Viper
A Verification Infrastructure for Permission-based Reasoning

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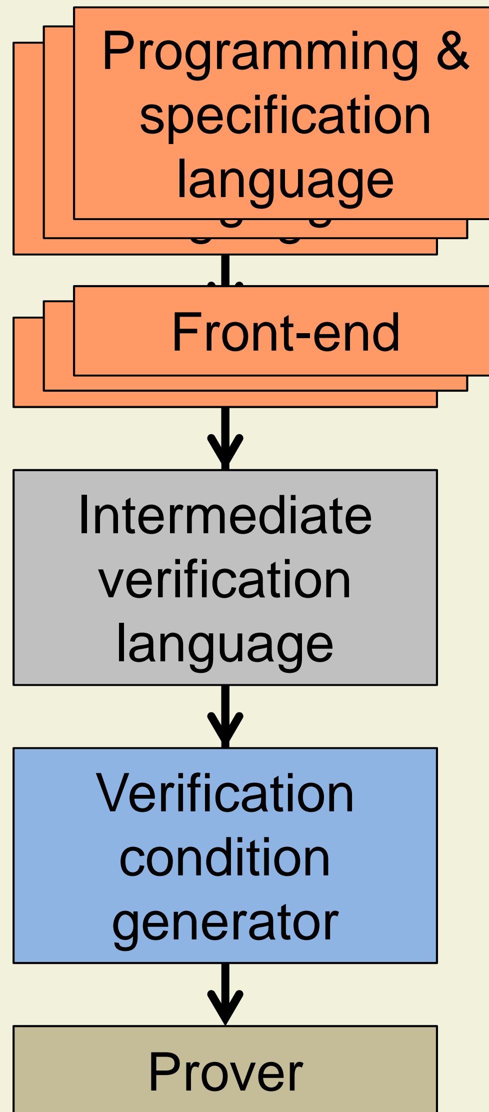
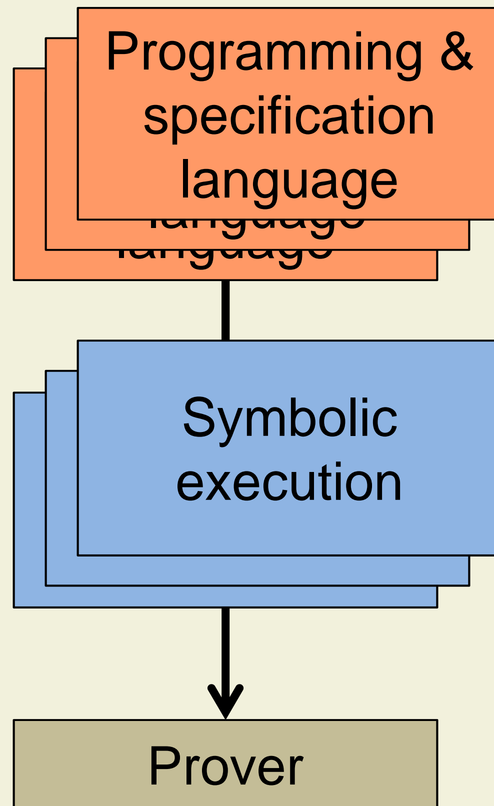
Automatic Program Verification



- Most automatic deductive verifiers use solvers for first order logic (Z3, CVC4)
- Verification conditions are computed via translation to intermediate verification language (Boogie, Why)
- Many success stories: Corral, Dafny, Frama-C, Spec#, VCC

Verifiers for Permission Logics



- Separation Logic (and other permission logics) use custom logics to reason about heap-manipulating programs
- Custom verification engines (jStar, Smallfoot, VeriFast)

