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

2023– **Formal Verification Engineer**, Formal Methods Team, IO, Boulder
Machine-checked specification of the Cardano blockchain ledger in Agda, with the Formal Methods team. The formal spec 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 must type-check, compile, and agree with the system that live nodes run. It tracks the chain across hardforks. I am the single largest contributor by commits to the formal spec's repository; the design is described in our FMBC 2024 paper.
Project · Specification · Contributors

2022–2023 **Senior University Lecturer**, Computer Science, New Jersey Inst. of Technology, Newark
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 **Software Engineer**, Library Team, RelationalAI, New York
Developed the Standard Library of the Rel declarative programming language. 9 months.

2019–2021 **Postdoctoral Research Fellow**, Algebra Dept., Charles University, Prague

2017–2019 **Burnett Meyer Instructor**, Mathematics Dept., University of Colorado, Boulder

2016–2017 **Visiting Assistant Professor**, Mathematics Dept., University of Hawaii, Honolulu

2014–2016 **Postdoctoral Associate**, Mathematics Dept., Iowa State University, Ames

2012–2014 **Visiting Assistant Professor**, Mathematics Dept., Univ South Carolina, Columbia

2001–2006 **Senior Research Scientist**, Imaging Research Dept., Textron Systems Corp., Maui
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

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

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

- **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 Kurzweil–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). Over 330 literate modules and 65,000 lines of Agda, type-checked in CI against Agda 2.8.0; the documentation site publishes its current 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 Venanzio Capretta.
  Work in progress.
- **Complex Analysis Exams**
  Work in progress.
- **Real Analysis Exams**
  Work in progress.

Teaching

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

- **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

- **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

- **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

- **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

- **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

- **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