

# William DeMeo

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## Research interests

*What mathematics is mechanizable and which machine-checked results can we trust?* These questions have become the throughline of my work on the following: congruence lattices of finite algebras and the finite lattice representation problem; algebraic approaches to the complexity of constraint satisfaction problems; formalization of mathematics in dependent type theory; formal methods for a production blockchain ledger; AI agents that work inside a proof assistant, where the typechecker is the verifiable reward signal.

**Theory.** Universal algebra and lattice theory, and the algebraic theory of constraint-satisfaction complexity that grew out of them; constructive dependent type theory as a foundation for machine-checked mathematics; and proof search with the typechecker as the only judge, including what its verdicts can and cannot teach a learned policy.

**Practice.** Proof mechanization in Agda, in a research library and in a production specification; and the infrastructure that lets language models work inside a proof assistant, built so that every claim about it is a measurement someone else can reproduce.

## Education

**Doctor of Philosophy in Mathematics**, University of Hawaii, Honolulu

Thesis: Congruence lattices of finite algebras.

Advisor: Ralph Freese.

**Master of Science in Mathematics**, Courant Institute of Mathematical Sciences, NYU, New York

Thesis: Approximating eigenvalues of large stochastic matrices.

Advisor: Jonathan Goodman.

**Bachelor of Arts in Economics**, University of Virginia, Charlottesville

## Appointments

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| 2023–     | <b>Formal Verification Engineer</b> , Formal Methods Team, IO, Boulder<br>Machine-checked specification of the Cardano blockchain ledger in Agda, with the Formal Methods team. The specification is literate Agda: the human-readable ledger specification is generated from it, and Haskell is extracted from it and run in conformance tests against the production implementation, so it has to type-check, compile, and agree with a separately written system that live nodes run. It tracks the chain across its eras, the Conway era complete and Dijkstra in progress. The largest single share of commits in the repository's history; the design is described in the FMBC 2024 paper below.<br><a href="#">Project</a> · <a href="#">Specification</a> · <a href="#">Contributors</a> |
| 2022–2023 | <b>Senior University Lecturer</b> , Computer Science, New Jersey Inst. of Technology, Newark<br>Taught courses in foundations of computing, big data, and artificial intelligence; the AI course was built around a substantial Python programming project. 18 months.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2022–2023 | <b>Software Engineer</b> , Library Team, RelationalAI, New York<br>Developed the Standard Library of the Rel declarative programming language. 9 months.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| 2019–2021 | <b>Postdoctoral Research Fellow</b> , Algebra Dept., Charles University, Prague                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 2017–2019 | <b>Burnett Meyer Instructor</b> , Mathematics Dept., University of Colorado, Boulder                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| 2016–2017 | <b>Visiting Assistant Professor</b> , Mathematics Dept., University of Hawaii, Honolulu                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| 2014–2016 | <b>Postdoctoral Associate</b> , Mathematics Dept., Iowa State University, Ames                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| 2012–2014 | <b>Visiting Assistant Professor</b> , Mathematics Dept., Univ South Carolina, Columbia                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| 2001–2006 | <b>Senior Research Scientist</b> , Imaging Research Dept., Textron Systems Corp., Maui<br>Developed algorithms and parallel (smp and mpi) programs under AFOSR contracts for images from the Haleakala Observatories, including Multi-frame Blind Deconvolution to remove atmospheric distortion from images of satellites and other NEOs, executed on the MHPCC supercomputer.                                                                                                                                                                                                                                                                                                                                                                                                                  |

## Grants and awards

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- 2015–2018    **NSF Research Grant** no. 1500218  
*Algebras and algorithms, structure and complexity theory.*  
Postdoctoral research fellow on a team with 6 senior scientists and 3 postdocs.  
3-yr collaborative research on algebraic approaches to constraint satisfaction problems.
- 2013–2014    **Magellan Scholar Grant**  
*What does a nonabelian group sound like?*  
Faculty mentor for undergraduate research.
- 2011          **ARCS Sarah Ann Martin Award** for Outstanding Research in Mathematics, Honolulu
- 2004          **Best Paper Award**, International Symposium on Musical Acoustics, Nara, Japan

