Detecting Anomalies in the Order of Equally-typed Method Arguments

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Image to have two different keys...

Image to have two different keys...

Which key fits which keyhole?

```
int high = ...
int low = ...
```

Image to have two `int` variables...

```
void setEndPoints(int, int)
```

```
int high = ...
int low = ...
```

Image to have two `int` variables...

```
void setEndPoints(int, int)
```

Which argument fits which position?

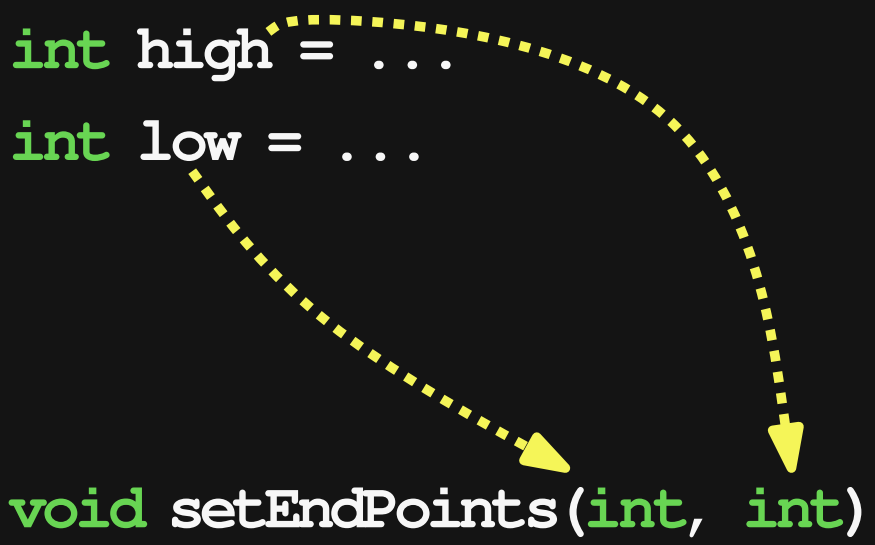


Image to have two `int` variables...

Which argument fits which position?

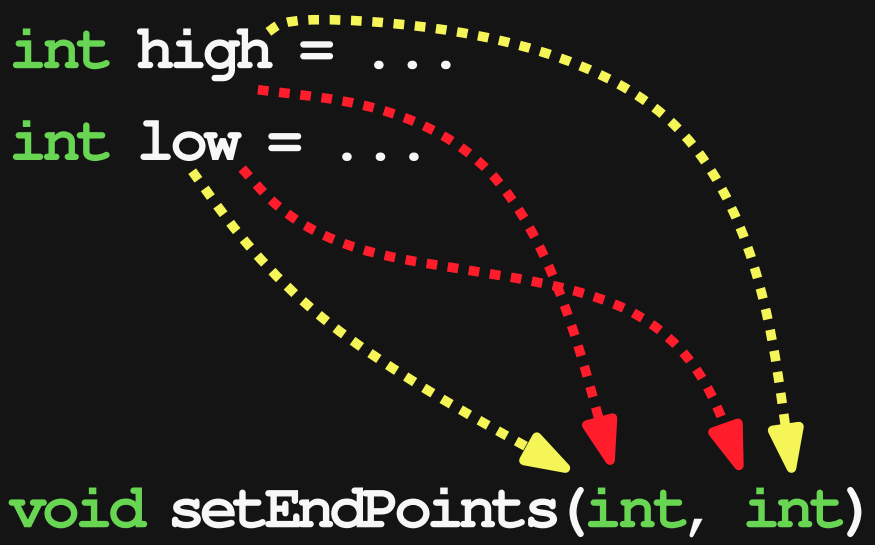


Image to have two `int` variables...

Which argument fits which position?

