Behavioral Program Queries using Logic Source Code Templates

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Context: Program Queries

identify elements

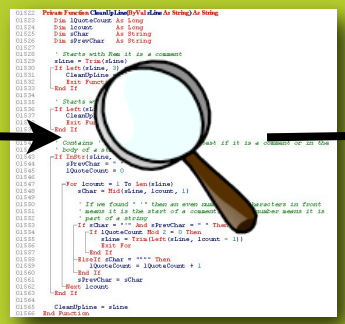
implementing

faulty
well-known
prescribed
suboptimal

behavior

effective identification
+
declarative specification

abstract definition



concrete instances

Context: Program Queries

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heterogeneous code

similar behavior

effective identification
+
declarative specification

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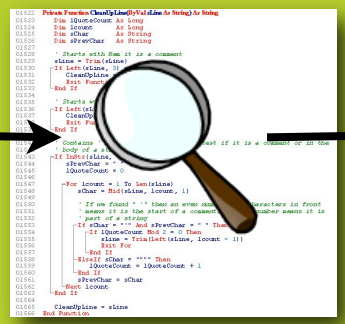

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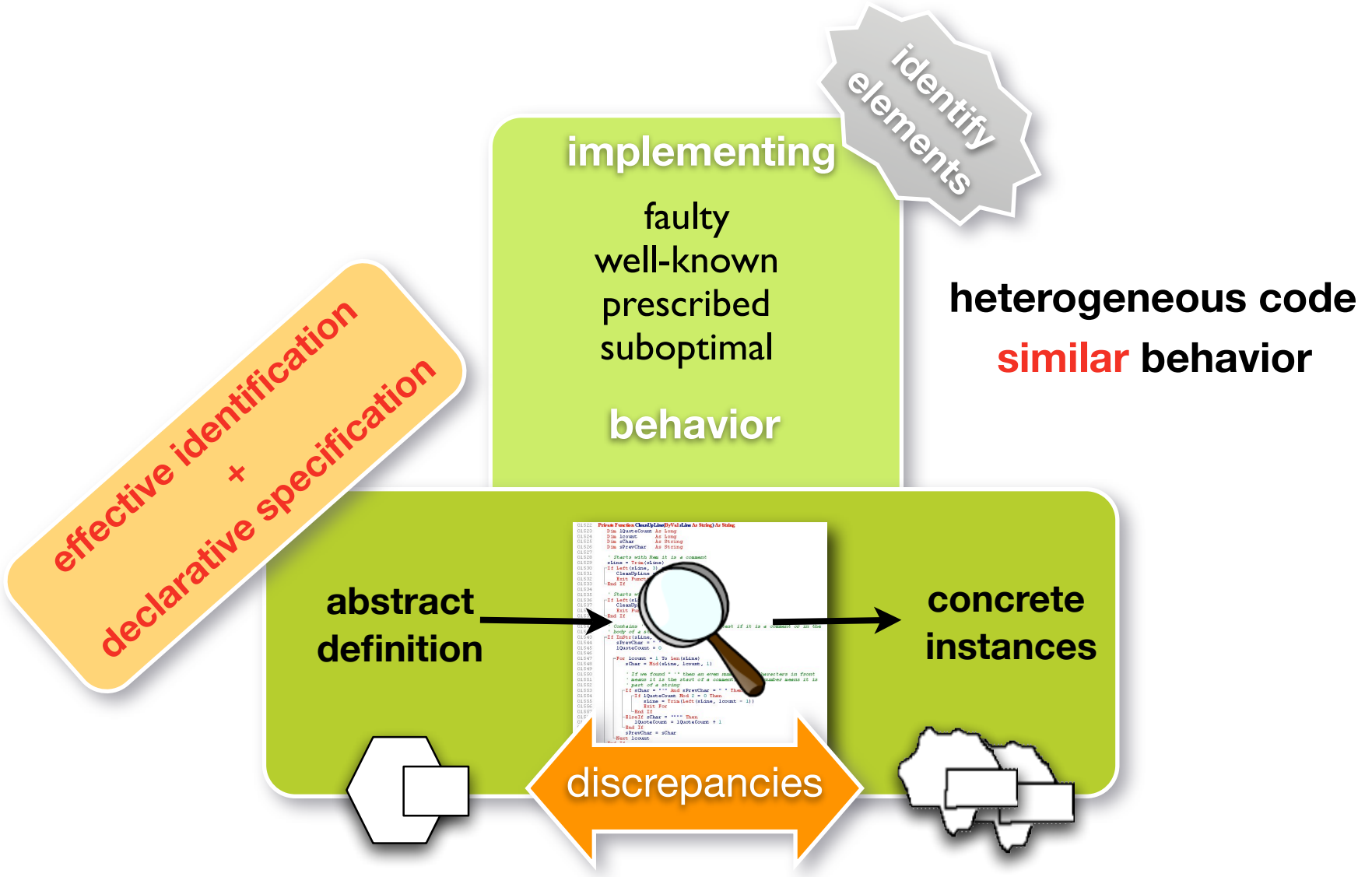

Motivating Example: Detecting Getter Methods

```
1 ?m getsFragment: ?g ofFieldDeclaration: ?f in: ?c if
2  ?f isFieldDeclarationInClassDeclaration: ?c,
3  ?f fieldDeclarationHasFragment: ?g,
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5  ?m isMethodDeclarationInClassDeclaration: ?c
6  ?m methodDeclarationHasBody: block(?s),
7  ?s contains: returnStatement(?name)
```

Should detect getter methods in an imaginary* LMP language.

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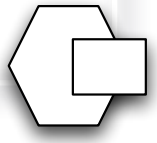

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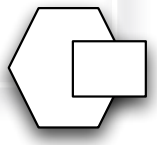

```
class Y {
 private X var;
 private Y self() {
   return this;
 }
 public X getVar() {
      return this.self().var;
 }
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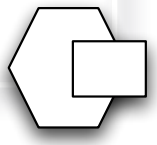

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}
```

```
class Y {
 private X var;
 public X notGetVar(X var) {
      return var;
   }
}
```

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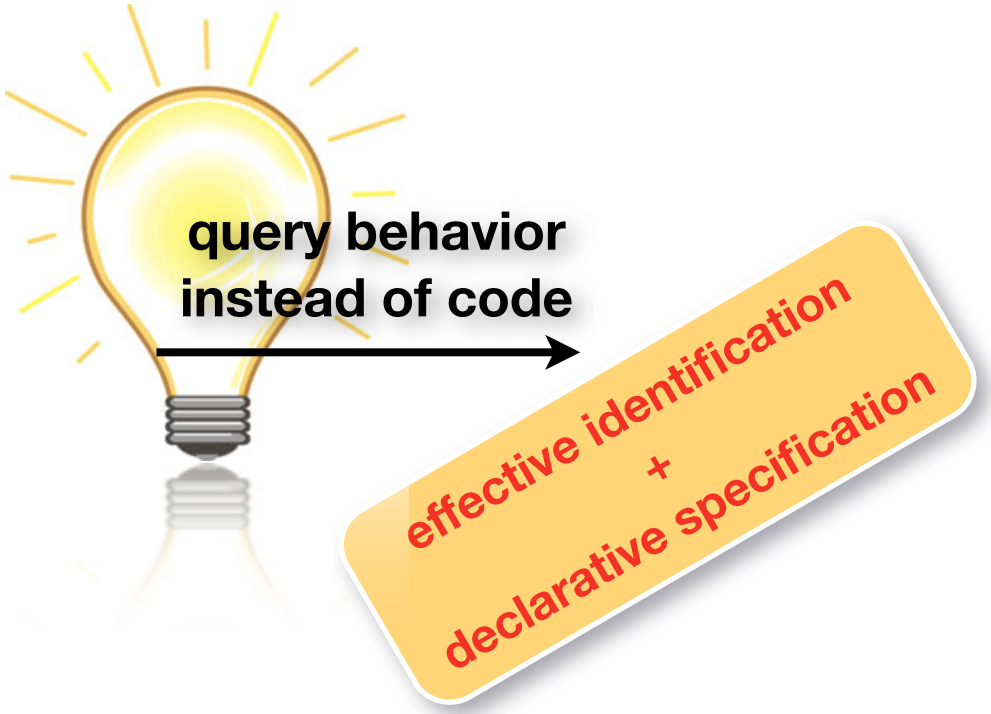
Isn't there a Straightforward Solution?



