Research Report; IFIP WG 10.4 July 2001

Connecting Tools Together

John Rushby

Computer Science Laboratory
SRI International
Menlo Park, California, USA

Horses for Courses

- No one formal methods tool is universally effective
  - Often want to apply several tools to a single design description
  - Tool suites are usually of uneven quality
- Results from one tool can help further analysis by another
- The components of one tool may be useful to another

Apply Several Tools To A Single Description

- Cf. IF, Möbius, Veritech,. . .
- Our approach, SAL, is based on transition relations (nondeterministic state machines) as the common representation
- Natural representation for several kinds of computational systems
- And used by many Off-The-Shelf tools

SAL Language

- A way to specify transition relations and their properties
- Developed in a loose collaboration with Stanford (David Dill), Berkeley (Tom Henzinger), and Verimag (Saddek Bensalem)
  - InVeSt has adopted the SAL language
- Has definitions, guarded commands, modules, synchronous and asynchronous composition
- External representations use XML

SAL Tools

We provide

- Parser and prettyprinter
- Typechecker

  Like PVS, can use theorem proving to discharge certain "well-formedness" requirements

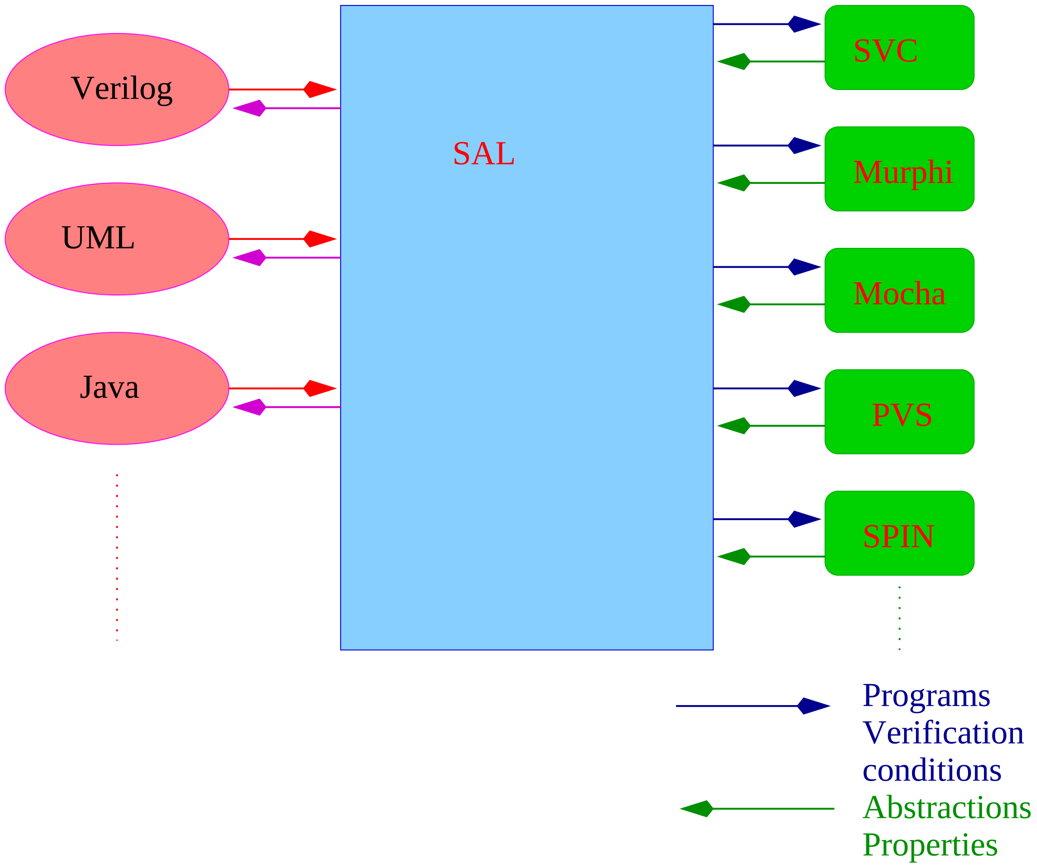
  - E.g., no causal loops in synchronous composition
- Predicate and data abstractor
- Explicit-state model-checker
- Tool Bus