Equally-typed Method Arguments

Problem: Type system doesn’t help

What Can Go Wrong? (1)

```
int high = ..;
int low = ..;

setEndPoints(?, ?);

void setEndPoints(int i, int j) {
   ...
}
```

What Can Go Wrong? (1)

```
int high = ..;
int low = ..;

setEndPoints(?, ?);

void setEndPoints(int i, int j) {
   ...
}
```

Bad names for formal parameters

→ Understandability problem

What Can Go Wrong? (2)

```
int high = ..;
int low = ..;

setEndPoints(low, high);

void setEndPoints(int high, int low) {
   ...
}
```

What Can Go Wrong? (2)

```
int high = ..;
int low = ..;

setEndPoints(low, high);

void setEndPoints(int high, int low) {
   ...
}
```

Arguments passed in wrong order

→ Correctness problem

What Can Go Wrong? (3)

```
int high = ..;
int low = ..;

setEndPoints(low, high);  // invert end points

void setEndPoints(int high, int low) {
   ...
}
```

What Can Go Wrong? (3)

```
int high = ..;
int low = ..;

setEndPoints(low, high);  // invert end points

void setEndPoints(int high, int low) {
   ...
}
```

Unexpected but correct argument order

$\rightarrow$ **Maintainability problem**

Is This Important?

11% of all call sites have two
or more equally-typed arguments

I.e., 1 unchecked call per 20 LOC

(DaCapo benchmarks, 1.6 MLOC Java code)

Static Anomaly Detection

Program → Argument Naming Examples → Anomalies

```
void m(int a,
       int b) {}
m(a, b);
m(b, a);
```

(a,b)
(a,b)
(b,a)

```
m(b, a);
```

Reverse?!

Static Anomaly Detection

Simple yet effective

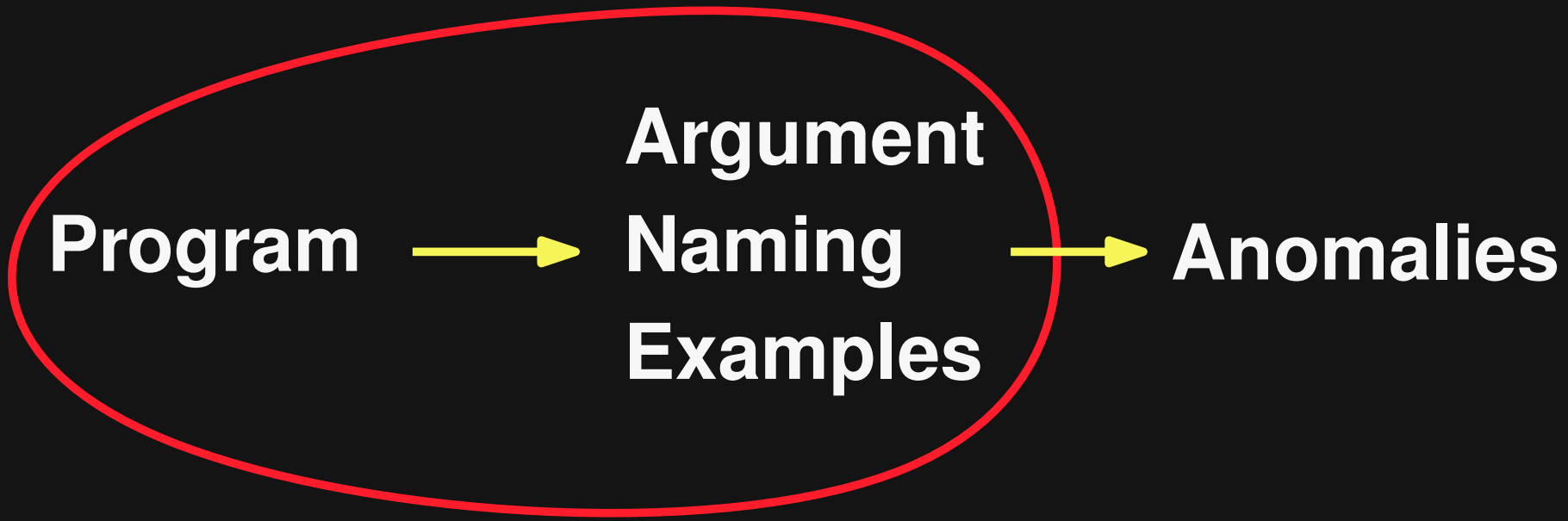
```
void m(int a,
       int b) {}
m(a, b);
m(b, a);
```

(a,b)
(a,b)
(b,a)

```
m(b, a);
```

Reverse?!

Static Anomaly Detection




```
void m(int a,
       int b) {}
m(a, b);
m(b, a);
```

(a,b)
(a,b)
(b,a)

```
m(b, a);
```

Reverse?!

