Viper
A Verification Infrastructure for Permission-Based Reasoning

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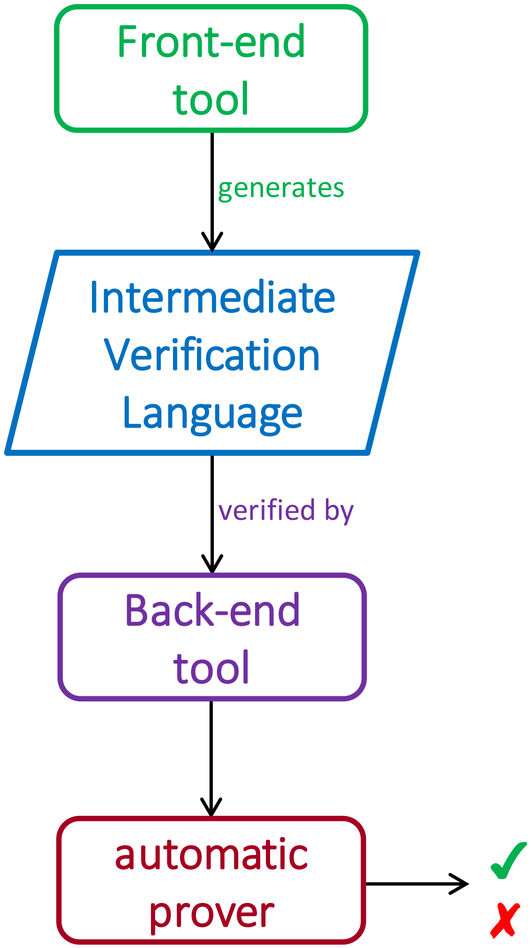
(and many students)

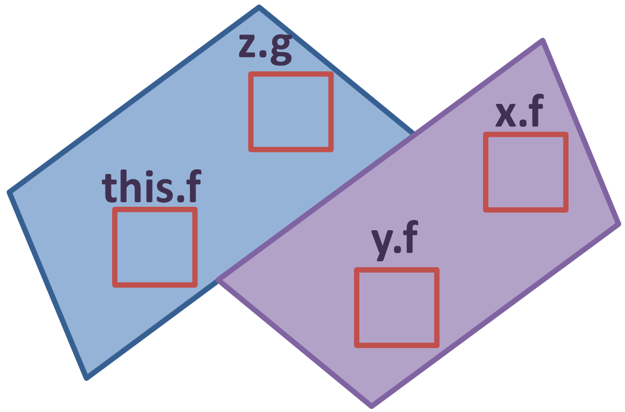
16th July 2015, Imperial Concurrency Workshop

Verification via Automatic Provers



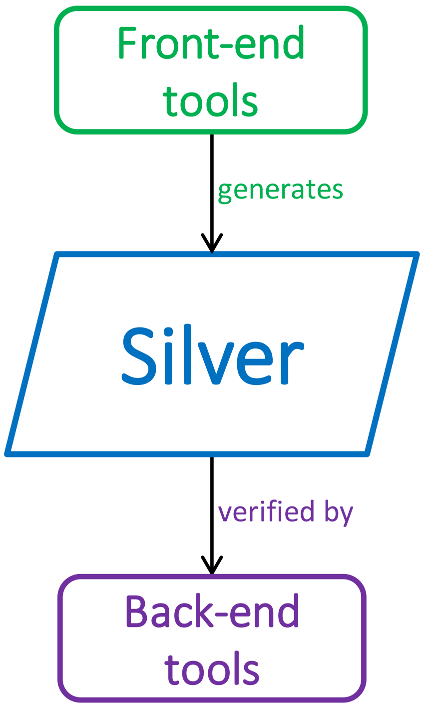
- Last 10 years: rapid progress in automatic tools for first-order logics (SMT solvers, provers)
- Intermediate Verification Languages: e.g. Boogie and Why
- Provide common infrastructures for building program verifiers
- Many success stories and tools
  - Microsoft Hypervisor (VCC)
  - Device-drivers (Corral)
  - .. and many more, e.g., Why3, GPUVerify, Spec#, Dafny, Vericool, Krakatoa, etc....

Permission-Based Reasoning



- Separation Logic (and others): custom logics for heap reasoning
- control of ownership/sharing of *partial heaps* (heap fragments)
- First-order prover technology *difficult* to directly exploit
  - Custom verification engines (usually symbolic execution)
  - Lots of work to implement
  - Hard to reuse for new work
  - … fewer tools available ☹

The Viper Project



- We have designed **Silver**: a new intermediate verification language
  - Reusable *native support* for permission-based heap reasoning
  - Few, expressive constructs
- The tool infrastructure is called Viper
  - Includes back-ends (two verifiers)
- Some front-end tools also available:
  - Proof-of-concept translators for
    - *Chalice*, *Scala* (fragment), etc..
    - used for various other projects

