Improving the Proof Experience in Coq

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Santiago, Chile — March 2018

What is this talk about?

Certified
Cryptography

Proof about
R / JavaScript
programs

Coq User Experience & Wishlist

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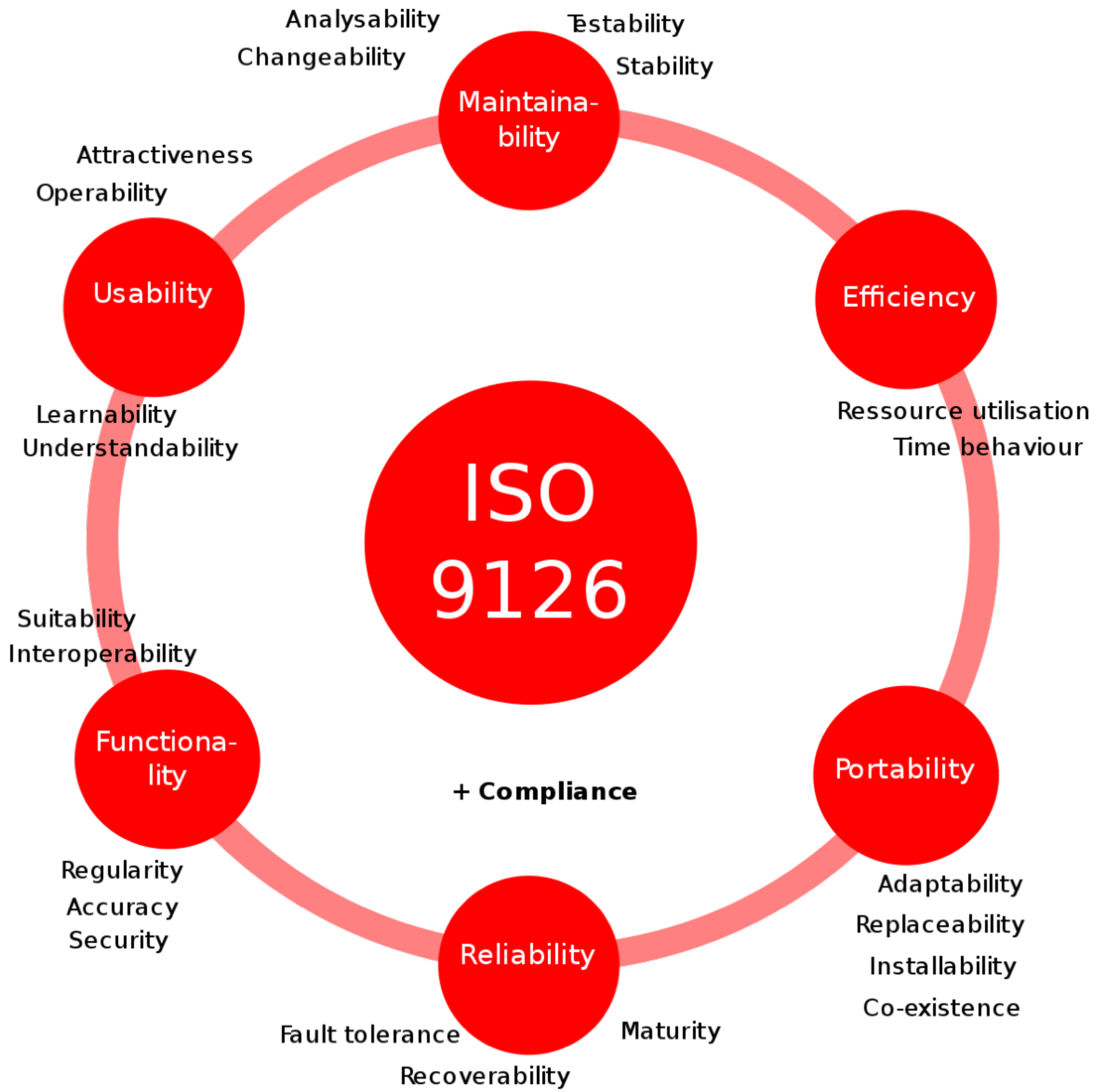
Software quality attributes



Proof developers **tend to** *neglect* **elementary engineering qualities**

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Practices precluding the robustness of Coq developments

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Proof scripts that are sensitive to the naming of automatically generated terms

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| Const : nat -> exp
| Plus : exp -> exp -> exp.
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Fixpoint eval (e : exp) : nat :=
  match e with
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  end.
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  end.

