Università della Svizzera italiana
Faculty of Informatics
Software Testing and Analysis Research group

Intrinsic Software Redundancy
for Self-Healing Software Systems and Automated Oracle Generation

Antonio Carzaniga, Alberto Goffi, **Andrea Mattavelli**,
Nicolò Perino, Mauro Pezzè
Università della Svizzera italiana (USI) - Switzerland

Alessandra Gorla
IMDEA Software Institute - Spain

Paolo Tonella
Fondazione Bruno Kessler - Italy

Software Redundancy

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code**.

Software Redundancy

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code**.

- compute **same results**
- lead to **same states**

Intrinsic Software Redundancy

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Google Guava

```
MultiMap m = new MultiMap();
//…
//check if element is already in map
if (m.contains(x))
```

Intrinsic Software Redundancy

Google Guava

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MultiMap m = new MultiMap();
//…
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if (m.contains(x))
 if (m.elementSet().contains(x))
 if (m.count(x) > 0)
```

Intrinsic Software Redundancy

Google Guava

```
MultiMap m = new MultiMap();
//…
//check if element is already in map
if (m.contains(x))
 if (m.elementSet().contains(x))
 if (m.count(x) > 0)
```

0 LOC

Intrinsic Software Redundancy

Joda-Time

SWT

4700+

equivalences

GraphStream

Exploiting

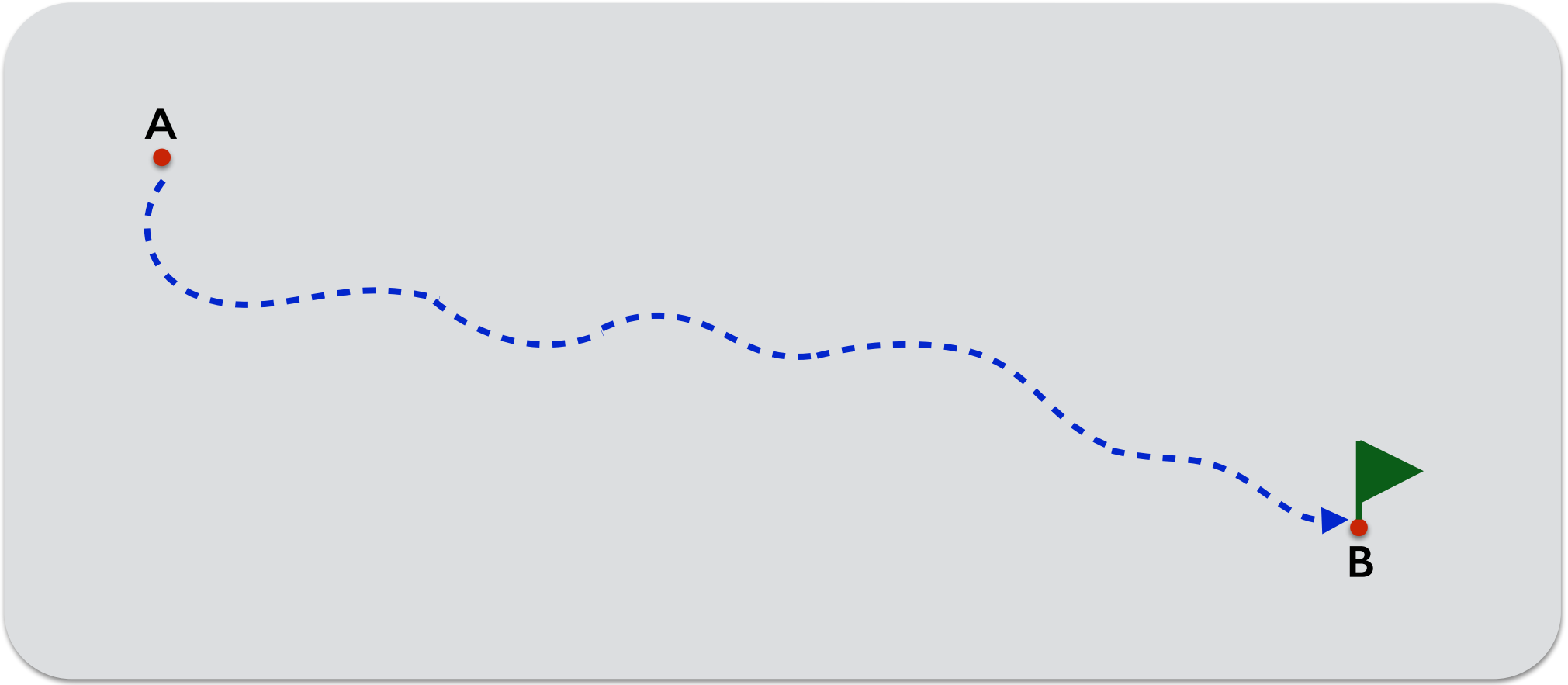
the Intrinsic Redundancy of Software

Redundancy for Self-Healing

Automatic Recovery from Runtime Failures [ICSE 2013]