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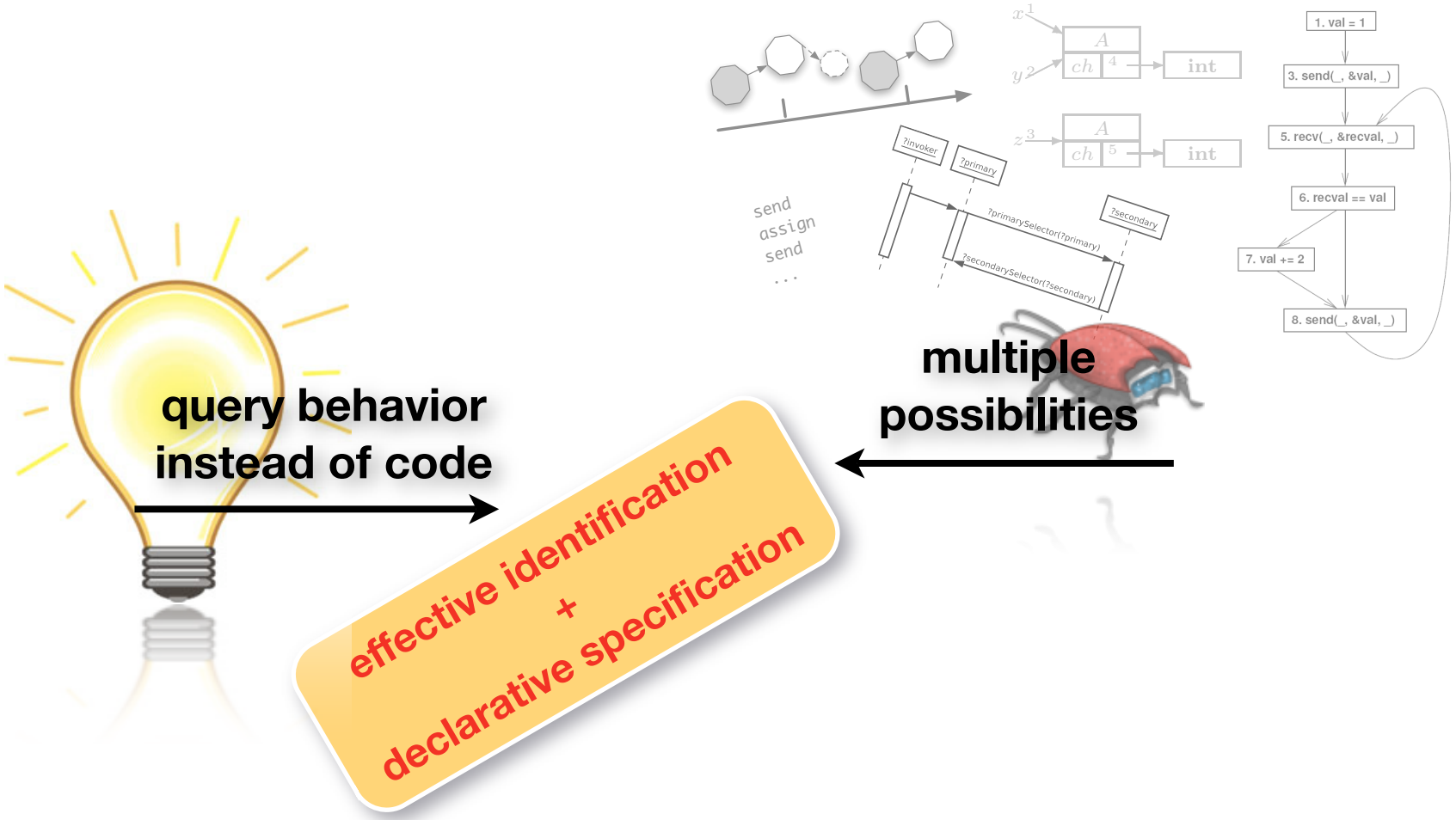

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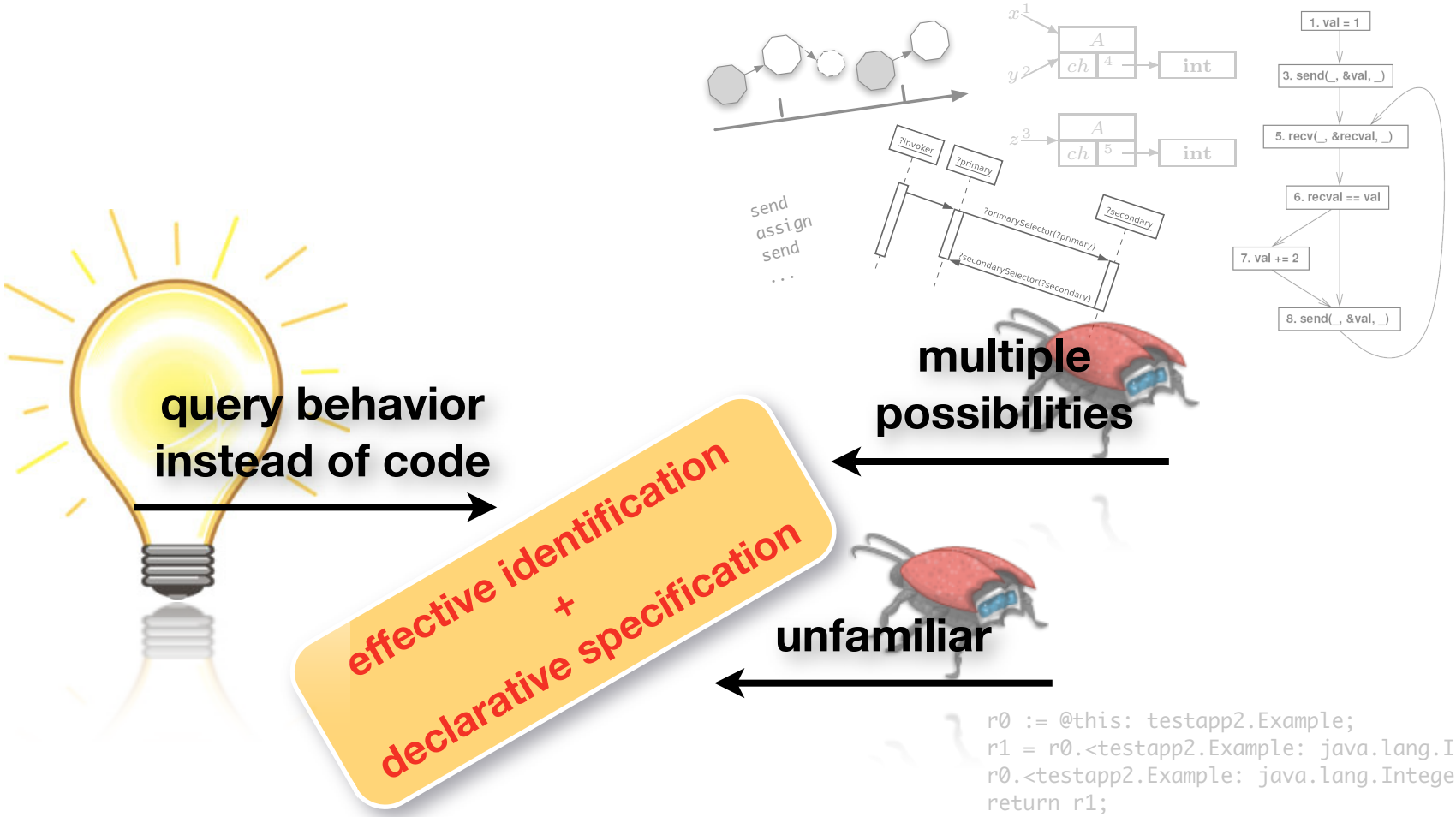

