

# Siddharth Bhat

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## Skills

I'm an expert in formal verification, optimizing compilers, and AI4maths.

**Functional Programming & Formal Verification:** I have been working on functional programming since I was a teenager, and as an intern at Tweag, I helped implement the WebAssembly GC and runtime for Asterius, a Haskell to WebAssembly compiler. I am the #2 contributor to Asterius, which was eventually merged into the Glasgow Haskell Compiler. I am in the top 20 contributors to the Lean theorem prover overall, and one of the top two contributors of the Lean bitvector theory. I'm an author of the Lean4 metaprogramming book and have written a large part of the theory for proving Lean's bitblaster (`bv_decide`) correct.

**Compilers & HPC:** I have deep experience on high performance computing and loop optimization: Polly is a research loop optimizer for the LLVM project, a production-grade compiler optimization framework. Polly was the first to create a framework for loop analysis and optimisation that brought mathematical research ideas in polyhedral compilation to real-world ideas. Technical successors of Polly that use many of its innovations are used to accelerate large machine learning models today. I have contributed 121 patches to Polly, making me the #3 contributor to the Polly. Thanks to my work, the Polly loop optimizer gained the ability to perform high-performance GPU code generation for realistic climate models, including the dynamical core of COSMO, Switzerland's official climate model. I mentored students working on the Polly project as a Google Summer of Code mentor in 2016.

**AI for Maths:** My long term vision is to build scalable systems for mathematical theorem proving, as the bitter lesson teaches us that only search scales. As an intern at Microsoft Research (2023), I worked on RL approaches for proof repair in the F\* proof assistant ("Towards neural synthesis for SMT-assisted proof-oriented programming" @ ICSE 25, best paper). I have also worked on showing that decision procedures scale for symbolic problems such as geometry versus neural approaches.

## Education

PhD **University of Cambridge.**

(2024 - Ongoing)

PhD **University of Edinburgh (*moved to Cambridge*).**

(2022 - 2024)

Master by **International Institute of Information Technology Hyderabad India.**

Research (2020 - 2021)

Undergraduate **International Institute of Information Technology Hyderabad India.**

2015 - 2020

## Publications

Certified Decision Procedures for Width-Independent Bitvector Predicates: **Siddharth Bhat**, Léo Stefanescu, Chris Hughes, Tobias Grosser. OOPSLA 2025

Interactive Bit Vector Reasoning using Verified Bitblasting: Henrik Böving, **Siddharth Bhat**, Alex Keizer, Luisa Cicolini, Leon Frenot, Abdalrhman Mohamed, Léo Stefanescu, Harun Khan, Josh Clune, Clark Barrett, Tobias Grosser. OOPSLA 2025

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Verifying Peephole Rewriting in SSA Compiler IRs: **Siddharth Bhat**, Alex Keizer, Chris Hughes, Andres Goens, Tobias Grosser. ITP 2024

Verifying Wu's Method can Boost Symbolic AI to Rival Silver Medalists and AlphaGeometry to Outperform Gold Medalists at IMO Geometry: Shiven Sinha, Ameya Prabhu, Ponnuram Kumaraguru, **Siddharth Bhat**, Matthias Bethge. NeurIPS 2024 Workshop MATH-AI

Verifying Peephole Rewriting in SSA Compiler IRs: **Siddharth Bhat**, Alex Keizer, Chris Hughes, Andres Goens, Tobias Grosser. ITP 2024

Towards Neural Synthesis for SMT-Assisted Proof-Oriented Programming: Saikat Chakraborty, Gabriel Ebner, **Siddharth Bhat**, Sarah Fakhoury, Sakina Fatima, Shuvendu Lahiri, Nikhil Swamy. ICSE 2024

Rewriting Optimization Problems into Disciplined Convex Programming Form: Ramon Fernandez Mir, **Siddharth Bhat**, Andres Goens, Tobias Grosser. CICM 2024

Guided Equality Saturation: Thomas Koehler, Andres Goens, **Siddharth Bhat**, Tobias Grosser, Phil Trinder, Michel Steuwer. POPL 2024

Lambda the Ultimate SSA: **Siddharth Bhat**, Tobias Grosser. CGO 2022

QSSA: An SSA based IR for Quantum Computing: Anurudh Peduri, **Siddharth Bhat**, Tobias Grosser. CC 2021

Optimizing Geometric Multigrid Computation using a DSL Approach: Vinay Vasista, Kumudha KN, **Siddharth Bhat**, Uday Bondhugula. Supercomputing (SC), Nov 2017

Word Embeddings as Tuples of Feature Probabilities: **Siddharth Bhat**, Alok Debnath, Souvik Banerjee, Manish Shrivastava Representation Learning for NLP, 2020

## Internship Experience

Sep-Nov '24 **Amazon Web Services, Automated Reasoning Group, Austin.**

Deciding memory (non)interference in `Insym`, a Lean-based ARM symbolic simulator

Jul-Sep '23 **Microsoft Research, Redmond.**

Retrieval Augmented theorem proving for the Fstar proof assistant.

July 1-10 '23 **Adjoint School, Glasgow.**

Researched Markov categories and their relationship to probabilistic programming.

May-Jul '19 **Intern at Tweag.io, Paris, France.**

Re-implemented portions of GHC(Glasgow Haskell Compiler) runtime for **Asterius** ([link](#)), a Haskell to WebAssembly compiler. Involved Haskell, C, and WebAssembly.

