Why Lean is Winning

Dr.-Ing. Sebastian Ullrich
Head of Engineering, Lean FRO

Google Munich, February 25, 2026

Lean is an open-source programming language and proof assistant

Lean and its tooling are implemented in Lean. Lean is very **extensible**.

LSP, Parser, Macro System, Elaborator, Type Checker, Tactic Framework, Proof automation, Compiler, Build System, Documentation Authoring Tool.

Lean has a **small trusted kernel**, proofs can be exported and independently checked.

> "Lean is not just interesting as a theorem prover. It is an example of a ***well-designed, modern programming language*** that can serve as a model for current and future languages."
>
> — Harry Goldstein (University of Buffalo)

lean-lang.org

Recognition in 2025

JUNE 2025

ACM SIGPLAN Programming Languages Software Award

Recognizing Lean's impact on programming languages research and practice

*"Lean has had and continues to have a **broad impact** on industrial practice and scientific research. [...] Lean has become the **de facto choice for AI-based systems** of mathematical reasoning."*

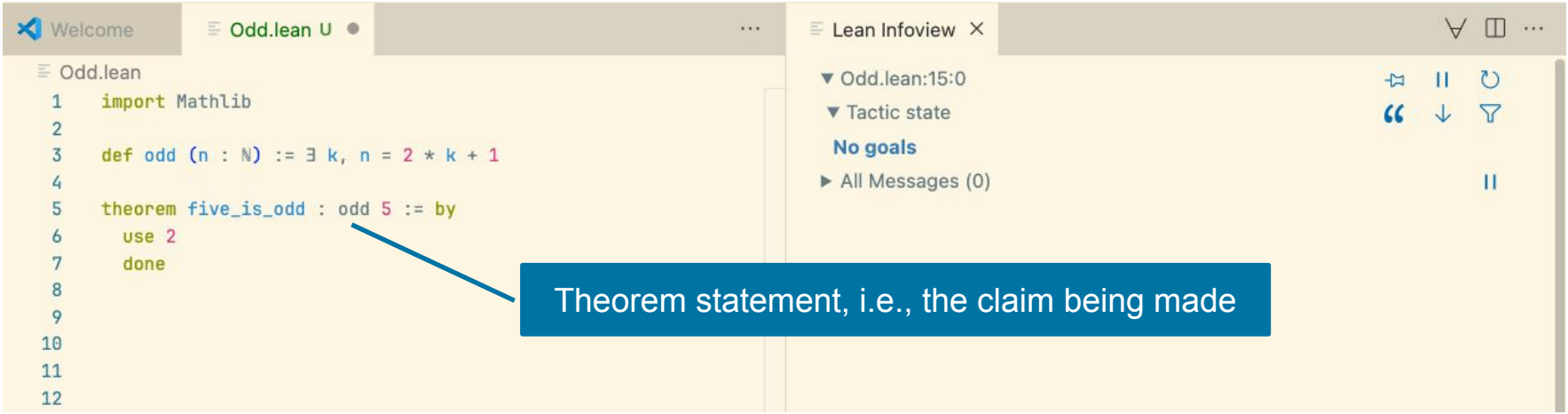
JULY 2025

Skolem Award (Test of Time)

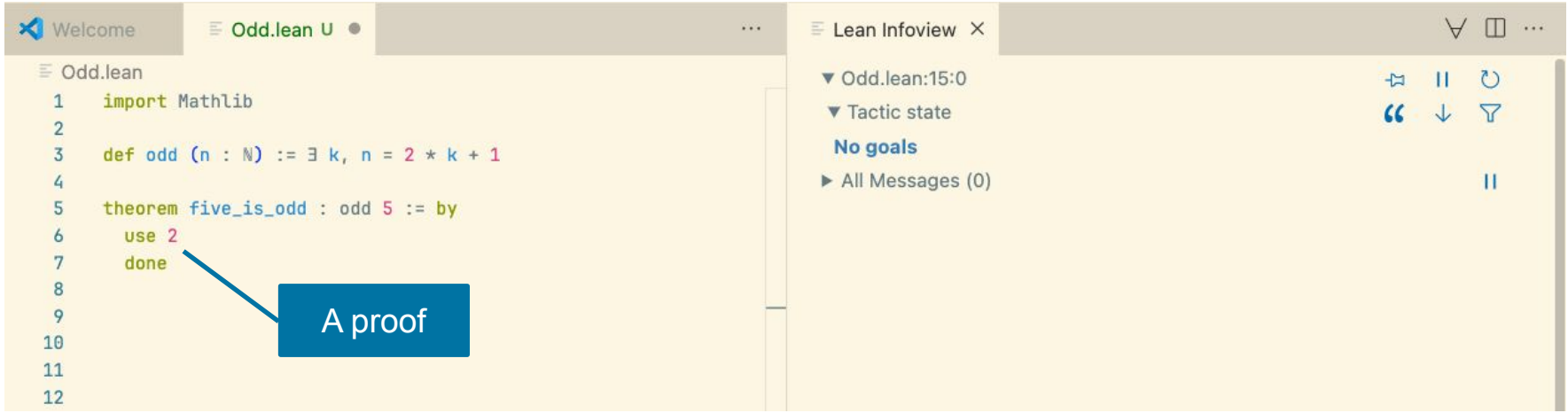
For the 2015 CADE paper "The Lean Theorem Prover (System Description)"