Redundancy for Self-Healing

Automatic Recovery from Runtime Failures [ICSE 2013]



Application state space

Redundancy for Self-Healing

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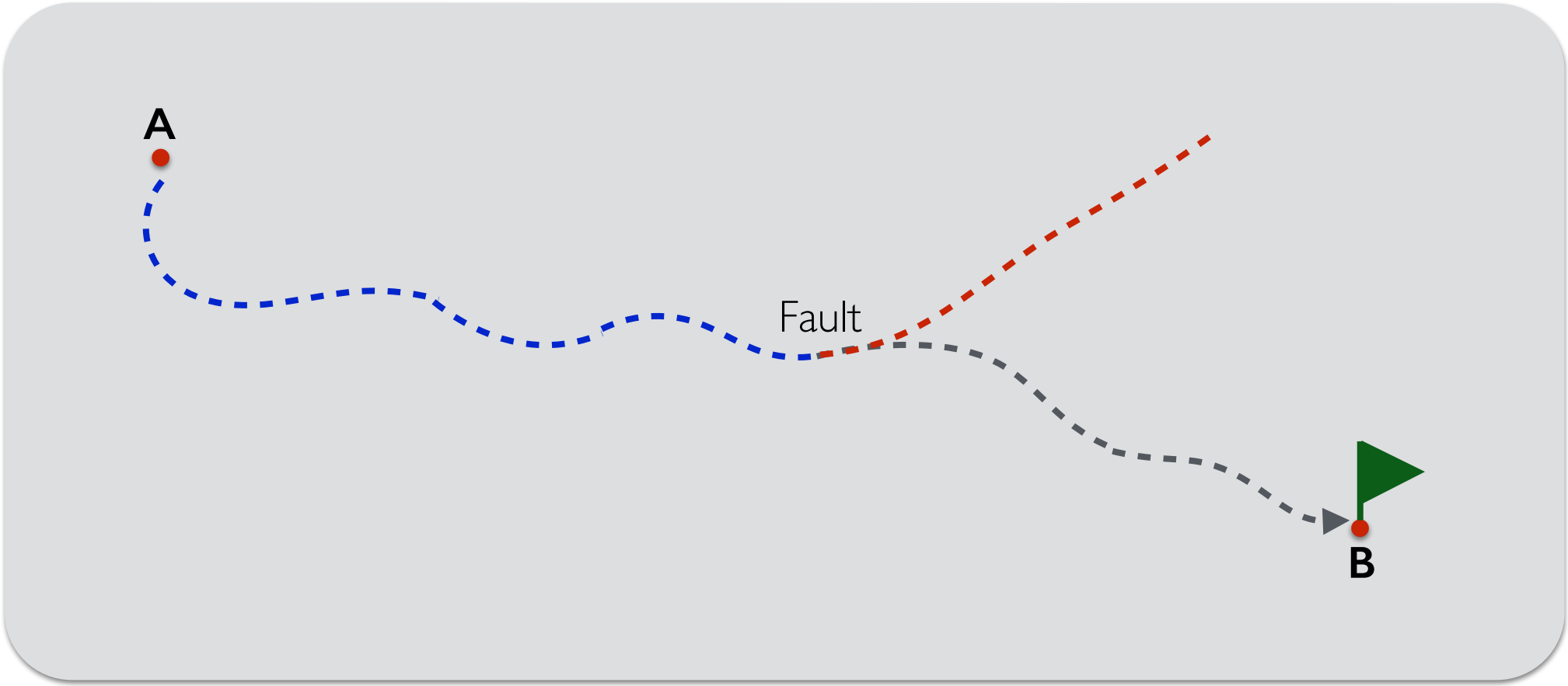

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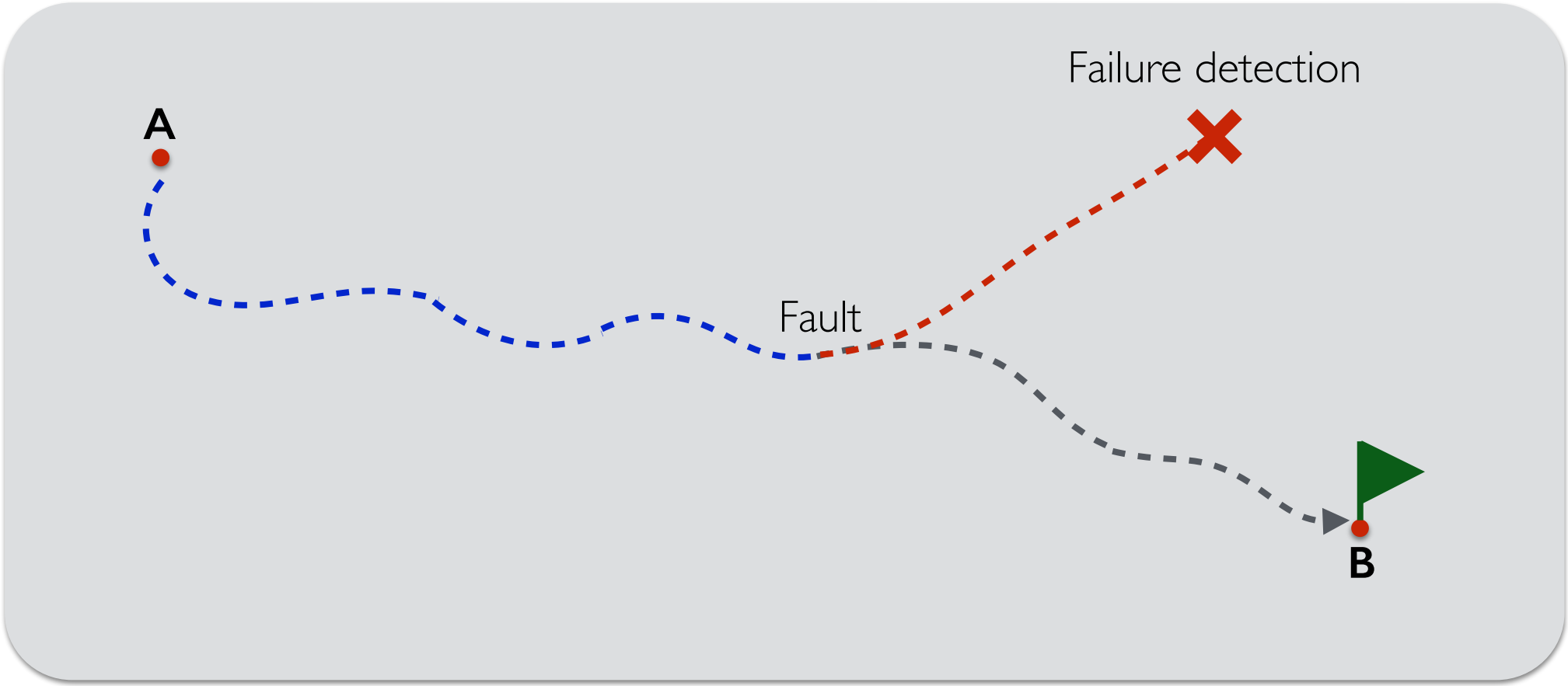

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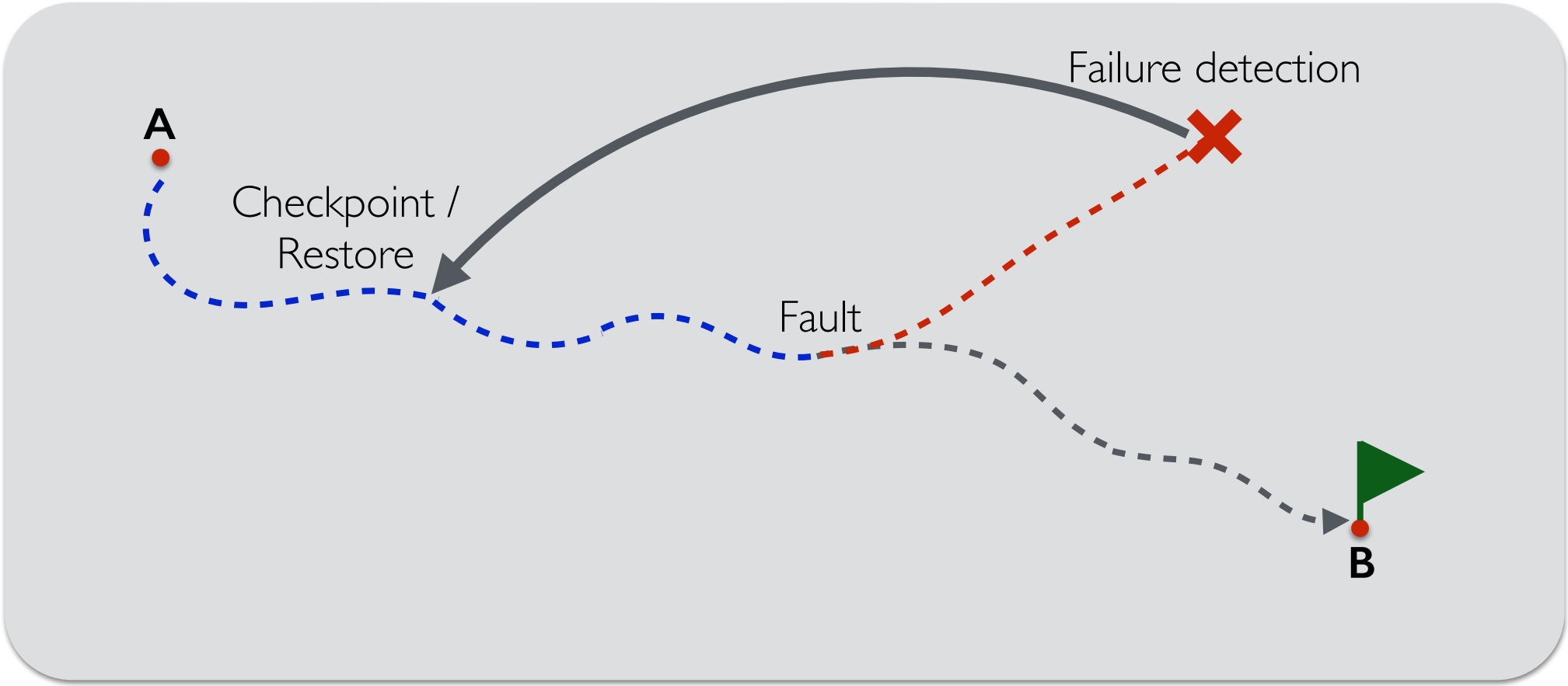

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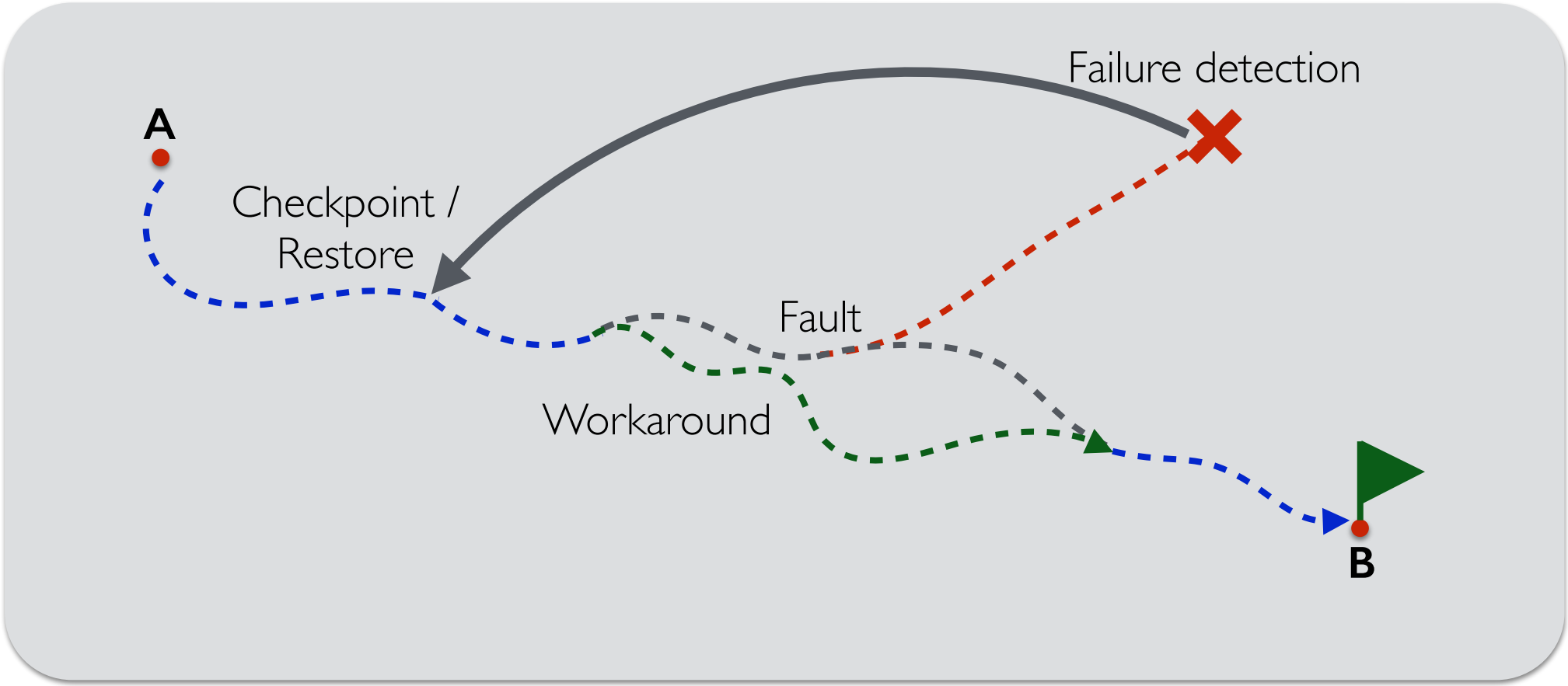

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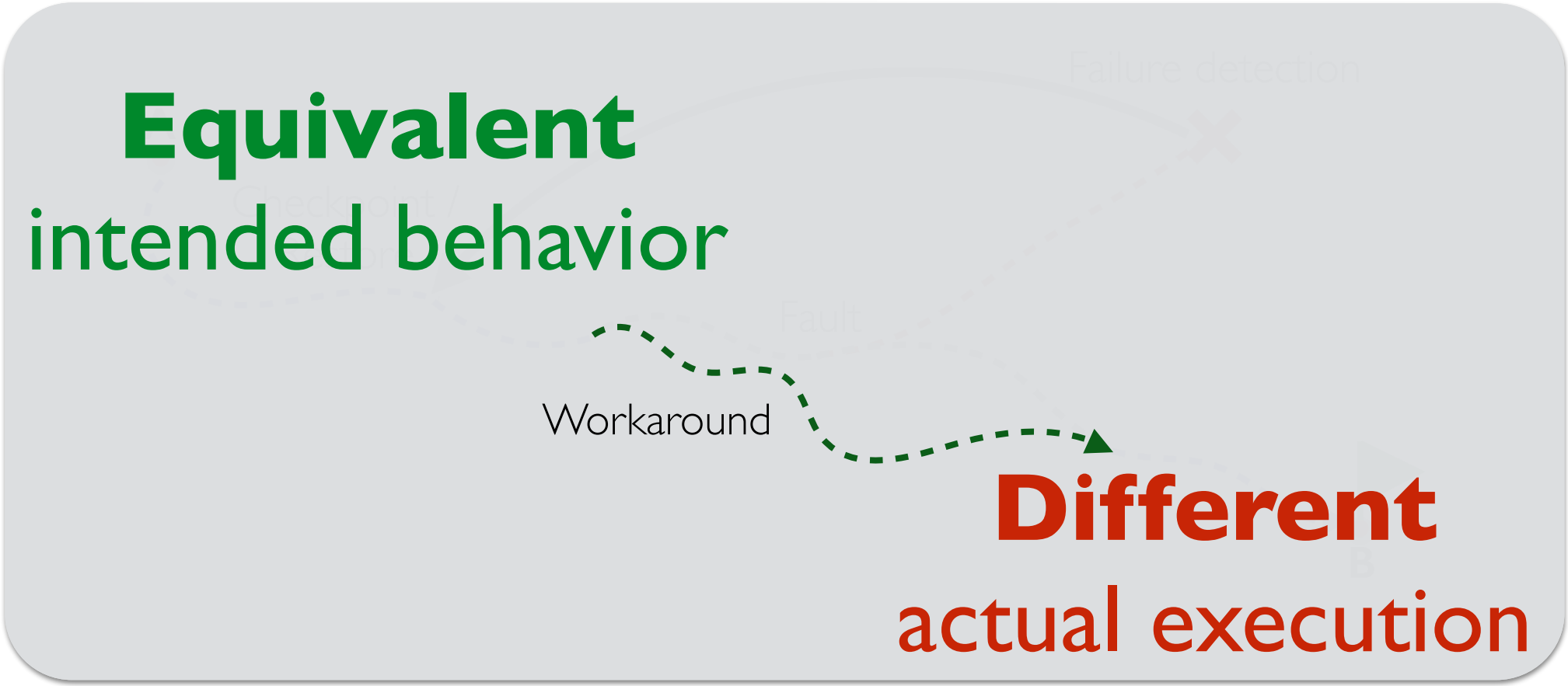

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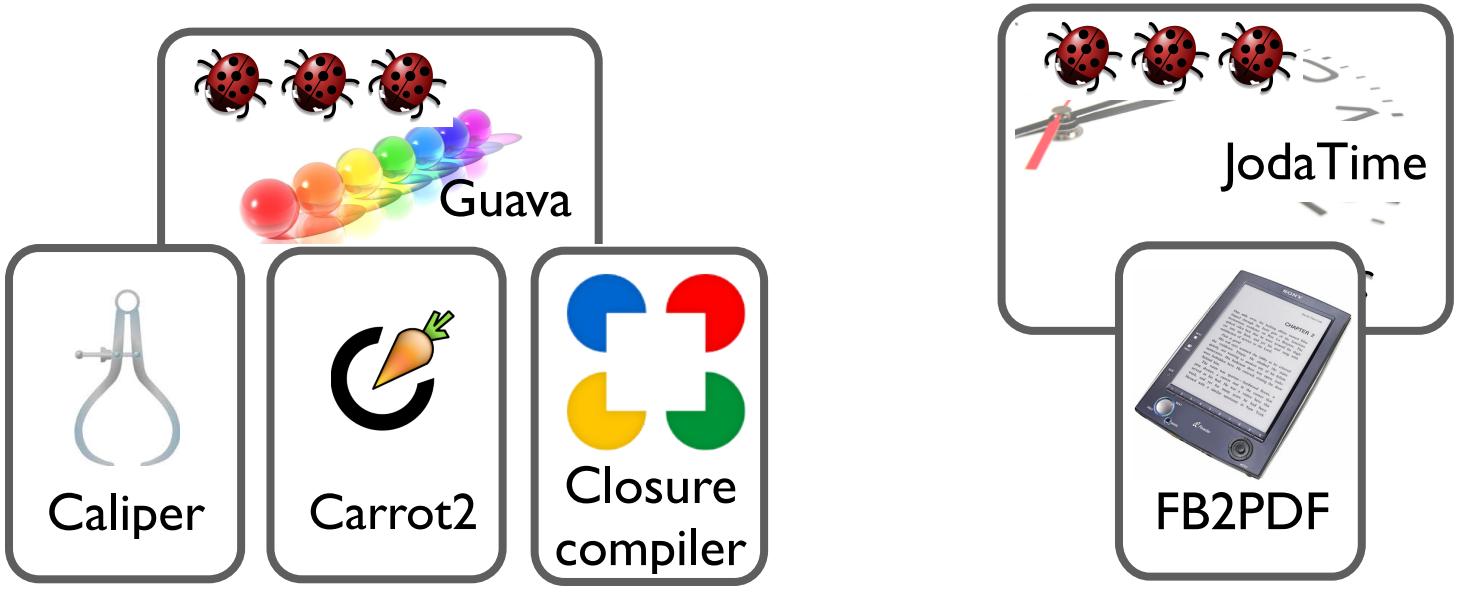

Mutants	87	50	148	347

Redundancy for Self-Healing

