Ltac Internals

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Coq Implementor Workshop

Disclaimer: what follows applies to trunk (next 8.6)

(And I don't want to discuss history in this talk anyway)

1. Bird's eye view
2. Engine
3. Tactics
4. Ltac
5. Future plans

Overall organization of the code

- Lower strata (`engine` folder)
- ML-defined tactics (`tactics` folder)
- Ltac itself (`ltac` folder)

Some folders also of interest: `pretyping`, `proofs`

Engine

This part defines the basic blocks upon which Ltac relies.

- The `Evd.evar_map` proof state
- The α `Proofview.tactic` monad
- The α `Ftactic.t` monad (or is it?)

The evar map (`evd.ml`)

"The one proof state to rule them all"

```
type Evd.evar_map
```

It contains many things defining the proof term being built.

- A map from evars to partial terms
- The current universe unification graph
- Some ugly stuff from the past (the infamous metas)
- More stuff I don't want to talk about
- Extensible state for clever hacks

The evar map (continued)

Relevant files:

- Low-level definitions: `evd.ml`
- Statically monotonous variant: `sigma.ml`
- High-level interaction: `evarutil.ml`

Note that I'm actively promoting the use of `Sigma` to get static guarantees, but the API is not entirely ported, so your mileage may vary. You may have to use glue code that will eventually disappear.

Proofview (`proofview.ml`)

"I would like backtrack. And state. And IO."

`type` α `tactic`

Monadically defines the core effects of the proof engine.

- *Tarte à la crème* (`tclUNIT`, `tclBIND`)
- Backtrack (`tclZERO`, `tclOR`)
- Backtracking state (`tclEVARS`, `tclEVARMAP`, ...)
  - Contains an evar map, but not only
- IO (`NonLogical`, I am not too fond of this API)

(See my CoqHoTT-minute blog post for semantics)

Proofview (continued)

Correct mental model of tactics:

From a state, produce a list of results that have a local state

where State $\equiv$ evar map + goals + focus

and Goals $\equiv$ hypothesis + conclusion

`tclZERO` $\equiv$ `nil`, `tclPLUS` $\equiv$ `app`

Proofview.Goal (`proofview.ml`)

Emulate the historical engine: `Proofview.Goal.enter` and variants

```
type (α, ρ) Proofview.Goal.t
val enter :  ... enter → unit tactic
```

- Indexed by a phantom normalization type + a stage just as `Sigma`
- Can be projected to recover data (concl, hyps, evar map, ...)
- `enter` apply a continuation on each focussed goal
- Two orthogonal flags
  1. `nf_*`: Do we normalize the goal w.r.t evars?
  2. `s_*`: Do we change the current state?

Ftactic (motivation)

From 8.5 onwards, tactics may act on several goals.

This conflicts with Ltac (lack of) semantics! E.g.

```
let t := constr:(x) in ...
```

- Is `x` a variable local to a goal (i.e. hypothesis)?
- Is `x` a global variable (i.e. definition or section variable)?

Ltac says: the former.

We need to focus on the fly!

Ftactic (`ftactic.ml`)

`type` α `Ftactic.t`

- Built upon `Proofview.tactic`
- Monadic API as well
- Two modes: global vs. focussed
- Once focussed, this is forever
- Currently incorrect implementation (not a monad)

Tactics

Not much to say here.

- Many files that implement Coq core tactics
- The kind of code that breaks from being looked at

Have a look at `tactics/tactics.ml` for 5 kloc of joyful code!

(Everything mentioning `clenv` not to be looked at)