*"Lean [...] has a **tremendous impact** in interactive and automated reasoning, with numerous applications, in particular to **formalized mathematics** and **software verification**."*

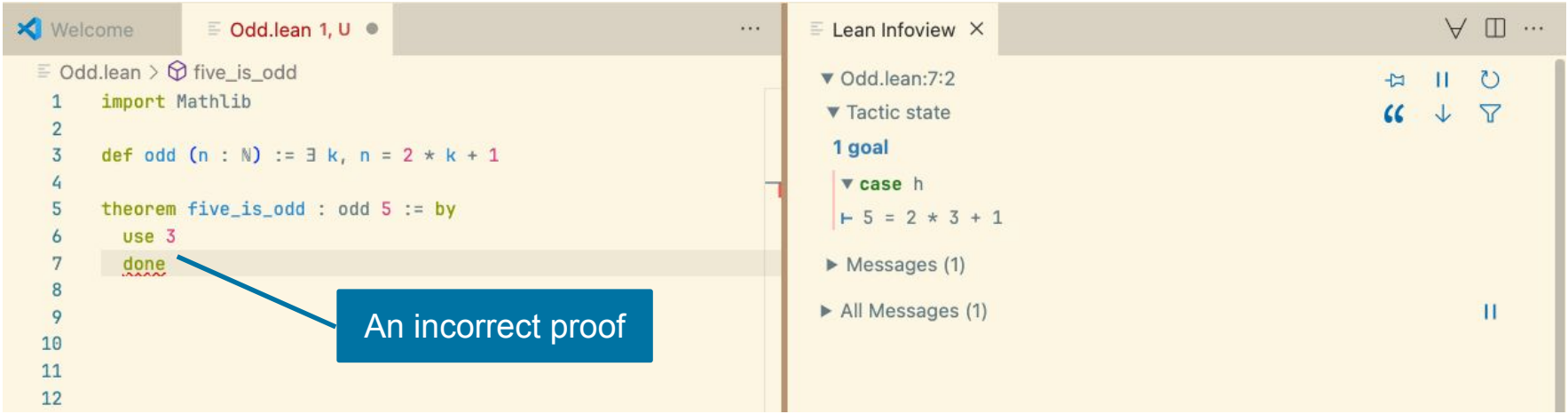
Our first theorem



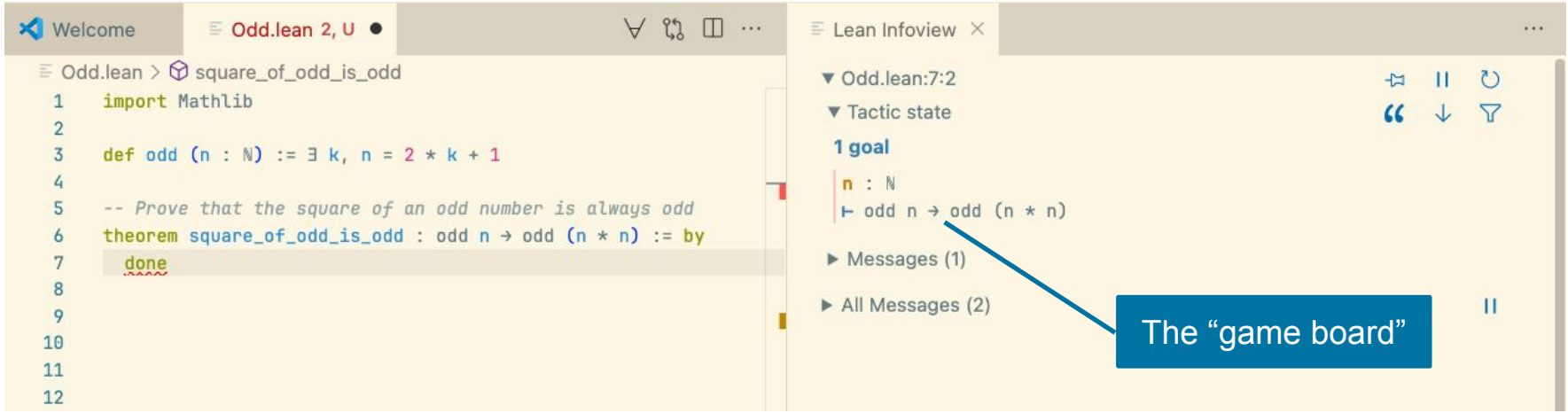
Our first theorem



Our first theorem



Theorem proving in Lean is an interactive game



“You have written my favorite computer game” – Kevin Buzzard (Imperial College London)


Mathematics
Software
AI

Mathematics

Mathlib github.com/leanprover-community/mathlib4

The Lean Mathematical Library supports a wide range of projects

It is an open-source **collaborative project** with over 750 contributors and 2.2M LoC

“I’m investing time now so that somebody in the future can have that amazing experience” – Heather Macbeth (Fordham University)

KEVIN HARTNETT SCIENCE OCT 11, 2020 8:00 AM

The Effort to Build the Mathematical Library of the Future

A community of mathematicians is using software called Lean to build a new digital repository. They hope it represents where their field is headed next.

The Challenge

In November of 2020, Fields medallist Peter Scholze posits the Liquid Tensor Experiment challenge

> *“I spent much of 2019* ***obsessed with the proof of this theorem****, almost getting crazy over it. In the end, we were able to get an argument pinned down on paper, but I think nobody else has dared to look at the details of this, and so* ***I still have some small lingering doubts****”*

Success

The full challenge was completed in Lean in July 2022 by a team under Johan Commelin.

The team not only verified the proof but also simplified it.
Moreover, they did this without fully understanding the entire proof.

