



Institute for Computer-Aided Reasoning in Mathematics

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Director

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Overview of the Institute



Institute for Computer-Aided
Reasoning in Mathematics

Overview

The *Institute for Computer-Aided Reasoning in Mathematics* will support:

- Interactive Proof Assistants and Formalization
- Automated Reasoning and Symbolic AI
- Machine Learning and Neural AI

In the press, these are, collectively, “AI for Mathematics.”

Overview

The digital library, Mathlib, has more than 225K theorems and 1.9M lines of code.

High-profile formalizations of contemporary research in Lean:

- The Liquid Tensor Experiment
- the Polynomial Freiman–Ruzsa Project
- a strengthening of Carleson’s Theorem

High-profile uses of symbolic AI:

- refutation of the Kaplansky unit conjecture
- the empty hexagons problem
- The equational theories project

High-profile advances in neural AI:

- DeepMind’s AlphaProof and AlphaGeometry
- sensitivity analysis in representation theory, knot theory
- reinforcement learning in graph theory and combinatorics
- finding singularities in PDEs

JUNE 8, 2024 | 12 MIN READ

AI Will Become Mathematicians' 'Co-Pilot'

Fields Medalist Terence Tao explains how proof checkers and AI programs are dramatically changing mathematics

BY [CHRISTOPH DRÖSSER](#)



Score on IMO 2024 problems



Graph showing performance of our AI system relative to human competitors at IMO 2024. We earned 28 out of 42 total points, achieving the same level as a silver medalist in the competition.

AlphaProof: a formal approach to reasoning

Overview

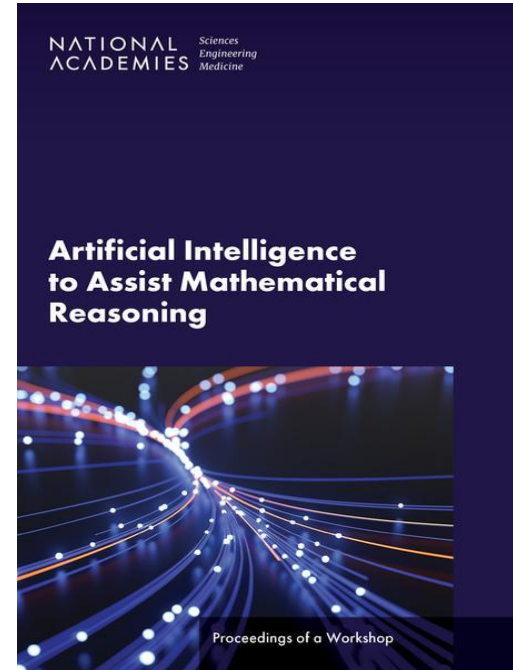
These technologies will impact mathematics:

- verification of mathematical results and mathematical computation
- communication and collaboration
- mathematical reference and search
- exploration and discovery of new mathematics
- teaching and learning

Overview

In 2023, a workshop by the *National Academies for Science, Engineering, and Medicine* explored the promise of these technologies and the challenges that lie ahead.

The *Institute for Computer-Aided Reasoning in Mathematics* is designed to meet the challenges.



Challenges

Challenges

The transformation is being driven by forces outside the core mathematical research community:

- Technological advances are coming from computer science.
- AI and formal methods are developed by industry (AWS, OpenAI, DeepMind, X.AI, Harmonic, ...).
- Lean is developed by the Lean Focused Research Organization.
- Early adopters are overwhelmingly postdocs, PhD students, or younger.

The academic mathematical community *must* be centrally involved.

Challenges

Machine learning and large language models raise a host of concerns:

- reliability
- explainability
- alignment.

Mathematical language, concepts, and rigor are needed to supplement these.

There is a growing awareness that a combination of neural and symbolic methods is the key to general intelligence, and that AI for mathematics is the frontier.

Challenges

As long as we continue to reason, deliberate, and communicate with one another, mathematical language and concepts will be essential.

Mathematics is fundamental to human endeavors from science and technology to public policy and finance.

We need to preserve mathematical values and maintain a mathematical outlook, and pass them on to the next generation.

The new technologies must enhance our ability to do mathematics, not replace it.

Meeting the Challenges



Institute for Computer-Aided
Reasoning in Mathematics

Meeting the Challenges

The mission of the *Institute for Computer-Aided Reasoning in Mathematics* is to:

- empower mathematicians to keep mathematics central to everything we do, in the face of technological change;
- unite mathematicians of all kinds, computer scientists, students, and researchers, to face the challenges together; and
- ensure that mathematics and the new technologies are accessible to everyone.

Empowering Mathematicians

Some key challenges:

- Existing tools aren't designed for mathematicians.
- Documentation isn't written for mathematicians.
- Mathematicians don't have the relevant expertise
- Collaborations are needed between computer scientists and mathematicians.
- Nobody "owns" AI for mathematics; it falls through the cracks.
- Some of the work is tedious, doesn't yield academic credit.
- The mathematics community doesn't know how to support/assess mathematicians using AI.

