Inferring Mutant Utility from Program Context

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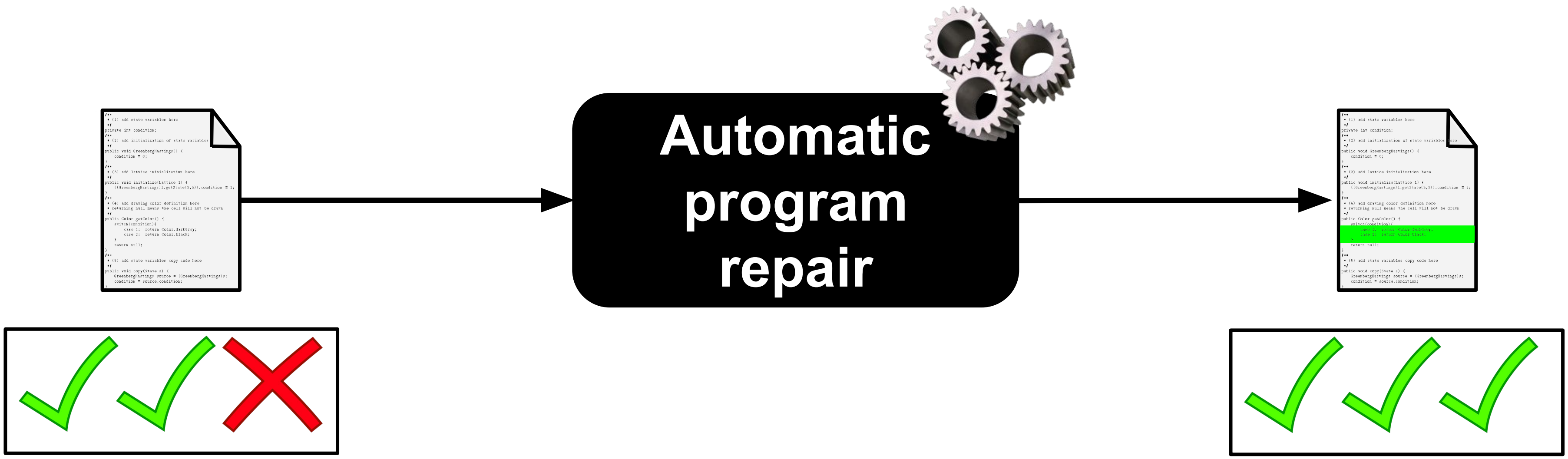
Automatic program repair



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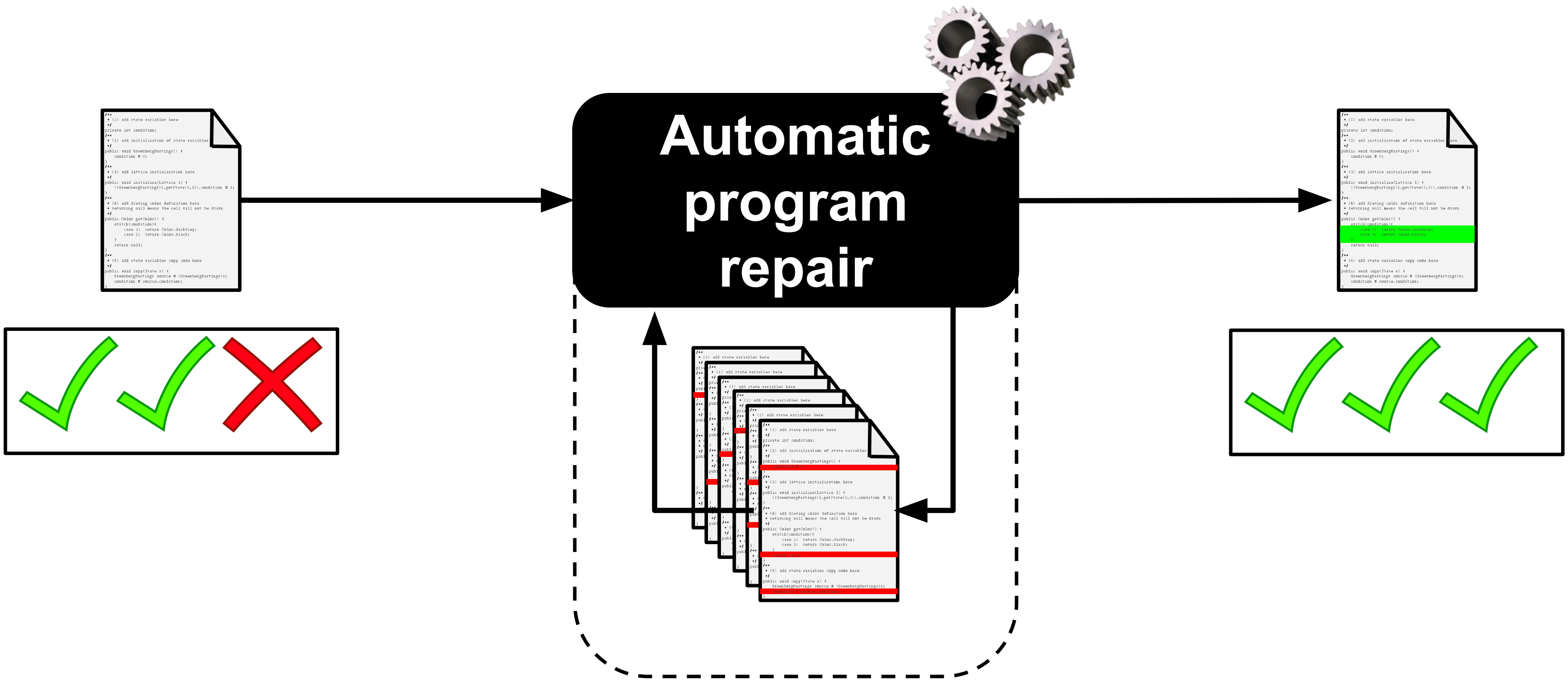