## Selected publications

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1. **Formal Specification of the Cardano Blockchain Ledger, Mechanized in Agda**  
Andre Knispel, Orestis Melkonian, James Chapman, Alasdair Hill, Joosep Jääger, **William DeMeo**, and Ulf Norell.  
*5th International Workshop on Formal Methods for Blockchains (FMBC 2024)*, OASiCs Volume 118, 2024, pages 2:1-2:18.  
Proceedings
2. **Universal algebraic methods for constraint satisfaction problems**  
Clifford Bergman and **William DeMeo**.  
*Logical Methods in Computer Science (LMCS)*, Volume 18, Issue 1, 2022.  
Journal · arXiv preprint
3. **A machine-checked proof of Birkhoff's variety theorem in Martin-Löf type theory**  
**William DeMeo** and Jacques Carette.  
*27th International Conference on Types for Proofs and Programs (TYPES 2021)*, LIPIcs Volume 239, 2022, pages 4:1-4:21.  
Proceedings · arXiv preprint
4. **Constraint satisfaction problems over finite structures**  
Libor Barto, **William DeMeo**, and Antoine Mottet.  
*36th ACM/IEEE Symposium on Logic in Computer Science (LICS 2021)*, Rome, Italy, 2021, pages 1-13.  
Proceedings · arXiv preprint
5. **Bounded homomorphisms and finitely generated fiber products of lattices**  
**William DeMeo**, Peter Mayr, and Nik Ruškuc.  
*International Journal of Algebra and Computation (IJAC)*, Volume 30, Issue 4, 2020, pages 693-710.  
Journal · arXiv preprint
6. **Polynomial-time tests for difference terms in idempotent varieties**  
**William DeMeo**, Ralph Freese, and Matthew Valeriote.  
*International Journal of Algebra and Computation (IJAC)*, Volume 29, Issue 6, 2019, pages 927-949.  
Journal · arXiv preprint

The complete record, with abstracts, is on the [publications](#) page.

## Projects

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### • **AI for formal verification (agda-native-air)**

Principal author; active since 2025.

Infrastructure that lets language models work inside the Agda proof assistant with the typechecker as the oracle and final arbiter of truth. `agda-mcp` is a server that exposes Agda's interaction protocol to coding agents under a verdict discipline: every verdict is derived from a batch Agda process's exit code and travels with the command it is equivalent to, while a persistent interaction lane answers questions in milliseconds and never decides. A proof-search loop drives that server with Agda judging every step. Structured extraction turns whole libraries into released corpora with recorded provenance, and benchmark tests against gold solutions with per-run honesty ledgers make every claim about the loop reproducible. The tooling was the instrument for a new machine-checked formal proof of the Kurzwel–Netter duality theorem in agda-algebras.

[releases](#) · [benchmark](#) · [agda-mcp adr](#) · [proof search adr](#) · [field reports](#)

### • **The Agda Universal Algebra Library (agda-algebras)**

Principal author, with contributions by Jacques Carette; active since 2019.

A formalization of universal algebra in Agda, in constructive Martin-Löf type theory with no classical axioms: general algebras, homomorphisms, congruences, terms, varieties, and the equational logic and model theory beneath them. Its flagship result is a fully constructive machine-checked proof of Birkhoff's HSP theorem that postulates no function

extensionality (TYPES 2021, below). About 300 literate modules and 60,000 lines of Agda, type-checked in CI against Agda 2.8.0; the documentation site publishes its own size. Now also the substrate for a machine-checked research program on the finite lattice representation problem.

docs · credits · thm: Birkhoff HSP · thm: Maltsev · thm: Kurzweil-Netter

- **Category Theory: a concise course**

With Charlotte Aten and Venzio Capretta.

Work in progress.

- **Complex Analysis Exams**

Work in progress.

- **Real Analysis Exams**

Work in progress.