Users provide

- Translators from front-end notations into SAL
- Wrappers/translators from SAL to back-end tools

SAL Architecture

The SAL Language serves as a hub



Not all of these boxes are populated yet

Automated Abstraction

- Calculate simplified system description that (hopefully) preserves the property of interest (cf. Predicate abstraction, abstract interpretation)
- The calculation is done by automated theorem proving
- The general theorem proving problem is undecidable
    - Full automation requires heuristics, which sometimes fail
- Classical verif'n poses correctness as single "big theorem"
    - So failure to prove it (when true) is catastrophic
- Abstraction creates a context for failure-tolerant theorem proving
    - Prove lots of small theorems instead of one big one
    - In a context where some failures can be tolerated

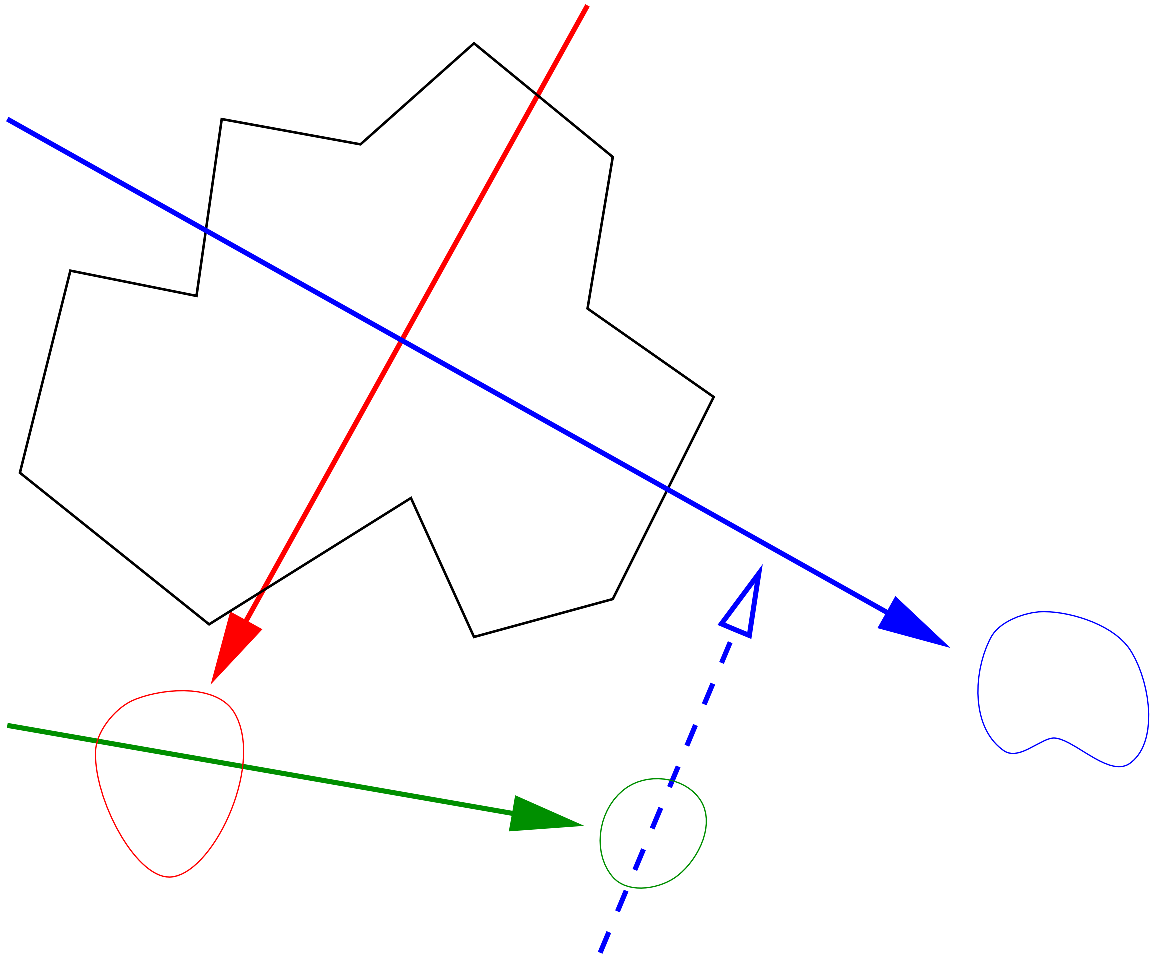
Integrated, Iterated Analysis

Results from one tool can help further analysis by another

Example

- Abstraction can work better if you know invariants
- A model checker can calculate the reachable states (strongest invariant) of a finite state system
- Concretization of the reachable states of an abstraction is an invariant of the original
- So calculate crude finite state abstraction, generate invariant with model checker, concretize, and iterate
- Final verification by model checking accurate, simple model

Integrated, Iterated Analysis



Even More Integrated, Iterated Analysis!

- (Approximations to) fixpoints of weakest preconditions or strongest postconditions also generate invariants and can strengthen those extracted from an abstraction