> *"The Lean Proof Assistant was really that:* ***an assistant in navigating through the thick jungle*** *that this proof is. Really, one key problem I had when I was trying to find this proof was that I was essentially unable to keep all the objects in my RAM, and I think the same problem occurs when trying to read the proof"* – Peter Scholze

Only the Beginning

Independence of the Continuum Hypothesis, Han and van Doorn, 2021

Sphere Eversion, Massot, Nash, and van Doorn, 2020-2022

Unit Fractions, Bloom and Mehta, 2022

Consistency of Quine's New Foundations, Wilshaw and Dillies, 2022-2024

Polynomial Freiman-Ruzsa Conjecture, Tao and Dillies, 2023

Prime Number Theorem And Beyond, Kontorovich and Tao, 2024-ongoing

Carleson Project, van Doorn, 2024-2025

Equational Theories Project, Tao, Monticone, and Srinivas, 2024-2025

Fermat’s Last Theorem, Buzzard, 2024-ongoing

Sphere Packing, Birkbeck et al., 2025-ongoing

Software

Lean in Software Verification

Lean is a programming language, and is used in **many software verification projects**

You can write code and reason about it simultaneously

You can prove that your code has the properties you expect

> *"Testing can show the presence of bugs, but not their absence"* – E. Dijkstra

Lean is not only for verified programming: it comes with a rich standard library with async I/O and networking, date time types, concurrency primitives, verified collection types, iterators, …

SampCert

A project led by Jean-Baptiste Tristan at AWS

An **open-source** Lean library of formally **verified differential privacy primitives**

Their implementation is not only verified, but it is also **twice as fast as the previous one**

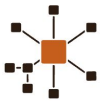
They managed to implement **aggressive optimizations** because Lean served as a guide, ensuring that **no bugs** were introduced