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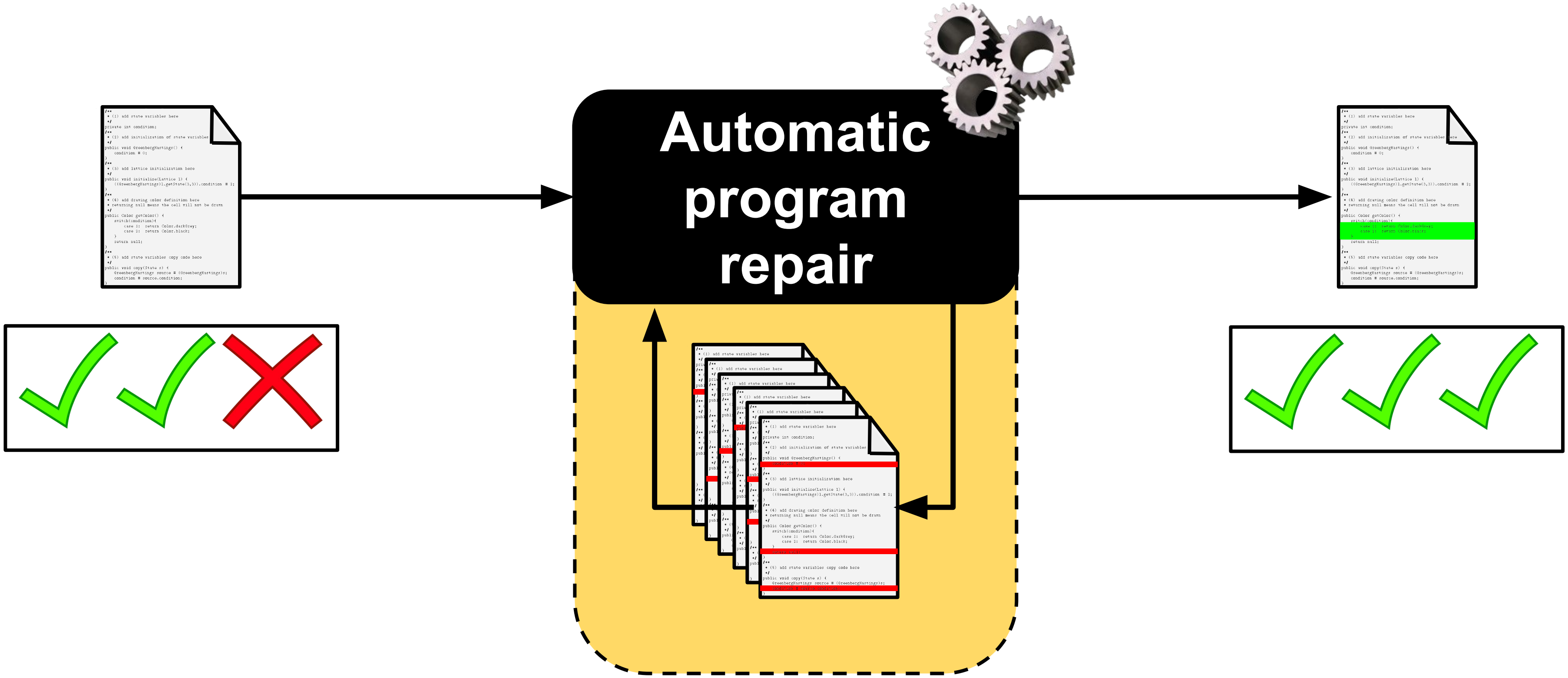
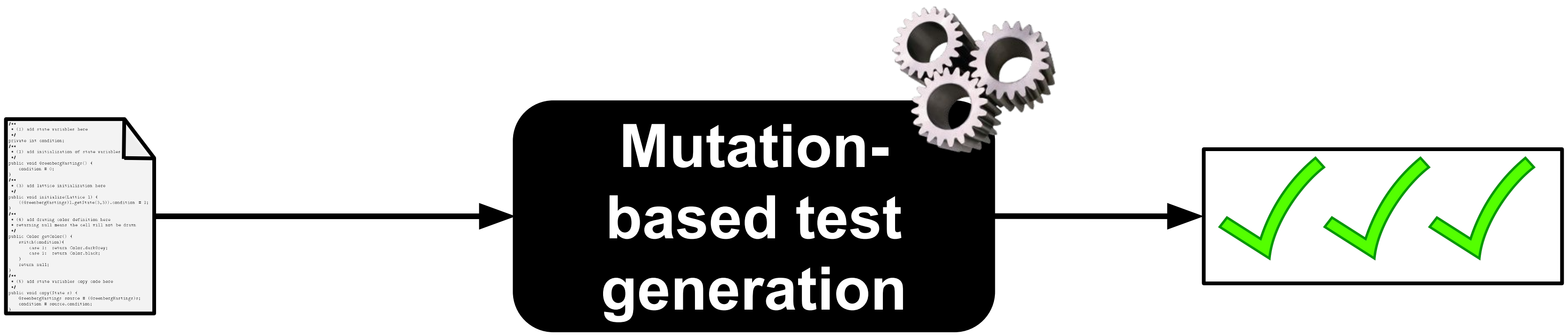


Goal: generate **mutants** that **improve** the **functional correctness** of the original program.