  - Mechanized by theorem proving
  - (Strongest postconditions are equivalent to symbolic simulation, which is independently useful)
- Counterexamples from failed model check help distinguish bugs from weak abstractions, and also help refine the abstraction
  - Suggest additional properties (invariants) that will help the theorem prover construct a tighter model
  - Suggest additional predicates on which to abstract

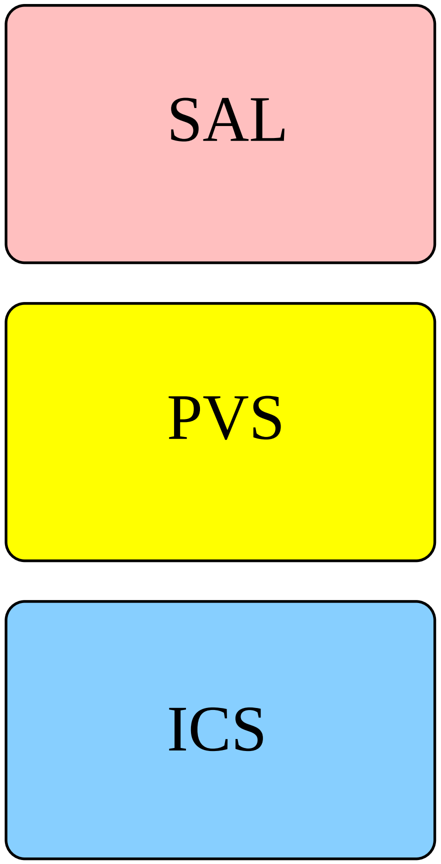
Truly Integrated, Iterated Analysis!

- Recast the goal as one of calculating and accumulating properties about a design (symbolic analysis)
- Rather than just verifying or refuting a specific property
- Properties convey information and insight, and provide leverage to construct new abstractions
    - And hence more properties
- Requires restructuring of verification tools
    - So that many work together
    - And so that they return symbolic values and properties rather than just yes/no results of verifications
- This is what SAL is about: Symbolic Analysis Laboratory

The Components Of One Tool May Be Useful To Others

- Lots of people use PVS just to get at its decision procedures
- We are making new faster version of these available as ICS
  - ICS = Integrated Canonizer-Solver (= ICanSolve)
- Decides combination of: propositional satisfiability, equality over uninterpreted function symbols with (linear) arithmetic, arrays, datatypes
- Will later extend to quantifier elimination for decidable fragment of these
- Differs from other packaged decision procedures (e.g., SVC) in having rich API for adding/retracting facts, testing formulas
- Aim is to enable invisible or ubiquitous formal methods

