Monthly Community Meeting

Lean FRO
13 October 2023

Focused Research Organization (FRO)

A new type of nonprofit startup for science developed by Convergent Research.

convergentresearch.org

CONVERGENT RESEARCH
A member of the Schmidt Futures Network

The Lean FRO

Missions:

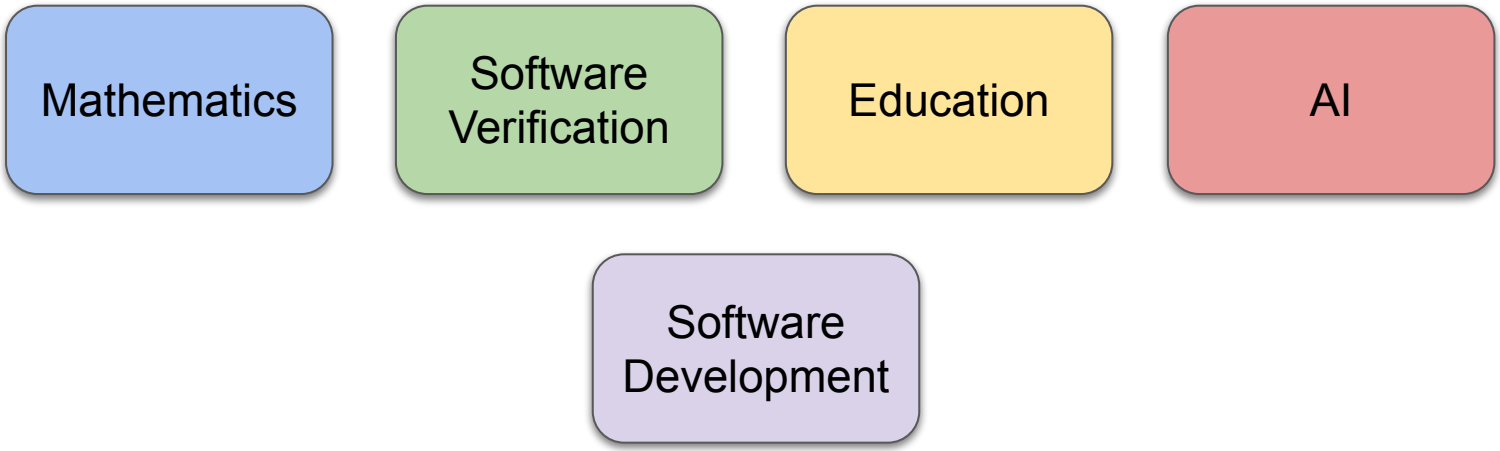
- Address **scalability**, **usability**, and **proof automation** in Lean.
- Support formal mathematics.
- Achieve self-sustainability in 5 years.

~7 FTEs by end of year

Supported by Simons Foundation International, Alfred P. Sloan Foundation, and Richard Merkin

lean-fro.org

The Lean FRO serves the Lean community



The Lean FRO: team

Leo de Moura (AWS)
Chief Architect, Co-Founder

Sebastian Ullrich
Head of Engineering, Co-Founder

Joachim Breitner
Senior Research Software Engineer

David Thrane Christiansen
Senior Research Software Engineer

Joe Hendrix
Principal Research Software Engineer

Marc Huisinga
Research Software Engineer

Mac Malone
Research Software Engineer

Scott Morrison
Senior Research Software Engineer

The Lean FRO: team responsibilities

- **Leo** (Chief Architect): technical direction, management, backend.
- **Sebastian** (Head of Engineering): management, frontend.
- **Joachim Breitner**: backend.
- **David Christiansen**: documentation tools, documentation, outreach, frontend.
- **Joe Hendrix**: management, standard library, sledgehammer.
- **Marc Huisinga**: language server, VS Code plugin.
- **Mac Malone**: Lake, frontend.
- **Scott Morrison**: Mathlib & Lean, standard library, AI ambassador, proof automation.

Backend = kernel, compiler, proof automation.

Frontend = parser, macro system, elaborator.

Development philosophy: ownership model

- Each file/model has a clear **owner** that is responsible for raising the bar.
  - Code is properly documented & tested.
  - Merging PRs that affect the module.
- Owner must be a Lean FRO employee.
- **Long-term goal**: transfer the ownership of many existing files.
- **Challenge**: we need more tests and benchmarks.