Argument Name Extraction

Goal: Find examples for argument names

```
int highEP;
int[] lowEP;
Data data;

setEndPoints(highEP, lowEP[i]);

setEndPoints(data.h, data.low());
```

Argument Name Extraction

Goal: Find examples for argument names

```
int highEP;
int[] lowEP;
Data data;

setEndPoints(highEP, lowEP[i]);

setEndPoints(data.h, data.low());
```

local variable: ”highEP”

Argument Name Extraction

Goal: Find examples for argument names

```
int highEP;
int[] lowEP;
Data data;

setEndPoints(highEP, lowEP[i]);

setEndPoints(data.h, data.low());
```

local variable: "highEP"

array access: "lowEP"

Argument Name Extraction

Goal: Find examples for argument names

```
int highEP;
int[] lowEP;
Data data;

setEndPoints(highEP, lowEP[i]);

setEndPoints(data.h, data.low());
```

local variable: ”highEP”

array access: ”lowEP”

field access: ”h”

Argument Name Extraction

Goal: Find examples for argument names

```
int highEP;
int[] lowEP;
Data data;

setEndPoints(highEP, lowEP[i]);

setEndPoints(data.h, data.low());
```

local variable: ”highEP”

array access: ”lowEP”

field access: ”h”

method call: ”low”

Parameter Name Extraction

More examples: Formal parameter names

```
void setEndPoints(int high, int low) {
  ...
}
```

Static Anomaly Detection

Program → Argument Naming Examples → Anomalies

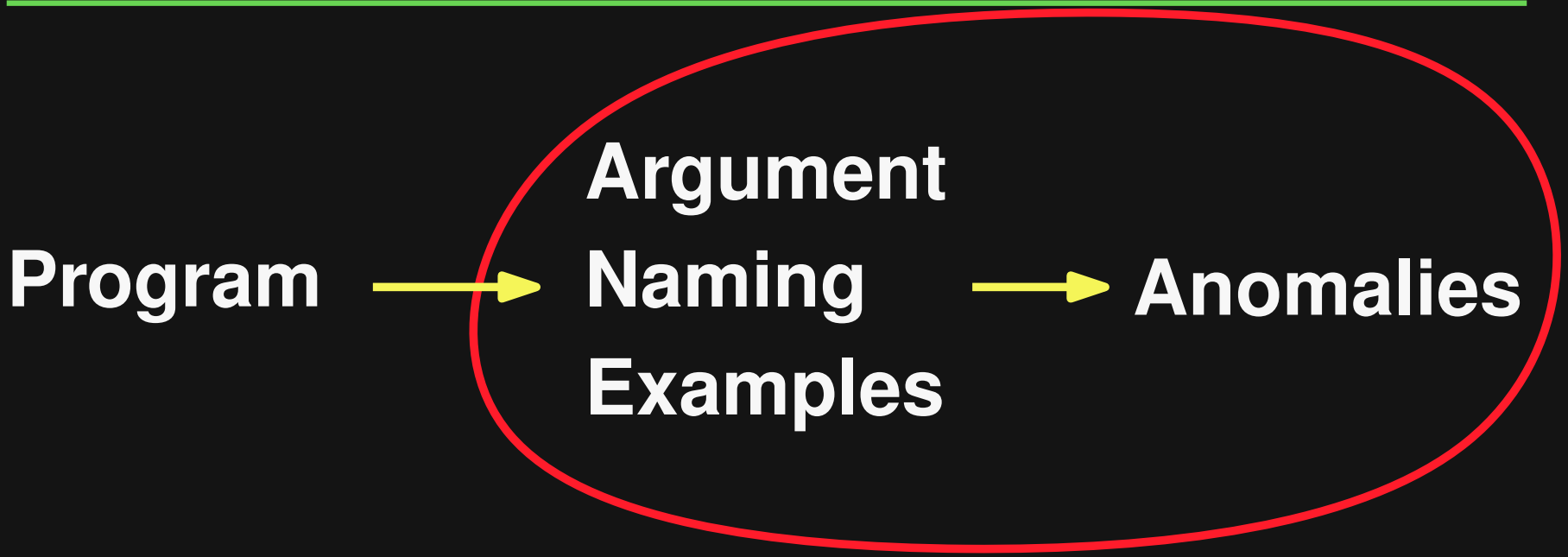
```
void m(int a,
       int b) {}
m(a, b);
m(b, a);
```

(a,b)
(a,b)
(b,a)

```
m(b, a);
```

Reverse?!