## Teaching

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**New Jersey Institute of Technology**, Senior University Lecturer

- **DS 644** Introduction to Big Data, graduate course, Spring 2023
- **CS 644** Introduction to Big Data, graduate course, Fall 2022
- **CS 370** Introduction to Artificial Intelligence, Fall 2022
- **CS 370** Introduction to Artificial Intelligence, Spring 2022
- **CS 241** Foundations of Computer Science I, Spring 2022

**Charles University in Prague**, Postdoctoral Research Fellow

- **NMAG 405** Universal Algebra, Winter 2020

**University of Colorado, Boulder**, Burnett Meyer Instructor

- **Math 2001** Discrete Mathematics, with Lean prover component, Spring 2019
- **Math 2001** Discrete Mathematics, with Lean prover component, Fall 2018
- **Math 3140** Abstract Algebra, Fall 2018
- **Math 6000** Model Theory, graduate course, Spring 2018
- **Math 2130** Linear Algebra, Spring 2018
- **Math 2130** Linear Algebra, Fall 2017

**University of Hawaii**, Visiting Assistant Professor

- **Math 215** Applied Calculus, Spring 2017
- **Math 480** Senior Seminar, Spring 2017
- **Math 244** Calculus IV, Fall 2016
- **Math 321** Introduction to Advanced Math, Fall 2016

**Iowa State University**, Postdoctoral Associate

- **Math 317** Linear Algebra, Spring 2016
- **Math 317** Linear Algebra, Fall 2015
- **Math 160** Survey of Calculus, Fall 2015
- **Math 207** Elementary Linear Algebra, Spring 2015
- **Math 165** Calculus I, Spring 2015
- **Math 301** Abstract Algebra, Fall 2014
- **Math 165** Calculus I, Fall 2014

**University of South Carolina**, Visiting Assistant Professor

- **Math 700** Linear Algebra, graduate course, Spring 2014
- **Math 141** Calculus I, Spring 2014
- **Math 374** Discrete Structures, Fall 2013
- **Math 122** Calculus for Business and Social Sciences, Fall 2013
- **Math 374** Discrete Structures, Spring 2013
- **Math 122** Calculus for Business and Social Sciences, Spring 2013
- **Math 241** Vector Calculus, Fall 2012
- **Math 122** Calculus for Business and Social Sciences, Fall 2012

**University of Hawaii**, Graduate Student Instructor

- **Math 371** Probability Theory, Summer 2011
- **Math 100** Mathematical Reasoning, Summer 2010
- **Math 215** Applied Calculus I, Summer 2009