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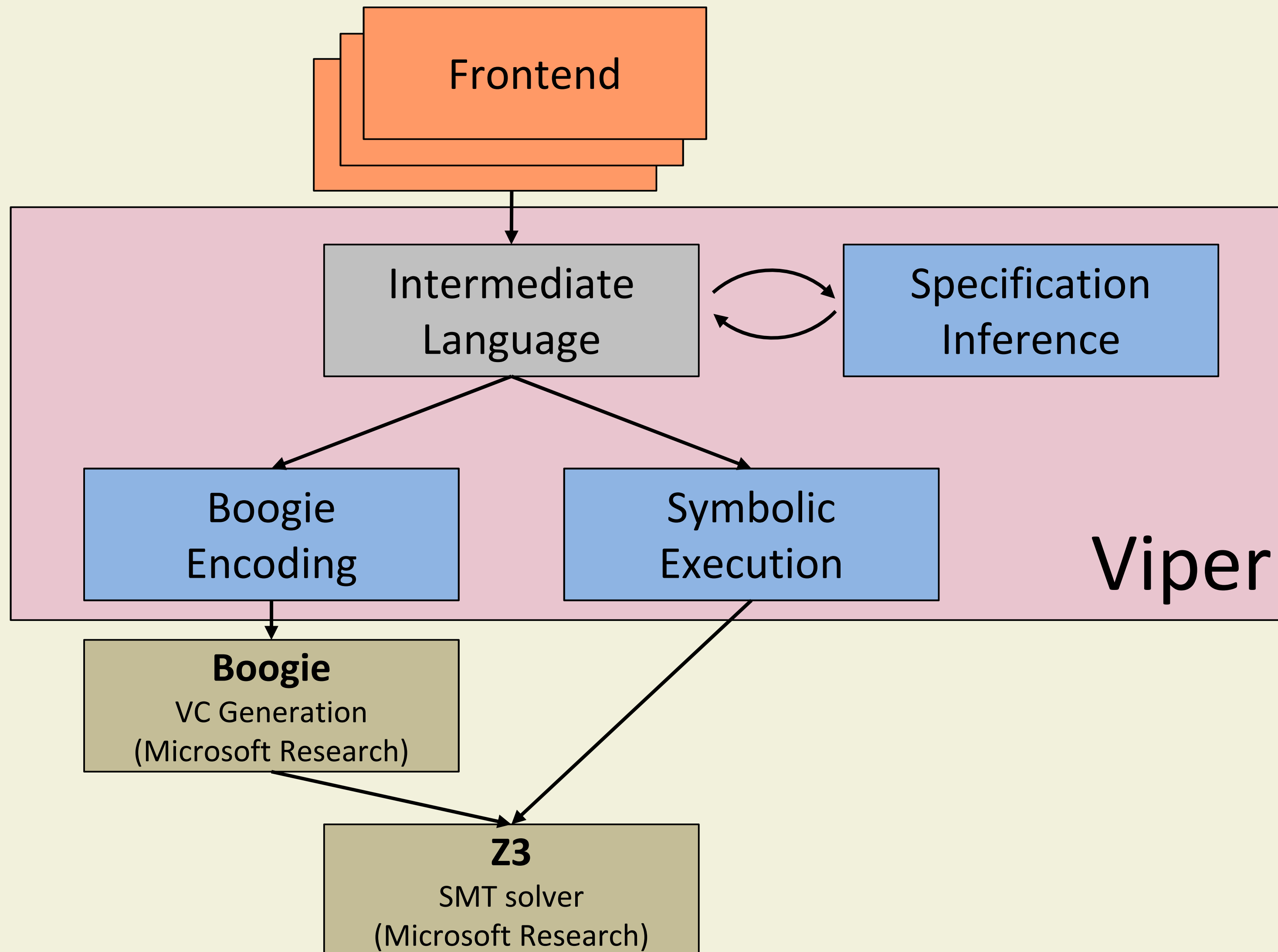
Viper Infrastructure



Permissions

- Permissions denoted by accessibility predicates
- Expressions e may depend on the heap
- Support for fractional permissions
- Conjunction is multiplicative (as in in separation logic)

acc(e.f)

acc(x.f) && x.f > 0

acc(x.f, ½)

acc(x.f, ½) && **acc**(x.f, ½)

Inhale and Exhale

- **inhale** A means:
  - all permissions required by A are obtained
  - all logical constraints (e.g., x.f > 0) are assumed
- **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)
- Analogues of **assume** and **assert**

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Example: Modeling Locks

```
class C {
  @GuardedBy(“this")  int[ ] data;

  void Foo( ) {
    acquire this;
    int i = data.length;
    while( 0 < i ) {
      …;
      i = i – 1;
    }
    release this;
  }
}
```

Mathematical Domains

```
domain Array {
  function loc( a: Array, i: Int ): Ref
  function length( a: Array ): Int

  axiom all_diff {
    forall a1: Array, a2: Array, i: Int, j: Int ::
      ( a1 != a2 || i != j ) ==> loc( a1, i ) != loc( a2, j )
  }

  axiom length_nonneg {
    forall a: Array :: length( a ) >= 0
  }
}
```

Symbolic Read Permissions

```
int eval( State s )
  requires acc( s.map, read ) && s.map != null
  ensures acc( s.map, read )
```

```
int eval( State s ) {
  leftTk := fork left.eval( s );
  rightTk := fork right.eval( s );
  return ( join leftTk ) + ( join rightTk );
}
```

Heap-Dependent Functions

```
class List {
  int value;
  List next;

  int len() {
    if( next == null ) return 1;
    else               return 1 + next.len();
  }

  int itemAt( int i ) {
    if( i == 0 )    return value;
    else            return next.itemAt( i – 1 );
  }
}
```


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Inhale-Exhale Pairs

- Proof principles

$$\frac{P(0) \qquad \forall n \in \mathbb{N} \bullet n > 0 \wedge P(n-1) \Rightarrow P(n)}{\forall n \in \mathbb{N} \bullet P(n)}$$

