Lean 4: A Guided Preview

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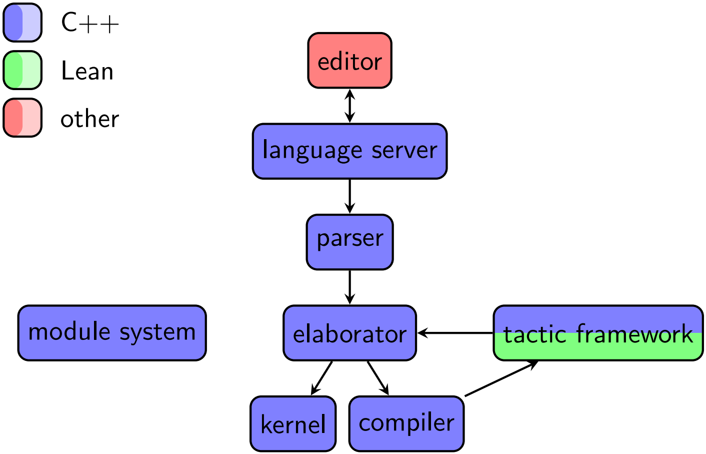
A brief history of Lean

- Lean 0.1 (2014)
- Lean 2 (2015)
  - first official release
  - fixed tactic language
- Lean 3 (2017)
  - make Lean a meta-programming language: build tactics in Lean
  - backed by a bytecode interpreter
- Lean 4 (201X)
  - make Lean a general-purpose language: native back end, FFI, ...
  - reimplement Lean in Lean

Lean 3 system overview



🟦 C++

🟩 Lean

🟥 other

editor

language server

parser

module system

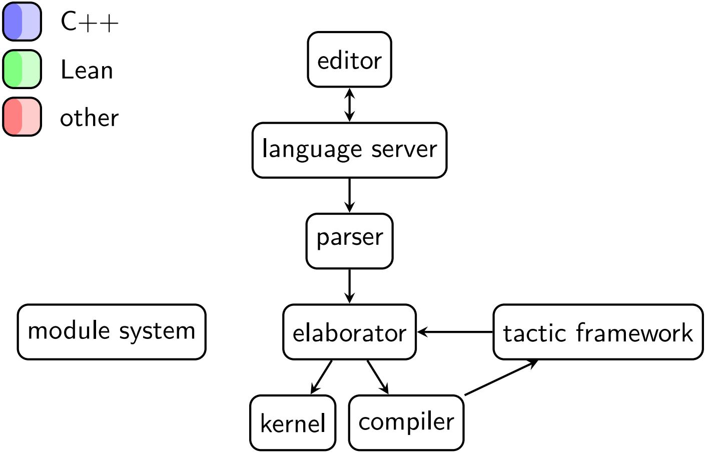
elaborator

tactic framework

kernel

compiler

Lean 4 system overview and progress



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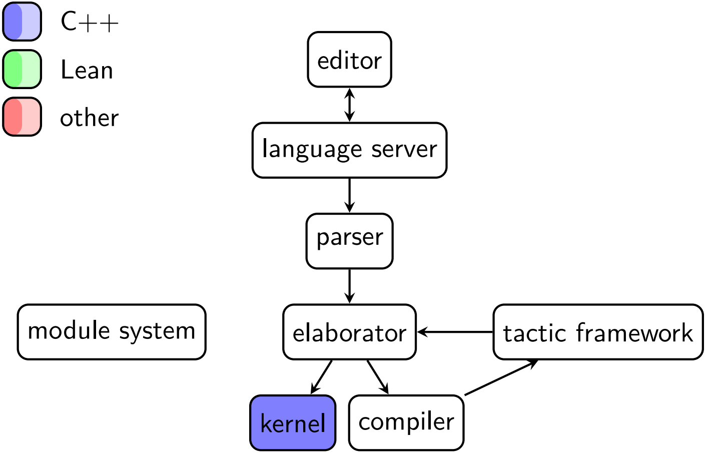