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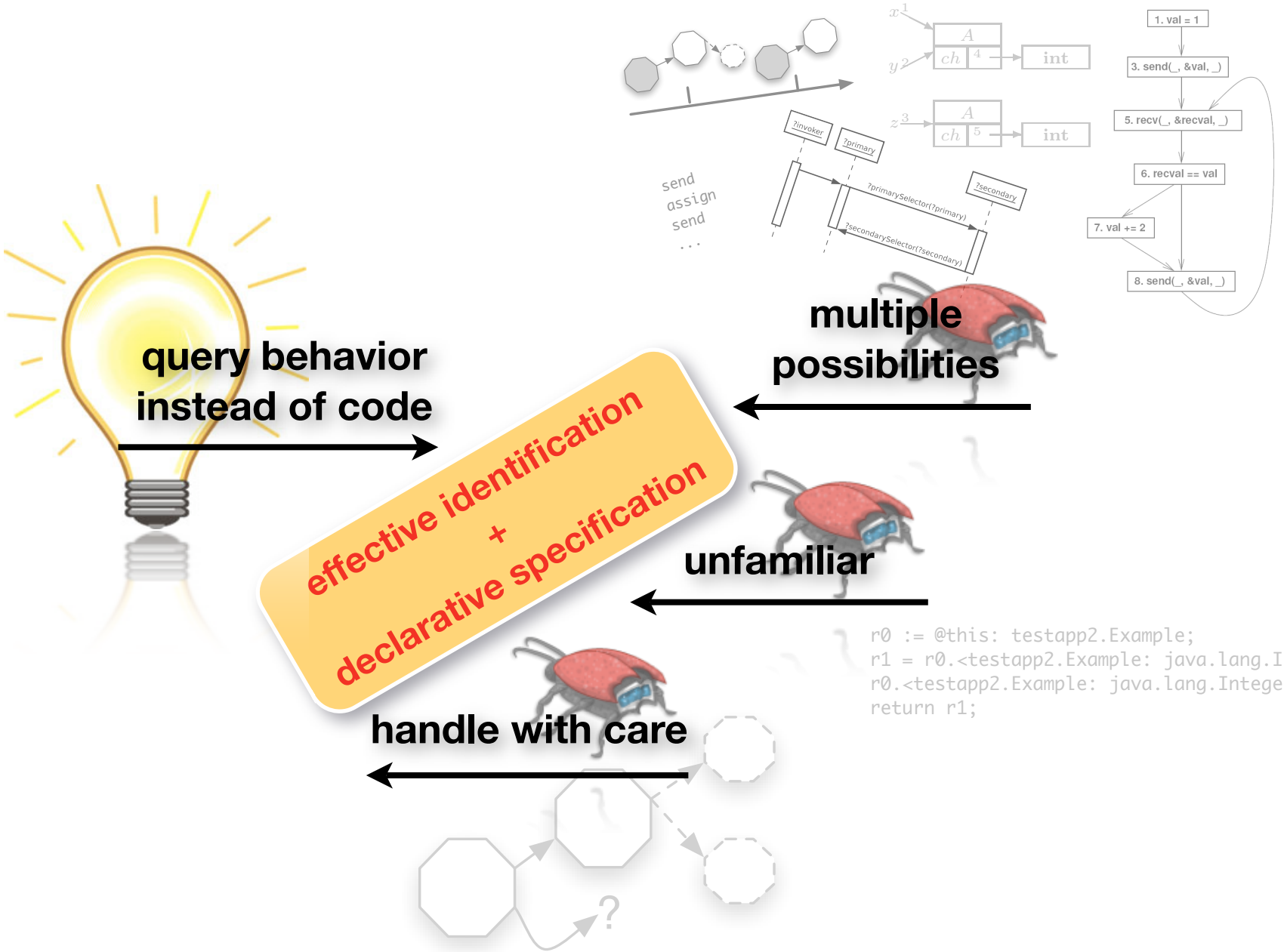

So, instead ..

```
if jtClassDeclaration(?c){
        class ?c {
            private ?type ?field;
            public ?type ?name() { return ?field; }
        }
}
```

```
public Integer gethour() {
    return this.hour;
}
public Integer gethourlazy() {
    if(hour==null)
      hour = this.currentHour();
    return hour;
}
public Integer getBuffer() {
    Integer temp;
    temp = this.self().buffer;
    return temp;
}
```

Solution Cornerstones

declarative pattern specification

concrete source code templates

integrated in logic language

effective pattern identification

resolved by fuzzy logic program

behavioral similarity determined statically

by open unification framework

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declarative pattern specification

user familiarity

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user familiarity → **concrete source code templates**

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user familiarity → **concrete source code templates**

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similarity template/match ← **resolved by fuzzy logic program**

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by open unification framework → approximated results

family of analyses

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Fuzzy Logic Programming

logic of quantified truth

rules annotated with partial **truth degrees**

✓ ***confidence*** *in instances detected by rule*

fuzzy logic

weighted logic rules

$q : c$ **if** $q_1,...,q_n$ **where** $c \in]0,1]$

similar to f-Prolog [1990:liu]

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fuzzy resolution procedure

conclusions from **partially satisfied premises**

✓ *detect partially adhering instances*

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$T(q) = c * \min(T(q1),...,T(qn))$

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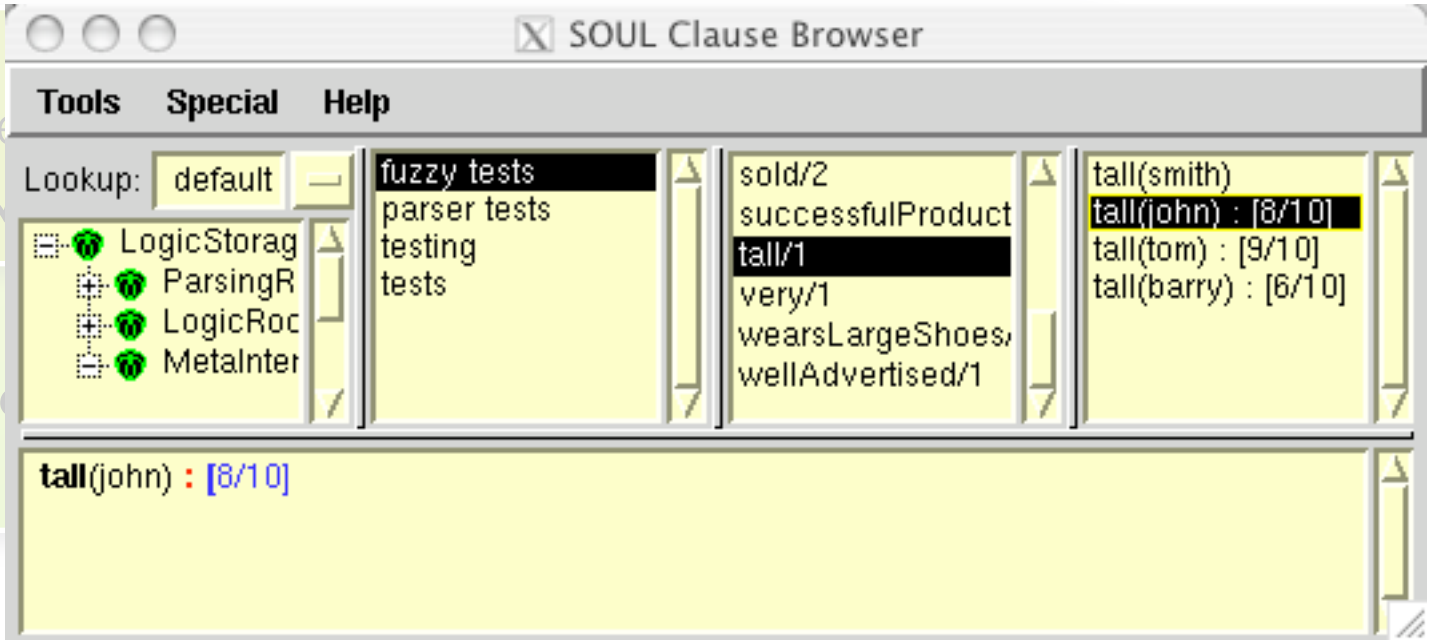