Basic Assertion Language

- Based on *Implicit Dynamic Frames* [Smans et al. '09]
- Permission assertions: *accessibility predicates* acc(e.f)
  - exclusive: similar to $e.f \mapsto \_$ in separation logics
- Expressions e may depend directly on the heap
  - e.g. acc(x.f) && x.f > 0
- *Fractional permissions* [Boyland'03], e.g. acc(x.f, ½)
  - allow reading (and framing), not writing
- Conjunction && is multiplicative for permissions
  - e.g. acc(x.f, ½) && acc(x.f, ½) ≡ acc(x.f, 1)

Silver primitives: Inhale and Exhale

- A statement **`inhale A`** means:
  - all permissions required by are **`A`** gained
  - all logical constraints (e.g. x.f > 0) are *assumed*
- A statement **`exhale A`** means:
  - check, and remove all permissions required by **`A`**
  - all logical constraints (e.g. x.f > 0) are *asserted*
  - any locations to which all permissions is lost are implicitly *havoced* (their values are no-longer known)
- Can be seen as the *permission-aware analogues* of assume/assert statements used in first-order verification
  - used to model ownership transfer of partial states
  - cf. “produce” and ”consume” in symbolic execution

Example : Encoding Locks (CSL-style)

```
class C {
  int[ ] data; int count = 0;

  monitor invariant this.data↦_ * this.count↦_


  void Foo( ) {
    acquire this;
    int i = data.length;
    while( 0 < i )
      invariant this.data↦_ * this.count↦_
      invariant holds( this );
    { ... ; i = i - 1; }
    count = count + 1; release this;
  }
}
```

A few powerful Viper features….

- *Paired assertions* **`[A,B]`**
  - **`A`** used when inhaled, **`B`** used when exhaled
  - mismatches: external justification / proof obligations
- *Quantification over local state* **`forallrefs[f] x ::`**
  - non-standard for separation logics (but handy)

Example : Two-state invariants

```
class C {
  int[ ] data; int count = 0;

  monitor invariant this.data↦_ * this.count↦_
                    && this.count > old(this.count)

  void Foo( ) {
    acquire this;
    int i = data.length;
    while( 0 < i )
      invariant this.data↦_ * this.count↦_
      invariant holds( this );
    { ... ; i = i - 1; }
    count = count + 1; release this;
  }
}
```

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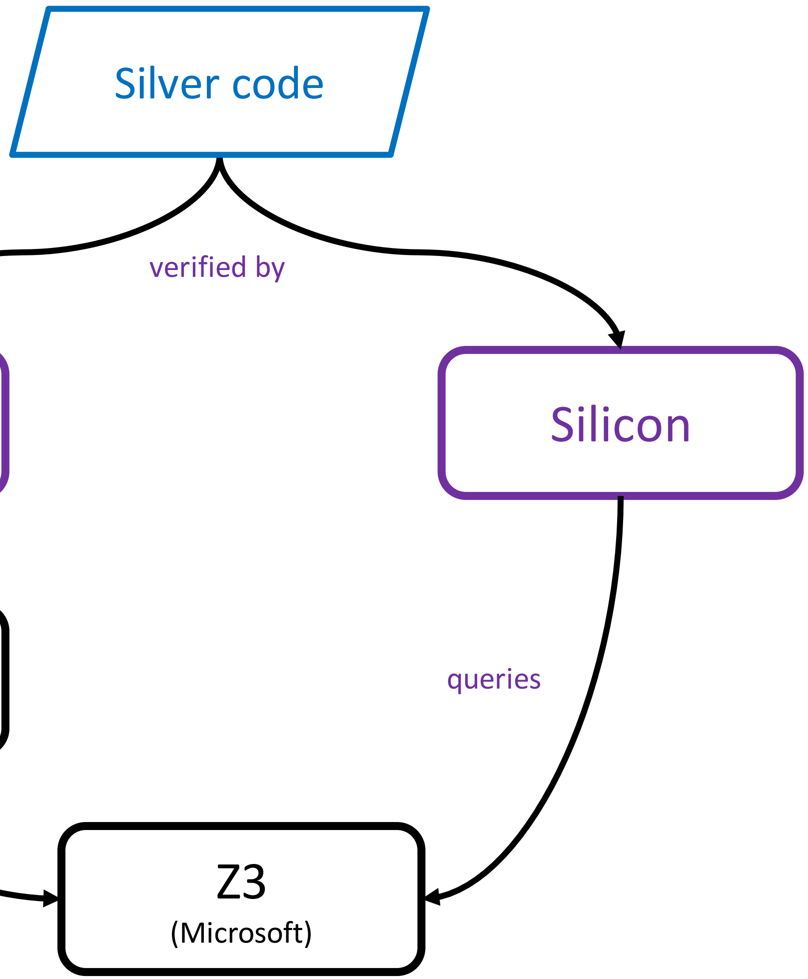
- *Quantification over local state* **`forallrefs[f] x ::`**
  - non-standard for separation logics
- *State snapshots, labelled "old" expressions*
- *Custom predicates, heap-dependent functions* [ECOOP'13]
  - fold/unfold for predicates, functions mostly automatic
- *Constrainable permissions* [VMCAI'13, FTfJP'14]
  - Alternative to fractional permissions (angelic amounts)
- *"Magic wand" support* [ECOOP'15]
  - Powerful connective from separation logic
- *Custom domains, sets and sequences, quantifiers*