Summer 2018 **Visiting research intern at ETH Zurich, Zurich, Switzerland.**

Investigating formal verification of polyhedral compilation. **PolyIR** ([Link](#)) is a formal specification of polyhedral programs.

Summer 2018 **GSoC mentor, Polly Labs.**

Mentoring a project to enable Polly's loop optimisations into Chapel.

Mar-Dec '17 **ETH Zurich, Research Intern at SPCL, Zurich, Switzerland.**

Worked on Polly, a polyhedral loop optimizer for LLVM.

May-Jul '16 **Research Intern, IISc Bangalore, Bangalore.**

Worked on PolyMage, DSL compiler for optimising loop transforms. Contributed to ISL and PLUTO. Implemented tiling patterns, optimised PolyMage for stencils.

Summer 2016 **Selected for GSoC 2016, Google.**

Binding SymEngine, a symbolic math library to Haskell. Had to drop this to intern at IISc, Bangalore. Still maintain the library ([symengine.hs](#))

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Summer 2015 **GSoC 2015**, *Google*.

Worked on VisPy, a pure Python graphics library which uses OpenGL internally for performance. Successfully completed.

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## Open Source Contributions

- Lean Theorem Prover** Co-developed the bitblasting theory for Lean's bitvector automation, wrote the LLVM backend for the compiler.
- Rocq** Submitted issues, bug-fixes, helped improve developer documentation.
- VE-LLVM** Collaboration with VE-LLVM, a formal semantics of the LLVM compiler toolchain in Coq
- Polly** Implementing support for Fortran, added unified memory abilities to the CUDA backend within Polly, a polyhedral loop optimiser for LLVM. ([Link to commits](#))
- Symengine.hs** GSoC 2016. Haskell bindings to SymEngine, a C++ symbolic manipulation library.
- VisPy** GSoC 2015. Rewrote scene graph for performance. Added visuals, high level API for easy use of plotting. Implemented auto-resizing with **Cassowary**, a linear optimisation library.
- Rust** Contributed to the Rust compiler and ecosystem. Found compiler errors, fixed libraries. Was part of **Piston**, group of Rust programmers that experimented with writing game engines.
- Haskell** Contributed to the Haskell ecosystem. Reported and fixed bugs in *stack*, *stackage*, *diagrams*, *GHC*, etc. ([Link to GHC commits](#)).
- PLUTO** Source to Source C optimiser for loop nests. Improved the PLUTO API that had gone out of sync with master. Discovered bugs in PLUTO for diamond tiling transforms
- PolyMage** DSL Compiler than generates C code. Uses **Polyhedral Compilation** Extended the compiler to add stencils, time iterated-stencils.
- PPSSPP** PPSSPP is a C++ open source PSP emulator. Wrote most of the touch handling code. Implemented atomic locks for audio performance.

## My Projects

- Lean-MLIR** Formal semantics for the MLIR compiler framework, defined within the Lean4 proof assistant.
- lz** An MLIR based compiler backend for the Lean4 proof assistant.
- Lean4 Metaprogramming Book** A textbook on metaprogramming in Lean4. I wrote the chapters on tactics and metaprogramming for embedded DSLs.
- Lean-to** A Jupyter kernel for the Lean4 proof assistant.
- Simplexhc** A custom compiler for a subset of Haskell. The goal is to try and apply *polyhedral compilation* ideas to compile a lazy, pure, functional programming language. with LLVM as a backend. Has **64 stars** on github.
- Sublime Bookmarks** A plugin for sublime text to quickly jump between pieces of your codebase. **26k downloads** and counting.
- Cellular Automata** A collection of Cellular Automata written in Haskell. Uses **Comonads** for abstraction. **130 stars** on Github.
- Teleport** A simple tool to switch between projects written in Haskell. Shows how to write "real world Haskell". Published as a **Literal Haskell tutorial**. **90 stars** on github
- TIMi** A visual interpreter of the **template instantiation machine** to understand evaluation of lazy functional languages. **51 stars** on github.

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## Miscellaneous

- Barvinok** Talk at ETH Zurich: Slides describing the barvinok algorithm to count lattice points in polyhedra
- FunctionalConf '19** Talk on implementing embedded probabilistic programming languages in Haskell ([Slides](#))
- Haskell Exchange 2020** Talk on optimizing `smallpt-hs` (a port of a raytracer to haskell) to beat C++ performance ([Slides](#))
- FPIIndia** Talk on egg: fast and extensible equality saturation. ([Slides](#))
- Theory seminar, winter '19** Talk on impossibility of compass-straightedge constructions using field theory.
- math.se** Answer on **math.stackexchange**. **8312 reputation, top 4% overall**. Abstract algebra and differential/algebraic geometry.

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## Talks & Presentations

**Euro LLVM Dev 2025:** [How to trust your peephole rewrites: automatically verifying them for arbitrary width!](#). **US LLVM Dev 2024:** [lean-mlir: A workbench for formally verifying peephole optimizations in MLIR](#). **US LLVM Dev 2023:** [\(Correctly\) Extending dominance to MLIR Regions](#). **US LLVM Dev 2023:** [MLIR Side Effect Modelling](#). **Euro LLVM Dev 2022:** [MLIR for Functional Programming](#). **FPIIndia 2021:** [Equality Saturation](#). **Functiona Conf 2019:** [Monad-bayes: Probabilistic programming in Haskell](#).

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## Awards

<https://www.renaissancephilanthropy.org/mathbench-towards-evaluating-natural-language-proofs>  
One of 30 research groups that was awarded out of over 280 applicants.