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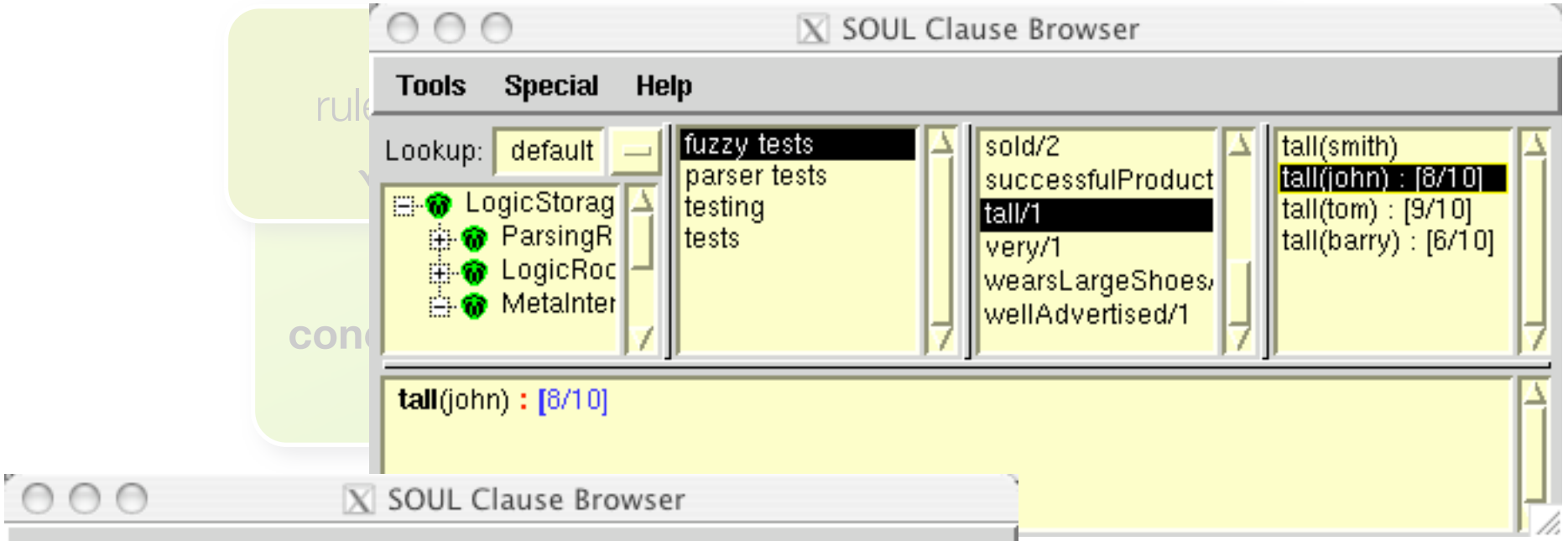

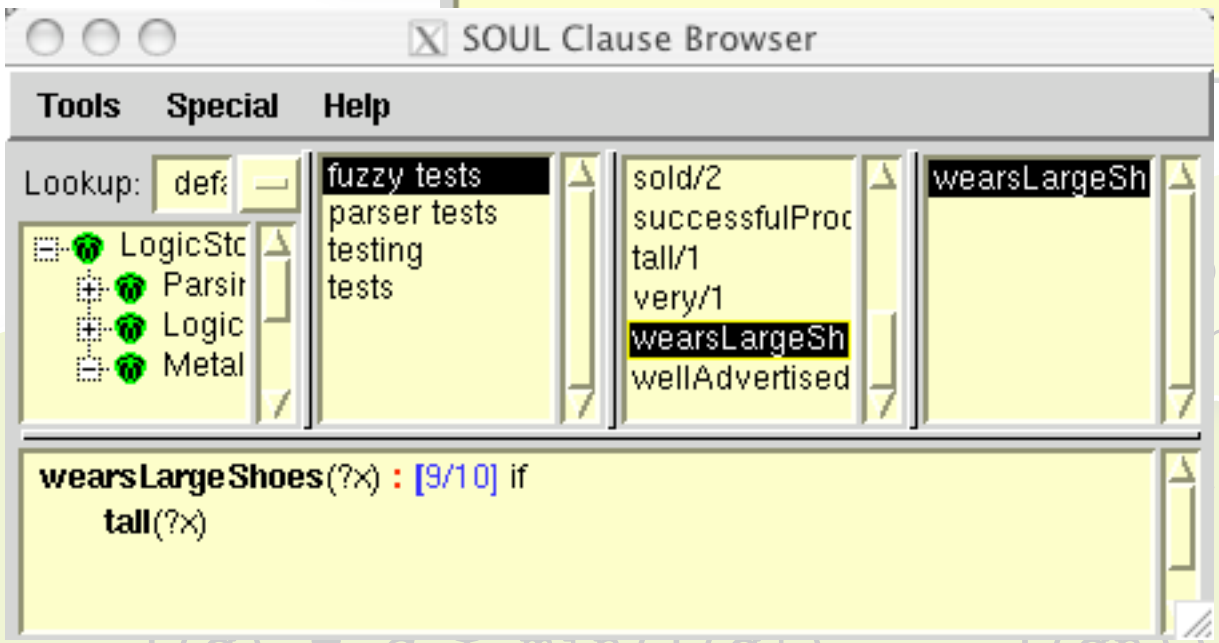

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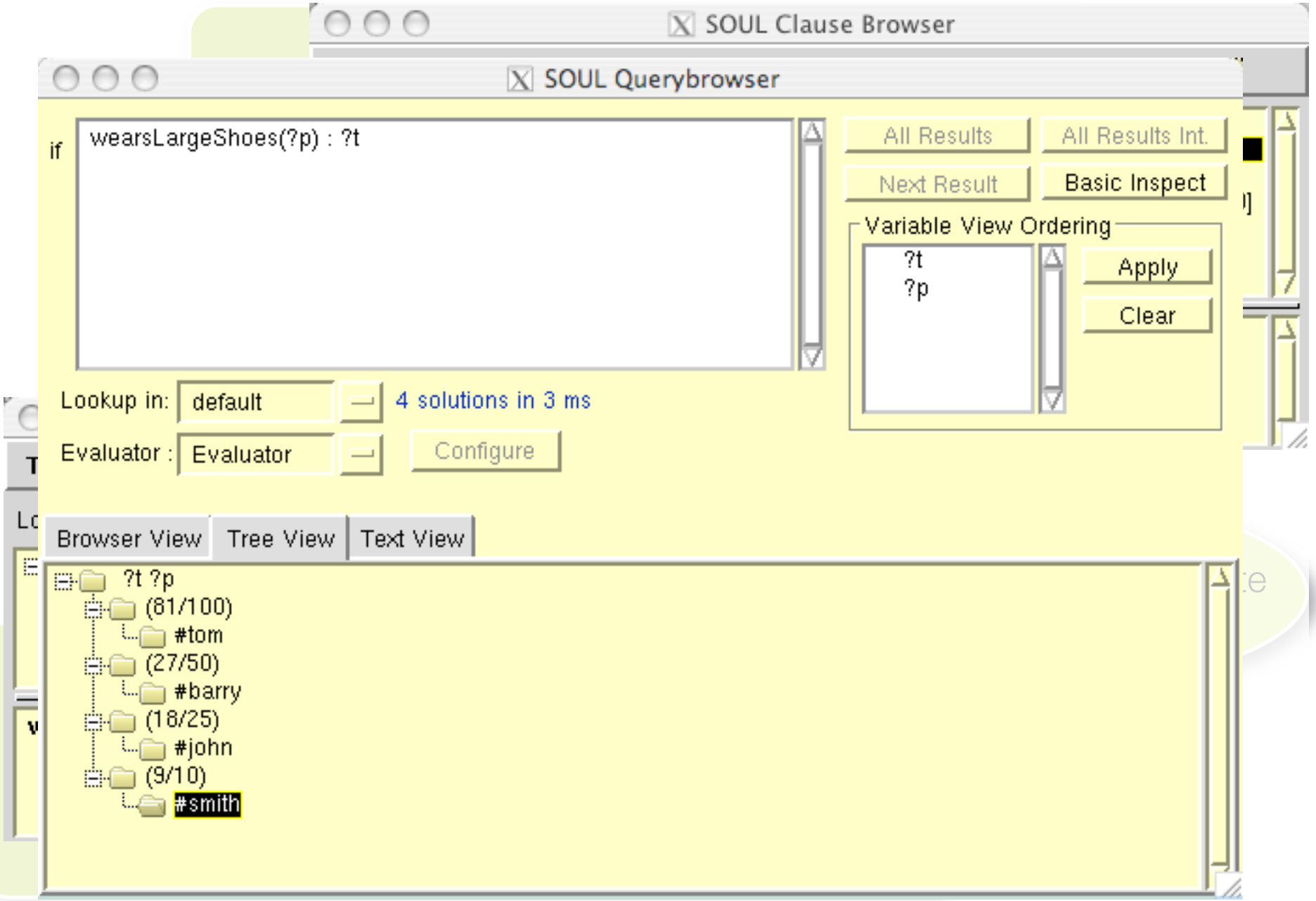