Mutation-based test generation



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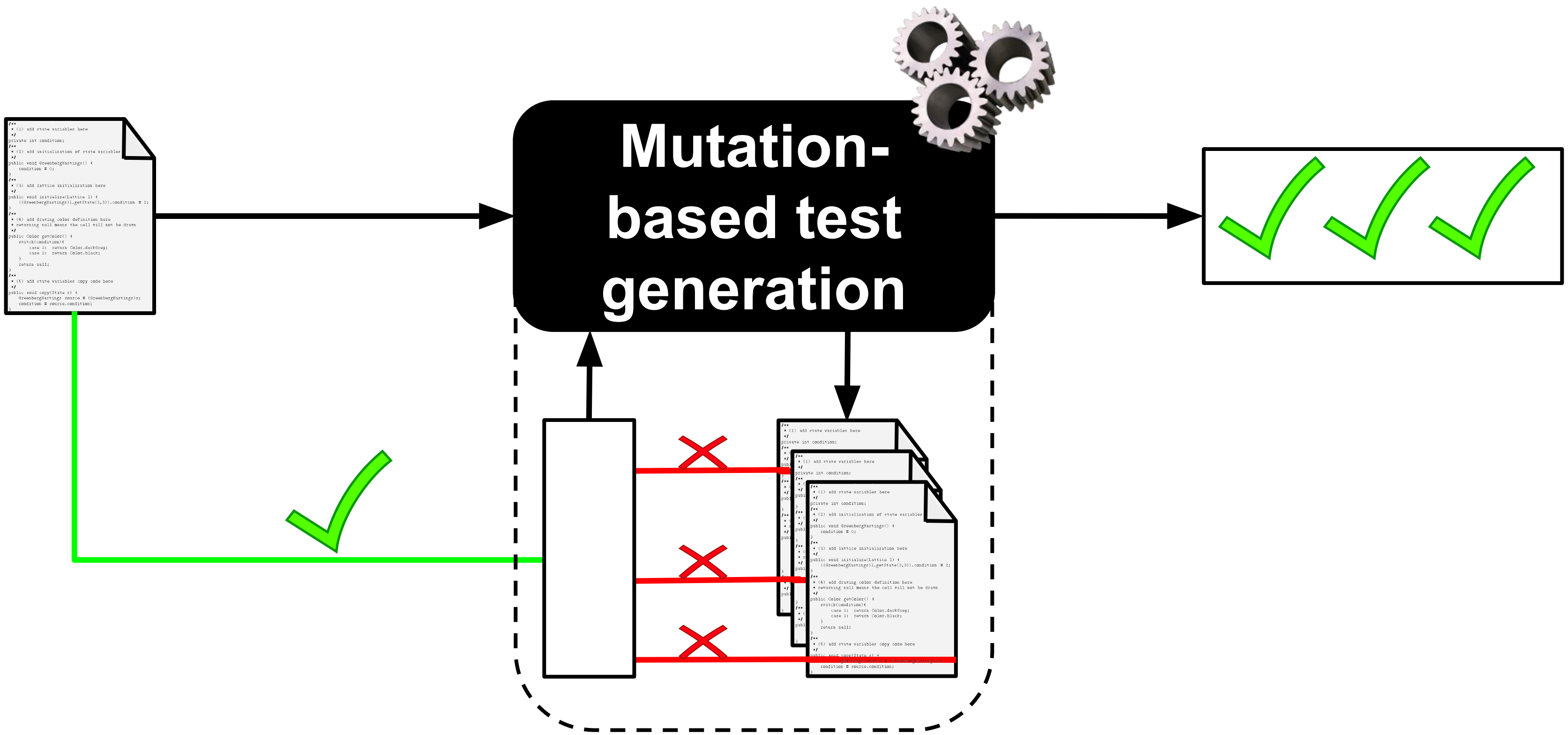

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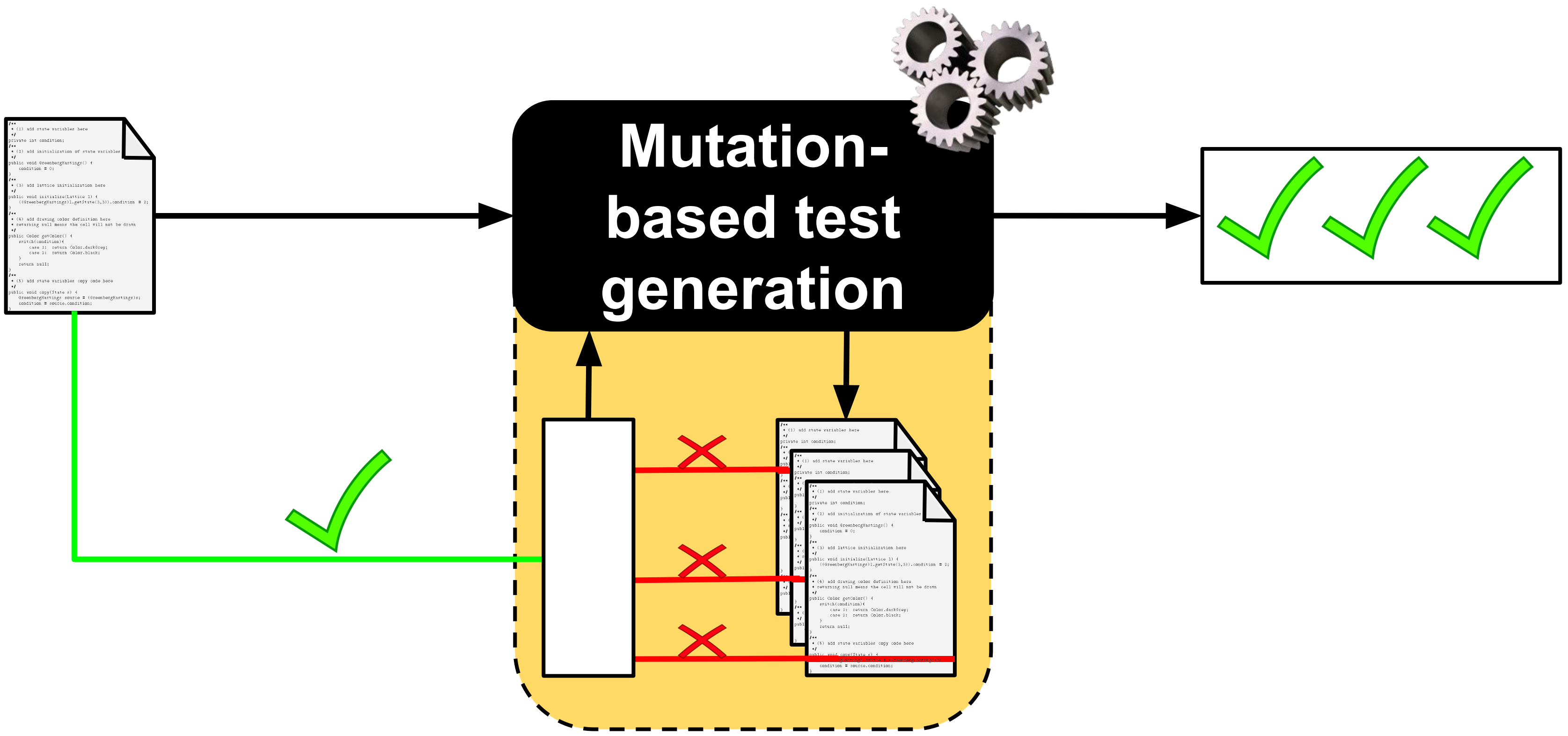