## Talks

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- **A gratuitously general relation type**  
Agda Implementors' Meeting XXXIX, Chalmers University, Gothenburg, Sweden, 2024 · the REL type in agda-algebras
- **Birkhoff's Theorem in Dependent Type Theory**  
TYPES 2021, Online, 2021  
Preprint
- **Complexity of the Homomorphism Problem for Boolean Models**  
European virtual CSP seminar, Online, 2020  
Preprint
- **Computational Tools for Universal Algebra Research**  
CSP World Congress 2020, Vols am Schlern, Italy, 2020
- **Formalizing Universal Algebra with Dependent and Inductive Types**  
AMS Joint Mathematics Meetings; Special Session: Algebras and Algorithms, Denver, CO, 2020  
Docs
- **Computing Difference Term Operations in Polynomial Time**  
BLAST Conference, University of Denver, Denver, CO, 2018  
Preprint
- **Why Universal Algebra Needs Inductive, Dependent Types**  
Oregon Programming Languages Summer School, Eugene, OR, 2018
- **A Tutorial Introduction to the Lean Prover**  
University of Colorado Logic Seminar, Boulder, CO, 2018
- **The Lambda Calculus and Dependent Type Theory**  
University of Colorado Logic Seminar, Boulder, CO, 2018
- **Representing Finite Lattices as Congruence Lattices**  
Colorado State University Algebra Seminar, Fort Collins, CO, 2017
- **A Polynomial-time Test for Difference Terms in Idempotent Varieties**  
BLAST Conference, Vanderbilt University, Nashville, TN, 2017  
Preprint
- **Algebraic approach to complexity of constraint satisfaction**  
University of Hawaii Logic and Analysis Seminar, Honolulu, HI, 2017  
Preprint
- **Universal Algebraic Methods for Constraint Satisfaction Problems**  
AMS Fall Western Sectional Meeting; Special Session in Algebraic Logic, Denver, CO, 2016  
Preprint
- **The Rectangularity Theorem of Barto and Kozik**  
Algebras and Algorithms: Structure and Complexity Theory, Boulder, CO, 2016
- **Constraint Satisfaction Problems and Universal Algebra**  
Midlands Graduate School in the Foundation of Computing Science, Birmingham, England, 2016
- **Permutability in Diamonds**  
Iowa State Algebra and Combinatorics Seminar, Ames, IA, 2016
- **Which Commutative Idempotent Binars are Tractable?**  
Vanderbilt Shanks workshop: Open Problems in Universal Algebra, Nashville, TN, 2015
- **Some Small Finite Algebras Yielding Tractable CSP Templates**  
Iowa State Algebra and Combinatorics Seminar, Ames, IA, 2015
- **Algebraic CSP and Tractability of Commutative Idempotent Binars**  
BLAST Conference, University of North Texas, Denton, TX, 2015
- **Isotopic Algebras**  
Iowa State Algebra and Combinatorics Seminar, Ames, IA, 2015
- **What Does a Nonabelian Group Sound Like?**  
MAA Special Session: At the Intersection of Mathematics and the Arts, Baltimore, MD, 2014  
Abstract
- **Interval Enforceable Properties of Finite Groups**  
AMS Special Session on Finite Universal Algebra, Louisville, KY, 2013
- **Tutorial: UACalc at the command line and in the cloud**  
Workshop on Computational Universal Algebra, Louisville, KY, 2013
- **Approximating Eigenvalues of Large Stochastic Matrices**  
University of South Carolina Combinatorics Seminar, Columbia, SC, 2013

- **Congruence Lattices of Finite Algebras**  
BLAST Conference, Chapman University, Orange, CA, 2013 · plenary lecture
- **Transposition Principles for Subgroups and Equivalence Relations**  
Zassenhaus Group Theory Conference, Asheville, NC, 2013
- **Isotopic Algebras with Nonisomorphic Congruence Lattices**  
AMS Special Session on Algebras, Lattices, and Varieties, Boulder, CO, 2013
- **Synchronizing Automata and the Cerny Conjecture**  
Graduate Algebra Seminar, University of Colorado, Boulder, CO, 2013
- **The Finite Lattice Representation Problem in Four Parts**  
University of South Carolina Algebra and Logic Seminar, Columbia, SC, 2012
- **Interval Sublattice Enforceable Properties of Finite Groups**  
The 31st Ohio State-Denison Mathematics Conference, Columbus, OH, 2012
- **Expansions of Finite Algebras and their Congruence Lattices**  
American Mathematical Society sectional meeting, Honolulu, HI, 2012
- **Intervals in Subgroup Lattices and Permutation Representations**  
Western Carolina University Group Theory Seminar, Cullowhee, NC, 2012
- **Recent Progress on the Finite Lattice Representation Problem**  
Achievement Rewards for College Scientists: Scholar Presentations, Honolulu, HI, 2011
- **The Finite Lattice Representation Problem**  
First Joint Meeting of the Korean and American Mathematical Societies, Seoul, KOR, 2009
- **Object reconstruction from multiple views**  
Air Force Office of Scientific Research AMOS Program Review, Maui, 2004
- **Approximating eigenvalues of large stochastic matrices**  
8th Copper Mt. Conference on Iterative Methods, Colorado, 1998