Open Template Compilation

```
jtExpression(?cast){ (java.lang.Object) ?expression }
```

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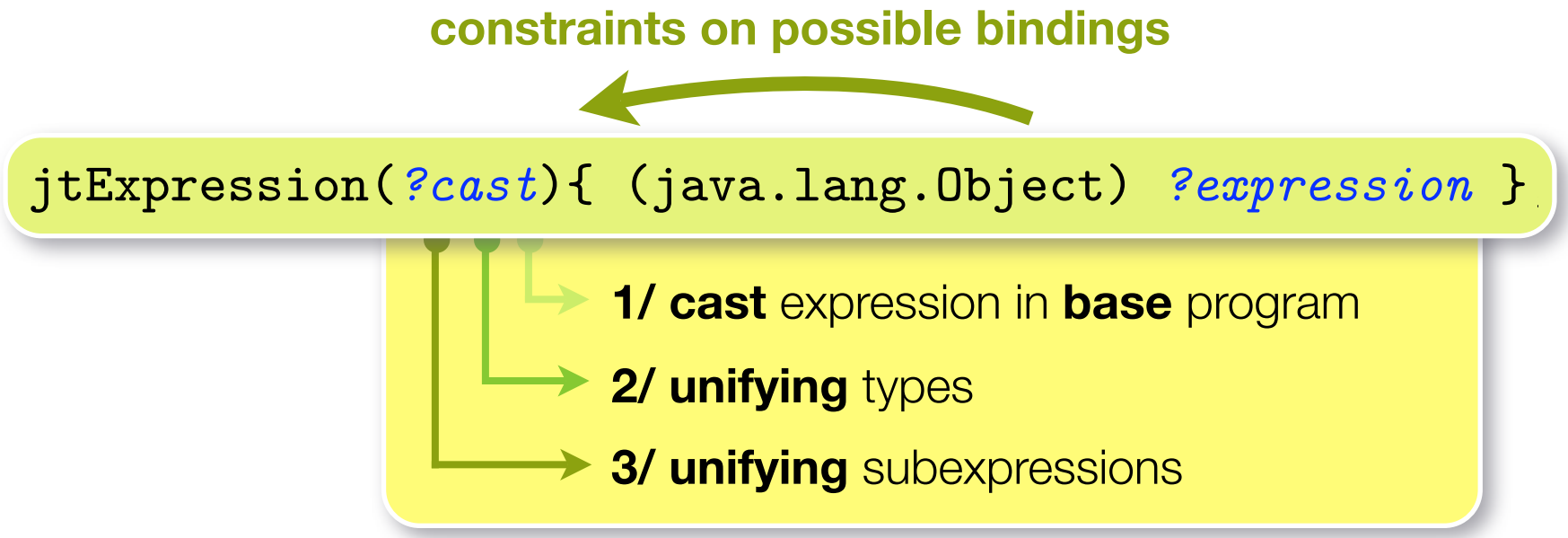

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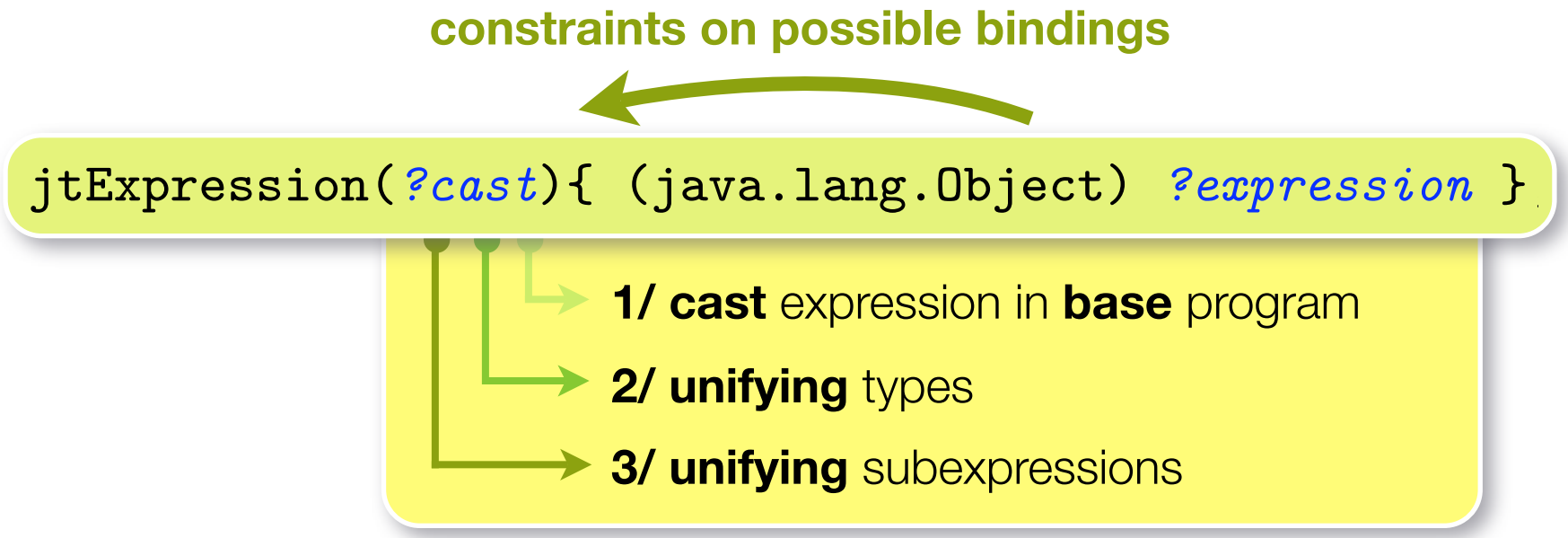