Goal: generate **strong tests** using **hard-to-detect mutants.**

Selecting a set of effective mutants

Goals:

1. Generate mutants that **improve functional correctness**.
2. Generate mutants that are **hard to detect**.

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Problem:

- **Many** mutants are non compilable, trivially crashing, or equivalent ⟹ **useless** and **costly mutants**.

Existing strategies:

- Selective mutation (e.g., pattern-based mutation).
- **Program-independent** and **no better than random**.

Gopinath et al., ICSE’16, Kurtz et al., FSE’16

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Hypothesis: Program context matters!

Gopinath et al., ICSE'16, Kurtz et al., FSE'16

Program context

Original program

```
public double getAbsAvg(double[] nums) {
  double sum = 0;

  for (int i = 0; i < nums.length; ++i) {
    if (nums[i] < 0) {
      sum -= nums[i];
    } else {
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  return sum / nums.length;
}
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Program context: Parent context

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Mutation operator

lhs **<** *rhs* ⇒ *lhs* **!=** *rhs*

⇒ **i != nums.length**

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equivalent

non-equivalent

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Mutation operator

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```

Identifier

Literal

Operator

Mutation operator

lhs < *rhs* ⇒ *lhs* <= *rhs*

trivial

equivalent

Context: kind of operands (**identifier** vs. **operator** vs. **literal**)

Program context: Data type context

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Mutation operator

`0` → `-1`

Program context: Data type context

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Mutation operator

$0 \rightarrow -1$

non-trivial

trivial

Context: data type (**double vs. int**)

Program context: Summary

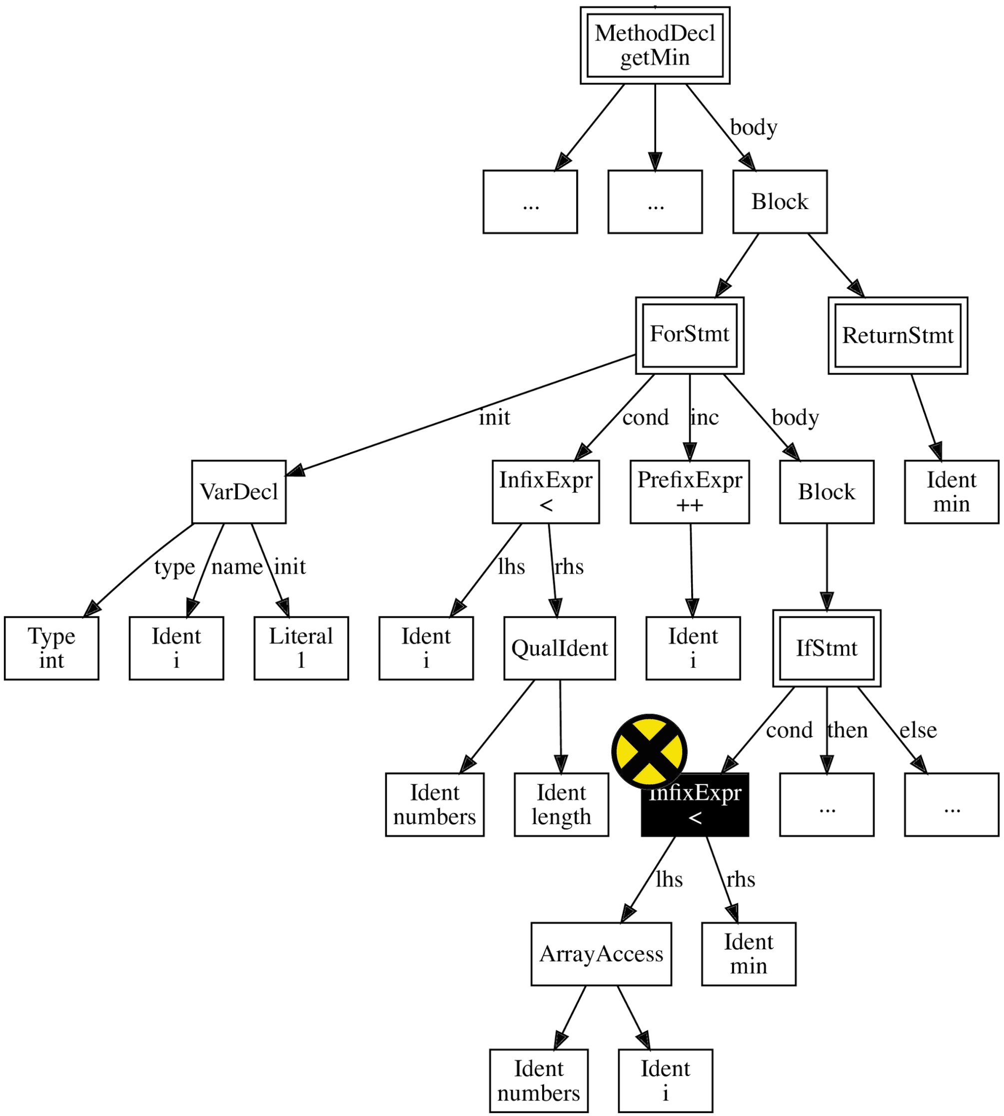
Mutation operator effectiveness differs, even **within** a **single method.**

Program context matters!

Different dimensions of program context

- **Parent context**: Kind of lexically enclosing statement(s).
- **Data type context**: Data types of operators and operands.