Static Anomaly Detection




```
void m(int a,
       int b) {}
m(a, b);
m(b, a);
```

(a,b)
(a,b)
(b,a)

```
m(b, a);
```

Reverse?!

Anomaly Detection

What is an anomaly?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
low	high

Anomaly Detection

What is an anomaly?

Pos. 1	Pos. 2
high	low
h	Low
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highEP	lowEP
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An unusual name is no anomaly

Anomaly Detection

What is an anomaly?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
low	high

An unusual permutation is an anomaly

Anomaly Detection

Which permutation is more normal?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
low	high

vs.

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
high	low

Anomaly Detection

How normal is this permutation?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
high	low

Anomaly Detection

How normal is this permutation?

$$fitPos(\textbf{high}, 1) = similarity(\textbf{high}, 1) - similarity(\textbf{high}, 2)$$

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
high	low

Anomaly Detection

How normal is this permutation?

$$fitPos(\textbf{high}, 1) = similarity(\textbf{high}, 1) - similarity(\textbf{high}, 2)$$

$$normality = fitPos(\textbf{high}, 1) + fitPos(\textbf{low}, 2) - fitPos(\textbf{low}, 1) - fitPos(\textbf{high}, 2)$$

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
high	low

Anomaly Detection

Which permutation is more normal?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
low	high

$normality = 0\%$

vs.

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
high	low

$normality = 86\%$

Anomaly Detection

Which permutation is more normal?

Pos. 1	Pos. 2
high	low
h	Low
high	low
highEP	lowEP
low	high

$normality = 0\%$

vs.

Anomaly!

Pos. 1	Pos. 2
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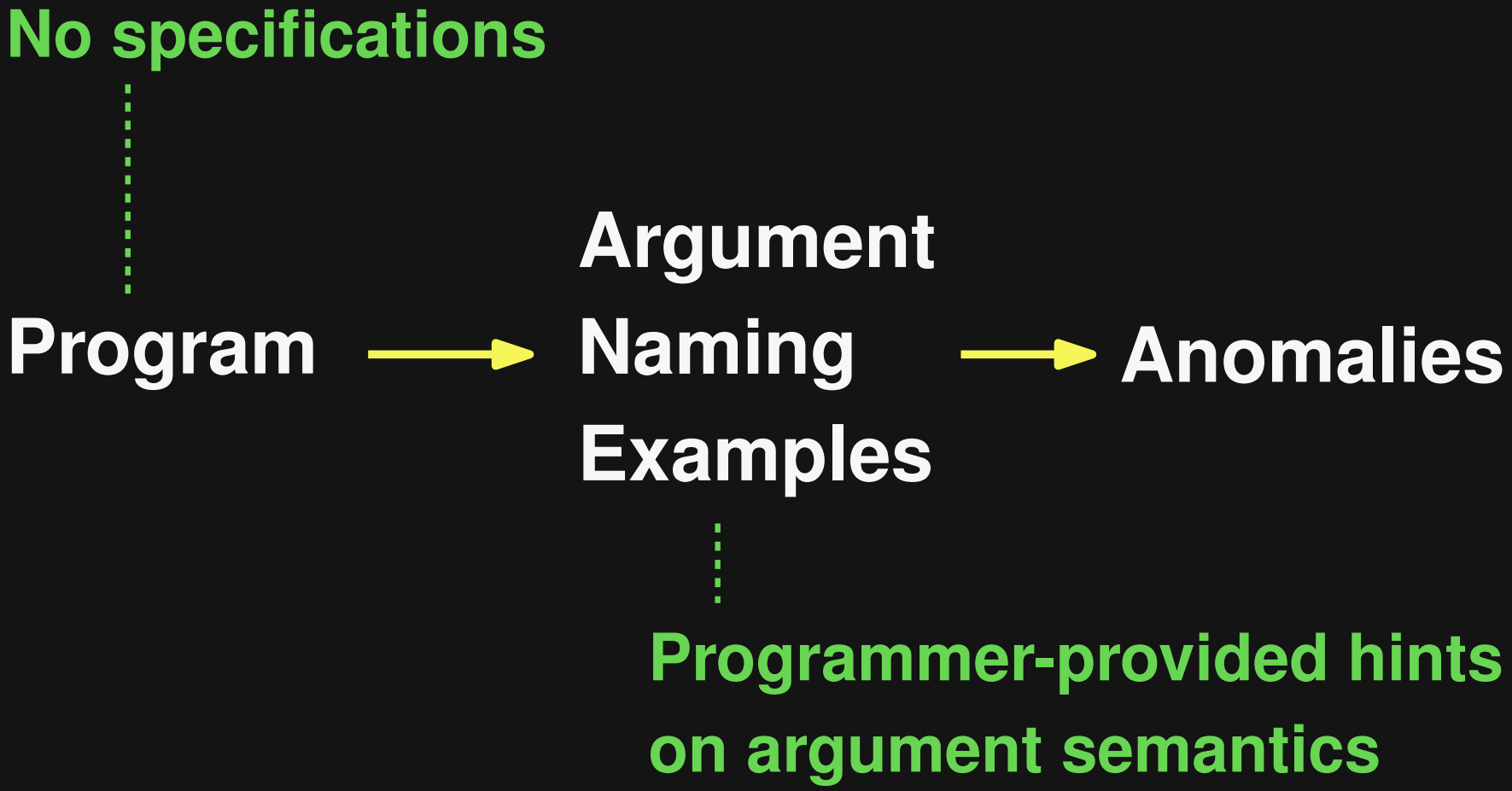
$normality = 86\%$