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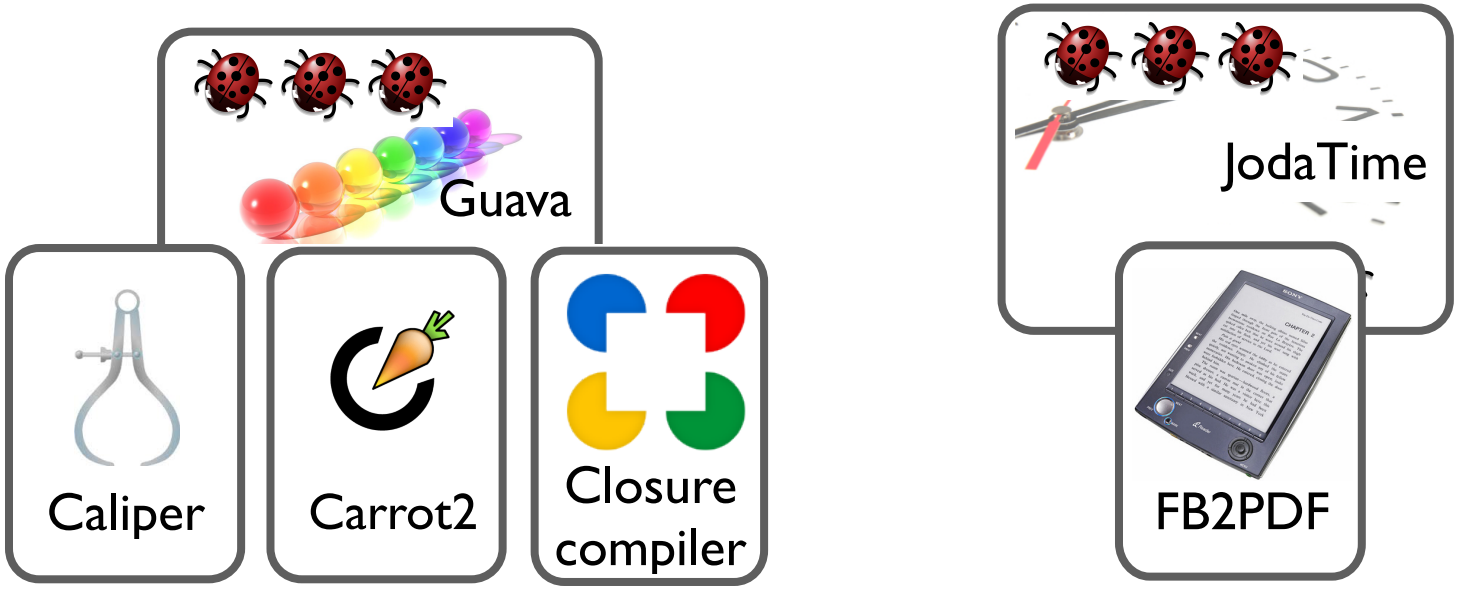

Mutants	87	50	148	347
Successfully recovered	24	24	64	67
	27%	48%	43%	19%

Redundancy as Test Oracle

Cross-Checking Oracles from Intrinsic Software Redundancy [ICSE 2014]

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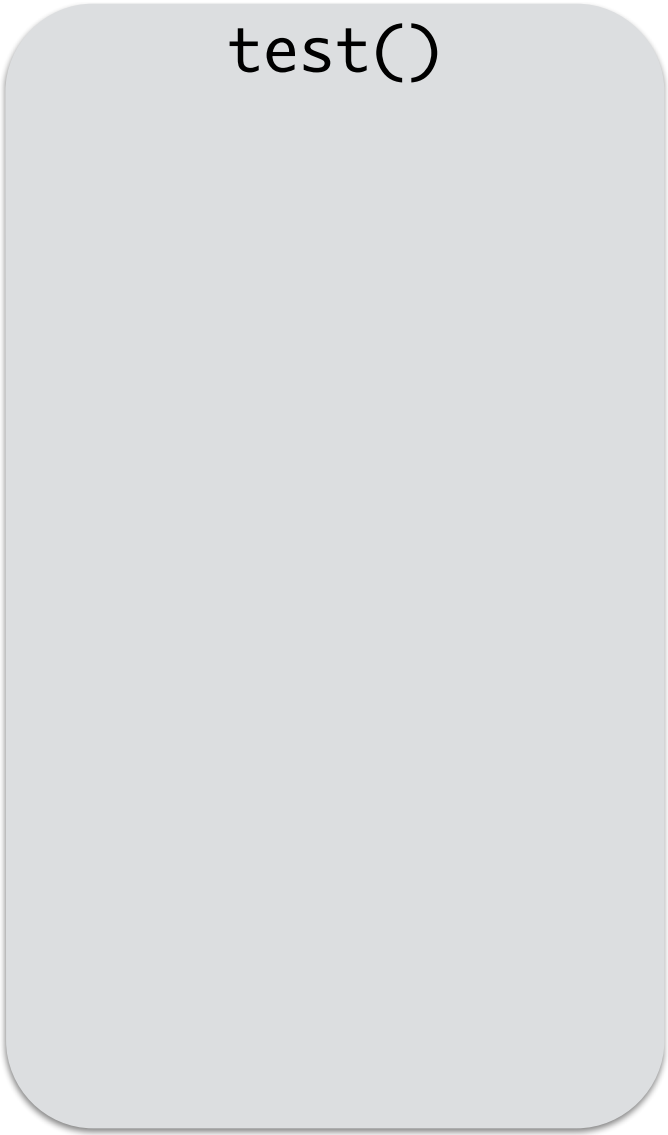


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test() {
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  put(k,v);
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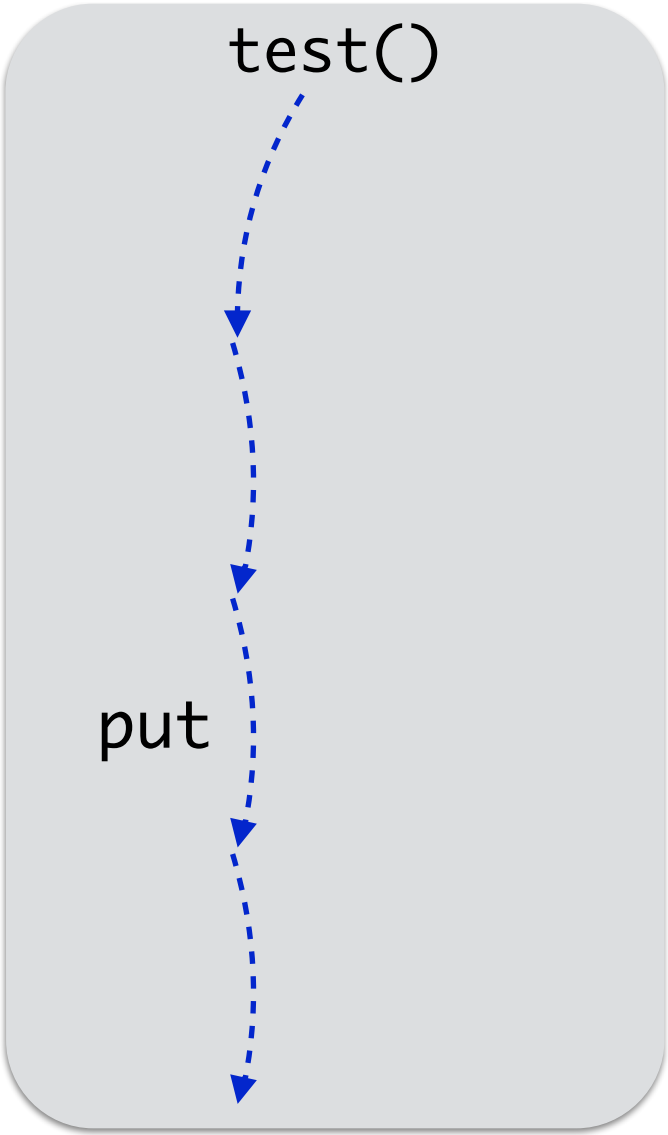


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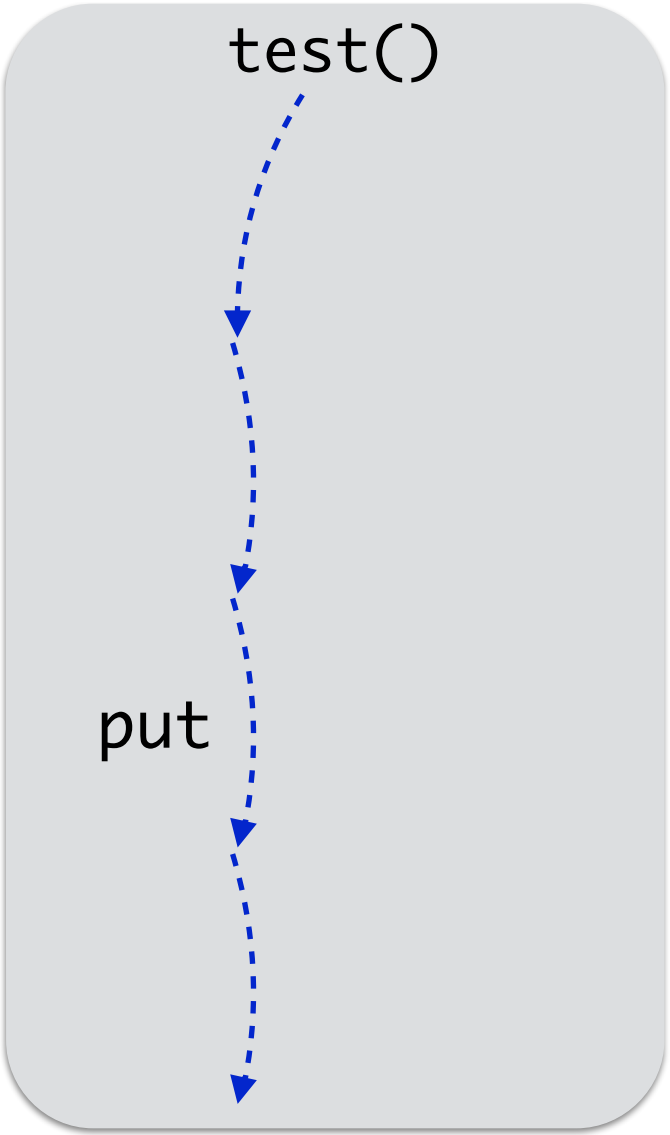


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test() {
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put ≡ putAll