Empowering Mathematicians

We will maintain a staff of *innovation engineers* that will:

- help mathematicians learn to use the technologies
- answer questions and provide technical support
- maintain documentation, tools, infrastructure, and other community resources
- serve as liaisons to computer science and industry
- carry out essential tasks that academics don't have time or incentives to do
- be community leaders in the use of technology
- gather resources and coordinate efforts.

Bringing Us Together

We will also provide:

- workshops
- summer schools
- collaborative visits
- an annual conference

These will build a community of students, researchers, mathematicians, computer scientists, engineers, and others to address the challenges together.

We need a combination of perspectives and expertise.

Improving Access

Technology can help improve access to mathematics:

- Students anywhere can find learning resources on the web.
- AI and formal systems provide immediate feedback.
- Online communities provide friendship and support.

But social, economic, and psychological factors can have the opposite effect:

- Mathematics may become restricted to those who master the technology.
- Some communities may not have the resources to support the next generation in learning to use the technology.

Improving Access

AI and the digitization of mathematics can lead to greater democratization but it can also lead to greater inequities.

A central goal of ICARM is to ensure that all communities have the resources they need to participate in mathematics and take advantage of the new technologies.

Our original proposal included a summer school for college students, a workshop for graduate students, and an after-school program for high school students to address this challenge head on.

Practicalities

Institute Leadership

- **Director:** Jeremy Avigad (Professor, Philosophy and Mathematical Sciences, CMU)
- **Associate Director, Scientific Activities:** Matthew Ballard (Professor, Mathematics, USC)
- **Associate Director, Operations:** Prasad Tetali (Head, Mathematical Sciences, CMU)
- **Assistant Director, Scientific Activities:** Marijn Heule (Associate Professor, Computer Science, CMU)
- **Assistant Director, Scientific Activities:** Sean Welleck (Assistant Professor, Language Technologies Institute, CMU)
- **Assistant Director, Educational Activities:** Irina Gheorghiciuc (Director of Undergraduate Research, Mathematical Sciences, CMU)
- **Assistant Director, Outreach:** Michael Young (Associate Dean for Community Engagement, Mellon College of Science, CMU)
- **Assistant Director, Outreach:** Aris Winger (Associate Professor, Mathematics, Georgia Gwinnett College and Executive Director, NAM)

Governance

We will be overseen by:

- A scientific advisory board
- A strategic advisory board
- A university oversight board

We are in the process of establishing these.

Institute Space

- Temporary space in the Collaborative Innovation Center
- Centrally located on campus
- Offices for leadership and staff
- Offices for collaborative visits
- Room for a small workshop (30 people)
- Access to classrooms



Where We Stand

NSF invests over \$74 million in 6 mathematical sciences research institutes

From improving medical care to detecting planets in other solar systems, the institutes will explore mathematical sciences with a broad range of applications

August 4, 2025

The U.S. National Science Foundation is investing over \$74 million in six research institutes focused on the mathematical sciences and their broad applications in all fields of science, technology and many industries.

For over 40 years, NSF has funded Mathematical Sciences Research Institutes to serve as catalysts for U.S. research in mathematics and statistics and to produce mathematical innovations to rapidly address new and emerging challenges and opportunities. The institutes collectively investigate a wide range of mathematical research areas with potential impacts, including better patient outcomes in hospital emergency rooms, enhanced safety of semiautonomous vehicles, and detection of exoplanets using quantum physics. Previous research conducted at the institutes has had broad impacts, such as improved speed and accuracy of MRI imaging and the development of mathematical foundations of artificial intelligence-based technologies.

Our Current Status

The institute has been launched as a three-year pilot:

- 2-3 administrative staff
- 3 innovation engineers
- At least two workshops each year
- At least one summer school each year
- A conference in the second year
- Collaborative visits

Additional funding from the Simons Foundation is pending.

Getting Started

We are:

- Setting up administrative and financial infrastructure within CMU
- Constituting our governing boards
- Setting up our space
- Setting up our web pages and computing infrastructure
- Hiring staff and innovation engineers
- Starting to plan our first activities and events
- Collaborating with the other institutes

Getting Started

- Our [logo](#) is on the institute web pages.
- We are supporting special semesters on PDEs at SLMath with a [workshop](#) on formalization
- We have a [job ad](#) out for innovation engineers
- We will hold tutorials on SAT solving at the Joint Mathematics Meetings
- We are working on a spring workshop, "Algebraic Geometry, Computer Algebra, and Machine Learning" (François Charton, Matt Baker, ...)
- We will host the PI meeting for the [NSF AIMing program](#)
- We are working on a Lean summer school
- We will host a speaker and tutorial on neural methods for combinatorics at an ICM satellite meeting at CMU (Florian, Chris, and Kiumars organizing)

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