RFC & Pull requests

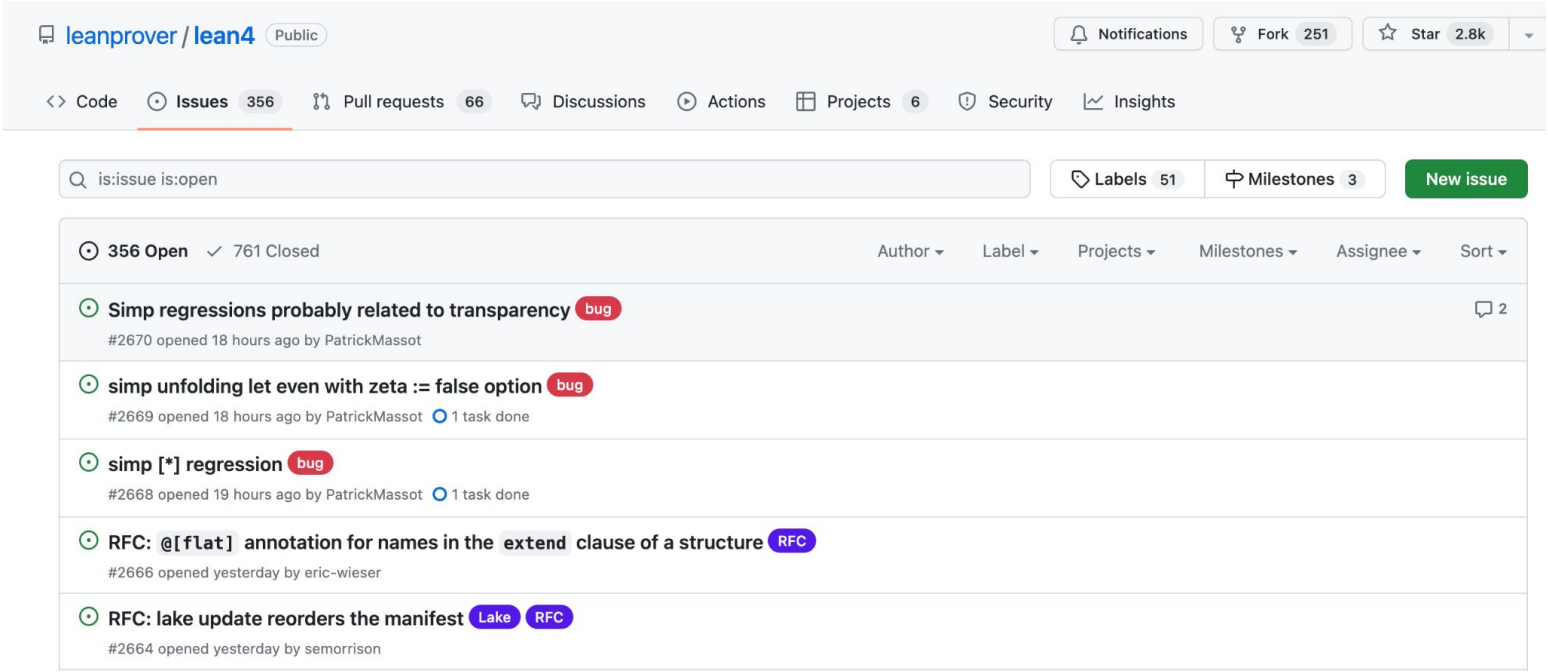
- https://github.com/leanprover/lean4/blob/master/doc/contributions.md
- Before You Submit a Pull Request, Start with an Issue.
  - **User Experience**: How does this feature improve the user experience?
  - **Beneficiaries**: Which Lean users and projects do benefit most from this feature/change?
  - **Community Feedback**: Have you sought feedback or insights from other Lean users?
  - **Maintainability**: Will this change streamline code maintenance or simplify its structure?
- Quality over Quantity.
- Coding Standards.

RFC & Pull requests

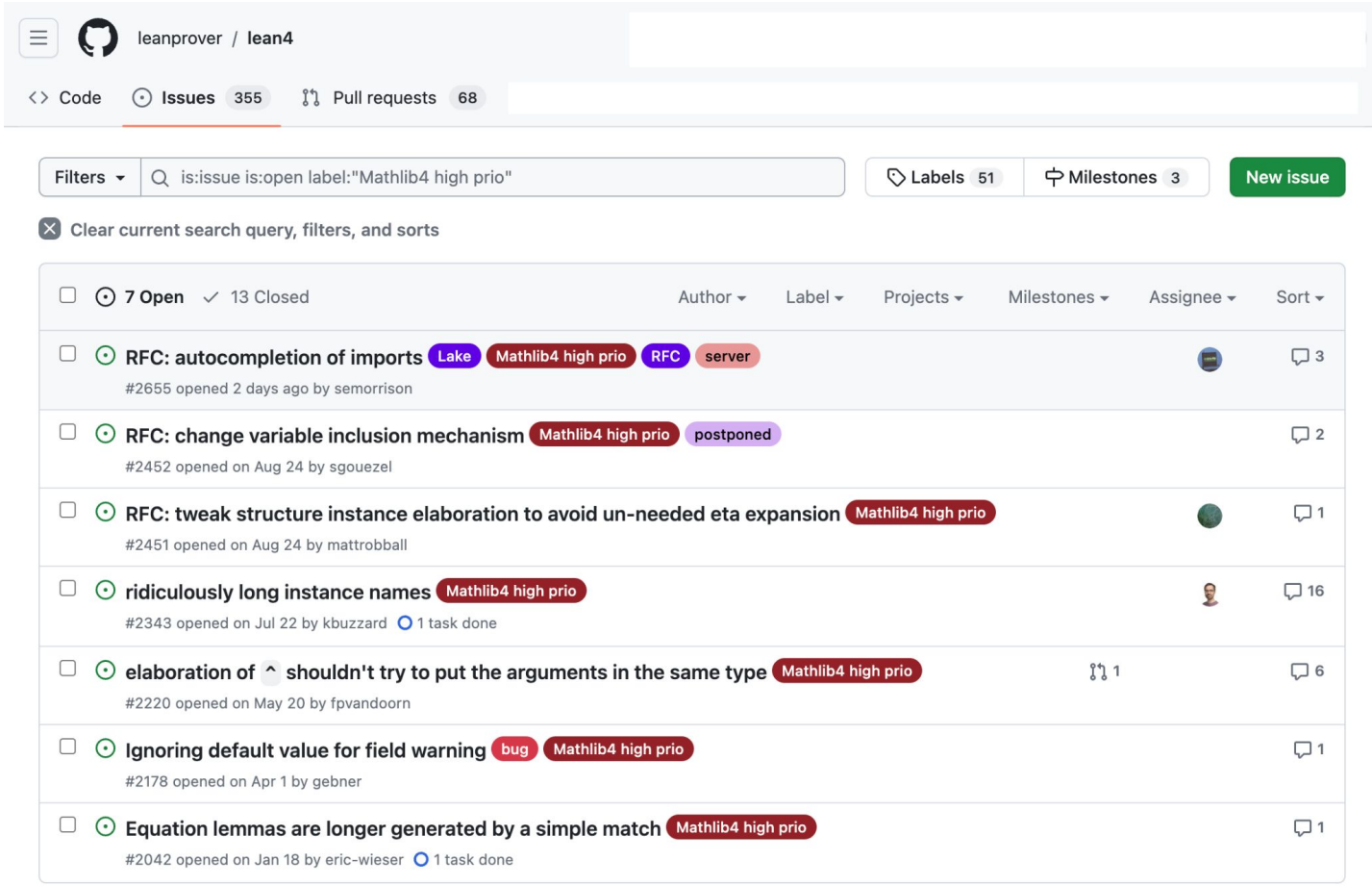
- Reviews and Feedback:
  - **Be Patient**: Given the limited number of full-time maintainers and the volume of PRs, reviews take some time.
  - **Engage Constructively**: Always approach feedback positively and constructively.
  - **Continuous Integration**: Ensure that all CI checks pass on your PR. Failed checks delay the review process.
- What to Expect:
  - **Not All PRs Get Merged**: While we appreciate every contribution, not all PRs will be merged.
  - **Feedback is a Gift**: It helps improve the project and can also help you grow as a developer.
  - **Community Involvement**: Engage with the Lean community on our communication channels. This can lead to better collaboration and understanding of the project's direction.