compiled by fuzzy logic program called by interpreter

results in multiple logic queries for each parse tree of a template

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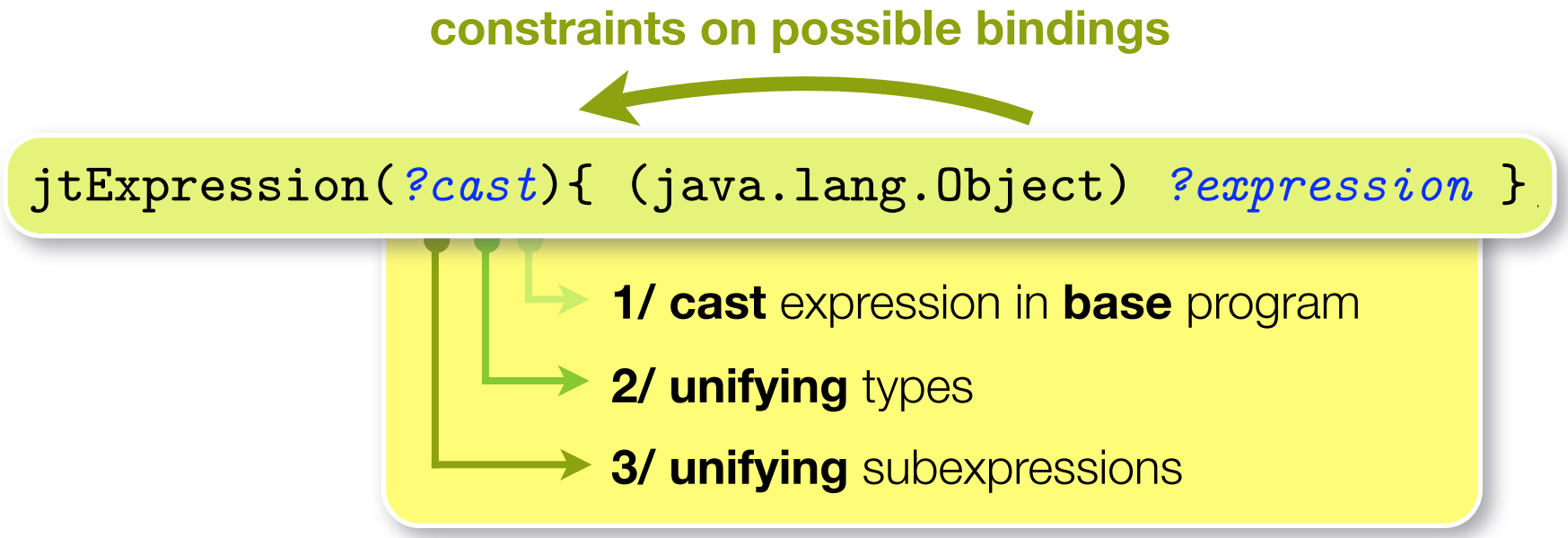

compiled by fuzzy logic program called by interpreter

results in multiple logic queries for each parse tree of a template

weighted by their **tolerance** for **mismatches**

```
if jtStatement(?block){ ?s1; ?s2; ?s3;}
```

layers of indirection, intertwining statement, loops, ...

Multiple Program Representations

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Abstract Syntax Tree

live  `org.eclipse.jdt.core.dom.ASTNode` instances

NOT reified as logic facts

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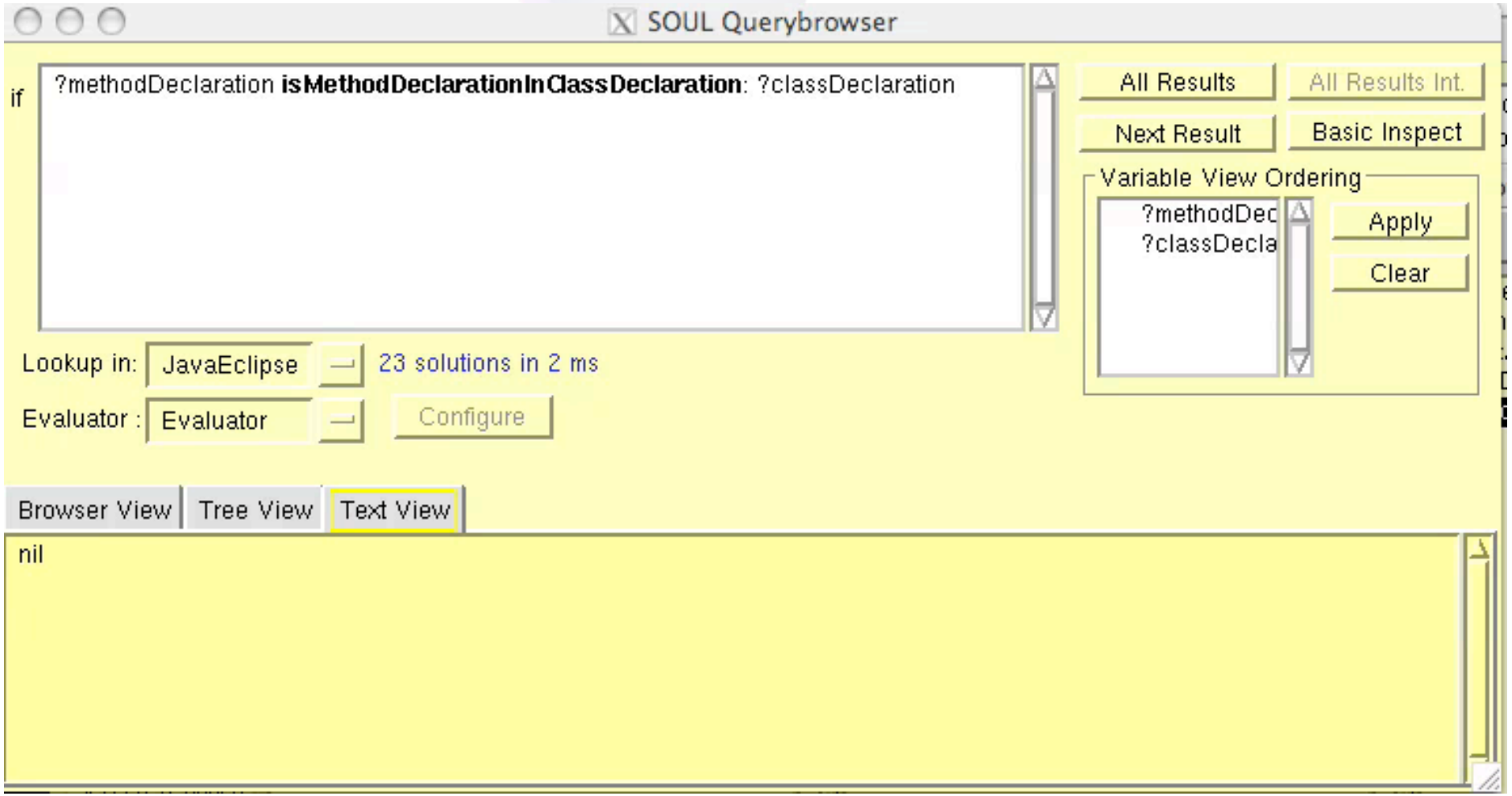

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Dataflow Analysis: points-to

safe approximation of run-time objects a reference points to

x.y →

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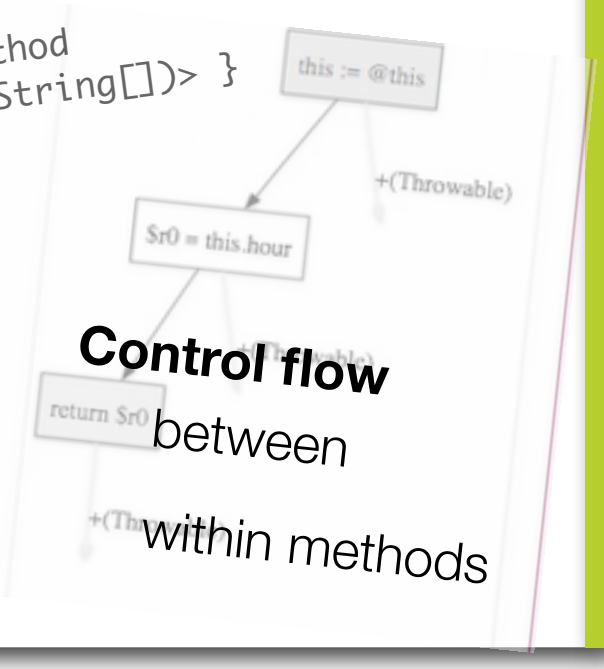