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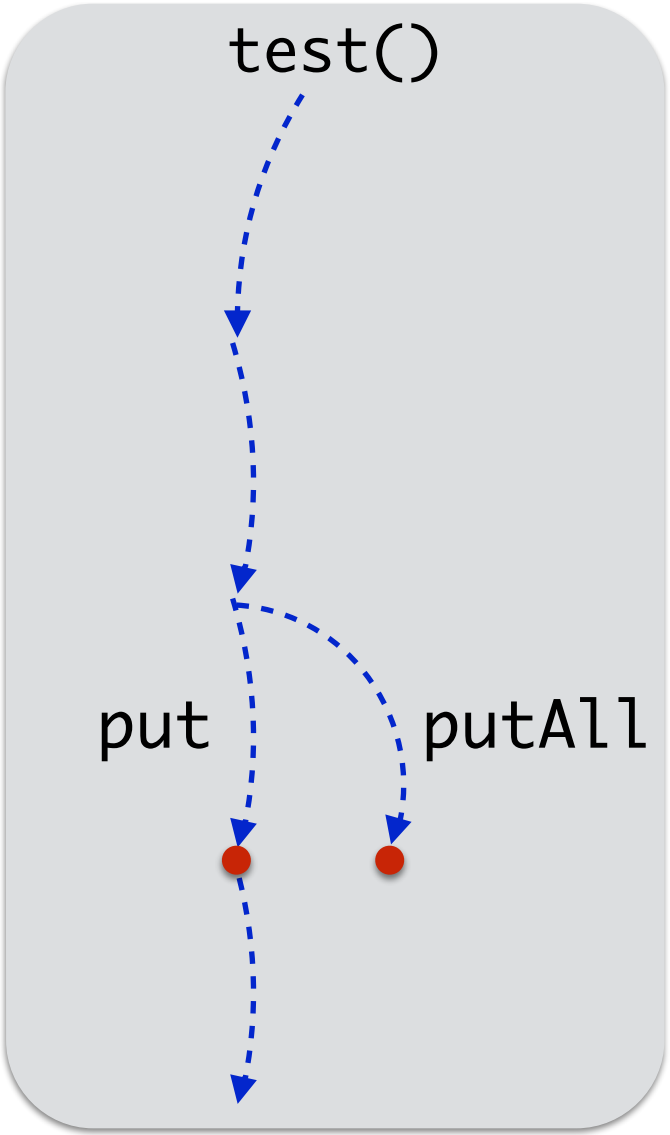


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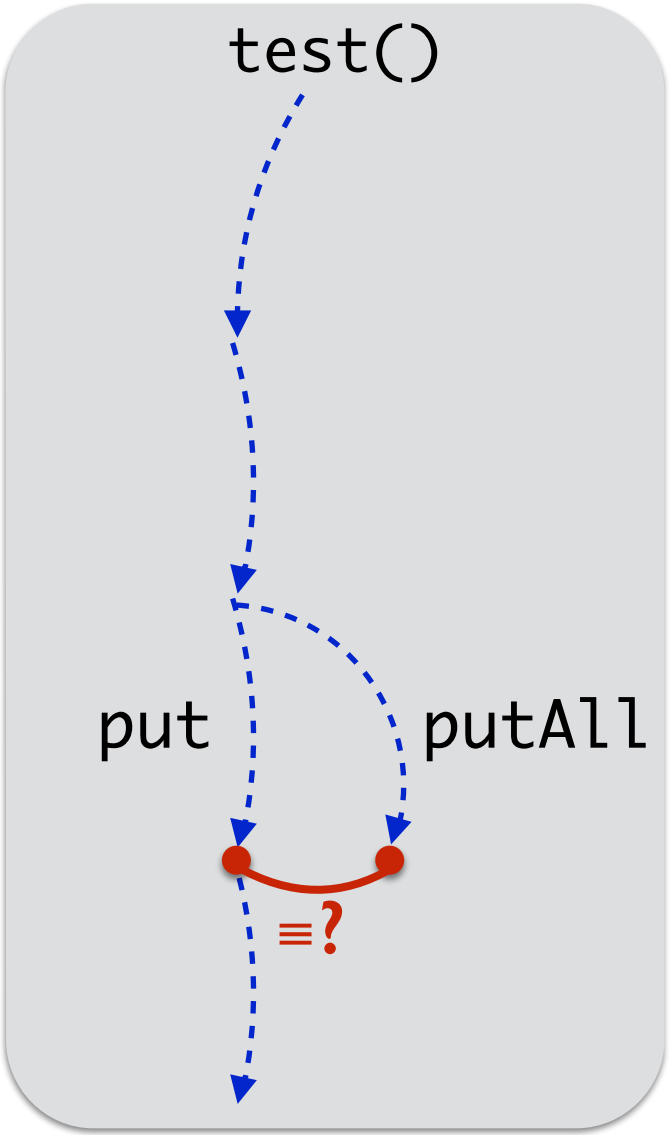


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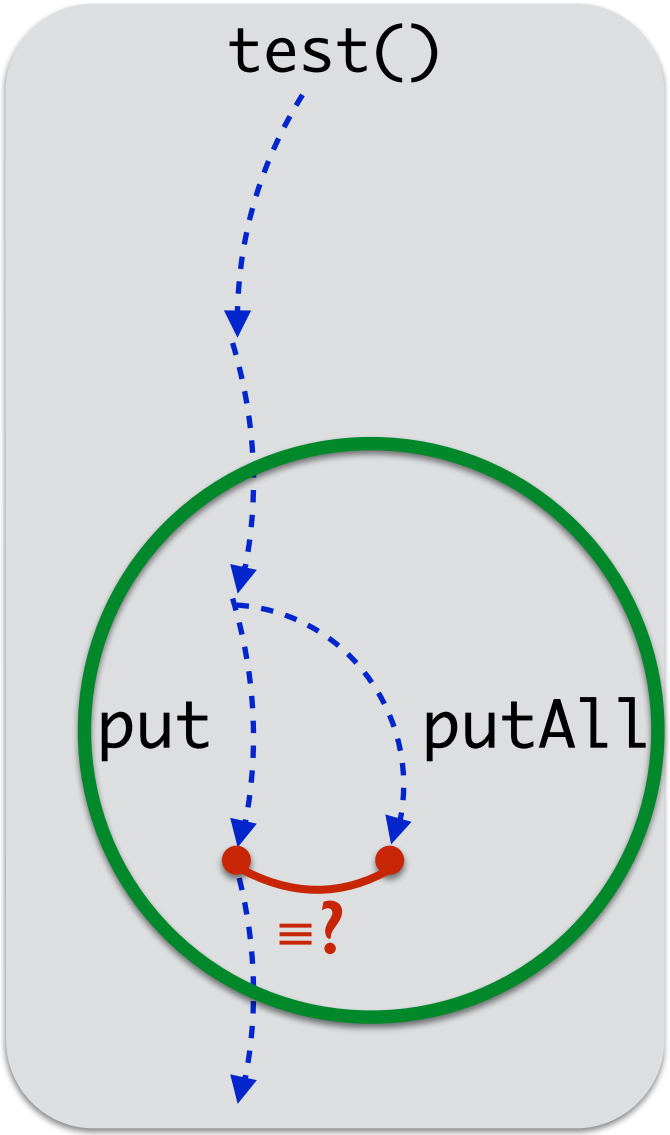


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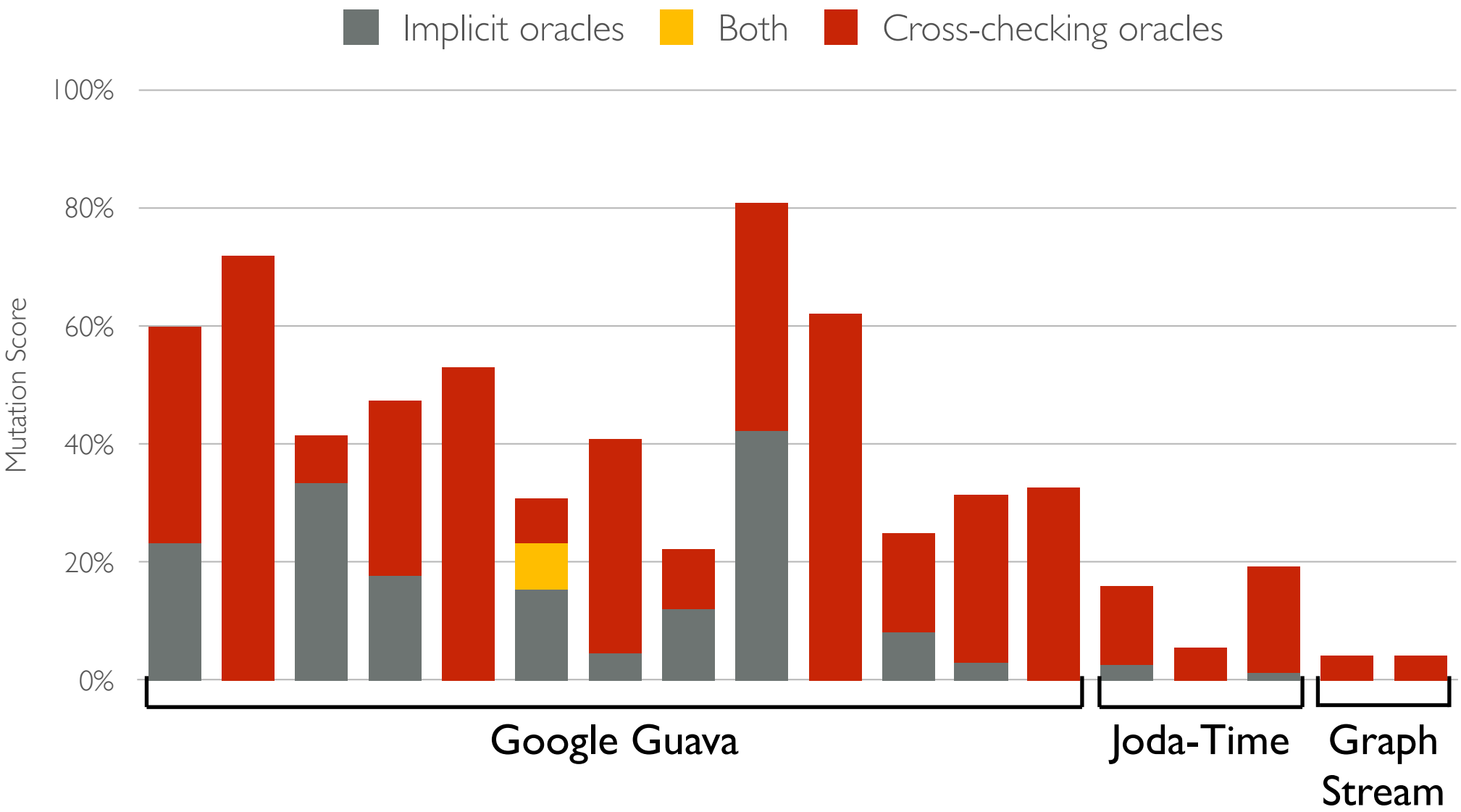
Cross-Checking Oracle

Cross-Checking vs Implicit Oracles

Cross-Checking Oracles from Intrinsic Software Redundancy [ICSE 2014]



Cross-Checking vs Developers' Oracles

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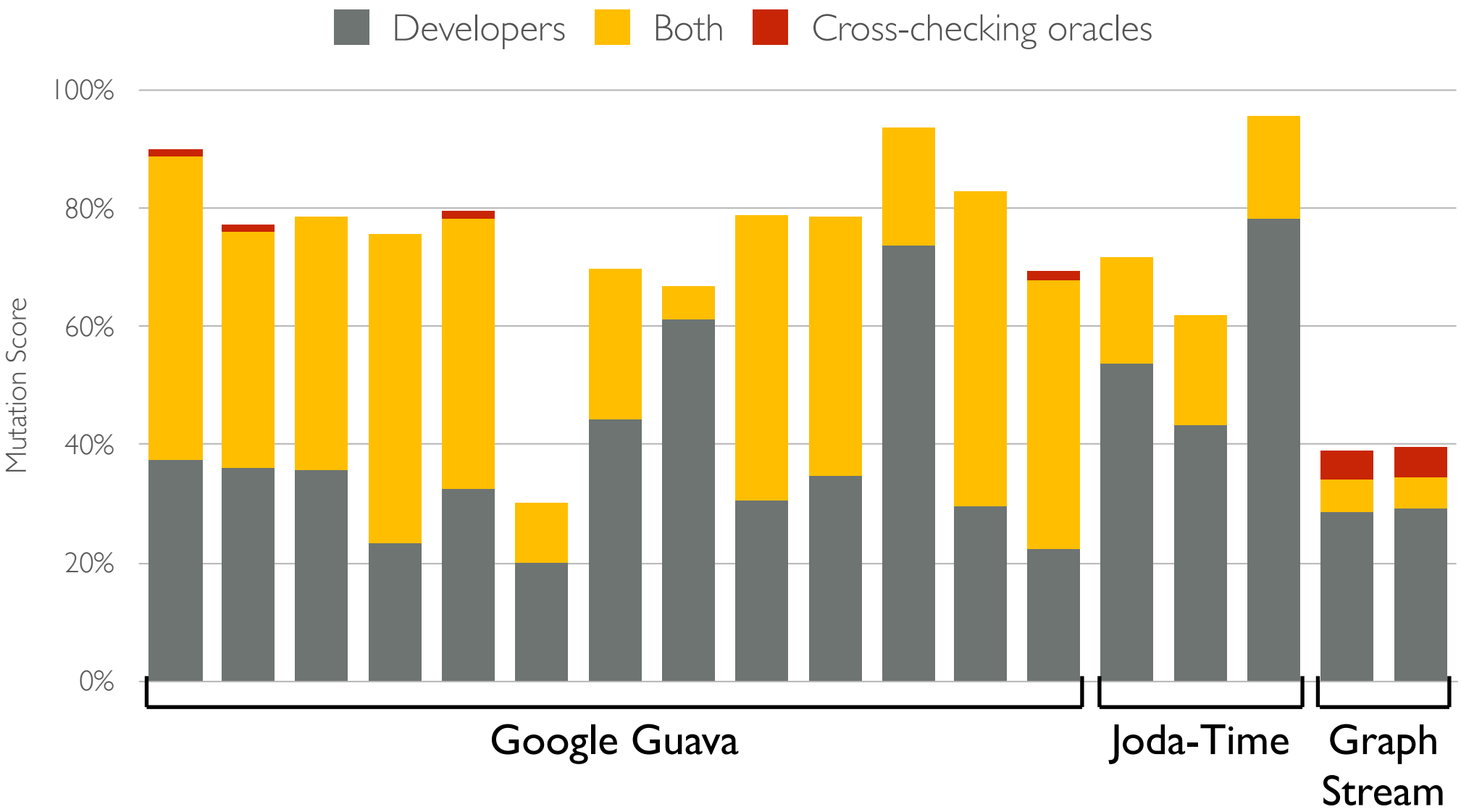

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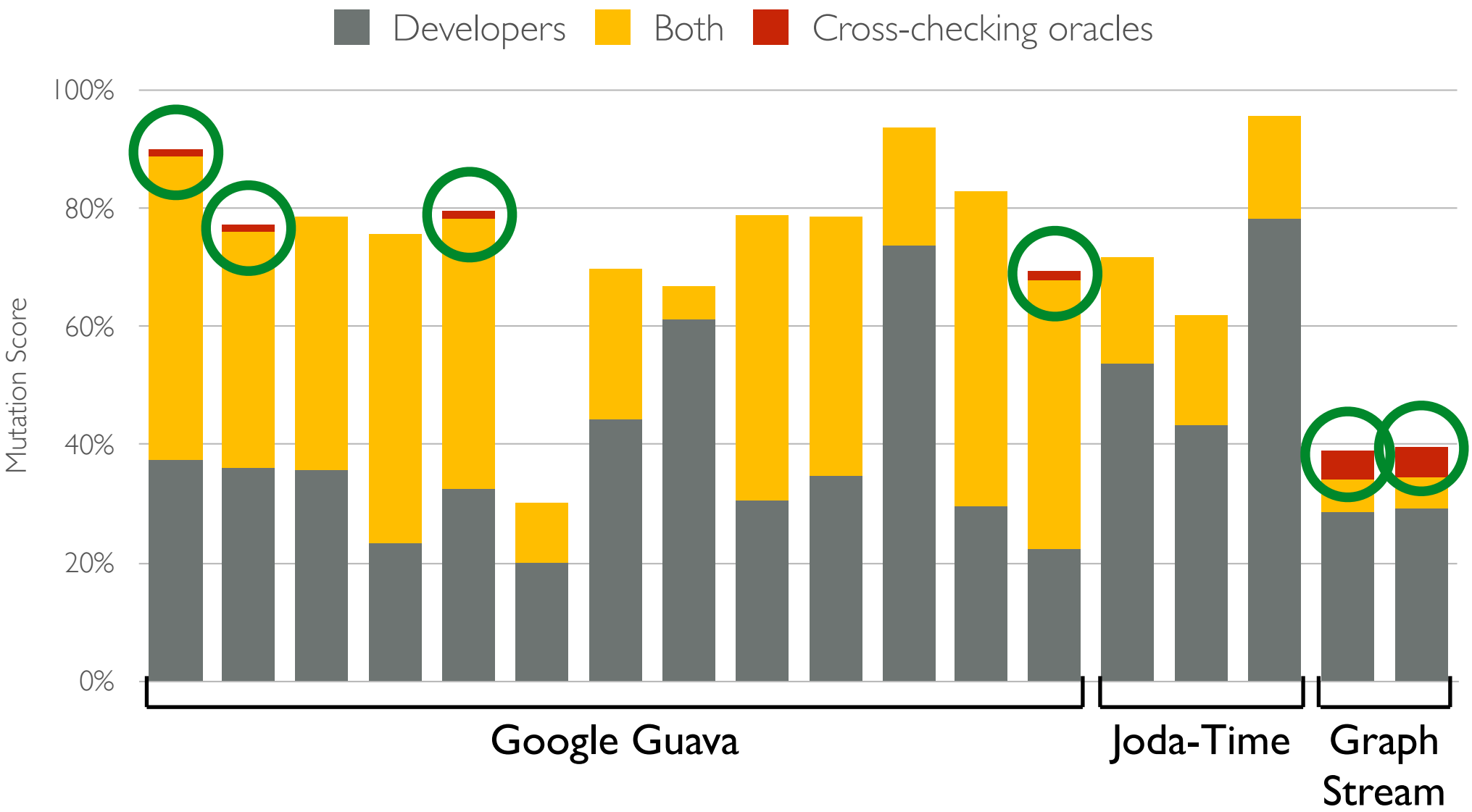

Intrinsic Software Redundancy