- **Children context**: Kind of operands.

Modeling program context using the AST



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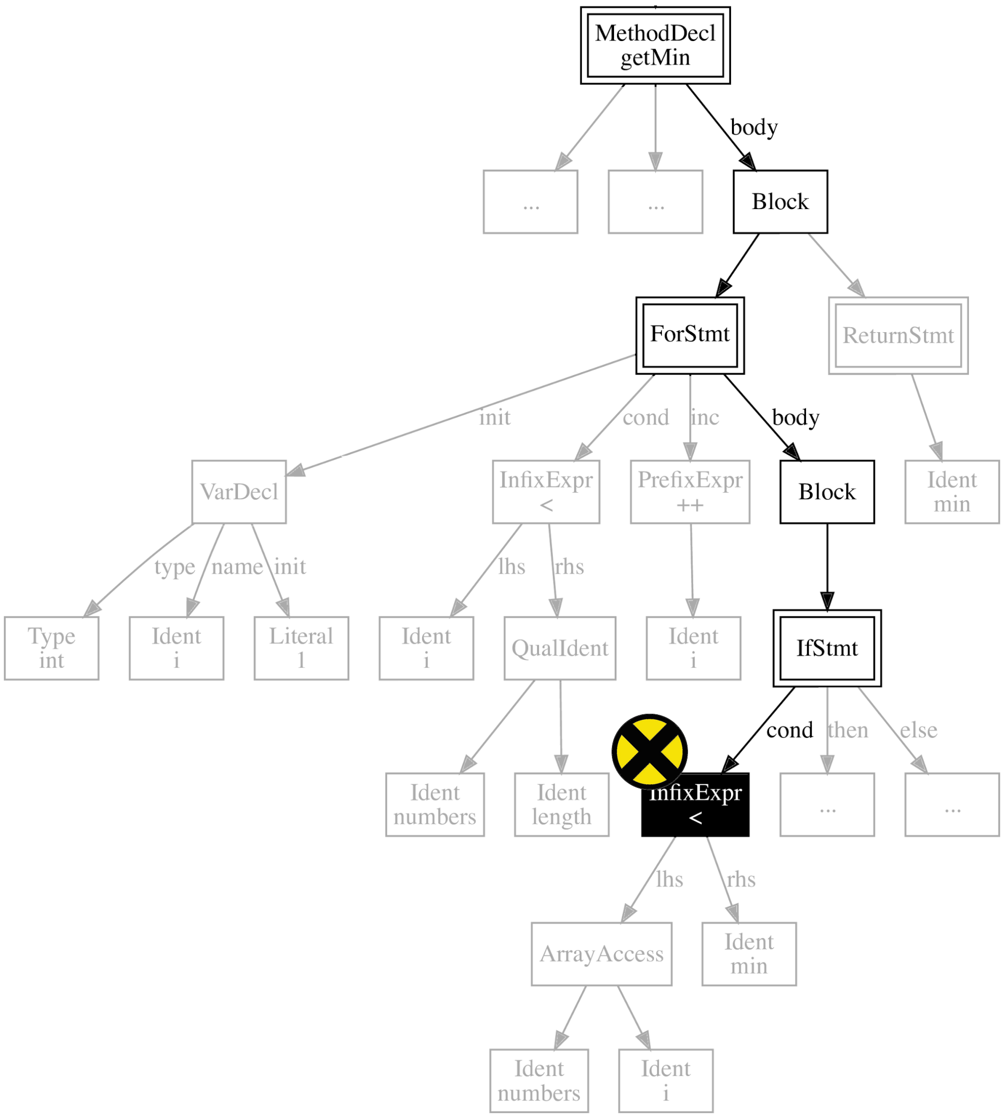

- **Parent context**

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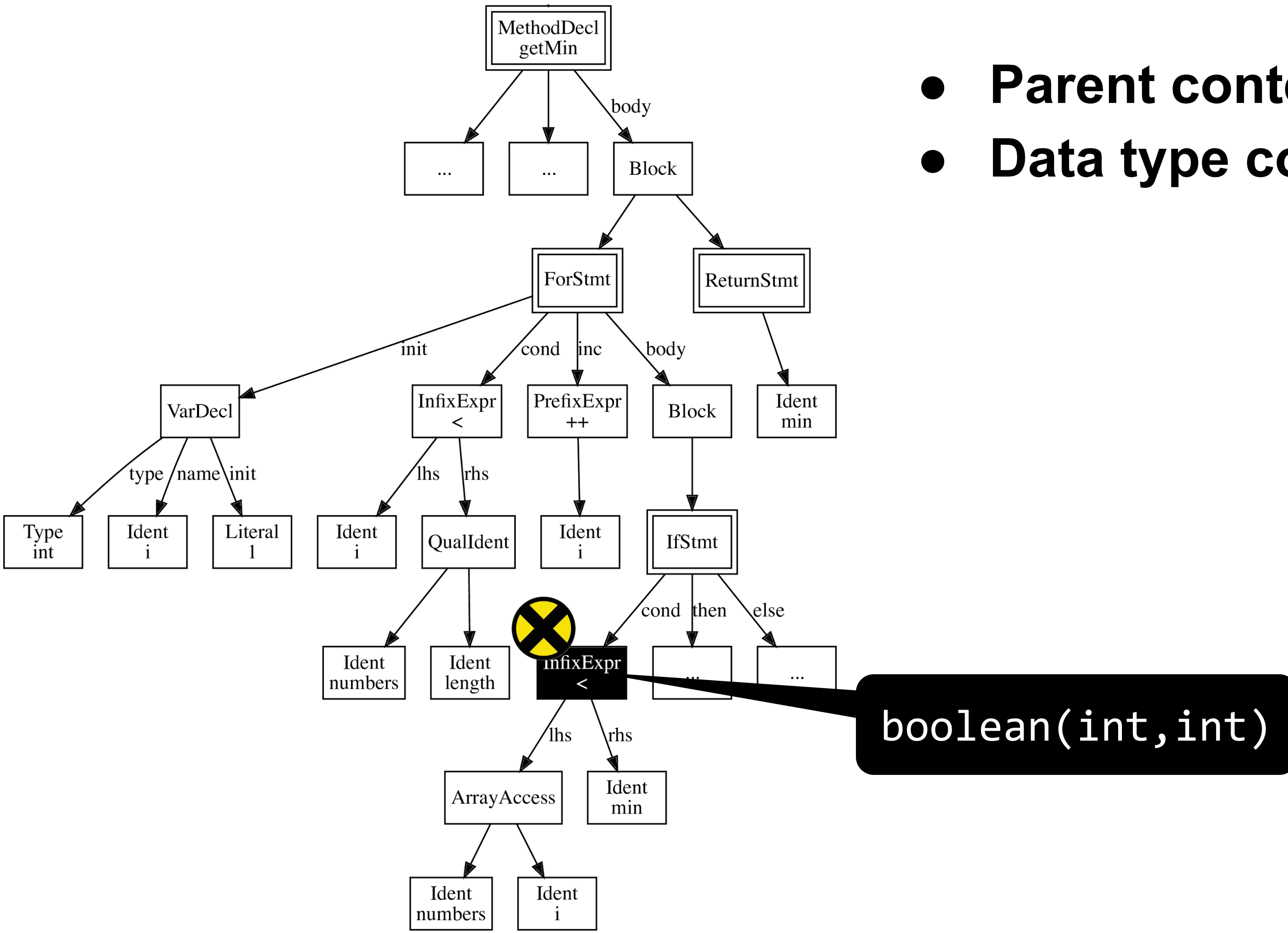

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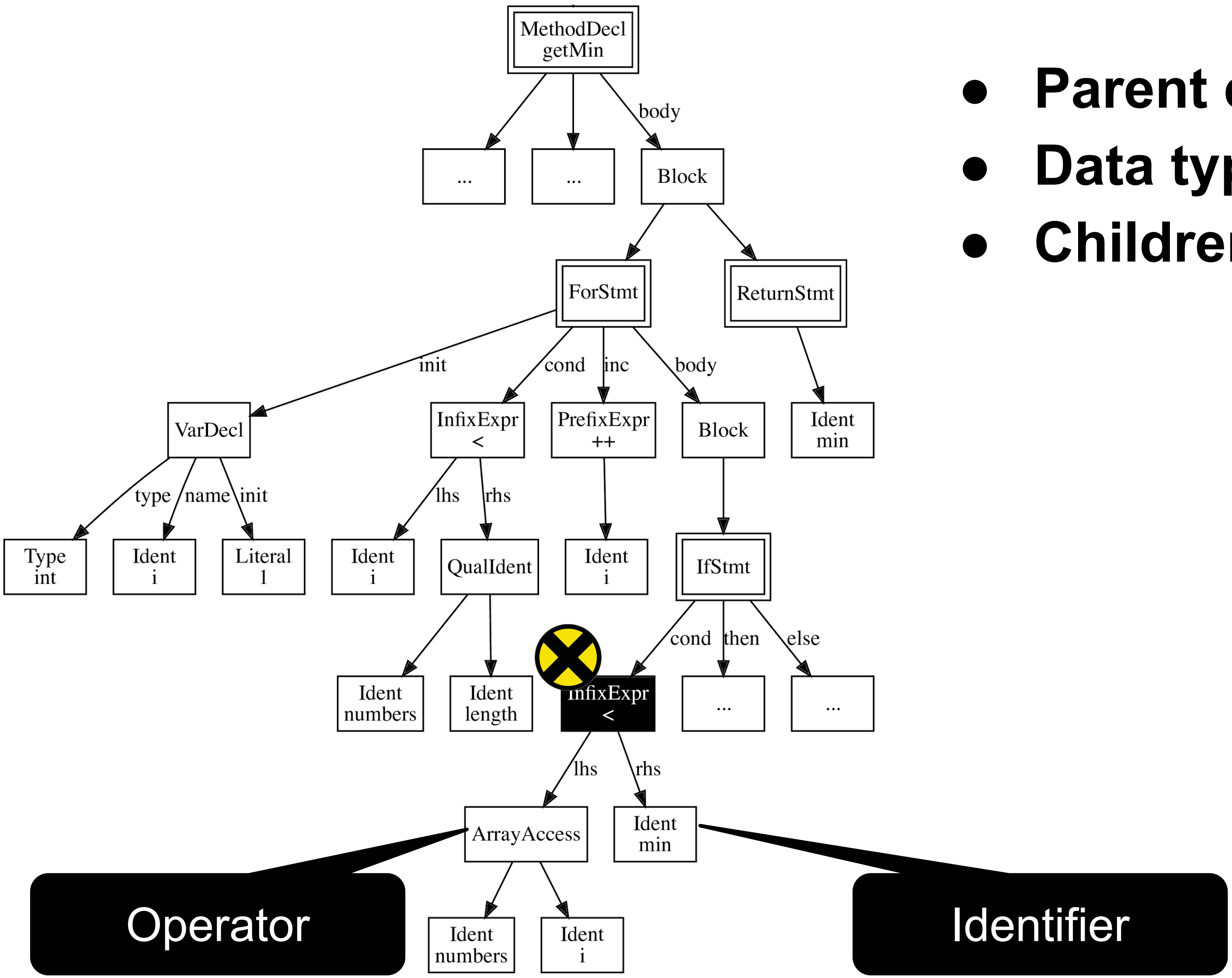

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Mutant utility

1. **Equivalence**: equivalent mutants have **low utility**.
2. **Triviality**: trivially crashing mutants have **low utility**.
3. **Dominance**: dominator mutants have **high utility**.

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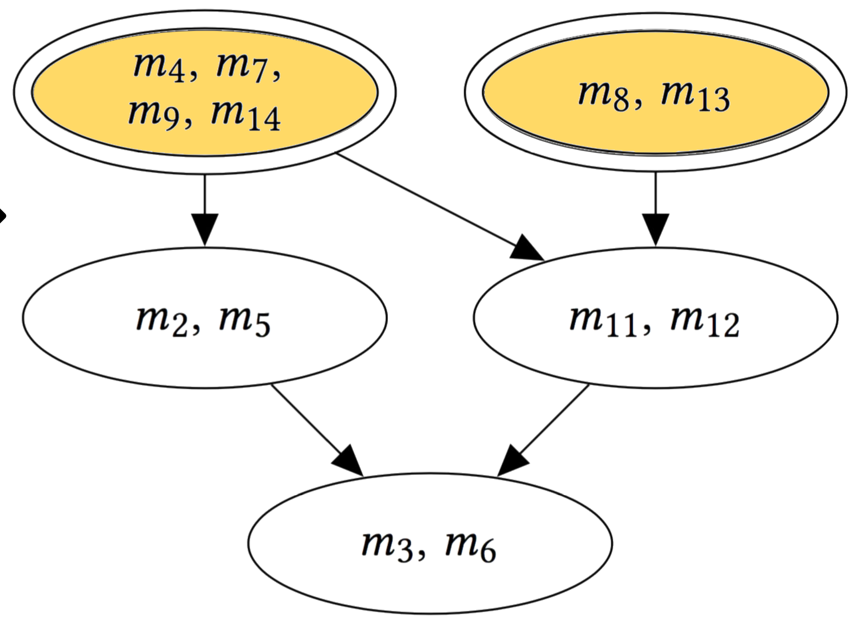