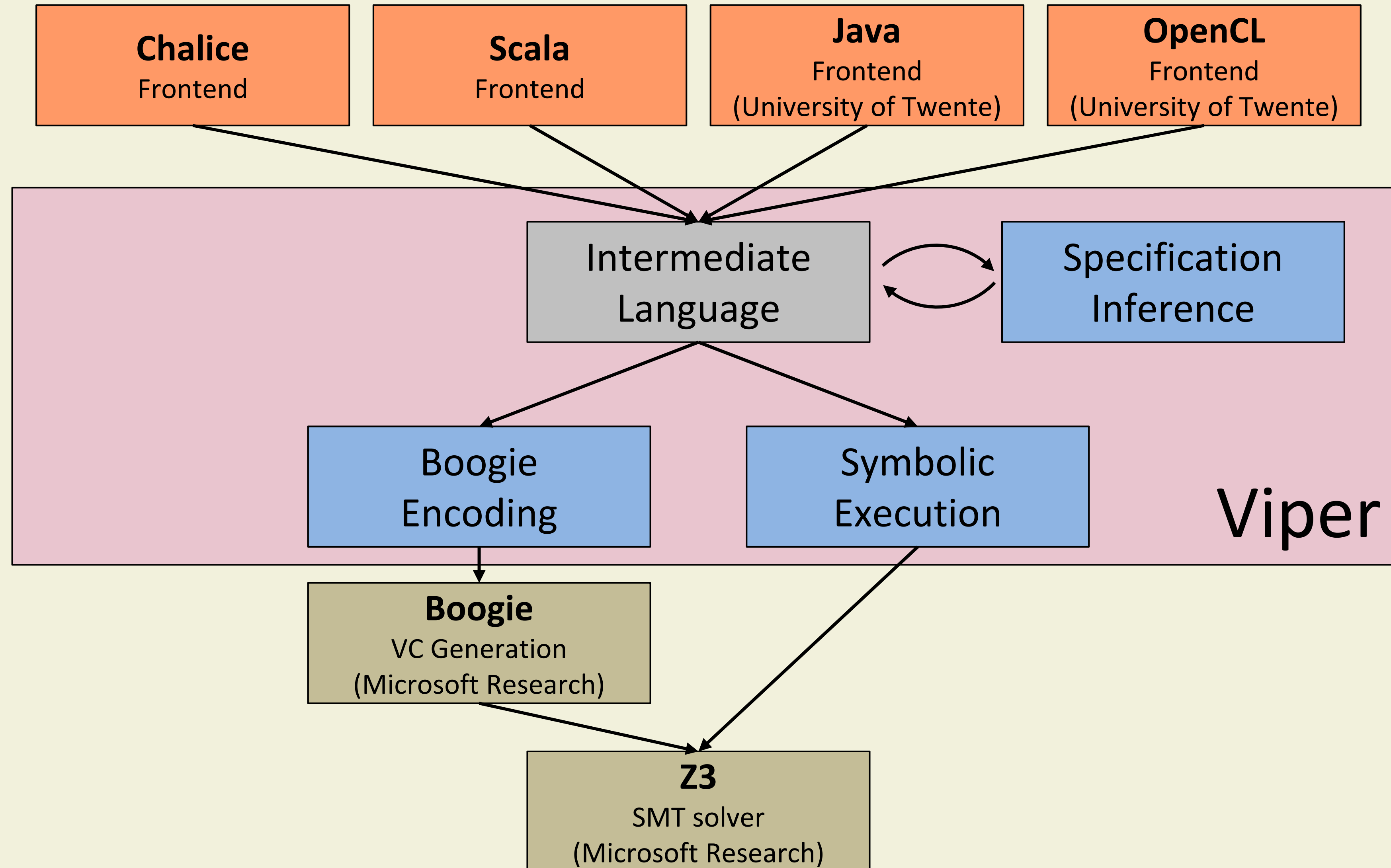
- Properties justified elsewhere

$$\frac{}{\text{type(this) <: T}}$$

- Context-dependent proof obligations

$$\frac{\textbf{forallrefs}\text{[holds] x :: }\textbf{false}}{\textbf{true}}$$

Viper – Frontends



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Conclusion

- Viper is useful to
  - Develop verifiers based on permission-logics
  - Prototype new verification techniques
  - Experiment with and integrate different back-ends
- Current work
  - Increase expressiveness of intermediate language
  - Encode more languages and program logics
  - Improve inference
- Try Viper online at viper.ethz.ch

Intermediate Language

- Top-level declarations
  - Fields
  - Methods
  - Heap-dependent functions
  - Predicates
  - Domains
- Types
  - Int, Bool, Ref, Perm
  - Set[T], Seq[T]
  - Types declared in domains
- Statements
  - Assignments, calls, conditionals, loops
  - inhale, exhale
  - fold, unfold
- Assertions
  - Permissions
  - Predicates
  - Magic wands
  - Quantifiers

Example: Leak Check

```
class C {
  @GuardedBy("this")  int[ ] data;

  void Foo( ) {
    acquire this;
    int i = data.length;
    while( 0 < i ) {
      …;
      i = i – 1;
    }
    release this;
  }
}
```

Example: Two-State Invariants

```
class C {
  @GuardedBy("this")  int[ ] data;
  @GuardedBy("this")  int count;

  monitor invariant count == old( count ) + 1;

  void Foo( ) {
    acquire this;
    count++;
    int i = data.length;
    while( 0 < i ) { …; i = i – 1; }
    release this;
  }
}
```