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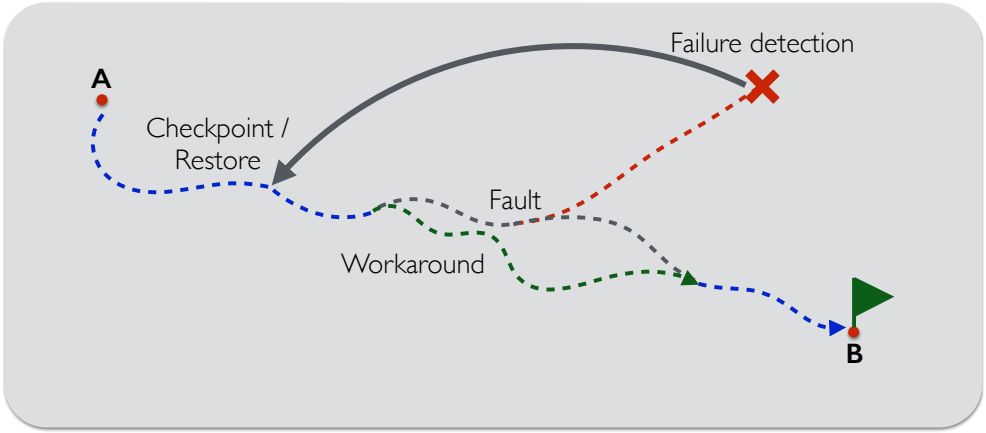

Application state space

Redundancy as Test Oracle

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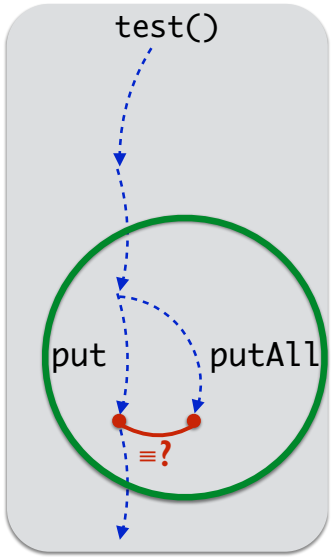


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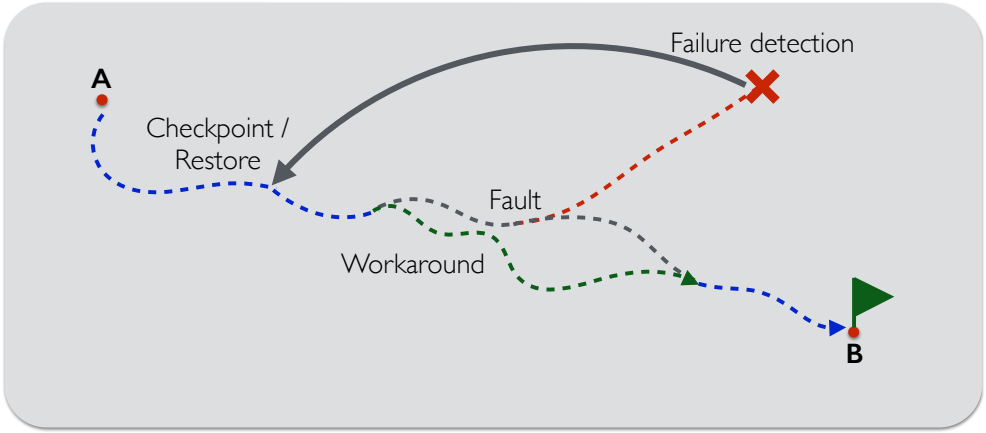

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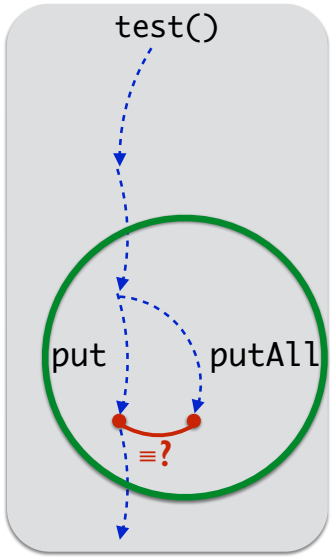


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Cross-Checking Oracle

Main cost: manual identification of equivalences

Automatic Synthesis of Equivalences

Search-Based Synthesis of Equivalent Method Sequences [FSE 2014]

Automatic Synthesis of Equivalences

Search-Based Synthesis of Equivalent Method Sequences [FSE 2014]

pop()

