### Tinycals: step by step tacticals

Claudio Sacerdoti Coen <sacerdot@cs.unibo.it>
Enrico Tassi <tassi@cs.unibo.it>
Stefano Zacchiroli <zacchiro@cs.unibo.it>

University of Bologna

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#### User-friendly structured procedural scripts

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Cfr. Structured (i.e. syntax oriented) script editing

- Takahashi, Hagiya. "Proving as editing HOL tactics"
- Syme's TkHOL

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## Outline

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## CtCoq/Proof General Interaction Mode

- An editable script window
- A sequents window (for the current state)
- Commands executed atomically and one at a time
- Already executed commands are locked

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- Commands are meaningful to the user
- The sequents window is not that useful
- The "script" is fully structured by delimited blocks
  - e.g.: show P ... done
  - e.g.: per cases on n case 0 ... case S

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• The structure reflects (is?) the proof tree

- Commands are meaningful to the system
- The sequents window is fundamental
- The script is not naturally structured
  - e.g. induction n. reflexivity. intros. rewrite H. auto. assumption.

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• The structure does not reflect the proof tree

- Formulae can contain metavariables
- A metavariable is a non-linear and typed placeholder
  - e.g. ∀x,y.?n[x] ≤ S x ∧ P ?n[x]
  - associated sequent: x:nat ⊢ ?n : nat
- Commands (e.g. tactics) can instantiate metavariables

• e.g. x:nat ⊢ ?n : nat := S x

- Instantiation acts on every sequent/branch (side effect)
- Sequents to prove are also metavariables (Curry-Howard)

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## Metavariables and Side Effects (2/2)

- Proof branches are not independent (and cannot become lemmas)
  - Cfr. Takahashi, Hagiya. "Proving as editing HOL tactics"
- Tactics acting on different sequents cannot be permutated
  - e.g. when the first sequent is ?n[x] = 0 is closed by reflexivity and the second sequent P ?n[x] is automatically closed
- Sometimes sequents must be addressed in strange orders to drive automation
  - Cfr. Syme's TkHOL (structured editing of HOL scripts by juxtaposition of subscripts)

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### Metavariables and Side Effects: Why?

- Metavariables and side effects difficult to handle
- Are they useful/necessary? (interesting question)
- We do not care: we want to address the most difficult case

# LCF Tacticals

- Higher order tactics: sequencing, branching, repetition, error recovery
- Used to form atomic tactics
- Make the script more robust and more synthetic (code factorization)
- Debugging is an issue
- Sequencing and branching primary way to machine understandable script structuring

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• A fully structured script is an atomic tactic

# LCF Structured Scripts: UI Issues

#### A fully structured script is an atomic tactic

- Difficult and time consuming to write
  - Write a non-structured script; make it structured if possible (side effects)
  - Add a tactic; execute the atomic script; undo; repeat until finished
- Difficult to replay
  - Impossible to statically de-structure it
    - e.g. T1; T2 becomes T1. T2. ... T2.

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- De-structure it bit by bit inserting execution points
- Difficult to debug
  - It fails atomically
  - Errors reported on hidden states

# LCF Structured Scripts: No, Thanks (1/2)

Coq/Isabelle/...scripts usually not structured with LCF tacticals

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- Indentation/blank lines used to structure the script
- Users are happy...

# LCF Structured Scripts: No, Thanks (2/2)

- until they change the order of hypotheses in a lemma!
- until they change the order of fields in a structure/record!
- until they change the order of constructors of an inductive definition!

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- No help by the system
- We propose a solution that
  - Is fully backward compatible
  - Does not force the user to abandon their style
  - No additional burden to write structured scripts; some advantages

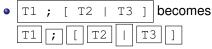
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• Try it once, you won't do without it!

# Matita Tinycals: branching and sequencing

- Branching and sequencing can be expressed with more fine grained sequential atomic operations (tinycals)
  - T1 ; T2 becomes T1 ; T2
    - After ; two sequents are selected at once
    - Tactics are executed in sequence on every selected sequent

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- Each tinycal can be parsed and executed immediately
- Requires an enriched proof status

# More Tinycals: unstructured editing and accept

- Embedding of unstructured script fragments allowed
  - i.e. 🗔 is a tinycal
  - e.g. T1 ; [ T2 T3 T4 | T5 ]
- Branches closed by side effects aknowledged by the user to preserve the correspondence with the proof tree

## More Tinycals: out of order execution

Out of order execution of (multiple) branches

- the tinycal n<sub>1</sub>,..., n<sub>i</sub>: selects inner branches by position
- e.g. T1 ; [ 2: T2 | 3: T3 | T4 ]
- special case: \*: selects all the remaining inner branches
- user not obliged to close the branch before moving to the next ones
- Out of order execution of far away branches

• focus 
$$n_1, \ldots n_i$$
 ... unfocus

- sometimes necessary for side effects
- the user is obliged to close the selected branches

# Are There More Tinycals?

- Tinycals execution is efficient: tactics are not executed twice
- This is a constraint on the semantics of the tacticals to be mimicked
  - e.g. sequencing can be implemented with tinycals since it is left associative: T1; T2; T3 = (T1; T2); T3

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- e.g. the right associative variant cannot be implemented efficiently using tinycals (because of side effects)
- Repetition and error recovery (try, first, OrElse) cannot be split into tinycals
- We allow atomic LCF tacticals as special cases of tactics

#### try/OrElse used

- Inside a repetition tactical (rare)
- After sequencing to apply a tactic only to some goals (frequent)
  - e.g. elim n; (trivial || (simplify ; try auto))

some sequents (which ones?) are trivial; the other ones are simplified and solved automatically if possible (which ones?)

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• The frequent case is handled by selection of multiple branches

### **Further Considerations**

- Code is not duplicated!
  - LCF tacticals still necessary to implement tactics
  - They can be implemented on top of tinycals to avoid code duplication and semantics mismatch
  - Not trivial: tactics work on a poorer proof status
  - Requires a parametric implementation of tinycals on abstract proof statuses with embedding/projections
- We provide a small steps formal operational semantics
  - Look for it in the paper
- A procedural proof language can be implemented more easily on top of tinycals
  - Because the proof status has been enriched
  - Tinycals reduce the gap between procedural and declarative implementations

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- LCF tacticals quite bad for proof structuring
- LCF tacticals quite bad with metavariables and side effects
- This is an user interface issue!
- We propose fine grained atomic tinycals that destructure LCF tacticals
- We put some care on the issue of side effects
- We provide a formal semantics and an efficient implementation without code duplication
- We show that the work cannot be extended any further

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