Fixpoint times (k : nat) (e : exp) : exp :=
  match e with
    | Const n => Const (k * n)
    | Plus e1 e2 => Plus (times k e1) (times k e2)
  end.
```

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Proof.
  induction e.
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k, n : nat
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eval (times k (Const n)) = k * eval (Const n)
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k : nat
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IHe1 : eval (times k e1) = k * eval e1
IHe2 : eval (times k e2) = k * eval e2
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eval (times k (Plus e1 e2)) = k * eval (Plus e1 e2)
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    simpl.
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✓

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Replace
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The reference **IHe1** was not found in the current environment!!!

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```

Attempt to save an incomplete proof

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Proof scripts that are sensitive to the order of lemmas’ hypotheses

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POSSIBLE SOLUTION:

Proof developers tend to *neglect* elementary engineering qualities—mainly *robustness*.

Possible Solution:

- "Proof analysis" identifying possible robustness issues
- Provide a linter implementing the analysis

2

Terrific formalisation in Coq

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  - What is the best way to implement it?

Terrific formalisation in Coq

Why not extend the result?

Ok! Let's see what it takes.

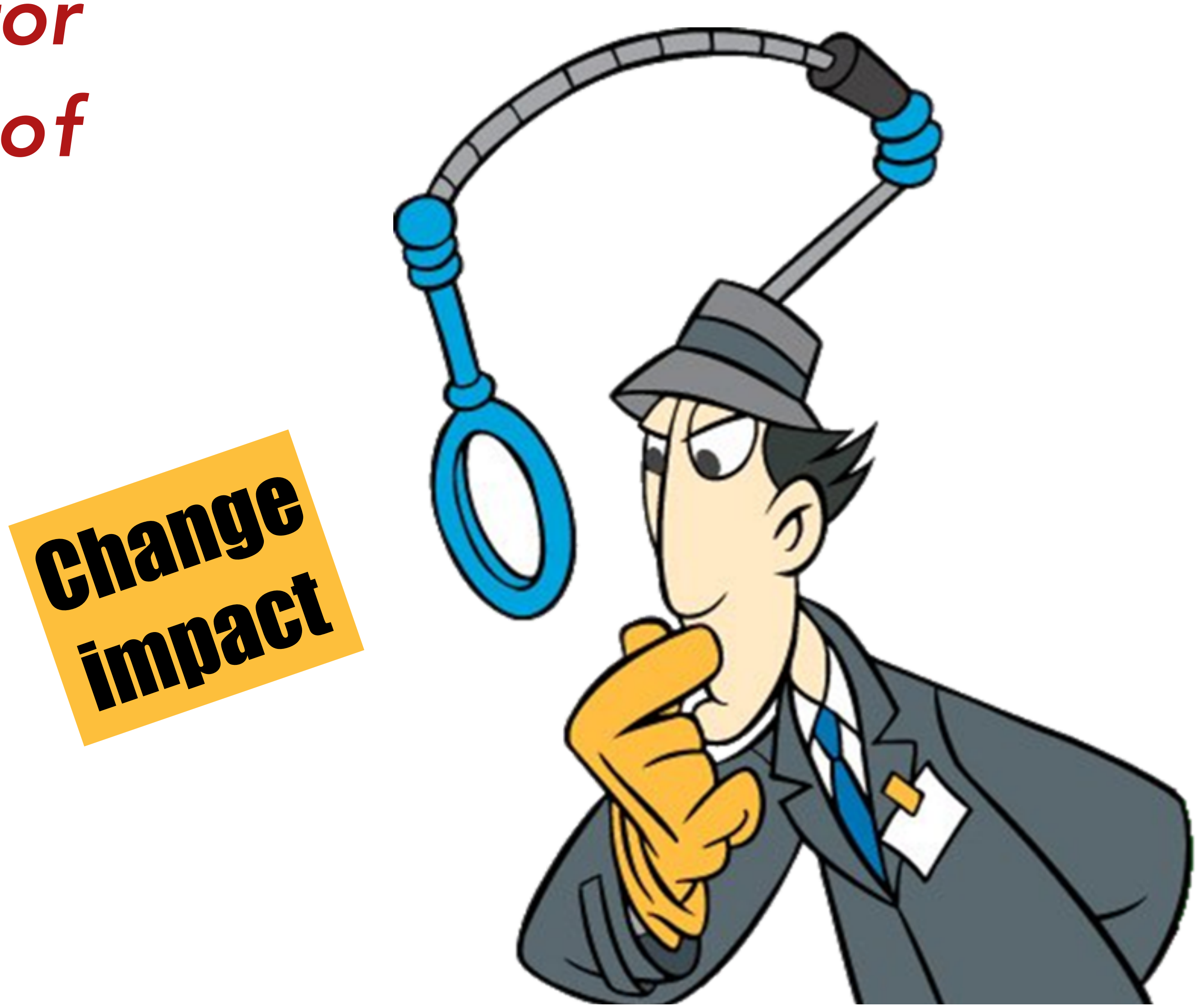
- How shall I do it?

  What is the best way to implement it?

- How much effort would it take?

  Is it really feasible?

Coq developments tend to evolve over time. However, there is *no mechanism for assessing the impact of* introducing *changes*.



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How does a change to a part of the development impact on the rest of the development?

- What else should be changed?
- What do these changes consist in: extension, removal, adaptation?
- Where should these changes take exactly place?

Desired tool support

Binary trees with elements in leaves