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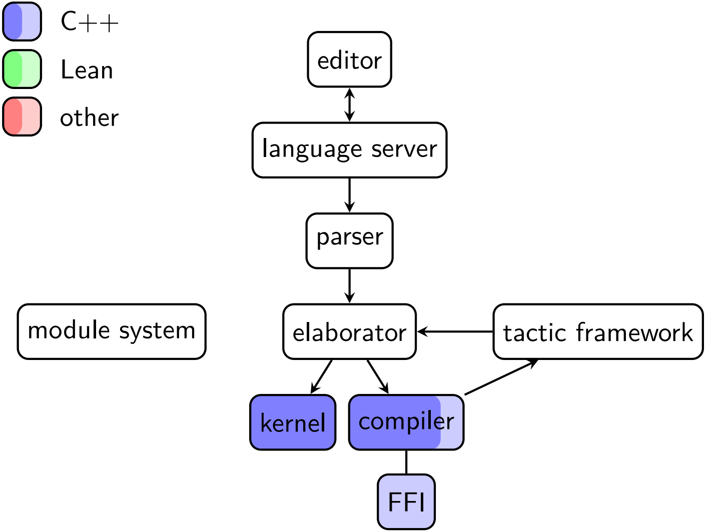

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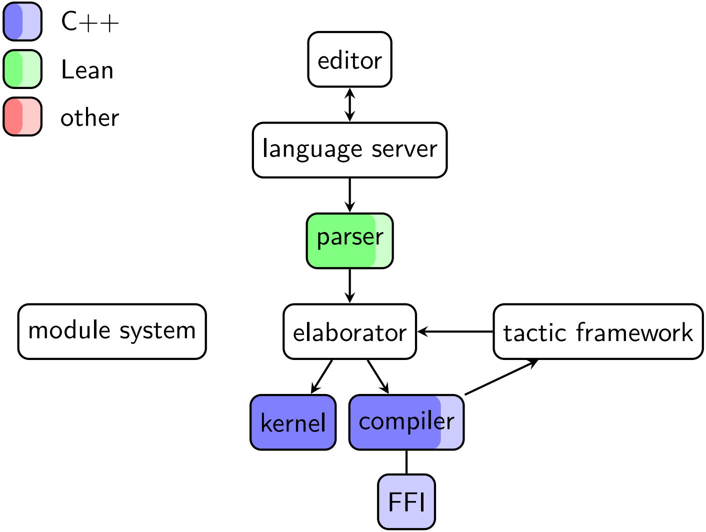

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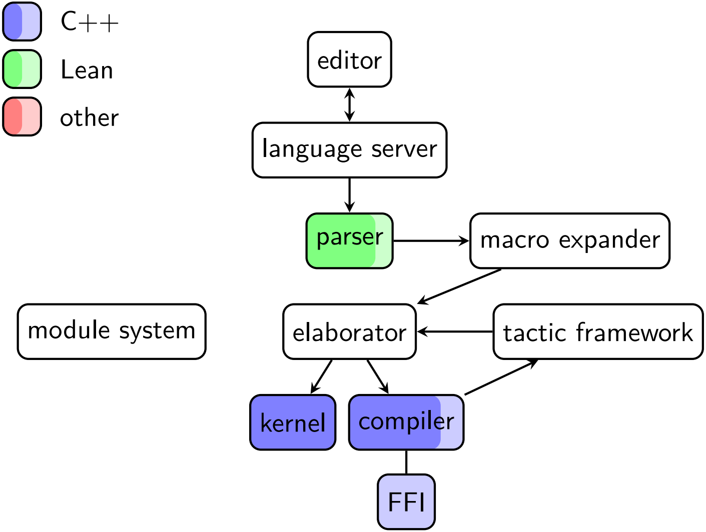

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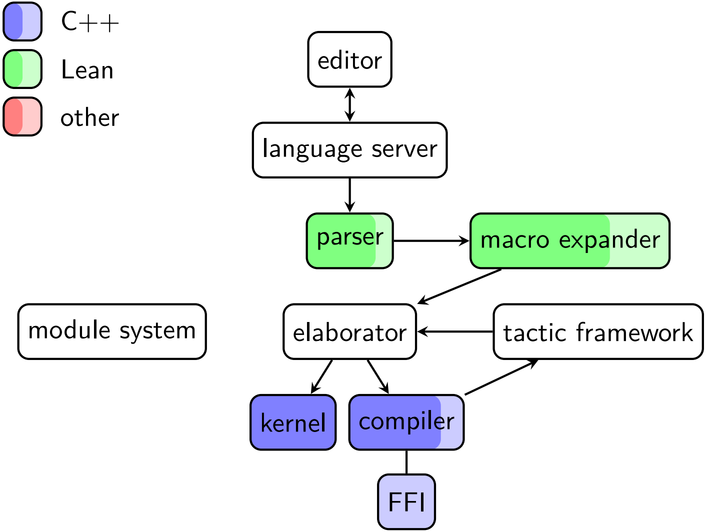