Many more open-source projects

Arklib (Ethereum Foundation), a SNARK verification framework

AMO-Lean (Lambda), a verified optimizing compiler for cryptographic primitives

FLoPS (Rutgers), a formalization of the upcoming IEEE P3109 floating-point standard



CSLib : A Focused Effort on Formalizing Computer Science in Lean

Supported by: AWS, Google DeepMind, SDU, Centaur (Stanford)

Software Verification Ecosystem

Velvet (NUS), an imperative program verifier embedded in Lean

Aeneas (Inria/MSR/Google), a Rust verifier via translation to Lean

Strata (AWS), a unified platform for formalizing language syntax and semantics

mvcgen (Lean FRO), a verification framework for monadic Lean programs

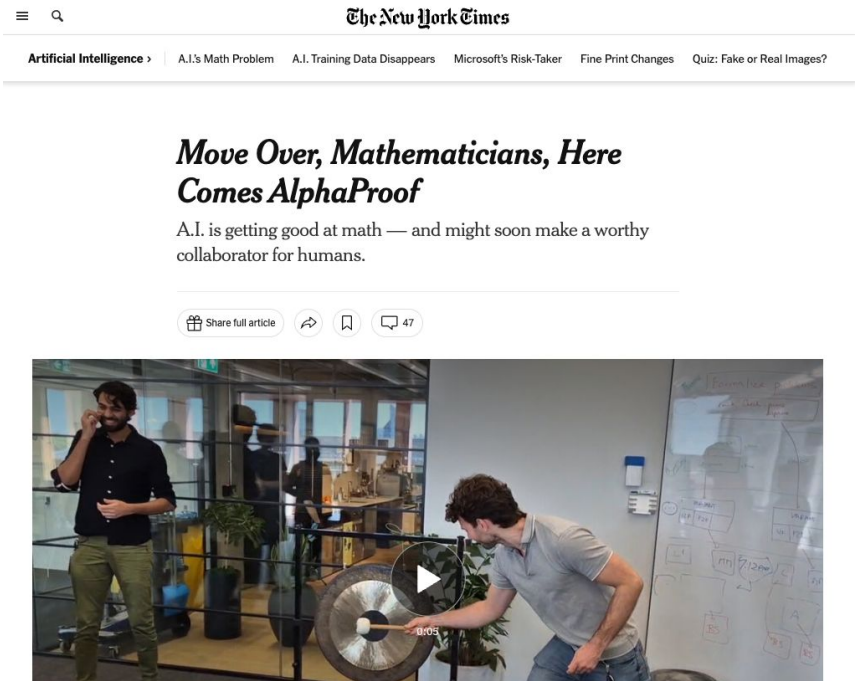
AI

Lean Enables Verified AI for Mathematics and Code

LLMs are powerful tools, but they are prone to **hallucinations**

In math, a **small mistake can invalidate the whole proof**

Machine-checkable proofs are the antidote to hallucinations



"At Google DeepMind, we used Lean to build AlphaProof, a new reinforcement-learning based system for formal math reasoning. ***Lean's extensibility and verification capabilities were key in enabling the development of AlphaProof****." — Pushmeet Kohli, Vice President of Research, Google DeepMind*

AlphaProof & the International Math Olympiad

Determine all real numbers α such that, for every positive integer n, the integer

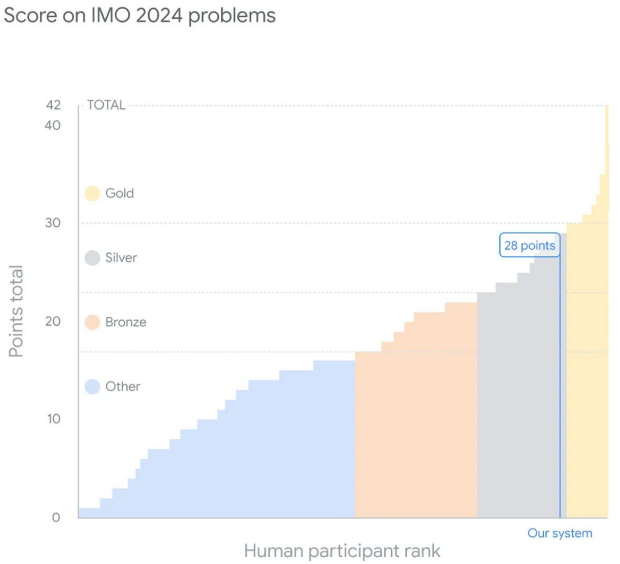
$$\lfloor \alpha \rfloor + \lfloor 2\alpha \rfloor + \cdots + \lfloor n\alpha \rfloor$$

is a multiple of n. (Note that $\lfloor z \rfloor$ denotes the greatest integer less than or equal to z. For example, $\lfloor -\pi \rfloor = -4$ and $\lfloor 2 \rfloor = \lfloor 2.9 \rfloor = 2$.)