From Achievements to Aspirations: A Glimpse of Our Journey and Horizon

Issues will be addressed



We know the Mathlib community desperately needs many issues fixed.



Lean releases

- Monthly stable releases with release candidates
  - Mathlib tracks release candidates (currently `v4.2.0-rc1`)
  - `nightly-testing` branch on Mathlib tracks Lean nightlies

- Lean PRs generate their own toolchain
  - `leanprover/lean4-pr-releases:pr-release-NNNN`
  - and automatically test Mathlib against this on a `lean-pr-testing-NNNN` branch
  - If your PR breaks Mathlib, please try to fix it, or ask for help!

We have our own servers now!!!

speed.lean-lang.org

loogle.lean-lang.org

live.lean-lang.org

reservoir.lean-lang.org

New domain name: **lean-lang.org**

Loogle!

#find

Try these

- `Real.sin`
- `Real.sin, tsum`
- `Real.sin (_ + 2*Real.pi)`
- `List.replicate (_ + _) _`
- `Real.sqrt ?a * Real.sqrt ?a`

Documentation

This website gives access to mathlib's `#find` command:

The `#find` command finds definitions and lemmas in various ways. One can search by: the constants involved in the type; a substring of the name; a subexpression of the type; or a subexpression located in the return type or a hypothesis specifically. All of these search methods can be combined in a single query, comma-separated.

1. By constant:

   ```
   #find Real.sin
   ```

   finds all lemmas whose statement somehow mentions the sine function.

2. By lemma name substring:

   ```
   #find "differ"
   ```


live.lean-lang.org/#code=inductive%20Palindrome%20%3A%20List%20α%20→%20Prop%20where%0A%20%20%7C%20nil%20%20...
Finish update
inductive Palindrome : List α → Prop where
| nil : Palindrome []
| single : (a : α) → Palindrome [a]
| sandwich : (a : α) → Palindrome as → Palindrome ([a] ++ as ++ [a])
theorem palindrome_reverse (h : Palindrome as) : Palindrome as.reverse := by
induction h with
| nil => exact Palindrome.nil
| single a => exact Palindrome.single a
| sandwich a h ih => simp; exact Palindrome.sandwich _ ih
theorem reverse_eq_of_palindrome (h : Palindrome as) : as.reverse = as := by
induction h with
| nil => rfl
| single a => rfl
| sandwich a h ih => simp [ih]
example (h : Palindrome as) : Palindrome as.reverse := by
simp [reverse_eq_of_palindrome h, h]
def List.last : (as : List α) → as ≠ [] → α
| [a], _ => a
| _::a₂:: as, _ => (a₂::as).last (by simp)
▼LeanProject.lean:16:22
▼Tactic state
▼case sandwich
α† : Type u_1
as as† : List α†
a : α†
h : Palindrome as†
ih : List.reverse as† = as†
⊢ List.reverse ([a] ++ as† ++ [a]) = [a] ++ as† ++ [a]
▼Messages (1)
▼LeanProject.lean:16:15
unused variable `h` [linter.unusedVariables]
▶ All Messages (1)

`lean4checker`

Lean is a general programming language, with powerful metaprogramming.
You can use metaprogramming to corrupt the whole system.

The new `lean4checker` tool allows easy reverification of files or libraries.

In Mathlib CI now!

We must to port Lean 3 external checkers to Lean 4!

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In Mathlib CI now!

We must to port Lean 3 external checkers to Lean 4!

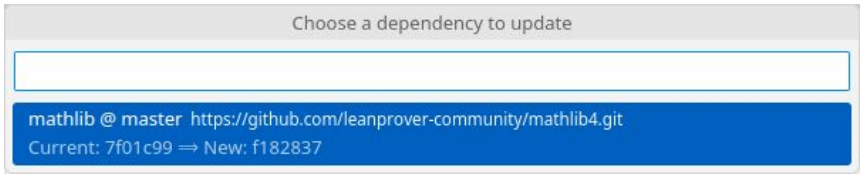
Mario just released Lean4Lean last night!!!

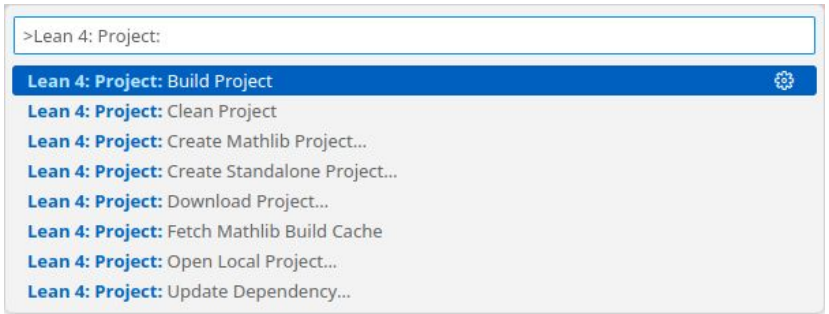
VS Code Extension Progress - Project Commands

Creating projects: Standalone (`lake new`) & Mathlib (`lake new math`)