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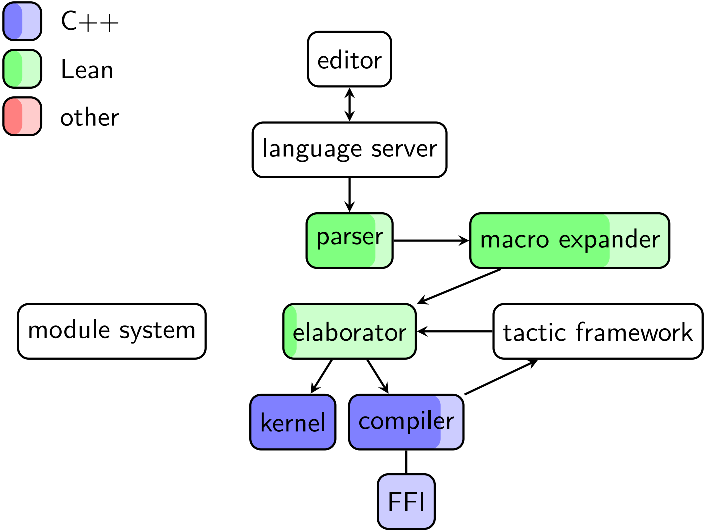

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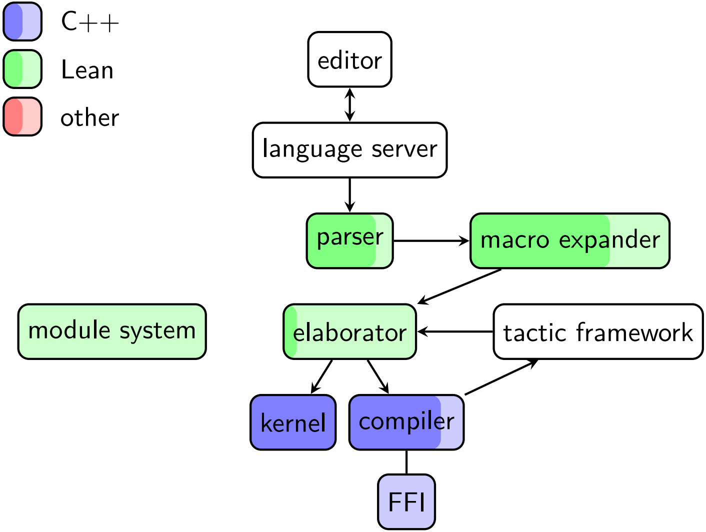

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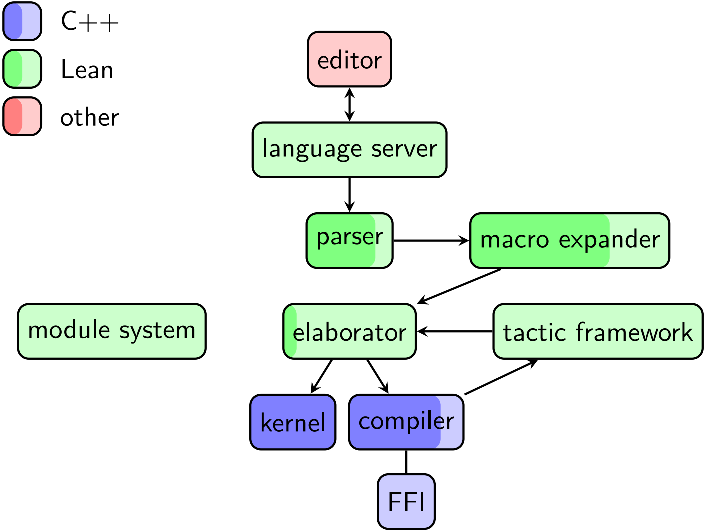

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New parser [mostly implemented]

- completely accessible and extensible

```
@[parser]
def my_inductive.parser : command_parser :=
node! my_inductive ["inductive",
  name: ident_univ_params.parser,
  sig: opt_decl_sig.parser,
  ext: node! my_inductive_base ["extends", base: term.parser]?,
  local_notation: notation_like.parser?,
  intro_rules: intro_rule.parser*]
```

New parser [mostly implemented]