What We Are building



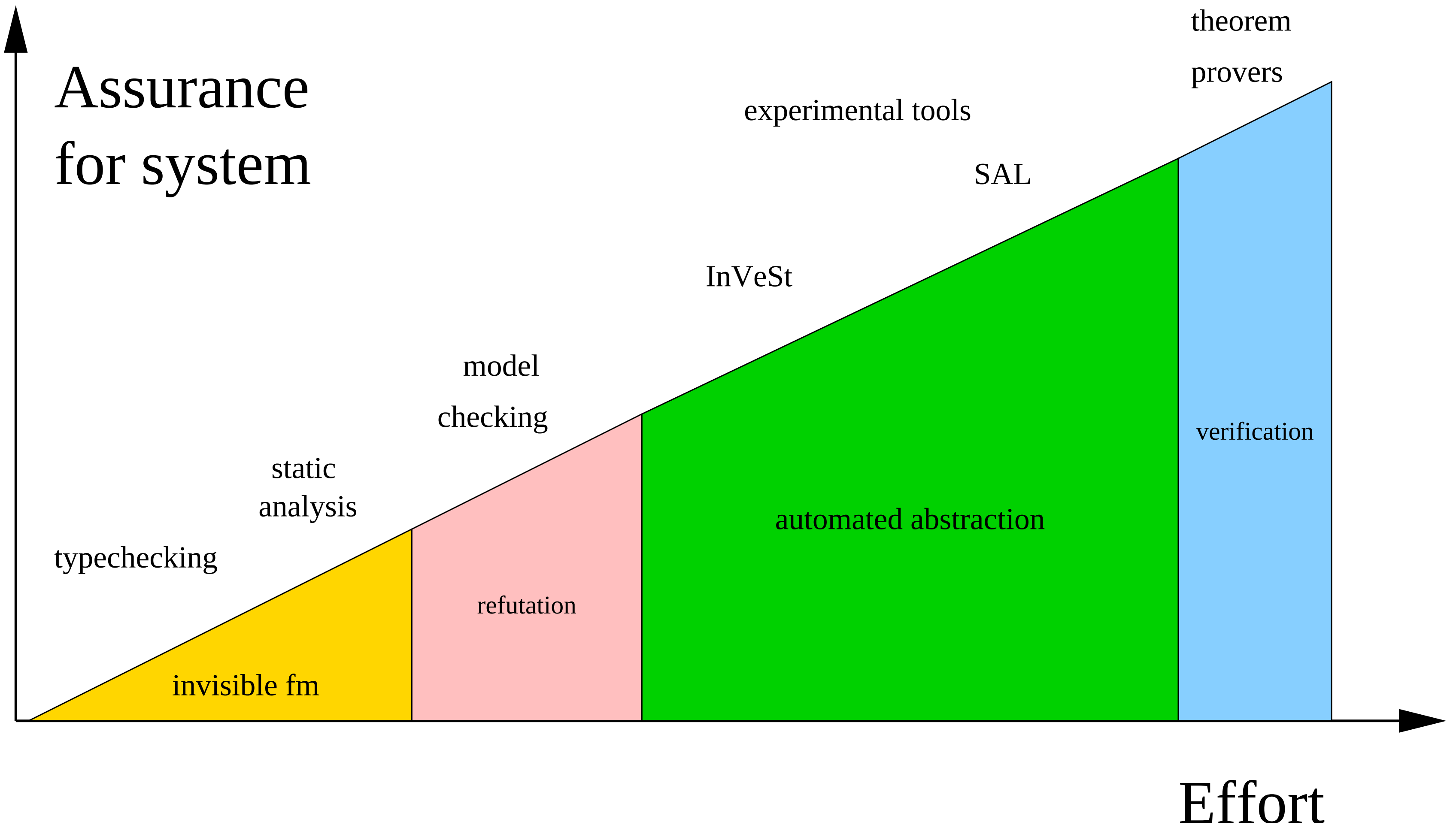
Invisible Formal Methods

Use the power of automated deduction, abstraction, and model checking to augment traditional tools

- Extended static checking (cf. Compaq SRC's ESC)
- Table checkers (cf. Ontario Hydro)
- Statechart/Stateflow property checkers (cf. OFIS)
- Test case generators (cf. Verimag/IRISA TGV)

And much more to come...

From Refutation To Verification



Acknowledgments

- N. Shankar, Sam Owre, Harald Rueß, Hassen Saïdi
- Saddek Bensalem, Jean-Christophe Filliâtre, Klaus Havelund, Friedrich von Henke, Yassine Lakhnech, César Muñoz, Holger Pfeifer, Vlad Rusu, Eli Singerman, and many others