Asynchronous Proof Processing with Isabelle/Scala and Isabelle/jEdit

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Introduction

Motivation

Aims:

- U-ITP: usable interactive theorem proving
  $\rightarrow$ Make our provers accessible to many more people out there.
- TP-UI: theorem provers for user interfaces
  $\rightarrow$ Make building front-ends for provers really easy.

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Issues:

- Viability of editor framework? Emacs?
- Viability of interaction model? Read-eval-print loop?

Beyond Proof General?

Implementations of "Proof General":

- Proof General / Emacs
- CoqIde: based on OCaml/Gtk
- Matita: based on OCaml/Gtk
- ProofWeb: based on HTML text field in Firefox
- PG/Eclipse: based on huge IDE platform
- I3P: based on large IDE platform (Netbeans)

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Limitations:

1. editor framework: single-core or even single-threaded (except for JVM-based frameworks)
2. interaction model: synchronous command loop with undo

Parallel proof checking and asynchronous interaction

Isabelle/Isar proof document structure

theory C **imports** A B **begin**

inductive $path$ **for** $rel :: \alpha \Rightarrow \alpha \Rightarrow bool$ **where**
  $base$: $path\ rel\ x\ x$
$|$ $step$: $rel\ x\ y \Longrightarrow path\ rel\ y\ z \Longrightarrow path\ rel\ x\ z$

theorem $example$: **fixes** $x\ z :: \alpha$ **assumes** $path\ rel\ x\ z$ **shows** $P\ x\ z$
using $assms$
proof $induct$
  fix x **show** $P\ x\ x$ $\langle proof \rangle$
next
  fix $x\ y\ z$ **assume** $rel\ x\ y$ **and** $path\ rel\ y\ z$
  moreover assume $P\ y\ z$
  ultimately show $P\ x\ z$ $\langle proof \rangle$
qed

end

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Potential for parallelism

1. DAG structure of theory development graph: cf. GNU `make -j`
2. toplevel AND/OR structure: explicit statements, irrelevant proofs
3. modularity of structured proofs: practically requires Isar
4. general parallelism in ML: practically requires immutable data

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Notes:

- all of this available in recent Isabelle2009-2 and Poly/ML 5.3.0
- max. speedup 3.0 for 4 cores, and 5.0 for 8 cores
- technical and conceptual correlation with asynchronous interaction

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- manage persistent history of versions to decouple editor from prover

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- *begin-document* and *end-document* bracketing
- static *define-command*
- dynamic *edit-document* (wrt. command spans)
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Note: "command prompt" finally abolished

Scala/JVM

JVM problems (Sun/Apple implementation)

- reasonably fast only after long startup time
- small stack/heap default size, determined at boot time
- no tail recursion for methods
- delicate semantics of object initialization; mutual scopes but sequential (strict) evaluation
- plain values (e.g. `int`) vs. objects (e.g. `Integer`) live in separate worlds — cannot have bignums that are unboxed for small values
- multi-platform is subject to subtle issues ("write once, debug everywhere")
- null (cf. Tony Hoare: *Historically Bad Ideas: "Null References: The Billion Dollar Mistake"*)

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But:

+ reasonably well-established on a broad range of platforms (Linux, Mac OS, Windows)
+ despite a lot of junk, some good frameworks are available (e.g. *jEdit* editor or *Jetty* web server)
+ Scala/JVM can use existing JVM libraries (without too much exposure to musty Java legacy)

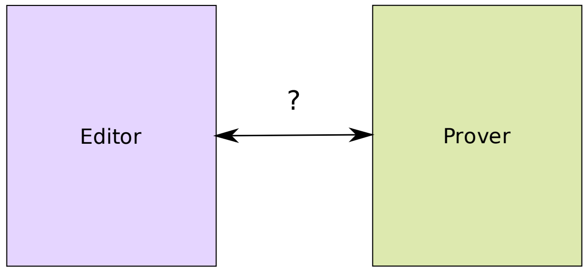
Scala language concepts (Martin Odersky et al)

- 100% compatibility with existing Java/JVM libraries — *asymmetric* upgrade path
- about as (in)efficient as Java
- fully object-oriented (unlike Java)
- higher-order functional concepts (like ML/Haskell)
- algebraic datatypes ("case classes") with usual constructor terms and pattern matching ("extractors")
- good standard libraries
  - tuples, lists, options, functions, partial functions
  - iterators and collections
  - actors (concurrency, interaction, parallel computation)
- flexible syntax, supporting a broad range of styles (e.g. deflated Java, or ML/Haskell style), or "domain-specific languages"