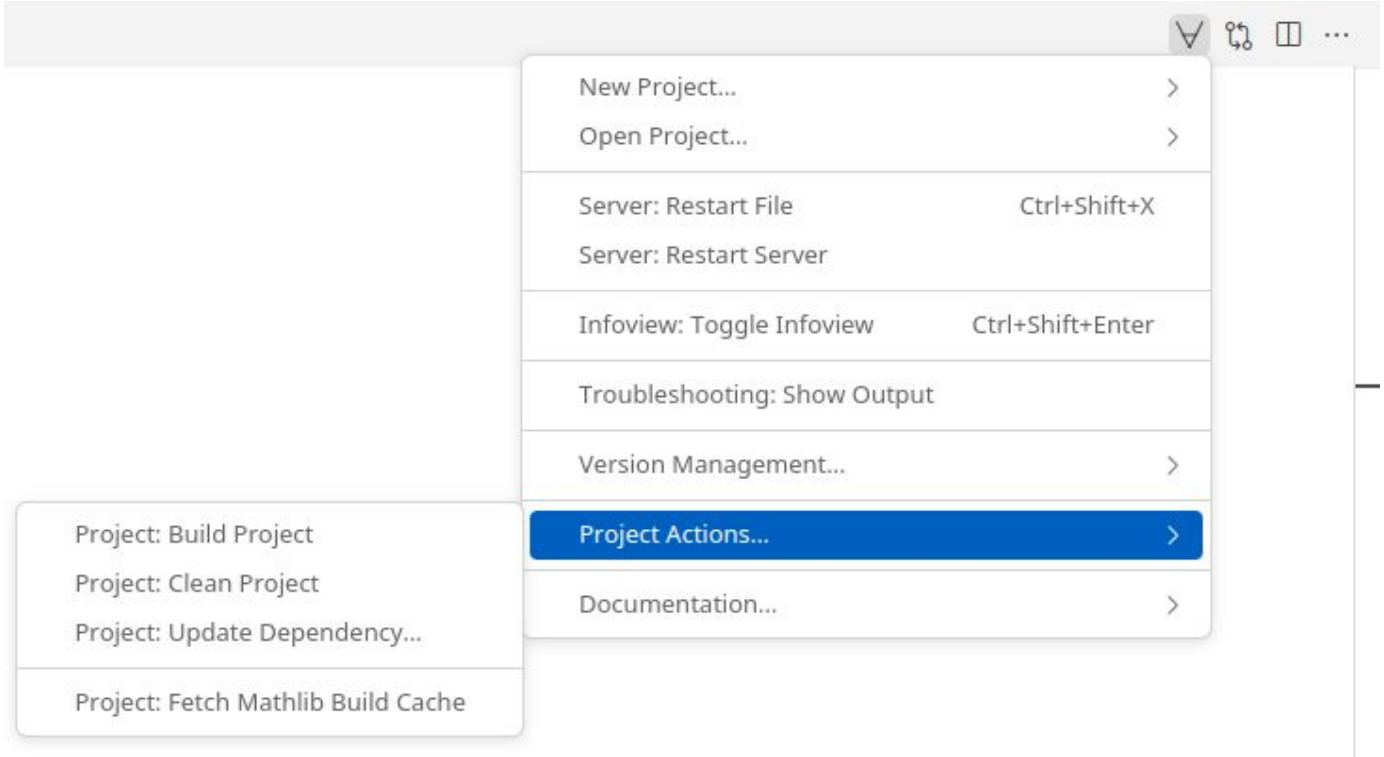
Opening projects: Local & Remote (via `git clone`)

Managing projects: `lake build`, `lake clean`, `lake exe cache get` and `lake update <...>`

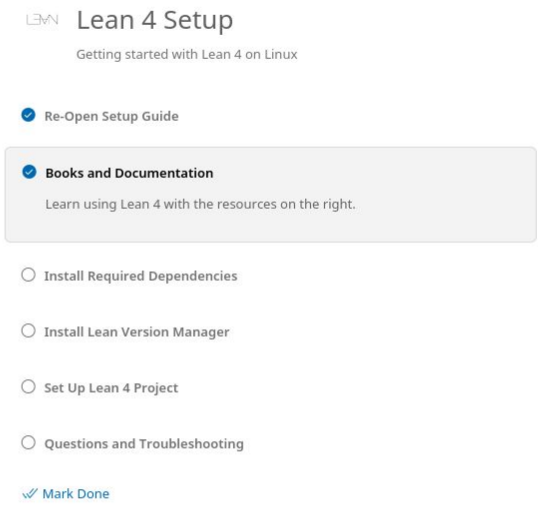




VS Code Extension Progress - Command Menu



VS Code Extension Progress - Walkthrough



Books

If you want to learn Lean 4, choose one of the following introductory books based on your background. If you are getting stuck or have any questions, click on the 'Questions and Troubleshooting' step at the bottom on the left side.

- Functional Programming in Lean
  The standard introduction for using Lean 4 as a general-purpose programming language.
- The Mechanics of Proof
  An introduction to Lean 4 as an interactive theorem prover for anyone who also wants to learn how to write rigorous mathematical proofs.
- Mathematics in Lean
  The standard introduction to Lean 4 as an interactive theorem prover for users with a mathematics background.
- Theorem Proving in Lean 4
  The standard reference for using Lean 4 as an interactive theorem prover. Suited as an introduction for users with a computer science background, advanced users and for general use as a reference manual.

Once you have completed one of these books and its exercises, you are ready to use Lean 4 for your own projects. If you want to use Lean 4 both as a general-purpose programming language and an interactive theorem prover, it is recommended to read both Functional Programming in Lean and Theorem Proving in Lean 4.

Hands-On Tutorial

If you want to dive right into using Lean 4 to prove elementary theorems about natural numbers, you can play the Natural Number Game. It can be played online using your browser without a local installation.

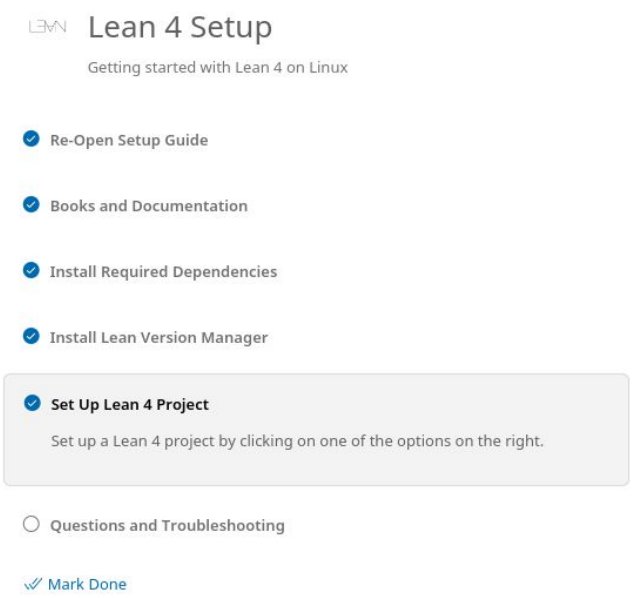
Additional Resources

Website
Lean's website links to learning resources, publications, talks and articles about Lean.

