ITP Uses and Challenges at Rockwell Collins

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Building trust every day

Rockwell Collins' core business is based on delivery of *High Assurance* Systems

- Commercial/Military Avionics Systems
- Flight Control Systems
- Heads Up Displays
- Navigation & Landing Systems
- Defense Communications

"Working together creating the most trusted source of communication and aviation electronic solutions"

HOL and ACL2

- Interactive theorem provers with a long pedigree
- Separate user groups, culture, and focus
- ACL2 : recursive mathematics in seemingly unquantified FOL
- HOL : higher order logic with simple types
- Example: divisibility.

```
ACL2:  divides a b = x <> 0 /\ integerp (y / x)
       least-divisor k n =
          if integerp(n) /\ integerp(k) /\ 1 < k <= n
            then if divides k n then k else least-divisor (k+1) n
            else nil
      prime(p) = integerp(p) /\ (least-divisor 2 p = p)
```

```
HOL:  divides a b = ?d. b = a * d
    prime p = (p <> 1) /\ !n. divides n p ➔ (n=1) \/ (n=p)
```

Impressions of ACL2

- Declarative proof is nice! Can start getting results right away.
- Learning curve has few handholds
- Implicit context is un-nerving (every previously proved fact is by default in the implicit context)
- Impressive online documentation
- I keep forgetting to set rule classes on proved theorems, which causes later proofs to fail
- Reading failed proof transcripts is depressing ("the method")
- Nostalgic for types.
- However, defining functions to work over the whole ACL2 universe is engaging once you understand a few basics.
- Monotonicity fails

Monotonicity

- At the level of deduction:
  - If Gamma |- A then Gamma, B |- A
- At the level of theory development
  - If Context |- A then Context,B |- A
- Having more info in context can derail existing proofs
- When monotonicity fails, proof developments tend to become "append only"
- Large-scale formalization steps, e.g. merging libraries, become more fragile
- BUT
- Implicit context v. helpful in controlling complexity of interaction

Computation

- Of the systems I've used, ACL2 treats the idea of computation most extensively.
- Evidence : executable counterparts, guards, mbe, stobj
- Seamless passage of functions and results back and forth between OL and ML.
- Only an implicit notion of computable function
- Logical functions do not have an operational semantics visible inside the logic or (alternatively) a visible EVAL
- The logic is a theory of s-expressions and those are identified (fully?) with the s-expressions of the ML.
- What would something like this look like for other systems?
- Possible starting point: an SML that had HOL types and terms as primitive?

Cultures

- Each prover has a high barrier to entry
- Logic is the least of it!
- HOL concepts: rule (primitive and derived), tactic, conversion, theory, library, plus vagaries of host ML.
- Isabelle concepts: rule (primitive and derived), h.o. unification, type class, locale, ISAR language
- ACL2 concepts: book, hints, rule classes, guards, mbe, stobj
- Behaviour of reasoners with hidden state (rewriters especially)
- BUT
- Ancient systems always provide a way to emulate behaviour (decision procedures as derived rules, rule-classes nil)
- Turing tarpit: computation in the ML can bridge gaps
- High degree of viscosity: people get invested (compare with SAT or SMT)

Theory structuring mechanisms

- HOL: theory segments, DAG of
- ACL2: books
- Meeting ground between software engineering and logic
- Issue: library development concurrent with development of theories using library.
- Issue: dependency maintenance. With separately compiled theories comes Makefiles. Tends to be a horror show (“do I have GNU make on this machine, or what?” etc). We wrote our own. Does everybody write their own?
- Issue: quarreling theories. Theories A and B overlap, but each offers significant functionality that the other doesn’t (e.g. proof automation or difficult theorems). But it is difficult to use both at the same time. Usually can be worked-around, though painful.

My ITP wish list

- If I know a proof in detail, I want to be able to get the proof system to do **that** proof. Without having to tinker extensively or drop down to an overly low level of interaction.
- If my conditional rewriter can't prove a condition and I really do want that rewrite to complete, then I should be able to force the rewrite and get the condition appearing as an extra proof obligation. (Peter Homeier's `dependent rewriting').
- In the middle of a proof I want to be able to add new facts, by asserting them on the spot and having the system prove them or by referring to previously proved facts.
- System should tell me at least something that is missing from failed proof attempt.
- What we are doing almost all the time is dealing with failure and trying to garner information that will show the cause of failure.