Control flow

between

within methods

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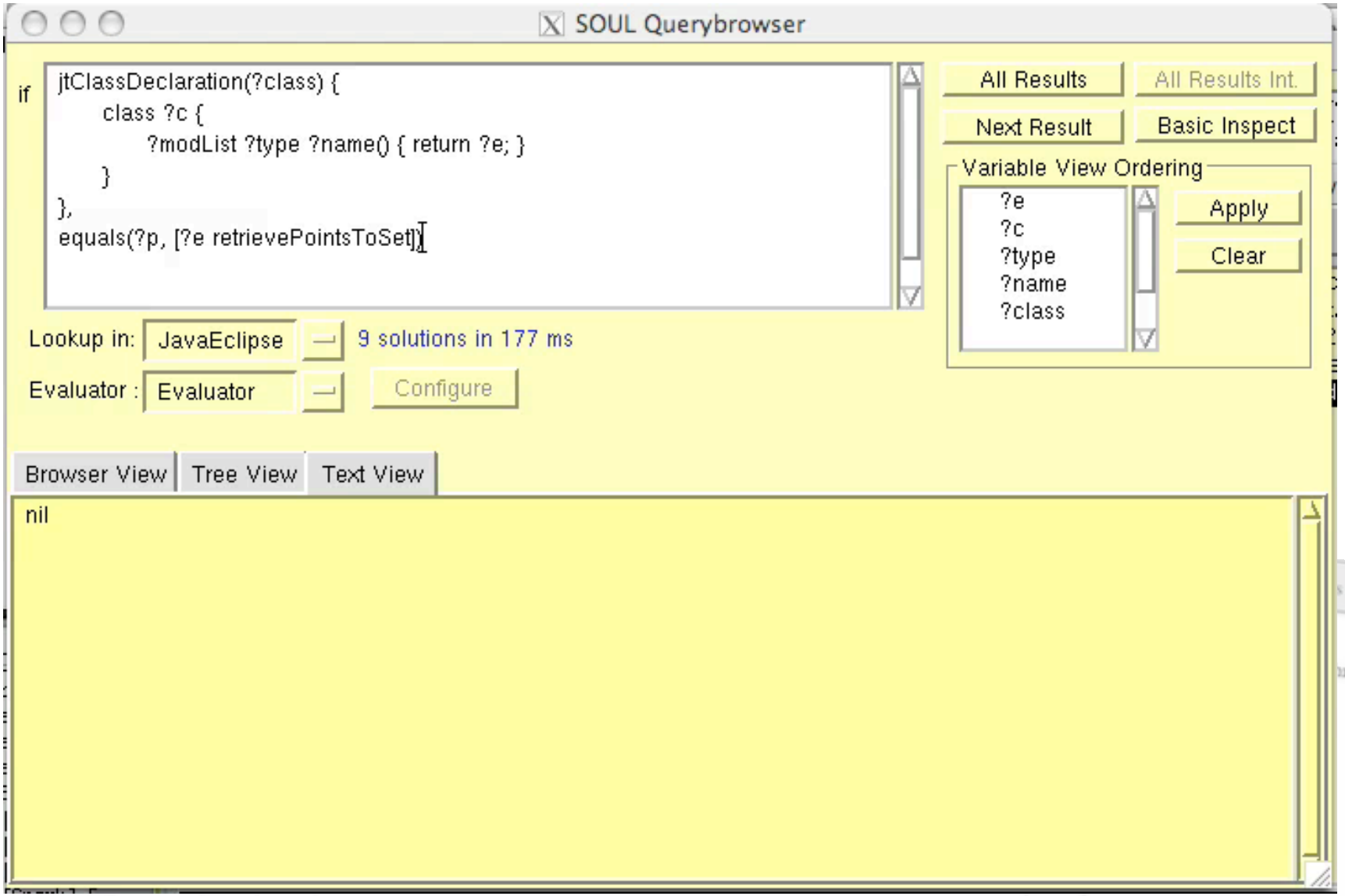

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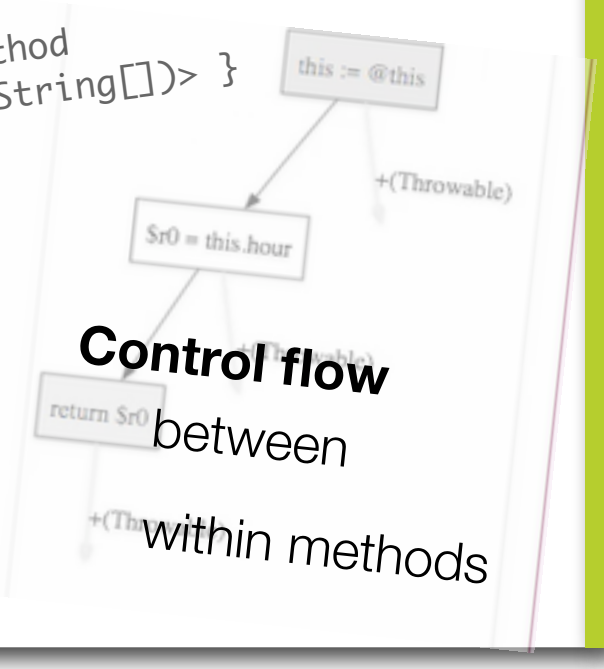

Control flow

between

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Smalltalk **Open Unification** **L**anguage

Unification with logic terms

Unification with other  **instances**

Smalltalk **Open Unification** Language

Unification with logic terms

easily identify elements of interest

```
1 if ?c isCompilationUnit,
2    [?c types size > 1]

3 if compilationUnit(packageDeclaration(simpleName(['testapp'])),?,?) isCompilationUnit

4 if ?c isCompilationUnit,
5    ?c hasPackage: ?p,
6    ?p hasName: ?n,
7    ?n isSimpleName,
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Unification with other  instances

Smalltalk **Open Unification** Language

Unification with logic terms powered by structural reflection

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Unification with other  **instances** overrides default identity comparison

implement recurring comparisons

```
Expression ≟ ParenthesizedExpression

Type ≟ TypeDeclaration

SimpleName ≟ QualifiedName
```

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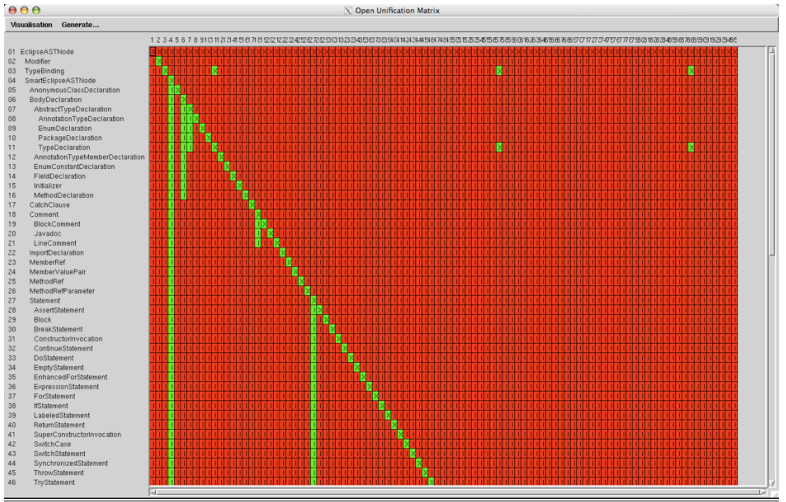

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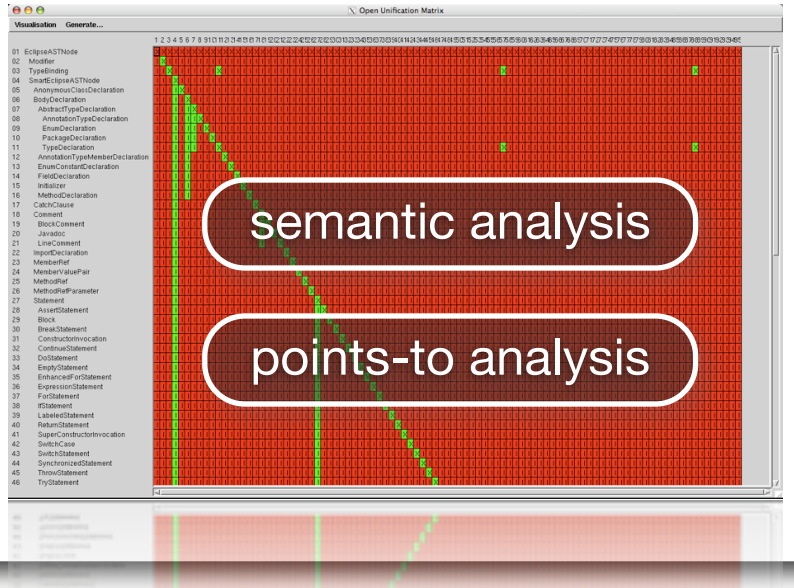

Unification based on Semantic Analysis

across logic and template conditions

Unification based on Semantic Analysis

Conciseness

across logic and template conditions

Unification based on Semantic Analysis

Conciseness

Correctness

across logic and template conditions

Unification based on Semantic Analysis

name resolution

Conciseness