```
Inductive tree (A : Set) : Set :=
| Leaf : A -> tree A
| Node : tree A -> tree A -> tree A.


Fixpoint size_tree (A : Set)  (t : tree A) : nat :=
  match t with
    | Leaf _ => 1
    | Node t1 t2  => 1 + (size_tree t1) + (size_tree t2)
  end.
```

Desired tool support

Binary trees with elements in leaves and internal nodes

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Requires attention
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  end.
```

```
Lemma size_map_mirror_tree : forall (A B : Set) (f : A -> B) (t : tree A),
 size_tree (map_tree f t) = size_tree (mirror_tree  t).
Proof.
  intros.
  rewrite size_map_tree, size_mirror_tree.
  trivial.
Qed.
```

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Proof.
  intros.
  rewrite size_map_tree, size_mirror_tree.
  trivial.
Qed.
```
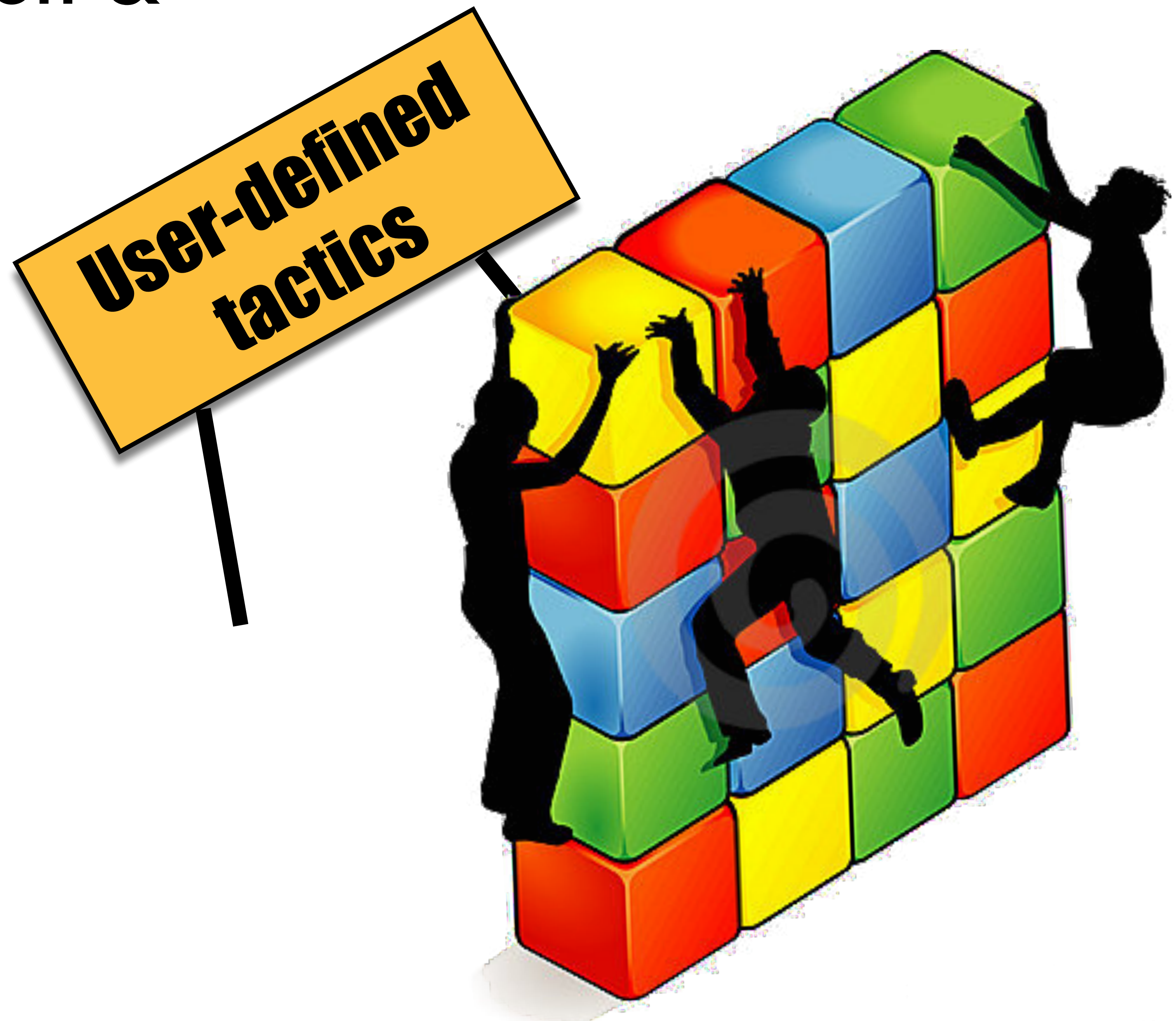

Requires no modification

3

User-defined tactics are awesome (for automation & robustness), but their use is hindered by several *limitations.*



Tactics support no query mechanism

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471
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→ **There probably are redundant definitions.**

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```
Print TLC.LibTactics.
```