- very powerful static type-system:
  - parametric polymorphism (similar to ML)
  - subtyping ("OO" typing)
  - coercions ("conversions", "views")
  - auto-boxing
  - self types
  - existential types
  - higher-kinded parameters
  - type-inference
- incremental compiler ("toplevel loop")

Isabelle/Scala for prover interaction

The connectivity problem



Problems:

- JVM: provers are better not implemented in Java
- JVM: even with Scala, the JVM is suboptimal for our purposes
- ML: lack of connectivity to GUI / Web frameworks etc.
- ML: even GTK/OCaml is a niche market
  (no serious editor frameworks; we depend on SML anyway)

Realistic assumption:

- Prover: SML (e.g. Isabelle)
- Editor: Java/JVM (e.g. jEdit)

Question: How to integrate the two worlds?

- separate processes: requires marshalling, serialization, protocols
- different implementation languages and programming paradigms
- different cultural backgrounds

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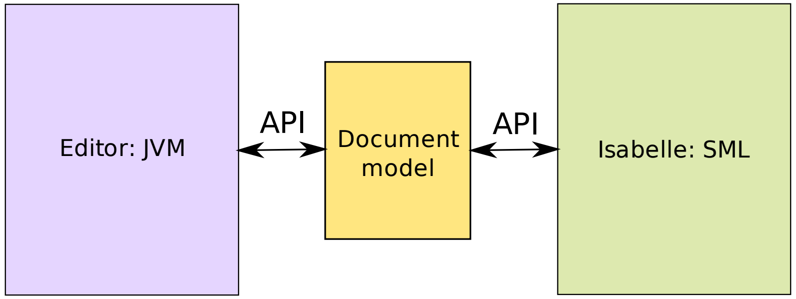
Our answer: bridge the gap via Scala (by Martin Odersky, EPFL)

Isabelle/Scala architecture

Conceptual view:



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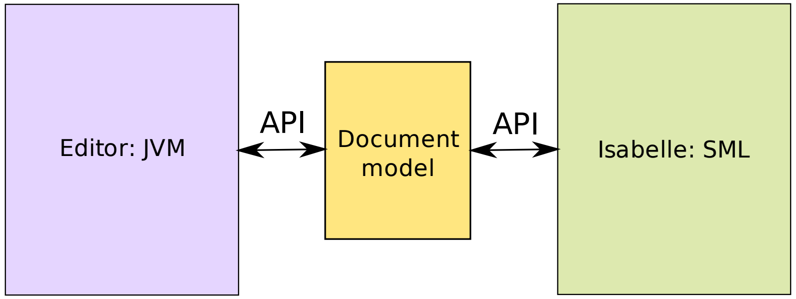
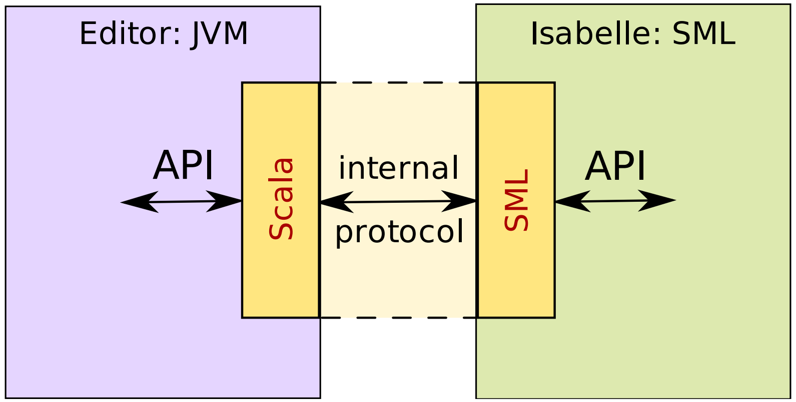


Implementation view:



Isabelle/Scala library

- public API, private internal protocol
- integral part of Isabelle distribution
- imitate Isabelle/ML style
- duplicate few Isabelle/ML modules on the Scala side
  (e.g. pretty printing, outer syntax lexer and command parsers)
- reduce public standards to required functionality
  (e.g. YXML encoding for pure XML trees)

Example: markup trees

Raw trees: untyped, uninterpreted

```
sealed abstract class Tree
case class Elem(name: String, attributes: Attributes, body: List[Tree]) extends Tree
case class Text(content: String) extends Tree
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Pretty markup: typed views on certain tree nodes

- derived objects `Block`, `Break` with `apply` and `unapply` methods
- pattern matching on extractors, e.g. in our `pretty.scala`