```
int el = s.peek();
int index = s.size();
index = index - 1;
s.remove(index);
return el;
```

Automatic Synthesis of Equivalences

Search-Based Synthesis of Equivalent Method Sequences [FSE 2014]

pop()

```
int el = s.peek();
int index = s.size();
index = index - 1;
s.remove(index);
return el;
```

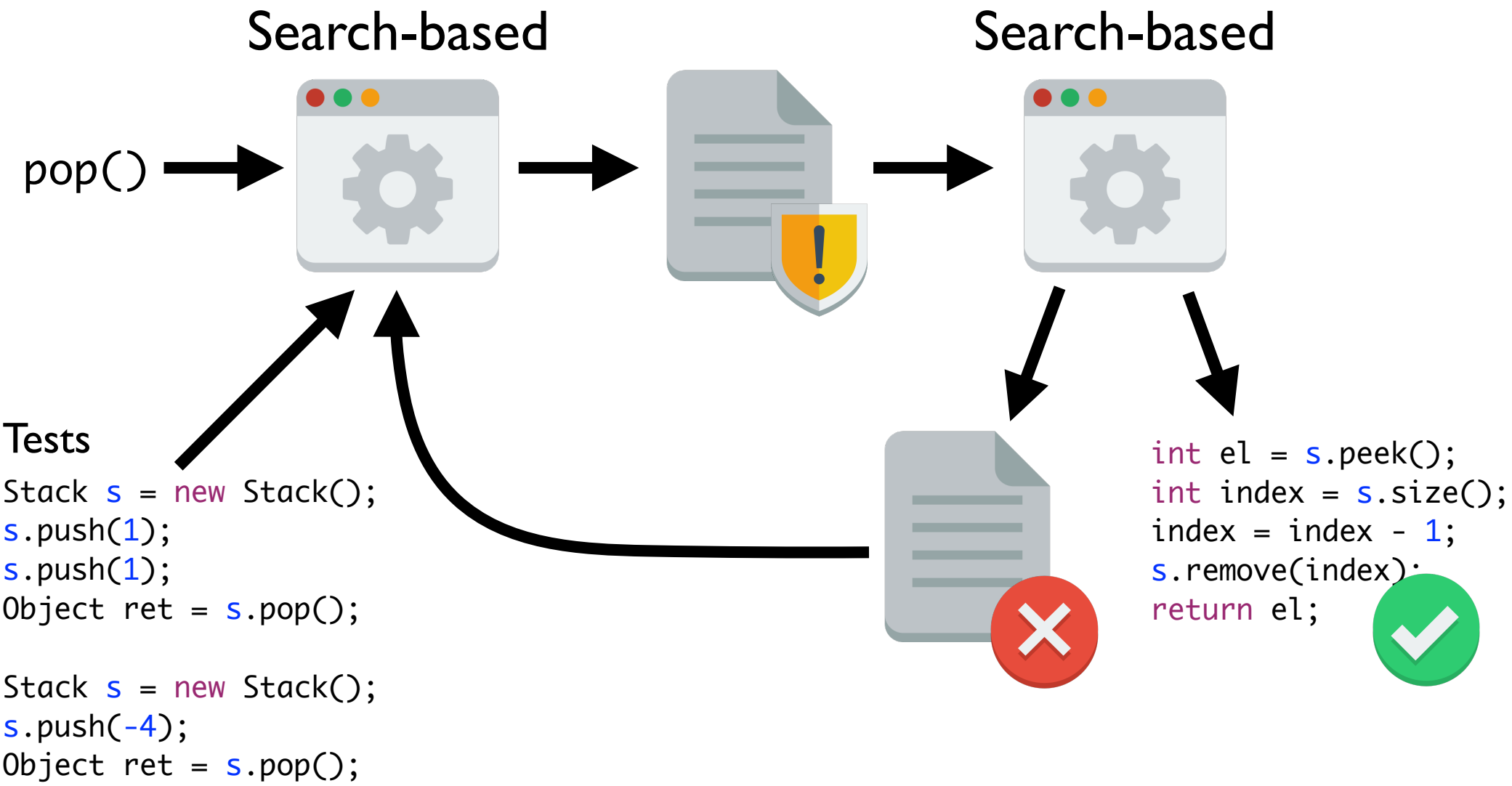
Tests