- completely accessible and extensible
- arbitrary local backtracking and tokenizing

```
notation `{` xs:(foldr `, ` (x xs, set.insert x xs) Ø `}`)      := xs
notation `{` binder ` // ` r:(scoped p, subtype p) `}`)         := r
notation `{` binder ` ∊ ` s ` | ` r:(scoped p, set.sep p s) `}` := r
```

```
def symbol_quote.parser : term_parser :=
node! symbol_quote [
  left_quote: raw_str "`",
  symbol: raw $ take_until (= '`'),
  right_quote: raw_str "`" tt, -- consume trailing ws
  prec: precedence.parser?]
```

New parser [mostly implemented]

- completely accessible and extensible
- arbitrary local backtracking and tokenizing
- concrete syntax tree fully accessible to tooling
  - auto completion, document generation, code formatting, refactoring, ...
  - jump to definition *and documentation* of any syntax

Macros [mostly implemented?]

- most general syntax sugars: arbitrary syntax tree transformations

```
@[parser]
def set_lit.parser : term_parser :=
node! set_lit ["{", elems: sep_by ", " term.parser, "}"]

@[transformer]
def set_lit.transformer : transformer :=
λ stx,
  let v := view set_lit stx in
  pure $ v.elems.foldr (λ x xs, `(set.insert %%x %%xs)) `(∅)
```

Macros [mostly implemented?]

- most general syntax sugars: arbitrary syntax tree transformations

```
syntax set_lit := `{` (sep_by ", " term.parser) `}`

syntax_translations set_lit
| {}             := ∅
| {%%x, %%xs...} := set.insert %%x {%%xs...}
```

(hypothetical Isabelle-like macro-macros)

Macros [mostly implemented?]

- most general syntax sugars: arbitrary syntax tree transformations

```
def my_inductive.transformer : transformer :=
λ stx, do
  let v := view my_inductive stx,
  pure $ review «inductive» {v with
    intro_rules := match v.ext with
    | some ext := {name := `base, sig := {params := [⟨`a, ext.base⟩]}} :: v.intro_rules
    | none     := v.intro_rules
  }
end
```

Macros [mostly implemented?]

- most general syntax sugars: arbitrary syntax tree transformations
- names are resolved (hygienically) only after expansion

```
@[parser]
def subty.parser : term_parser :=
node! subty ["{", x: binder.parser, " // ", cond: term.parser, "}"]

@[transformer]
def subtype.transformer : transformer :=
λ stx,
  let v := view subty stx in
  pure `(subtype (λ %%v.x, %%v.cond))
```

Macros [mostly implemented?]

- most general syntax sugars: arbitrary syntax tree transformations
- names are resolved (hygienically) only after expansion

```
syntax subty := `{` binder.parser ` // ` term.parser `}`

syntax_translations subty
| {%%x // %%cond} := subtype (λ %%x, %%cond)
```

Managing syntax [planned]

“How do I manage my domain-specific set of notations?”

Managing syntax [planned]

Karlsruhe Institute of Technology

“How do I manage my domain-specific set of notations?”

```
namespace my_domain
  -- @[parser]
  def my_notation1.parser : term_parser := ...
  ...
end my_domain
...
local attribute [parser] my_domain.my_notation1
local attribute [parser] my_domain.my_notation2
local attribute [parser] my_domain.my_notation3
...
```

Hardly scalable...

Managing syntax [planned]

“How do I manage my domain-specific set of notations?”

```
namespace my_domain
  @[parser]  -- scoped by default
  def my_notation.parser : term_parser := ...
  ...
end my_domain
...
open [parser] my_domain
...
```

Lean 2’s scoped attributes return!

Managing syntax [planned]

“How do I manage my domain-specific set of notations?”

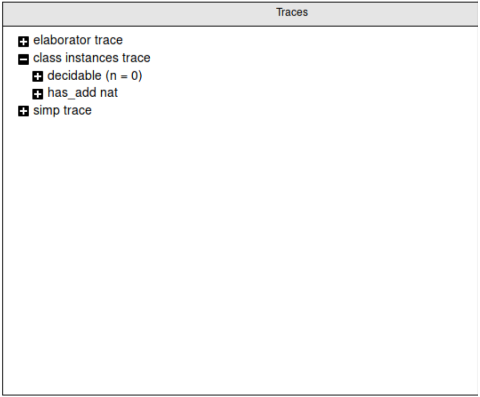
```
namespace my_domain
  @[parser]  -- scoped by default
  def my_notation.parser : term_parser := ...
  ...
end my_domain
...
open [parser] my_domain
...
```