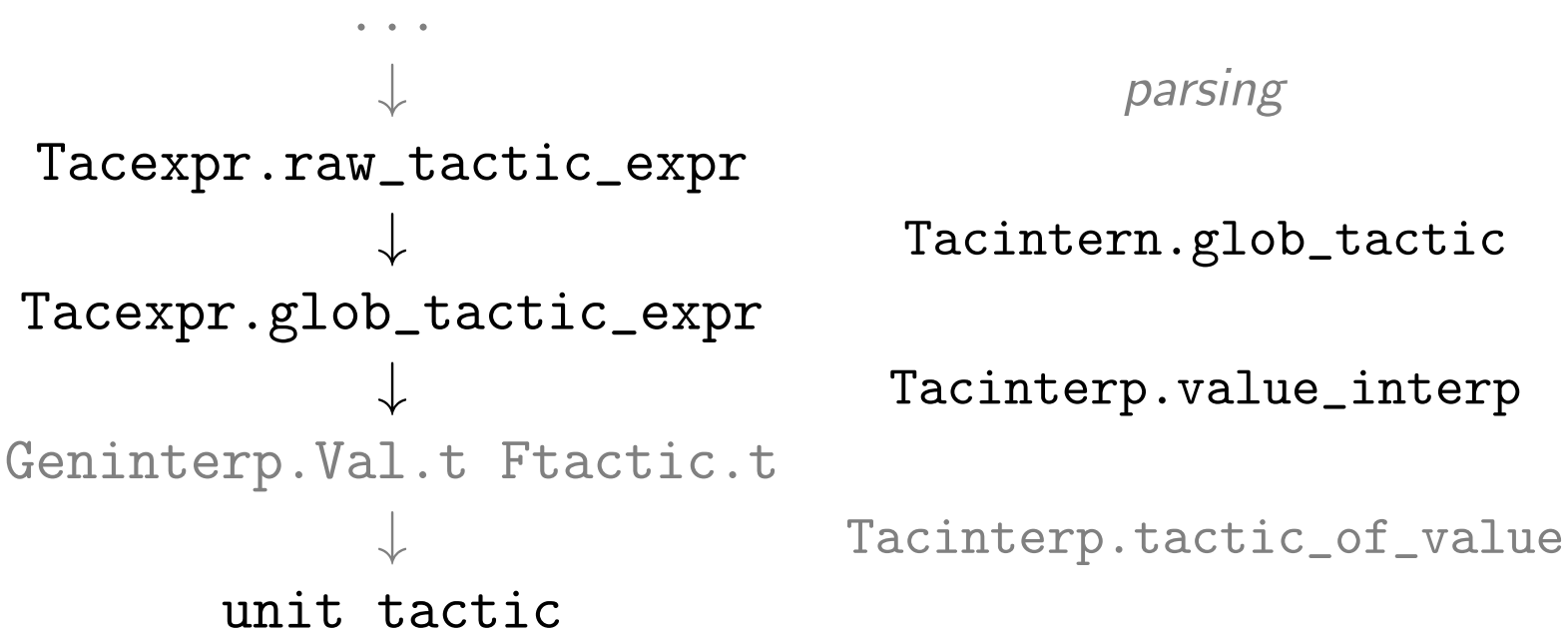
Vademecum

Essentially, the complete, most basic primitives you can use:

- `Proofview.Goal.enter` to focus on goals
- `Evarutil.new_evar` to introduce holes
- `Refine.refine` to solve a goal

Ltac overview

Same three-level steps as terms, with a bit of variations



User-facing expressions

`raw_tactic_expr` and `glob_tactic_expr` share the same skeleton.

- Defined in `Tacexpr`
- Essentially reflect the syntax
- Parameterized by the inner arguments
- Globalization is functorial

Mutually defined with tactic arguments and atomic tactics.

Toplevel values

Type `Val.t` is a dynamic extensible type.

- You can create new arguments (unique name)
- You can inject and project from this dynamic type

Interpretation function of Ltac parameterized by an environment

```
type interp_sign ∼ Val.t Id.Map.t
```

Ltac lack of semantics

The great catastrophe of Ltac:

When are things evaluated?

Answer: Do I look like I know?

Ltac lack of semantics II

Some constructs are evaluated upfront:

- closures
- `let`, `let rec`
- the various `match`
- tactic arguments

The remaining is thunked, and evaluated according to heuristics.

A lot to say and to fix here, but time is running. See `value_interp`.

Ltac lack of semantics III

Another problem: lack of variables

- Many hacks relying on dynamic typing
- TeX-like confusion between quoted code and meta

```
Tactic Notation "foo" ident_list(l) := intros l.
```

- No quotation feature, everything uses heuristics

```
intro x; let x := constr:(0) in exact x
```

- Horrendous parsing tricks to counter this

```
do int_or_var(x) tactic(t) := ...
```

See `tacinterp.ml` and `taccoerce.ml` for gory details.

Extensible language

Atomic tactics are historical remnants and should die.

The recommanded way of adding tactics is through the generic extension mechanism.

- `ARGUMENT EXTEND` (for arguments, see `TacGeneric`)
- `TACTIC EXTEND` (for tactics, see `TacML`)

Generic arguments (genarg.ml)

Those are dynamic types that implement some primitives.

$$\texttt{type } (\alpha, \beta, \gamma) \texttt{ Genarg.genarg\_type}$$

As for every Coq stuff, three levels

- The raw level (user facing)
- The glob level (internalized)
- The typed level (ML-side typing)

A few hardwired genargs are defined in `Stdarg` and `Constrarg`.

By convention, they are named `wit_*`.

Required operations

We can declare extensible operations on genargs.

```
module Genarg.Register
```

Important ones in the Coq codebase:

- Parsing to raw (`pcoq.ml`)
- Printing from raw, glob, typed (`genprint.ml`)
- Internalization from raw to glob (`genintern.ml`)
- Substitution from glob to glob (`genintern.ml`)
- Interpretation from glob to `Val.t` (`geninterp.ml`)
- Toplevel representation from `Val.t` to typed (`geninterp.ml`)

ARGUMENT EXTEND

There is a CAMLPX macro to generate such boilerplate.

```
ARGUMENT EXTEND auto_using
TYPED AS uconstr_list
PRINTED BY pr_auto_using
| [ "using" ne_uconstr_list_sep(l, ",") ] -> [ l ]
| [ ] -> [ [] ]
END
```

Simple example, there is a more complicated variant.
(See `extraargs.ml4`)

Extending tactics (`tacenv.ml`)

One can register ML code to use as tactics.

```
type ml_tactic = Val.t list → interp_sign → unit tactic
```

Such tactics are referred by a `ml_tactic_name`:

- A ML plugin name (`DECLARE PLUGIN foo`)
- A ML tactic name
- An integer corresponding to the entry number

No way to directly refer to those primitives from Coq side!

TACTIC EXTEND

Once again a CAMLPX macro to generate boilerplate.

```
TACTIC EXTEND econstructor
| [ "econstructor" ] -> [ Tactics.econstructor ]
| [ "econstructor" int_or_var(i) ] -> [ Tactics.econstructor_n i ]
END
```

This macro

- registers an ML tactic (with automatic casts from `Val.t`)
- adds a tactic notation referring to the TacML node.

Future plans

General guideline: turn Ltac into a ML.

- Fix the evaluation order (outch!)
- Add static typing (see above)
- Add datatypes
- Fix tactic notations
- Generic quoting mechanism