Solution: α is an even integer.

```
open scoped BigOperators

theorem imo_2024_p1 :
    {(α : ℝ) | ∀ (n : ℕ), 0 < n → (n : ℤ) | (∑ i in Finset.Icc 1 n, ⌊i * α⌋)}
    = {α : ℝ | ∃ k : ℤ, Even k ∧ α = k} := by
  rw [(Set.Subset.antisymm_iff ), (Set.subset_def), ]
  /- We introduce a variable that will be used
     in the second part of the proof (the hard direction)
```



deepmind.google/discover/blog/ai-solves-imo-problems-at-silver-medal-level

IMO 2025: 3 Gold, 1 Silver

OpenAI (informal)

DeepMind (informal)

Advanced version of Gemini with Deep Think officially achieves gold-medal standard at the International Mathematical Olympiad

Harmonic (Lean)

Aristotle Achieves Gold Medal-Level Performance at the International Mathematical Olympiad, iOS App Beta Launch

ByteDance (Lean)

ByteDance Seed Prover Achieves Silver Medal Score in IMO 2025

Putnam Bench is Next – Already Being Solved with Lean

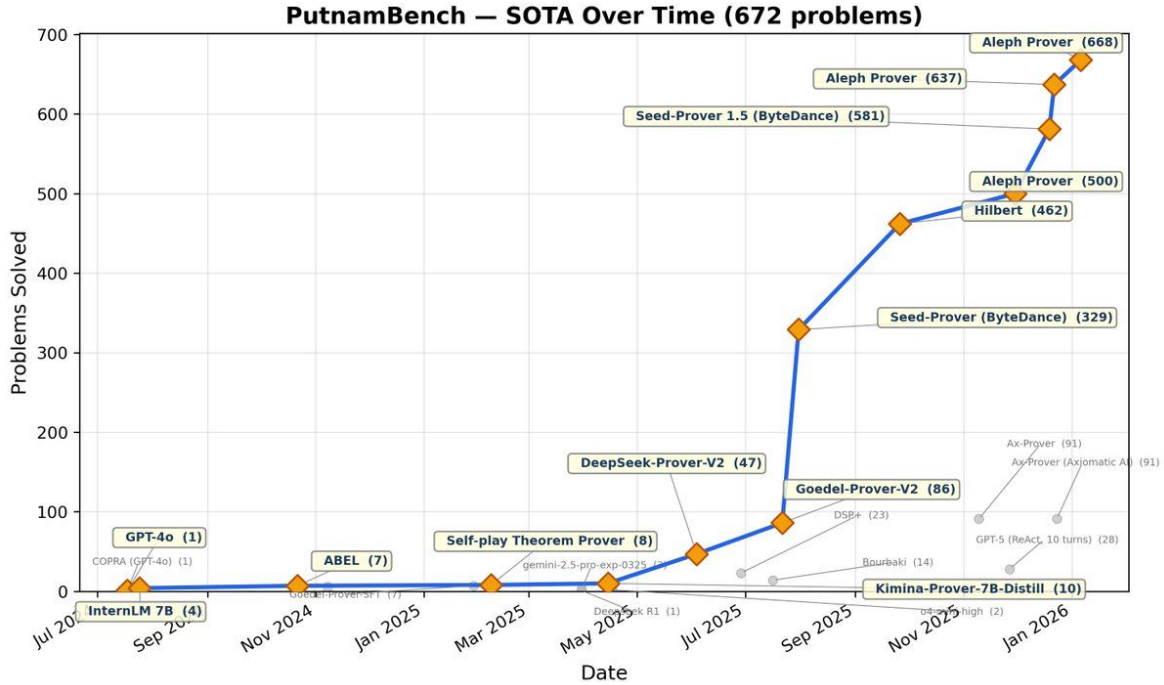


Illustration by Vasily Ilin (University of Washington), x.com/IlinVasily29521

Attacking Open Problems from Literature

Harmonic @HarmonicMath · Nov 29
Mathematical superintelligence is coming, faster than you imagined

