIGPLAN*.

Sept 2019 **PLMW SPLASH 2019**, *ACM SIGPLAN*.

Other Academic Activities

Summer 2025 **ETAPS 2025 Conference**, *Student Volunteer*, Hamilton, Canada.
Duties: Registration desk, Tech support

Fall 2019 - Winter 2022 **Sable Lab meetings**, *Co-ordinator*, McGill University, Montreal.
Duties: Room bookings, scheduling biweekly meetings.

Fall 2019 **Programming Languages and Compilers Reading Group**, *Co-ordinator*, McGill University, Montreal.
Duties: Room bookings, finding presenters, scheduling biweekly meetings.

Academic Group Member

2018-ongoing **Sable**, *McGill University*, Montreal, Canada.
Compilers and Optimizations Research Lab at McGill

2018-ongoing **Social Studies of Computing**, *McGill University*, Montreal, Canada.
The Social Studies of Computing Research Group provides a research community for scholars at McGill University studying the sociology, history and philosophy of computer science. This includes areas such as computer science education and gender studies in computing.

2024-lifetime **Academy of Discrete Mathematics and Applications (ADMA)**, *India*.
The Academy of Discrete Mathematics and Applications (ADMA) is a registered professional body functioning with the aim of promoting active and quality research in Discrete Mathematics and allied subjects.

Attended Conferences/ Winter Schools

2025 **Theoretical Aspects of Software Engineering (TASE)**, *Limassol*, Cyprus.

2025 **International Joint Conferences On Theory and Practice of Software (ETAPS)**, *Hamilton*, Ontario, Canada.

2024 **Big Specification: Specification, Proof and Testing At Scale** , *Virtual*.

2023 **International Symposium on Memory Management (ISMM)**, *Orlando*, Florida, USA.

2023 **Programming language Design and Implementation (PLDI)**, *Orlando*, Florida, USA.

2023 **Verified Trustworthy Software Systems (VeTSS) Inaugural Meeting**, *London*, UK.

2022 **Isaac Newton Institute (INI) Concurrency Workshop**, *Virtual*.

2021 **Midlands Graduate School (MGS)**, *Virtual*.

2021 **Programming language Design and Implementation (PLDI)**, *Virtual*.

2020 **Languages and Compilers for Parallel Computing (LCPC)**, *Virtual*.

2020 **Heidelberg Laureate Forum (HLF)**, *Virtual*.

2020 **Principles of Programming Languages (POPL)**, *New Orleans*, Louisiana, USA.

2020 **Verification Model Checking and Abstract Interpretation (VMCAI) Winter School**, *New Orleans*, Louisiana, USA.

2019 **Programming Languages Mentoring Workshop (PLMW)**, *Athens*, Greece.

2019 **Systems, Programming, Languages, and Applications: Software for Humanity (SPLASH)**, *Athens*, Greece.

2019 **CS-CAN Student Symposium**, *McGill University, Montreal*, Quebec, Canada.