Lean Community
The Lean Community website links to several other helpful learning resources not listed here and provides an introduction to mathlib, Lean's math library.

Manual
The Lean Manual documents several features of Lean 4 and can be consulted for some of the more technical details concerning Lean.

VS Code Extension Progress - Walkthrough



Project Creation

If you want to create a new project, click on one of the following:

- Create a new standalone project
  Standalone projects do not depend on any other Lean 4 projects. Dependencies can be added by modifying 'lakefile.lean' in the newly created project as described here.
- Create a new mathlib project
  Mathlib projects depend on mathlib, the math library of Lean 4.

If you want to open an existing project, click on one of the following:

- Download an existing project
- Open an existing local project

After creating or downloading a project, you can open it in the future by clicking the ∀-symbol in the top right, choosing 'Open Project...' > 'Open Local Project...' and selecting the project you created.

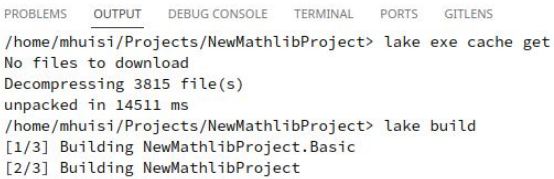
Complex Project Setups

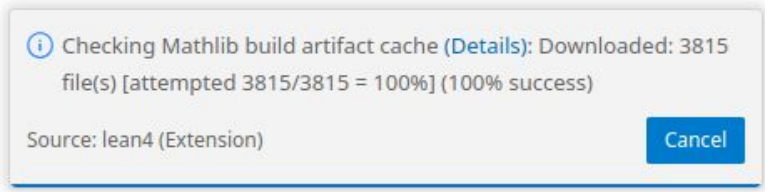
Using its build system and package manager Lake, Lean 4 supports more complex project setups than the ones described above. You can find out more about Lake in the Lean 4 GitHub repository.

VS Code Extension Progress - Other

- Lean client startup progress bar
  (no confusion while waiting for yellow bars to appear!)
- Better command output for troubleshooting purposes
- Cancellable external commands
- Opt-in for automatically building dependencies when opening files

Full list with more details on Zulip after the community meeting.





Plans - VS Code Extension

Short term plans:

- Fix race conditions in abbreviations that lead to inconsistent behavior
- Detect possibly outdated or broken setups and inform users about it

Rough long term plans:

- Add multi-toolchain single-folder workspace support
- Re-evaluate Live Share support after Sebastian's elaboration rework
- Use updated Lean 4 extension syntax highlighting on GitHub

Plans - Language Server

Short term plans:

- Add **import auto-completion**
- Improve find-references & auto-completion
- Implement call hierarchy

Rough long term plans:

- Integrate more **code actions** into core
- Make **language server more extensible**
- Improve tactic auto-completion
- Improve **trace browsing**

Lake

- There a have been a number of fixes, touch-ups, feature additions, and **performance improvements** to Lake since the launch of the FRO
- Some highlights:
  - `lake update <pkg>` and improved `lake update` error messages
  - Overhauled `lake env` that works without a lake configuration
  - Better `lake new/init` that provides a multi-file directory structure for libraries, fixes some previous bugs in naming, and uses the elan toolchain for the Lean version
  - Cache output file hashes and the elaborated configuration to improve performance
  - Lake is now part of doc-gen4's core documentation

Lake Startup Time

A number of performance improvements landed for Lake since Lean v4.0.0.
Cumulatively, these make for a **~4-6x** speedup in Lake startup time for mathlib.

macOS

```
$ hyperfine "lake-v4 build cache" "lake-nightly build cache" -w3 # no-op build
Benchmark 1: lake-v4 build cache
  Time (mean ± σ):     963.9 ms ±   3.7 ms    [User: 762.0 ms, System: 271.0 ms]
  Range (min … max):   957.4 ms … 967.3 ms    10 runs

Benchmark 2: lake-nightly build cache
  Time (mean ± σ):     158.7 ms ±   3.3 ms    [User: 94.1 ms, System: 183.2 ms]
  Range (min … max):   155.6 ms … 168.4 ms    18 runs

Summary
  'lake-nightly build cache' ran
    6.07 ± 0.13 times faster than 'lake-v4 build cache'
```

Lake Startup Time

A number of performance improvements landed for Lake since Lean v4.0.0.
Cumulatively, these make for a **~4-6x** speedup in Lake startup time for mathlib.

Windows

```
$ hyperfine "lake-v4 build cache" "lake-nightly build cache" -w3 # no-op build
Benchmark 1: lake-v4 build cache
  Time (mean ± σ):      3.113 s ±  0.034 s    [User: 2.263 s, System: 0.865 s]
  Range (min … max):    3.063 s …  3.156 s    10 runs

Benchmark 2: lake-nightly build cache
  Time (mean ± σ):     714.6 ms ±  12.3 ms    [User: 300.6 ms, System: 428.8 ms]
  Range (min … max):   697.8 ms … 734.2 ms    10 runs

Summary
  'lake-nightly build cache' ran
    4.36 ± 0.09 times faster than 'lake-v4 build cache'
```

Cache Get Speed

For `lake exe cache get`, this translates to an overall ~2x no-op speedup, since the `cache` program itself has not had as many performance improvements.

macOS

```
$ hyperfine "lake-v4 exe cache get" "lake-nightly exe cache get" -w3 # no-op get
Benchmark 1: lake-v4 exe cache get
  Time (mean ± σ):      1.447 s ±  0.024 s    [User: 1.121 s, System: 1.259 s]
  Range (min … max):    1.420 s …  1.502 s    10 runs

Benchmark 2: lake-nightly exe cache get
  Time (mean ± σ):     638.5 ms ±  12.2 ms    [User: 454.8 ms, System: 1.128 s]
  Range (min … max):   622.4 ms … 663.5 ms    10 runs

Summary
  'lake-nightly exe cache' get ran
    2.27 ± 0.06 times faster than 'lake-v4 exe cache get'
```

Cache Get Speed

For `lake exe cache get`, this translates to an overall ~2x no-op speedup, since the `cache` program itself has not had as many performance improvements.