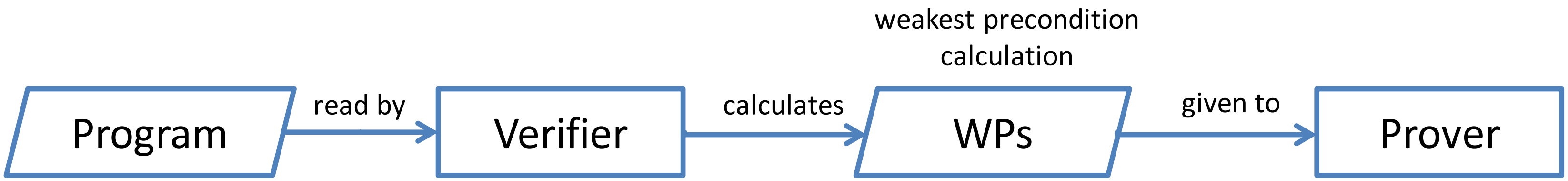
Verification of Silver Code (back-ends)



Verification Condition Generation

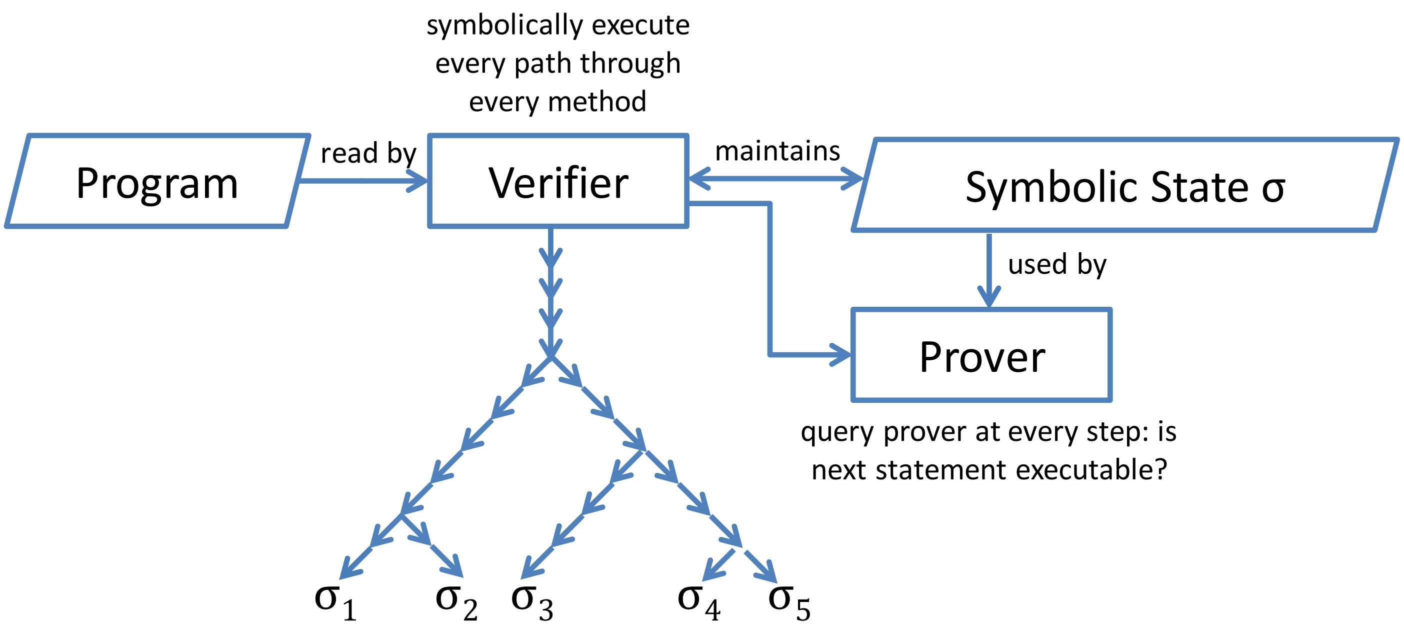
Symbolic Execution

Verification of Silver Code (back-ends)



VCG

Query prover once with full information (encode heap)



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Query prover often with limited information (no heap)

Tool Availability and Future Work

- Core tools released (open-source) in September 2014:

  `http://www.pm.inf.ethz.ch/research/viper.html`

  `https://bitbucket.org/viperproject`

  - we have (public!) issue trackers for known problems
  - Some advanced features are in the pipeline (but ask)

- Building / supporting new tools by translations into Silver
  - SL, dynamic frames, invariants, rely-guarantee, types
  - More-advanced program logics? Weak memory? …
  - Also interested in work we *cannot* encode (yet …)

- Make tools to implement your cool research with Viper ☺
  - coalesces much formal and practical past research
  - users can focus on the aspects relevant to their work

Any questions?