## Service

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- **Organizer**, BLAST 2019 Conference, Boulder, 2019
- **Organizer**, Algebras and Lattices in Hawaii Conference, to honor Freese, Lampe & Nation, Honolulu, 2018
- **Organizer**, Workshop on Computational Universal Algebra, Louisville, 2013
- **Editor**, Algebra Universalis, 2018–
- **Referee**, Algebra Universalis, Order, and J. Logic & Analysis, 2012–
- **Graduate Student Representative**, Working Group on Graduate Education, University of Hawaii  
Graduate Student Representative on a committee of deans and department heads; helped draft a resolution for the Committee on Research and Graduate Education.
- **Faculty Senate Student Rep., Academic Committee Chair, Math Department Rep.**, Graduate Student Organization, University of Hawaii
- **Mentor for Undergraduate Research**, Mathematical Biology Program, University of Hawaii  
Mentored students in math and dsp for classifying marine life audio signals.

## Advising and mentoring

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- **University of Colorado, Boulder**  
Served on the doctoral candidacy exam committee for the following ph.d. students: Jordan DuBeau, Ali Lotfi, Athena Sparks, Michael Wheeler. Served on the dissertation defense committee for Jeffrey Shriner.
- **Iowa State University**  
REU mentor for Charlotte Aten (mathematics major, University of Rochester); honors thesis advisor for Joshua Thompson (mathematics major, honors program); Putnam Exam mentor at weekly exam practice meetings; Undergraduate Tea cohost of weekly undergraduate student gatherings; Iowa 4-H Youth Conference volunteer mentor.  
[Link](#)
- **University of South Carolina**  
Honors thesis mentor for Matthew Corley (computer science major, honors program); South Carolina High School Math Contest exam design committee; Faculty mentor for Pi Mu Epsilon (math honors society).

## Certifications

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- **Selected online coursework**  
Coursera certificates in Smart Contracts and Blockchain Basics (SUNY at Buffalo, 2021); Big Data Analysis with Scala and

Spark, Functional Programming Principles in Scala, Functional Program Design in Scala, and Parallel Programming in Scala (EPFL, 2016 and 2017); and Startup Engineering (Stanford University, 2013).

## Summer schools and short courses

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- **Agda Implementors' Meeting XXXIX**  
Chalmers University, 25–30 Nov 2024  
Proposed the code sprint on AI tooling for Agda.
- **Agda Implementors' Meeting XXXVIII**  
University of Swansea, 13–18 May 2024
- **Midlands Graduate School in the Foundations of Computing Science**  
Lambda calculus, simply typed lambda calculus, domain theory, denotational semantics, type theory, univalent type theory in Agda, homotopy type theory, category theory, proof theory, univalent foundations.
  - Univ. of Sheffield, virtual, April 12–16, 2021
  - Univ. of Birmingham, April 14–18, 2019
  - University of Birmingham, April 11–15, 2016
  - University of Nottingham, April 22–26, 2014
- **Oregon Programming Languages Summer School**  
University of Oregon  
Type theory, logic, semantics, verification, parallelism and concurrency, dependent, gradual, substructural type systems.
  - July 3–21, 2018
  - June 26–July 8, 2017
  - June 16–28, 2014
- **Computer-aided Mathematical Proof**  
Cambridge University, July 10–14, 2017  
Bringing proof technology into mainstream mathematics.
- **LMS/EPSRC Short Course in Computational Group Theory**  
University of St. Andrews, Jul 29–Aug 2, 2013  
Permutation & finitely presented groups, constructive recognition.
- **NATO ASI on Computational Noncommutative Algebra**  
Il Ciocco, Italy, 2003

## References

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- **Clifford Bergman**, Professor Emeritus of Mathematics, Iowa State University (teaching reference)
- **Venanzio Capretta**, Assistant Professor of Computer Science, University of Nottingham
- **Ralph Freese**, Professor of Mathematics, University of Hawaii
- **Peter Jipsen**, Professor of Mathematics, Chapman University
- **George McNulty**, Professor of Mathematics, University of South Carolina
- **Peter Mayr**, Professor of Mathematics, University of Colorado, Boulder (teaching reference)
- **J.B. Nation**, Emeritus Professor of Mathematics, University of Hawaii