Windows

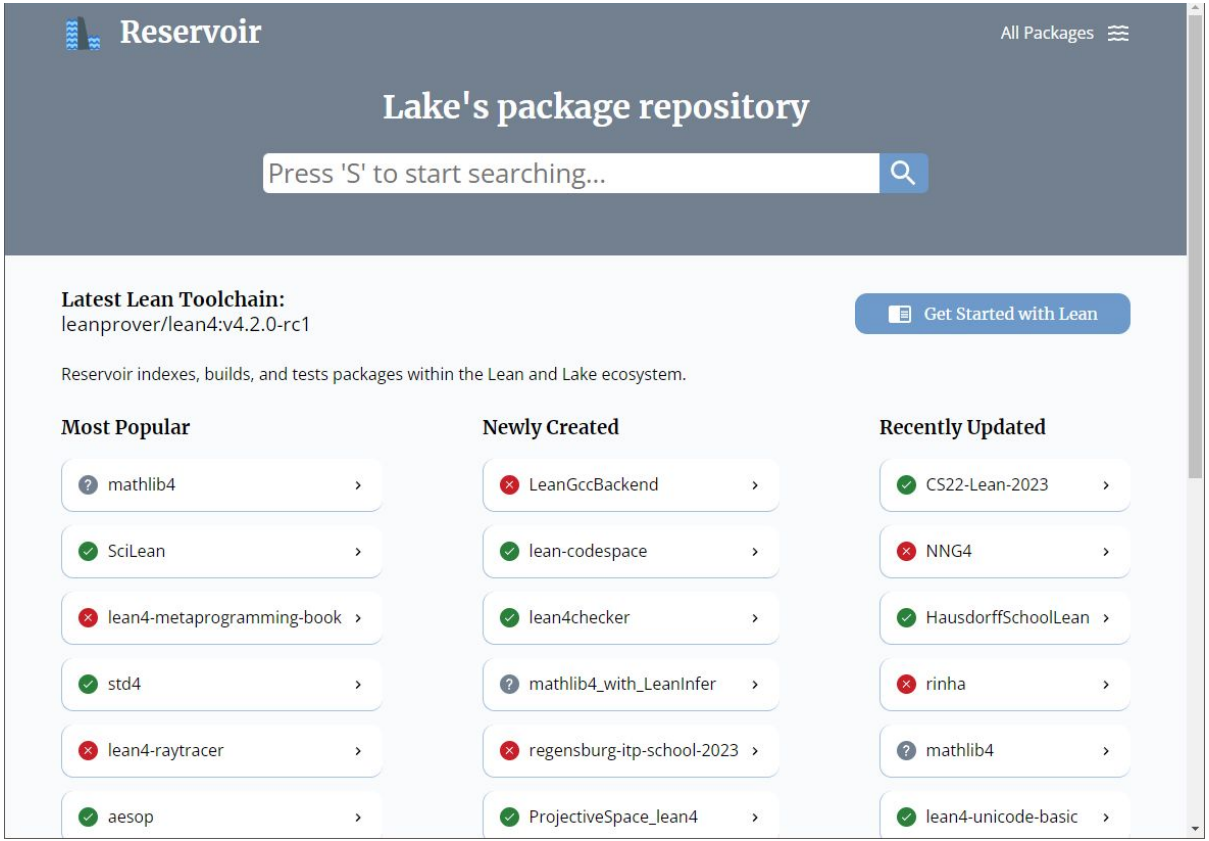
```
$ hyperfine "lake-v4 exe cache get" "lake-nightly exe cache get" -w3 # no-op get
Benchmark 1: lake-v4 exe cache get
  Time (mean ± σ):      5.121 s ±  0.127 s [User: 3.416 s, System: 2.401 s]
  Range (min … max):    5.008 s …  5.402 s     10 runs

Benchmark 2: lake-nightly exe cache get
  Time (mean ± σ):      2.682 s ±  0.016 s [User: 1.455 s, System: 1.890 s]
  Range (min … max):    2.662 s …  2.709 s     10 runs

Summary
  'lake-nightly lake exe cache get' ran
    1.91 ± 0.05 times faster than 'lake-v4 exe cache get'
```

Cloud Builds for All

- Our goal is to **provide a general service for caching cloud builds** that can meet the needs of both mathlib and other packages within the ecosystem (e.g., Kevin's FLT project, LeanInfer, FFIs, etc.)
- To do this effectively, Lean & Lake need a package index that can store metadata about packages and provide a online portal from which to distribute cloud builds.
- Thus, for this reason and others, we sought to create a package repository for Lean and Lake.