```
def format(trees: List[XML.Tree], ...): Text =
  trees match {
    case Nil => text
    case Block(indent, body) :: ts => ...; format(ts1, blockin, after, btext)
    case Break(wd) :: ts =>
      if (...) format(ts, blockin, after, text.blanks(wd))
      else format(ts, blockin, after, text.newline.blanks(blockin.toInt))

    case XML.Elem(name, atts, body) :: ts => ...; format(ts1, blockin, after, btext1)
    case XML.Text(s) :: ts => format(...)
  }
```

Basic Isabelle/Scala services

- platform abstractions (Linux, Mac OS, Windows/Cygwin)
- Isabelle symbols vs. Unicode (UTF-8)
- minimal AWT/Swing support, including Isabelle font
- XML trees and YXML encoding (simple and efficient)
- process management (prover, other tools)
- pretty printing and HTML rendering of prover output
- asynchronous document model (long story — to be continued)

Application: Isabelle/jEdit

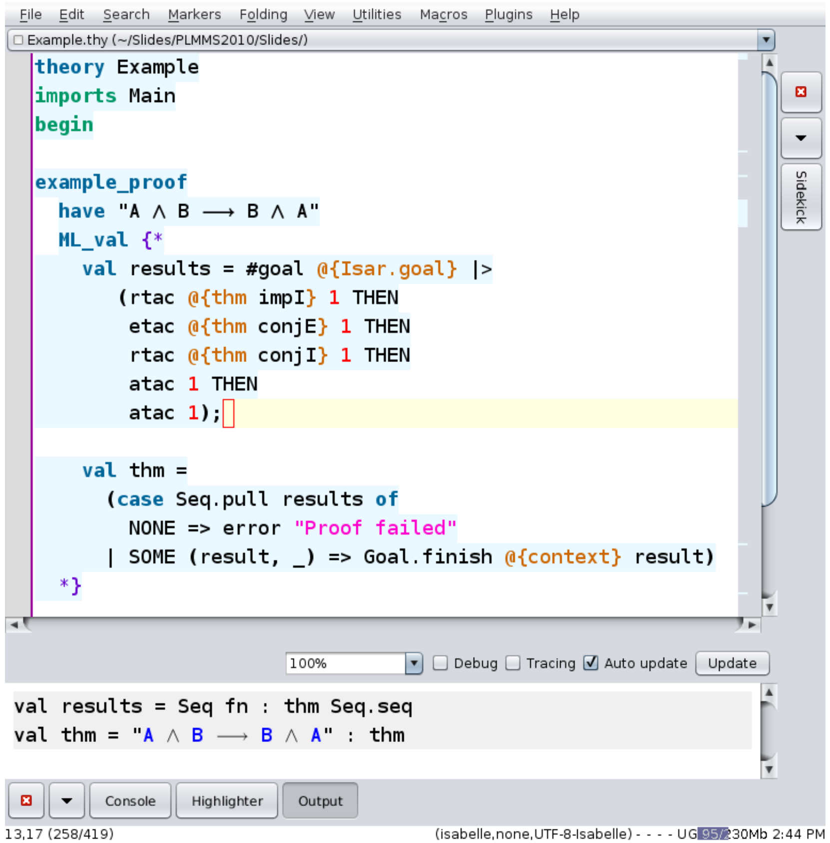
jEdit

Main characteristics:

- very powerful editor framework
- well-focused and well-written
- pure Java/Swing application for standard JVM 1.6
- easily extensible via plugins (officially in Java, we use Scala)
- worthy successor to Emacs
- general GUI metaphors similar to full-scale IDEs

Isabelle/jEdit

- "IDE" both for Isar and ML
- discontinues "locked region" of Proof General
- asynchronous proof processing
- sneak preview in Isabelle2009-2: run `isabelle jedit`



Conclusion

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Achievements:

- bridging the gap between ML and Java/JVM — thanks to Scala
- towards routine use of prover IDE technology

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Lessons learned:

- LCF-style provers can be adapted to accommodate interfaces
- many seemingly marginal issues need to be addressed (process, encodings, fonts, rich text rendering)
- actual GUI programming rather marginal
- asynchronous proof processing mostly concerned about persistent history management (cf. Mercurial SCM)

Future work

Scaling up:

1. large buffers — now: up to 5–10 pages
2. multiple buffers — without locking
3. connectivitiy with actual SCM history (Mercurial)
4. distributed multi-author editing (Wiki?)

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Exploiting semantic content from prover:

- generic CSS rules for GUI metaphors
- formal cross references everywhere
- hilighting of scopes, renaming of bindings
- templates, proof skeletons etc.