→ **All Gallina definitions, no Ltac definitions.**

A tactic “specification” language similar to SearchAbout?

Debugging

A debugger exists, but it is very basic.

9.4.2 Interactive debugger

The L_{tac} interpreter comes with a step-by-step debugger. The debugger can be activated using the command

```
Set Ltac Debug.
```

simple newline:	go to the next step
h:	get help
x:	exit current evaluation
s:	continue current evaluation without stopping
r *n*:	advance *n* steps further
r *string*:	advance up to the next call to "`idtac` *string*"

When debugging, we typically look for a failing branch. The tracing tool of Coq exactly ignores these.

9.4.1 Info trace

It is possible to print the trace of the path eventually taken by an L_{tac} script. That is, the list of executed tactics, discarding all the branches which have failed. To that end the `Info` command can be used with the following syntax.

Two kinds of tactics

Tactics building terms

```
Ltac ltac_inter l1 l2 :=
  match l2 with
  | nil =>
    constr:(@nil
      ltac:(match type of l1 with
                 list ?T => T end))
  | ?a :: ?l =>
    let is_in := ltac_mem a l1 in
    let r := ltac_inter l1 l in
    match is_in with
    | true => constr:(a :: l)
    | false => r
    end
  end.
```

Tactics with side effects

`rewrite`, `idtac`, everything using “;”, etc.

They can not be mixed

`idtac; constr:(1)` will always fail.

Type for tactics?

t ::= <effect> | <constr> | t -> t | 'a

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This would have detected my last week's bug:

```
Ltac get_something e k :=
  let aux k' :=
    let H := fresh "H" in
     assert (H : something e); [ prove_something | k' H ]
   in
   match goal with
   | L : lemma_for_something |- _ =>
     aux (fun H =>
       apply (change_something L) to H;
       k H)
  end.
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  end.
```

→ **Error: No matching clauses for match.**

Miscellaneous

- Fresh and its hints.

  “fresh "IH" e” fails when “e” is not an identifier.

- Lists of hypotheses.

  crush’s done, TLC’s boxer, SSReflect stack, etc.

- Getting constructors and projections as a list.

  ```
  let x := constr:(ltac:(constructor) : T) in ltac:(induction x; exact I) : True
  ```

- A timing and memory model for Ltac?

  My Coq development last month: Fatal error: out of memory.

Conclusion

We can develop in Ltac, but we are lacking some tools

- Any proof analysis tool would be greatly welcomed;
- Any way of looking through already defined tactics;
- Ltac definitely needs more types.

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Thanks!