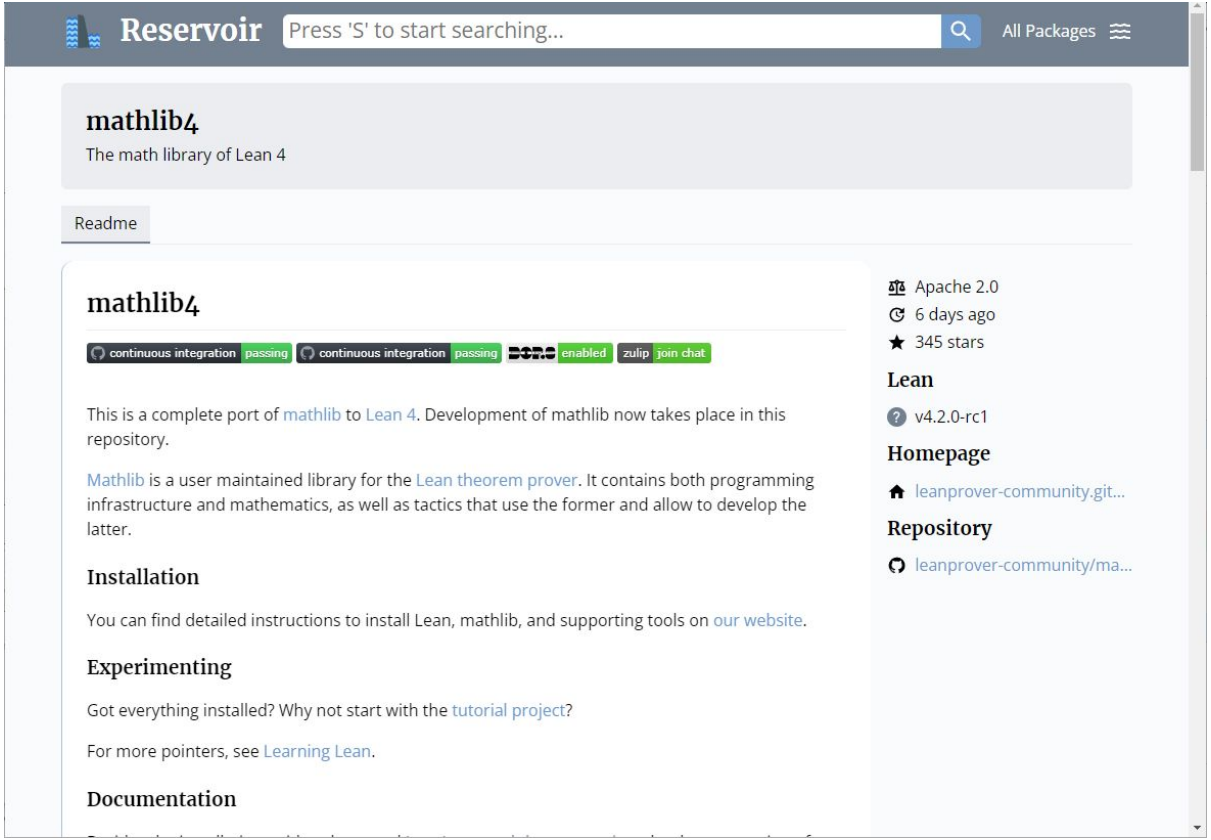
Reservoir

- crates.io for Lean/Lake
  - for LaTeX lovers, CTAN
- searchable package index
- includes a ecosystem-wide testbed which will build, test, and check the compatibility of popular packages with the latest Lean toolchain(s)



Package Pages

- as development progresses, individual package pages will provide more Lean/Lake-specific information than GitHub can provide
- syntax highlighting is also further tunable for Lean
- if you have any suggestions on what you would like to see here, please share them!



Some Near-Term Plans

Reservoir

- Store testbed builds in Reservoir cloud storage and fetch them with Lake
- Add data on a package's dependency tree to Reservoir
- Test packages across multiple toolchains, run external checkers

Lake

- Make more package configuration data available in the Lake manifest
- Intelligent toolchain versioning on `lake update` (lake#180)
- Proper support for C FFIs which depend on the C++ stdlib
- Support for shared external libraries

Elaboration Performance Plans

Done: significant improvements to reduction, defeq, server performance

Short-term: incremental execution of tactic blocks

Mid-term: file-level parallelism, of theorems and much more

Long-term: module system, to define abstract interfaces of files and cut down on rebuilds

Parser Plans

```
#lang Lean.Language.Programming
#lang Lean.Language.Math
#lang Lean.Doc.Manual
```

- **Extensibility:** new dialects.
- **Education:** use simplified subset.
- **DSLs:** domain specific languages.
- **Modularity:** allows you explicitly state the subset/dialect.

Reserved tokens per syntactic category.

Documentation Tooling - Plans and Dreams

- No documentation tool works well for everyone - bloggers, textbook authors, paper authors, and package doc writers have different but related needs
- **Plan: documentation as DSL in Lean**
  - Library of re-usable documentation components (code samples, embedded maths, section headers, figures, …)
  - Export to single HTML page, multi-page online book, epub, various journals' LaTeX, etc
  - Doc components in Lean packages like any other
  - Convenient syntax, mostly-Markdown-compatible

LeanManual.lean

```
#lang Lean.Doc.Manual

@import Lean.Doc.ExampleCode

@about
  title: The Lean Manual
  author:
    - One person
    - You too?

# Downloading and Installing Lean

There are two recommended ways to get Lean:
* Install the [VS Code extension](https://...) and then open a Lean file
* [Install `elan`](https://...), the commandline Lean toolchain management tool

# Using Lean

## Defining Functions

@open Lean.Doc.Examples
@example_context defuns

A function definition looks like this:
@example defuns (keep := false)
  def even : Nat → Bool
    | 0 => true
    | n + 1 => not (even n)

It could have also been written like this:
@example defuns (keep := true)
  def even (n : Nat) : Bool :=
    match n with
    | 0 => true
    | n' + 1 => not (even n')
```

- Use `#lang` to select the right syntax for the file on the first line and import the right libraries
- Lean provides highlighting to the editor, and all the usual features still work
- This code example library allows provisional examples that aren't in scope in subsequent examples

LeanManual.lean

```
#lang Lean.Doc.Manual

@import Lean.Doc.ExampleCode

@about
  title: The Lean Manual
  author:
    - One person
    - You too?

# Downloading and Installing Lean
```

Lean.Doc.Header.Section

A section header. Section headers are rendered relative to the current document's placement in the final document, and will accordingly end up as chapters, sections, or subsections.

```
Th                                    get Lean:
*                                     (https://...) and then open a Lean file
*                                     the commandline Lean toolchain management tool

#

## Defining Functions

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    | 0 => true
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```

Hovers will work as usual for custom syntax

```
#lang Lean.Doc.Manual

@import Lean.Doc.ExampleCode

@about
  title: The Lean Manual
  author:
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# Downloading and Installing Lean

There are two recommended ways to get Lean:
* Install the [VS Code extension](https://...) and then open a Lean file
  Go to Definition
  Go to Declaration
  Go to Type Declaration
  Go to References

  Change to Numbered List
  Change to Description List
...), the commandline Lean toolchain management tool

# Us

## D

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@example_context defuns

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    | 0 => true
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```

Right-click menu

Code actions for changing between list styles

```
#lang Lean.Doc.Manual

@import Lean.Doc.ExampleCode

@about
  title: The Lean Manual
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    - One person
    - You too?

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# Using Lean

## Defining Functions

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It could have also been written like this:
@example defuns (keep := true)
  def even (n : Nat) : Bool :=
    match n with
    | 0 => true
    | n' + 1 => not (even n')
```