Summary of Approach

Summary of Approach

No specifications

Summary of Approach



Evaluation

- Effectiveness in finding anomalies?
- Anomalies in mature programs?

Setup:

DaCapo benchmarks, 1.6 MLOC Java

Effectiveness

for each call site with equally-typed arguments
    for each permutation of the arguments
        seed anomaly and try to find it

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    for each permutation of the arguments
        seed anomaly and try to find it

$$\text{Precision} = \frac{\text{\# true pos.}}{\text{\# true pos.} \;+\; \text{\# false pos.}}$$

$$\text{Recall} = \begin{cases} 1 & \text{if seeded anomaly found} \\ 0 & \text{otherwise} \end{cases}$$

Effectiveness

Average over 49K seeded anomalies

Precision: 72%

Recall: 38%

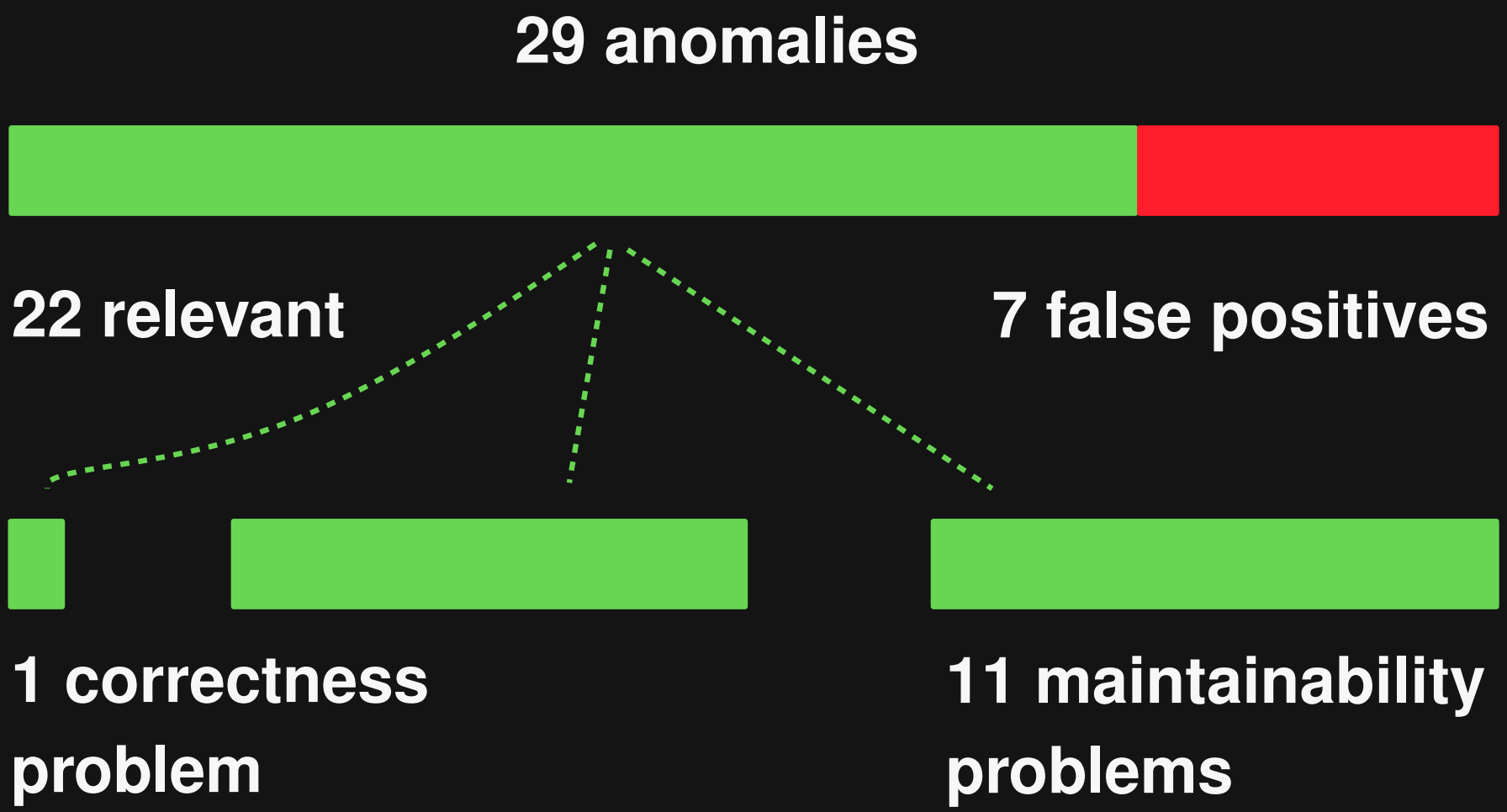
Anomalies in Real Programs

29 anomalies

22 relevant

7 false positives

Anomalies in Real Programs



Anomalies in Real Programs

Correctness problem in Eclipse

```
// call
createAlignment(name, mode,
   Alignment.R_INNERMOST, count, sourceRestart,
   adjust);

// called method
Alignment createAlignment(String name, int mode,
   int count, int sourceRestart, int continuationIndent,
   boolean adjust) { ... }
```

Anomalies in Real Programs

Correctness problem in Eclipse

```
// call
createAlignment(name, mode,
   Alignment.R_INNERMOST, count, sourceRestart,
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Alignment createAlignment(String name, int mode,
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Anomalies in Real Programs

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Anomalies in Real Programs

Understandability problem in Jython

```
// called method