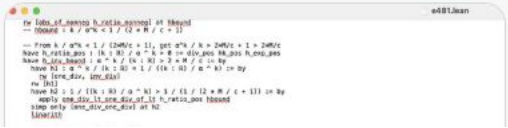
> **Vlad Tenev** @vladtenev · Nov 29
> We are on the cusp of a profound change in the field of mathematics. Vibe proving is here.
>
> Aristotle from @HarmonicMath just proved Erdos Problem #124 in @leanprover, all by itself. This problem has been open for nearly 30 ...
> Show more

17 40 561 89K

Axiom reposted

Carina Hong @CarinaLHong · Dec 2
AxiomProver solved Erdos problem #481 - took 5 hours

#124 simplified version took over 24 hours (oof) and was not as succinct as we'd like it to be



Logical Intelligence
@logic_int

🚀 Aleph prover just went BEAST MODE
4 math problems unsolved for 20+ years. Formal proofs in Lean 4. Less than 48 hours. Under $5k total.

✅ Binomial tail bounds conjecture (Telgarsky, 2009)
✅ Quantum gate lattice approximation (Greene & Damelin, 2015)*
✅ Erdős 124
✅ Erdős 481
✅ #1 on PutnamBench leaderboard

The era of AI mathematics is here.

Harmonic @HarmonicMath · Nov 30
✅

> **Bartosz Naskręcki** @nasqret · Nov 29
> Aristotle by @Harmonic is acing group-theory puzzles.
>
> Here is a complete formal proof of the popular Yu Tsumura 554 puzzle. What's nice is that the proof is very transparent, with easy-to-follow steps. It was generated in less than an hour without any hints. I am ...
> Show more

Startups using Lean & AI

Harmonic

Axiom

Math, Inc.

Logical Intelligence

Axiomatic_AI

...and more to come

A thriving startup ecosystem validates Lean as the platform of choice for verified AI reasoning

Wrap-Up

Lean FRO: Shaping the Future of Lean Development

The Lean Focused Research Organization (FRO) is a non-profit dedicated to Lean's development.

Its mission is to enhance critical areas: **scalability**, **proof automation, usability**, and **documentation.**

Founded in **August 2023**, the organization has 21 members.

We are very grateful for all philanthropic support we have received.

It must reach **self-sustainability in August 2028** and become the **Lean Foundation**.

29 releases and **7,500+ merged pull requests** in the main repository only since its launch in July 2023.

Lean being neither an industry nor academic product, we run the FRO as a startup.

The Lean FRO team

The Lean FRO team … in Europe











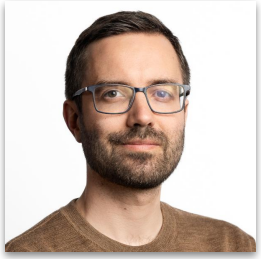
The Lean FRO team … in Germany








The Lean FRO team … in Munich



Conclusion

Lean is an **efficient programming language** and **proof assistant – no compromise**

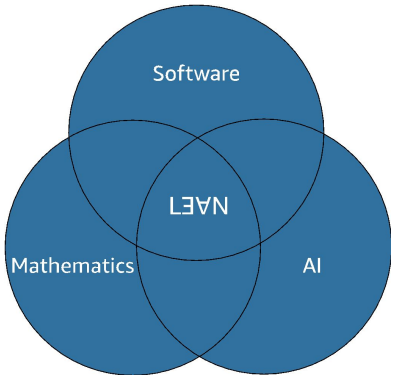
Lean is very **extensible** and is implemented in Lean: the ultimate extensibility test.

Proofs are machine-checkable, maintainable, and auditable.

The Lean FRO is shipping: module system, new compiler, grind, more to come.

Mathlib is changing how math is done.

Our goal: make verified software the norm, not the exception.



Thank You…

to Vangelis Parasidis and Google Munich for hosting us

to Christian Pfrang for the conception and organization

to you for joining us today!

Questions? Hungry?

lean-lang.org
lean-fro.org
Community chat: leanprover.zulipchat.com
Mastodon: @leanprover@functional.cafe