▼LeanManual.lean:28:22
▼Expected type
n : Nat
⊢ Bool

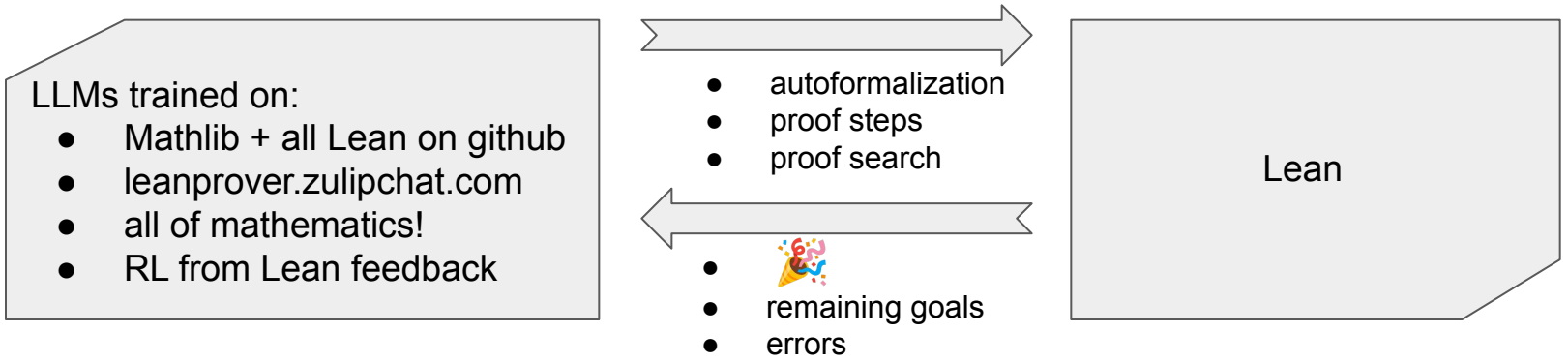
This code examples library invokes the elaborator in the usual way, so all interactive editing features can work as usual in the embedded examples

Documentation Tooling - Plans and Dreams

- Other goals:
  - Integrate nicely with docstrings, doc-gen4, etc
  - Support all existing documentation - port FPiL and the manual ASAP
  - Integrate with playgrounds, editors, and other tools
- Current status: design sketches, feasibility studies
- Please send your feedback and interesting use cases to david@lean-fro.org or say "hi" on Zulip

ML and Lean

Lean is an ideal framework for developing ML reasoning



Machine Learning and Lean

- We want tactic suggestion tools (`LeanInfer`, `LLMStep`, …) for all users.
- Smoothing the path for outside ML groups to “solve math” using Lean.
- We’d like to see **reusable ML components** for
  - Premise selection
  - Tactic suggestion
  - Proof search
  - Auto-formalization
- New features in the **Lean REPL targeting ML users**:
  - experimental tactic mode
  - pickling REPL states for distributed use
- **Data extraction tools at `lean-training-data`**.

What about?

- **Compiler**: more people joining soon.
- **Sledgehammer for Lean**: Yes, it is on our roadmap.
- **Efficient kernel reduction**: Joachim is starting next month ;)

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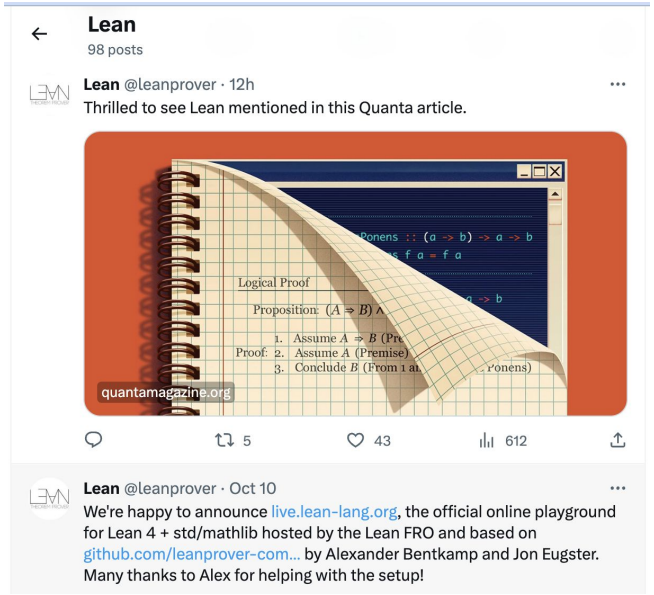

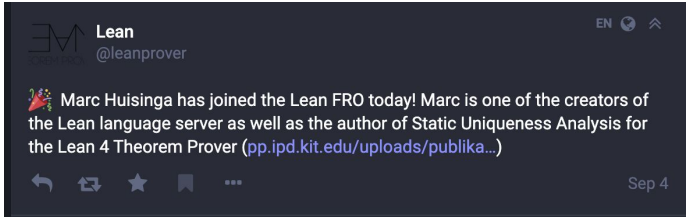

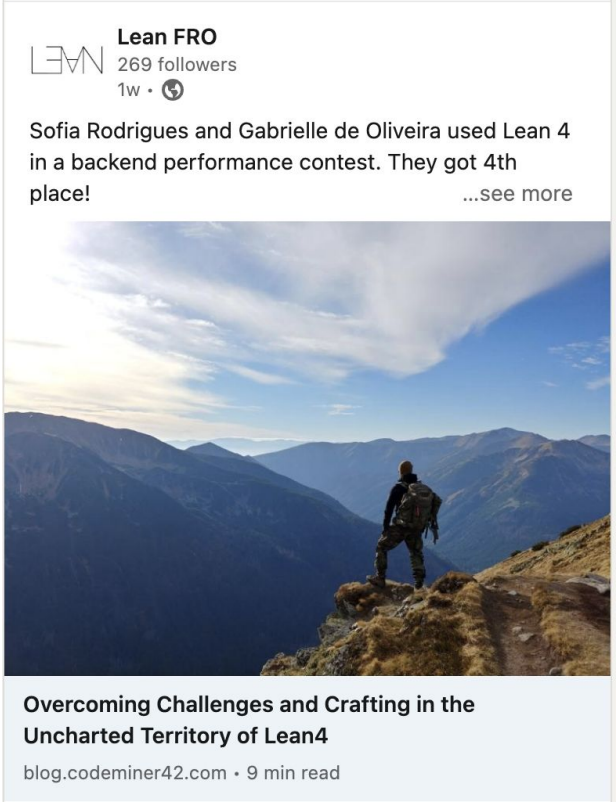

Q & A