PyFloat _pow(double value, double iw, PyObject modulo)
```

Anomalies in Real Programs

Understandability problem in Jython

```
// called method
PyFloat _pow(double value, double iw, PyObject modulo)
```

Exponentiation: What is base and what is exponent?

Anomalies in Real Programs

Understandability problem in Jython

```
// call
_pow(coerce(left), value, null)
```


```
// called method
PyFloat _pow(double value, double iw, PyObject modulo)
```

Exponentiation: What is base and what is exponent?

Anomalies in Real Programs

Maintainability problem in Eclipse

```
// call
generateOptimizedBoolean(
   currentScope, codeStream,
   falseLabel, trueLabel, valueRequired)

// called method
void generateOptimizedBoolean(
   BlockScope currentScope, CodeStream codeStream,
   Label trueLabel, Label falseLabel, boolean valueRequired)
```

Anomalies in Real Programs

Maintainability problem in Eclipse

```
// call
generateOptimizedBoolean(
   currentScope, codeStream,
   falseLabel, trueLabel, valueRequired)

// called method
void generateOptimizedBoolean(
   BlockScope currentScope, CodeStream codeStream,
   Label trueLabel, Label falseLabel, boolean valueRequired)
```

Unexpected but correct

Summary of Evaluation

- **Effectiveness in finding anomalies?**

  72% precision, 38% recall

- **Anomalies in mature programs?**

  22 relevant among 29 reported

What Does It Cost?

Only input:
Source code of program

Time to analyze 1.6 MLOC:
Less than two minutes

Conclusion

- Cheap technique to find anomalies involving **equally-typed arguments**
- **Simple** but **effective**
- Try it out!
  http://mp.binaervarianz.de/issta2011

Thank you!

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