LASIGE reliable software systems

Extending Java with Refinements

Catarina Gamboa, Paulo Santos and Alcides Fonseca

U LISBOA Ciências ULisboa FCT Fundação para a Ciência e a Tecnologia

Refinement Types

- Division by Zero
- Array access

$$\{v : T \mid p(v)\}$$

```
@Refinement("y > 0 && y < 50")
int y;
y = 10; // okay
y = 100; // okay in Java, refinement type error
```

Introduction

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WHY?

- First languages with refinements were not popular in industry
- Overhead for developers

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LiquidJava

Refinement Types

Introduction

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1. Refinements are optional.
2. Refinement type-checking works on top of existing Java type-checker
3. Expressive Refinements
4. Refinement type-checking should be decidable

RELATED WORK

Related Work

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$$\{v : T \mid p\ (v)\ \}$$

Static verification with SMT solvers

Runtime checks

Related Work

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Strongly typed functional languages

Mainstream languages

Streams – restrict notation

JML – Java Modeling Language

APPROACH

Approach

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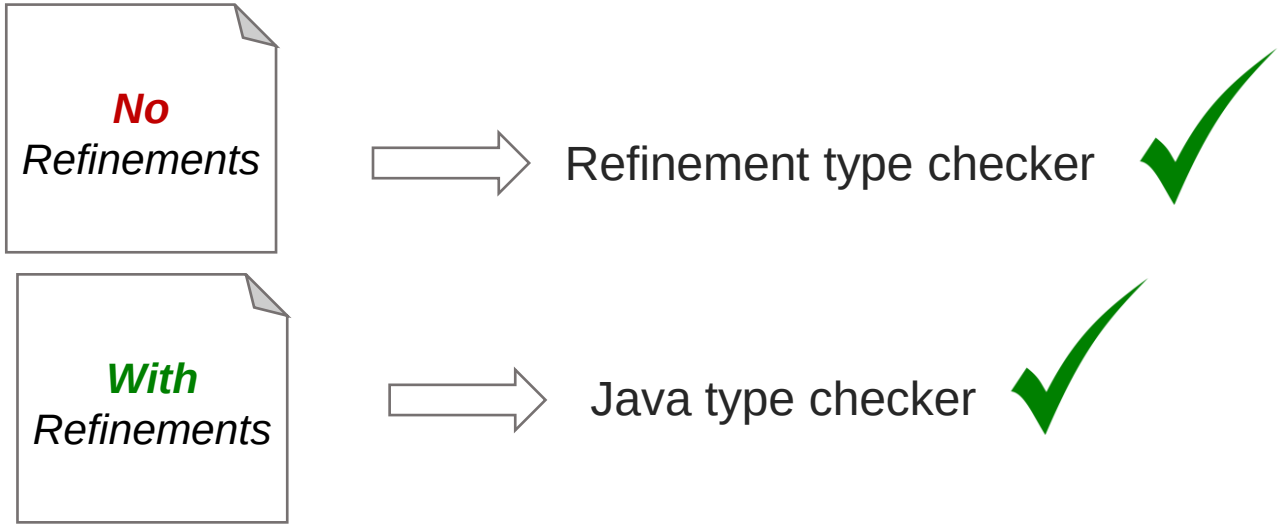
1

Refinements are optional



Annotations:

`@Refinement(…)`

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2

Refinement type-checking on top of existing Java type-checker

Java type checker   Refinement type checker 

Only valid Java programs are accepted in LiquidJava

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3

Expressive Refinements

```
@Refinement("y > 0 && y < 50")
```

4

Refinement type-checking should be decidable

Limit language to Liquid Types

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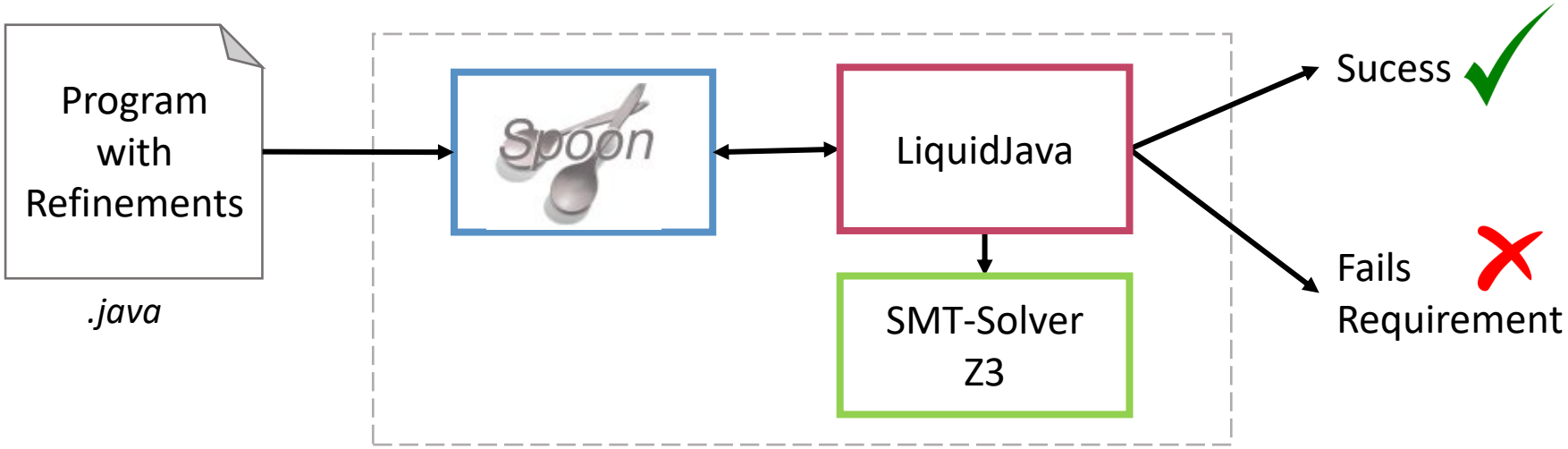

Expressions are checked against their expected types ⇨ **Subtyping**

Approach

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```
1  @Refinement("{x > 0} -> {\\v == 3 * x}")
2  private static int triplePositive(int x) {
3      return x + x + x;
4  }
5
6  public static void main(String[] args) {
7      @Refinement("k >= 10 && k < 100")
8      int k = 30;
9      @Refinement("t > 0")
10     int t = triplePositive(k);
11 }
```

Approach

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$$\{v{:}int \mid v == x + x + x\} <: \{v{:}int \mid v == 3 * x\}$$

$$\forall x : int.x > 0 \Rightarrow \forall v : int.v = x + x + x \Rightarrow v = 3 * x$$

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```
{k:int | k == 30} <: {k:int | k >= 10 && k < 100}
```

Approach

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{k:int | k >= 10 && k < 100} <: {k:int | k > 0}
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Approach

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$$\forall k : int.k \geq 10 \land k < 100 \Rightarrow \forall t : int.t = 3 * k \Rightarrow t > 0$$

CHALLENGES

Challenges

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- Expressiveness
- Object state
  - Uninterpreted functions
- Dynamic behaviour of method invocations
  - Overrider subtype of Overridden

Challenges

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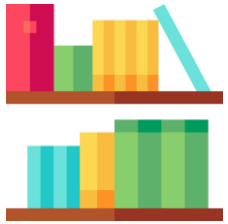
- Annotate standard library
  - Fault Localization



- Evaluate patches in software repair context

Thank you!

Contact us:
cgamboa@lasige.di.fc.ul.pt