Lean 2’s scoped attributes return!
Main lesson we learned from Lean 2:
Most attributes, like `[reducible]` and `[simp]` , should *not* be scoped (by default)

Better trace logs [planned]

make traces structured and lazy

- collect trace points during initial elaboration



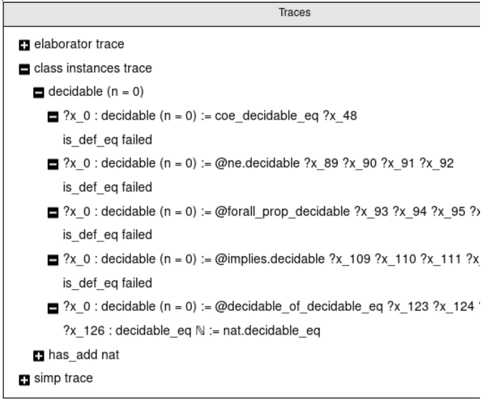
Traces

⊞ elaborator trace
⊟ class instances trace
  ⊞ decidable (n = 0)
  ⊞ has_add nat
⊞ simp trace

Better trace logs [planned]

make traces structured and lazy

- collect trace points during initial elaboration
- when full trace is requested, re-elaborate



Traces

```
⊞ elaborator trace
⊟ class instances trace
  ⊟ decidable (n = 0)
    ⊟ ?x_0 : decidable (n = 0) := coe_decidable_eq ?x_48
      is_def_eq failed
    ⊟ ?x_0 : decidable (n = 0) := @ne.decidable ?x_89 ?x_90 ?x_91 ?x_92
      is_def_eq failed
    ⊟ ?x_0 : decidable (n = 0) := @forall_prop_decidable ?x_93 ?x_94 ?x_95 ?x
      is_def_eq failed
    ⊟ ?x_0 : decidable (n = 0) := @implies.decidable ?x_109 ?x_110 ?x_111 ?x
      is_def_eq failed
    ⊟ ?x_0 : decidable (n = 0) := @decidable_of_decidable_eq ?x_123 ?x_124
      ?x_126 : decidable_eq ℕ := nat.decidable_eq
  ⊞ has_add nat
⊞ simp trace
```

More consistent namespacing [planned]

- `open` is now “sticky”

```
open nat
namespace nat
  def random := 0
end nat
#check random
```

[1] https://github.com/coq/coq/issues/6254#issuecomment-450641538

More consistent namespacing [planned]

- `open` is now “sticky”

```
open nat
namespace nat
  def random := 0
end nat
#check random
```

- `parameters` have been removed to simplify resolution[1]

[1] https://github.com/coq/coq/issues/6254#issuecomment-450641538

Clarifying imports [proposal]

```
import init.data.set
import data.set  -- ?

open set  -- ??

import ...two_dirs_up
```

Connection between modules, packages, and namespaces in Lean 3 is not very clear

Clarifying imports [proposal]

```
import init.data.set
import data.set  -- ?

open set  -- ??

import ...two_dirs_up
```

Connection between modules, packages, and namespaces in Lean 3 is not very clear

Proposal: Prefix module name with package name, use syntax more reminiscent of file paths

```
import "init/data/set"
import "mathlib/data/set"

open set

import "../../two_dirs_up"
```

Thoughts about eventual porting of Lean 3 code

- syntax changes: mostly superficial, automatable

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- syntax changes: mostly superficial, automatable

  One possible path: Incrementally reimplement Lean 3 syntax as macros first, then unfold them as final step

```
#lang lean3
import data.set
...
```

Thoughts about eventual porting of Lean 3 code

- syntax changes: mostly superficial, automatable
- elaborator changes: probably not too drastic

Thoughts about eventual porting of Lean 3 code

- syntax changes: mostly superficial, automatable
- elaborator changes: probably not too drastic
- library changes: mostly *missing* API, needs to be reimplemented
    - but not necessarily in the stdlib

Conclusion

- Many core features are starting to take shape
- Still much to be done
- Eventually should have many opportunities for community to get us back to and beyond Lean 3's library

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Thank you!

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- Eventually should have many opportunities for community to get us back to and beyond Lean 3's library

More presentations about Lean 4:

2018/08/03	Lean: past, present and future by Leo
2018/10/12	My internship report - new parser, mostly
2018/12/12	An optimized memory model for an interactive theorem prover

Find these and more at

`https://leanprover.github.io/publications`