```
1 if jtClassDeclaration(?class){
2      class FooClass extends testapp2.Example implements Collection {}
3 }
4 if jtClassDeclaration(?class){
5      class FooClass extends Example implements java.util.Collection {}
6 }
```

```
package testapp2;
public class FooClass extends testapp2.Example implements Collection {}
```

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scoping rules

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```

```
private Integer f;
public Integer notGettingF(Integer f) { return f; }
```

across logic and template conditions

Unification based on Points-to Analysis

```
if jtStatement(?s1){ return ?expression; },
   jtStatement(?s2){ return ?expression; },
   differs(?s1, ?s2)
```

Unification based on Points-to Analysis

```
if jtStatement(?s1){ return ?expression; },
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   differs(?s1, ?s2)
```

?s1 = return foo;	?s2
	return foo;
	return this.foo;
	return this.self().foo;
	x = foo; return x;
	return o.returnArgument(foo);

syntactically differing return statements possibly returning overlapping sets of objects

Unification based on Points-to Analysis

```
if jtStatement(?s1){ return ?expression; },
   jtStatement(?s2){ return ?expression; },
   differs(?s1, ?s2)
```

constraint over values returned at run-time

Behavioral Similarity

?s1 = return foo;	?s2
	return foo;
	return this.foo;
	return this.self().foo;
	x = foo; return x;
	return o.returnArgument(foo);

syntactically differing return statements
possibly returning overlapping sets of objects

Template Resolution Semantics

design guideline

close to concrete source code of prototypical implementation

match many implementation variants

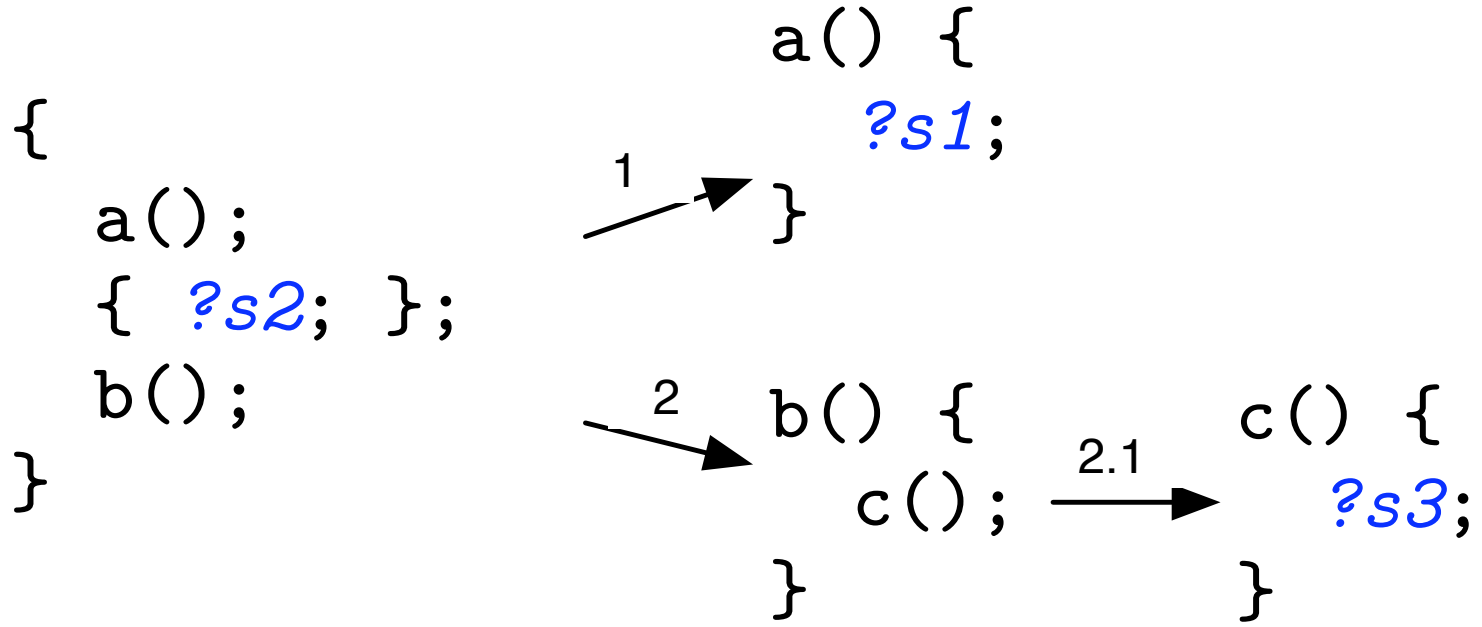
interpreted as freely as possible

BUT every single element in template adds constraints

```
while(?cond) ?s;    vs    while(?cond) { ?s; }
```

HOWEVER: an open implementation, so amenable by application programmer

Template Semantics: Sequences




```
if jtStatement(?block){ ?s1; ?s2; ?s3;}
```

1/ control flow constraint

?s's in interprocedural control-flow of *?block*

?s2 follows: *?s1*, *?s3* follows: *?s2*

2/ kind constraint (statement or expression statement)

Template Semantics: Statements and Expressions

```
public A method() {
   A local = ?x.m();
   return local;
}
```

```
jtMethodDeclaration(?m) {
   ?modList ?type ?name(?argList) {
         return ?x.m();
   }
}
```

- has a **return statement** `return(?val)` among its **lexical** statements
- has an expression `?e` which matches `?x.m()`
  - in its inter-procedural **control flow** (before the statement statement)
- the statement's returned expression `?val` **unifies with** `?e`

An Example: Concurrent Modification Exceptions

```
if jtStatement(?s) {
  while(?iterator.hasNext()) {
      ?collection.add(?element);
  }
},
jtExpression(?iterator){?collection.iterator()}
```

```
public List list;

public void insertElement(Object x) {
 Iterator i = list.iterator();
 while(i.hasNext()) {
   Object o = i.next();
   operation(x, (Collection) this.self().list);
 }
}

public void operation(Object o, Collection c) {
  c.add(o);
}
```

An Example: Concurrent Modification Exceptions

```
if jtStatement(?s) {
  while(?iterator.hasNext()) {
      ?collection.add(?element);
  }
},
jtExpression(?iterator){?collection.iterator()}
```

```
public List list;

public void insertElement(Object x) {
 Iterator i = list.iterator();
 while(i.hasNext()) {
   Object o = i.next();
   operation(x, (Collection) this.self().list);
 }
}

public void operation(Object o, Collection c) {
  c.add(o);
}
```

?s

in cflow of `while`

unify according to dataflow

Summary

concrete code templates integrated in logic program query language

- unification uniform across regular and template conditions
- composition by logic connectives
- open template compilation rules

quantified similarity template-match

- fuzzy logic

open unification framework

- incorporates static analyses in user-transparant way
  - query conciseness & correctness
  - statically determined behavioral similarity

The End