```
Stack s = new Stack();
s.push(1);
s.push(1);
Object ret = s.pop();

Stack s = new Stack();
s.push(-4);
Object ret = s.pop();
```

Automatic Synthesis of Equivalences

Search-Based Synthesis of Equivalent Method Sequences [FSE 2014]



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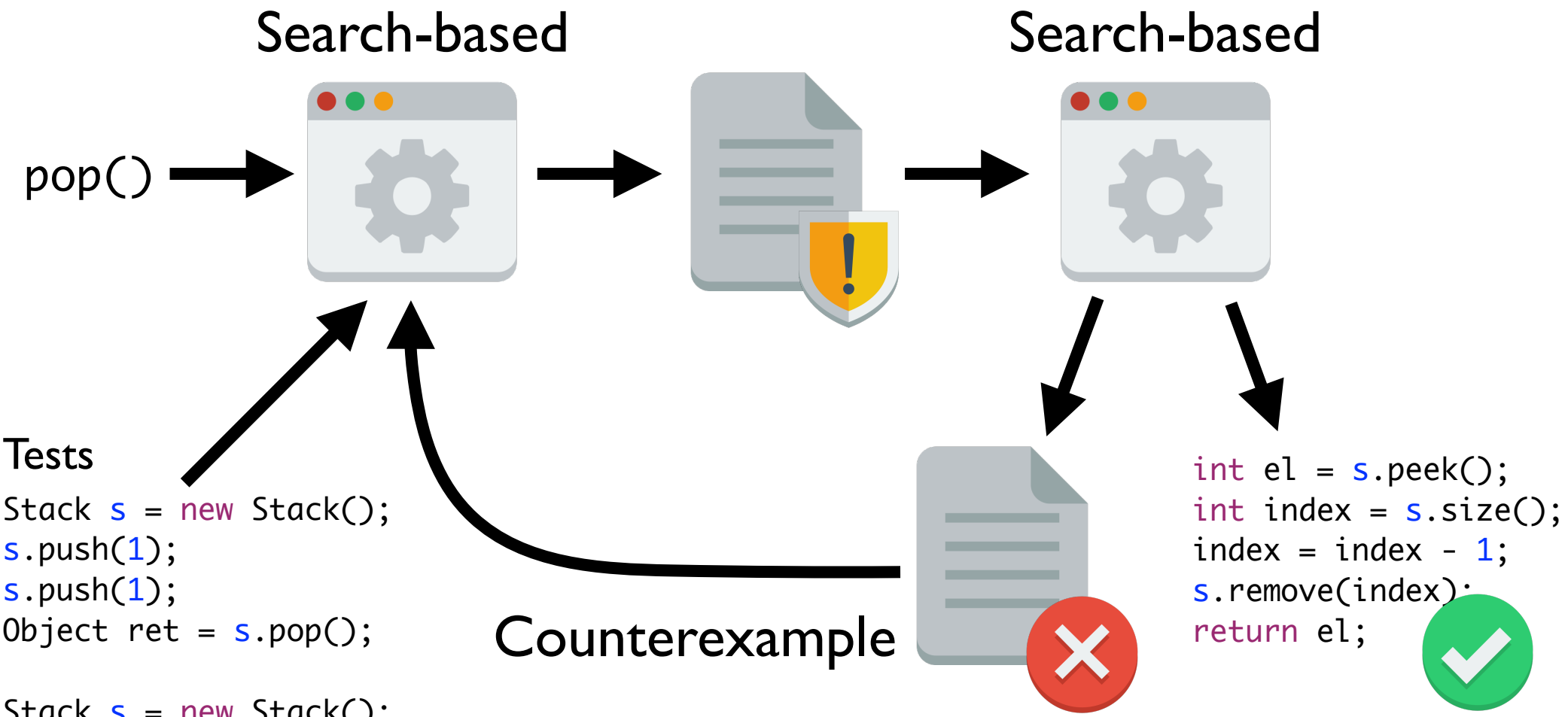

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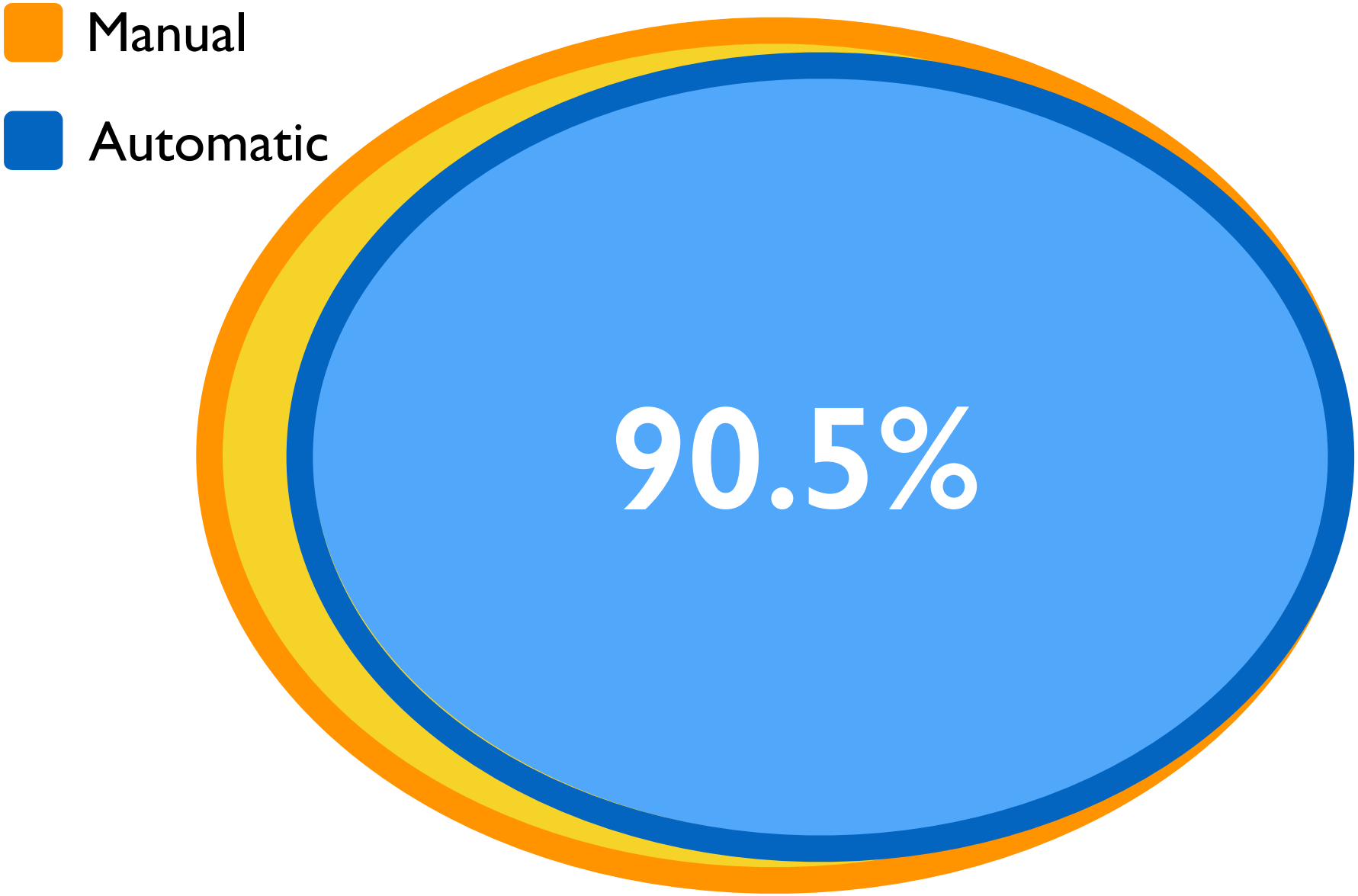

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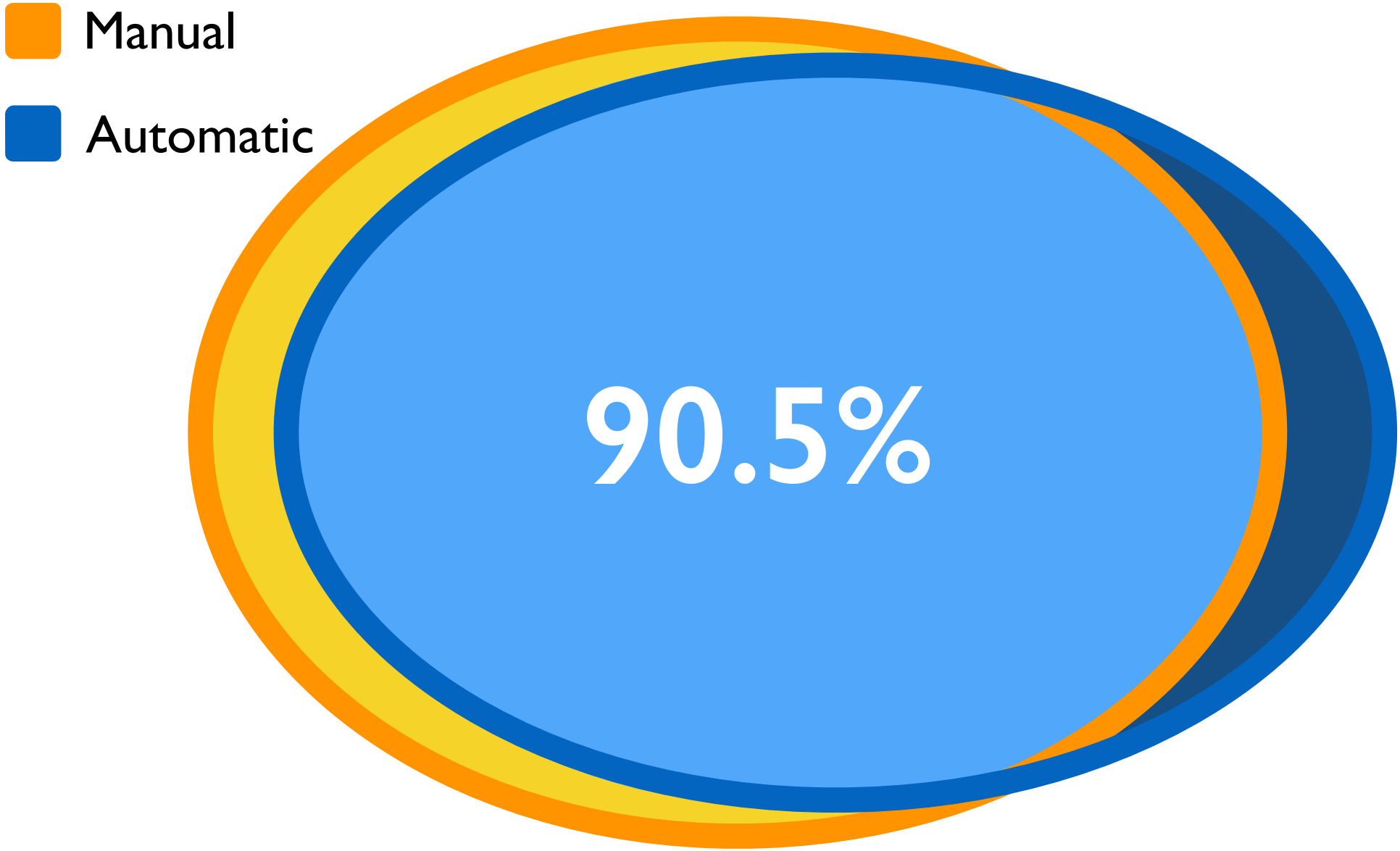


Software Redundancy

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code**.

Software Redundancy

What? **How to measure?**

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code**.

Software Redundancy

What? **How to measure?** **When?**

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code.**

Software Redundancy

How to measure?

> A system is redundant when it is able to perform **equivalent functionalities** by executing **different code.**

REDUNDANCY = f ( ,)

Measuring Software Redundancy

@ ICSE 2015

May 20th, Analysis 1

Intrinsic Software Redundancy

Joda-Time

<APACHE ANT>

eclipse SWT

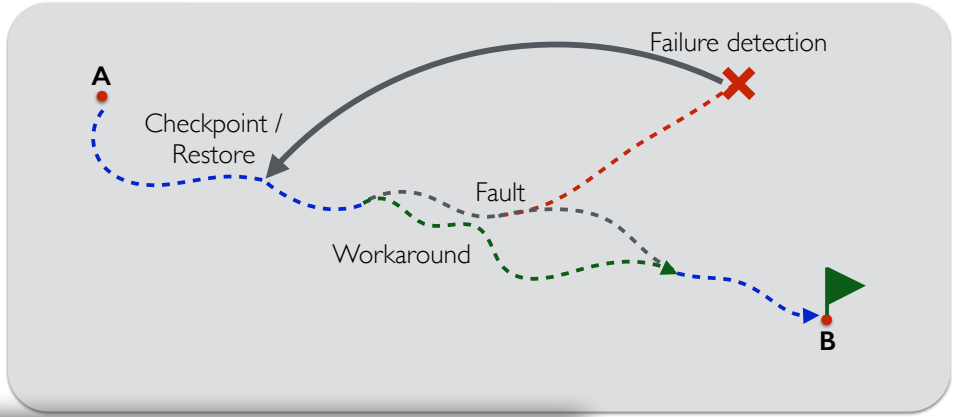
4700+
equivalences

Lucene

guava-libraries
Guava: Google Core Libraries for Java 1.6+

Redundancy for Self-Healing

Automatic Recovery from Runtime Failures [ICSE 2013]



star.inf.usi.ch

Redundancy as Test Oracle

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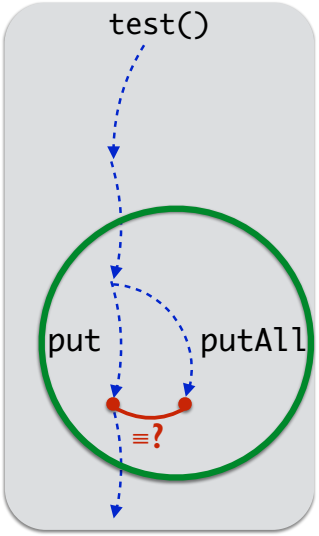


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Cross-Checking Oracle

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