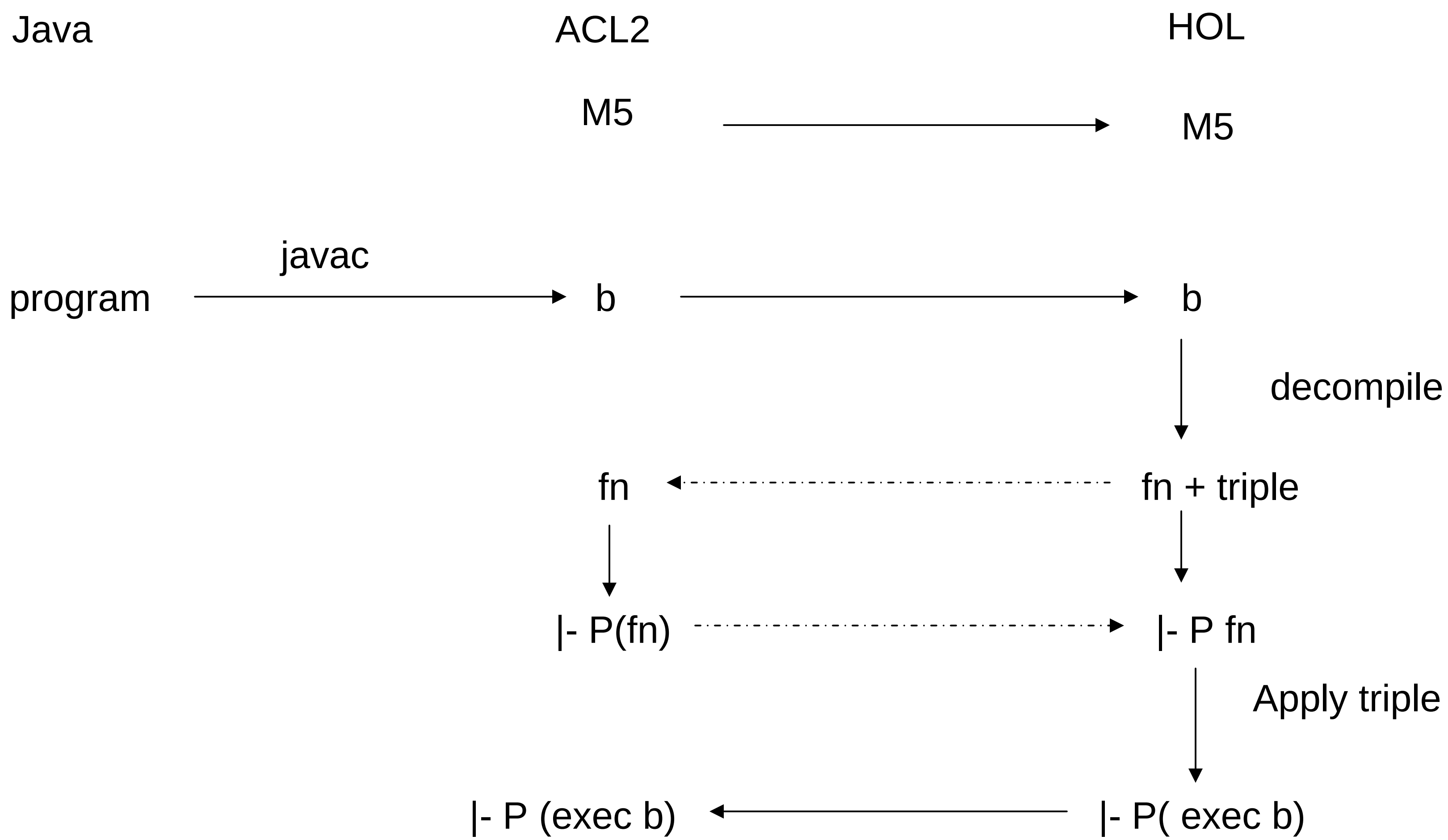
HOL—ACL2 interaction

- See the work by Matt Kaufmann and Mike Gordon
- The artifact exists. How can it be exploited?
- Two discernible starting points:
  - There's a difference in expressive power, so use HOL to formalize abstract notions. Use ACL2 in its sweet spot.
  - There's a less intrinsic difference, e.g. one system has a large formal model that the other lacks; or provides proof support that the other lacks; or a user is simply unwilling to learn a new system.
- Typically want to either make a case that the task can't be accomplished any other way, or that it is interesting that the task be broken across two proof systems.
- Compare with old QED proposal
- Compare with current mechanisms for sharing theories between proof systems.

Possible Application: bytecode proofs

- ACL2 has (thanks to J) a detailed JVM model
- HOL-4 has (thanks to Magnus) a decompiler
  - Decompile : assembly -> recursive fn + triple
  - Triple asserts that running asm on input equals fn on input
- Observation: direct verification of bytecode is too time-consuming and detailed
- Idea: use decompiler on bytecodes to see if reasoning about rec. fns can be more productive

Bytecode proof flow



The End

Thank you!