Mutant	Test			
	t_1	t_2	t_3	t_4
m_1:				
m_2:		✓		✓
m_3:	✓	✓	✓	✓
m_4:		✓		
m_5:		✓		✓
m_6:	✓	✓	✓	✓
m_7:		✓		
m_8:	✓			
m_9:		✓		
m_{10}:				
m_{11}:	✓	✓		
m_{12}:	✓	✓		
m_{13}:	✓			
m_{14}:		✓		



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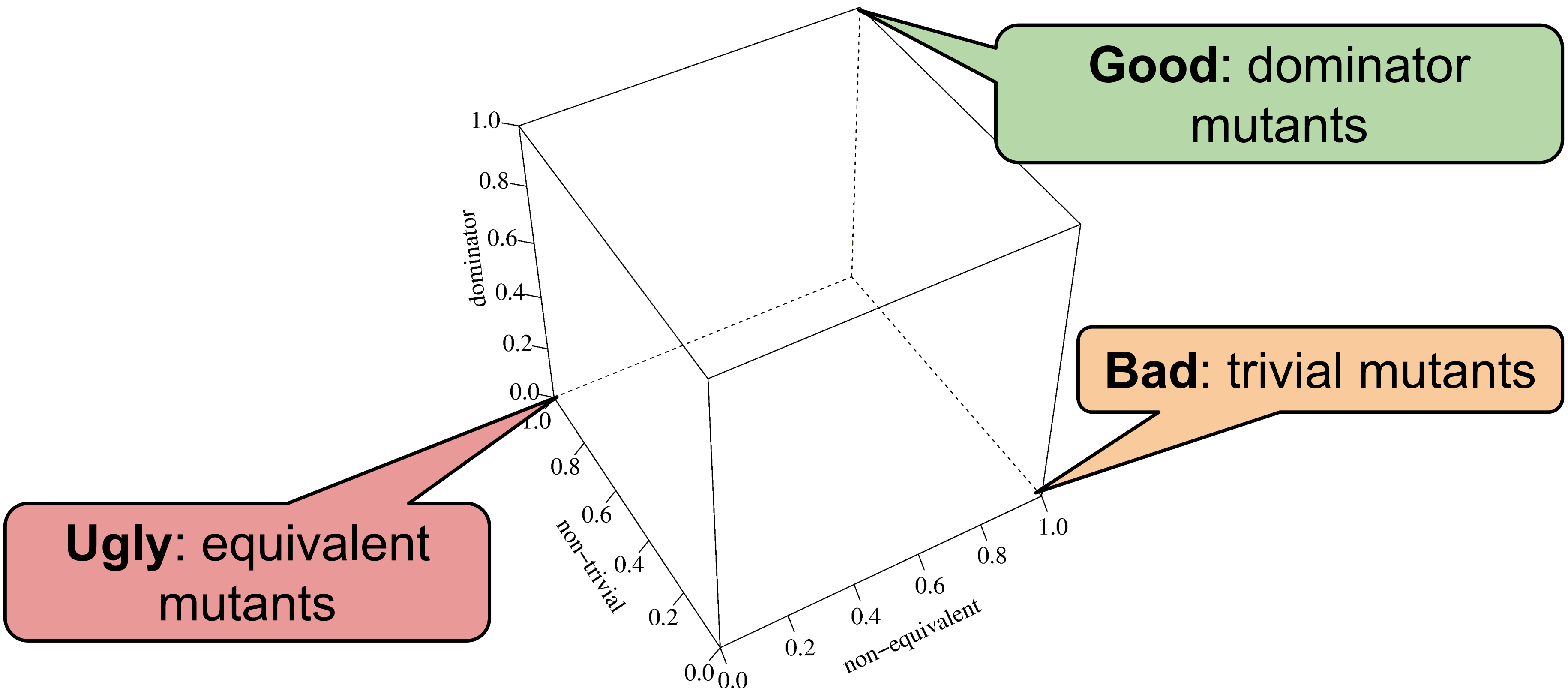


Is program context predictive of mutant utility?

Determining ground truth (equivalence, triviality, dominance)

- **Approximations** using extensive **test suites**.
- **95+% statement coverage**.

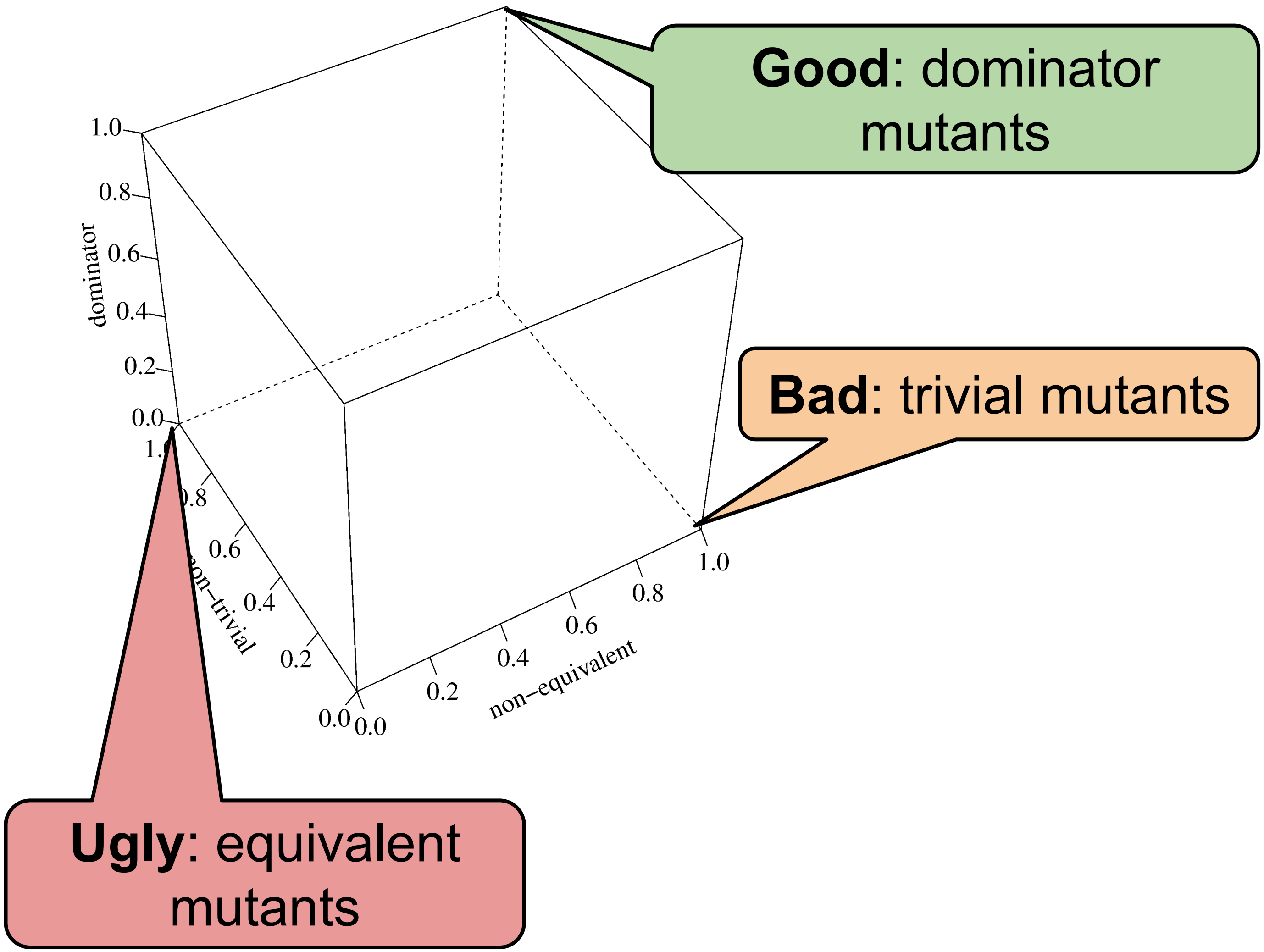
Selected subjects: 97 unique classes (4 real-world projects)

- 15,000 test cases
  - 64 test cases cover each mutant, on average
  - 23 test cases detect each mutant, on average

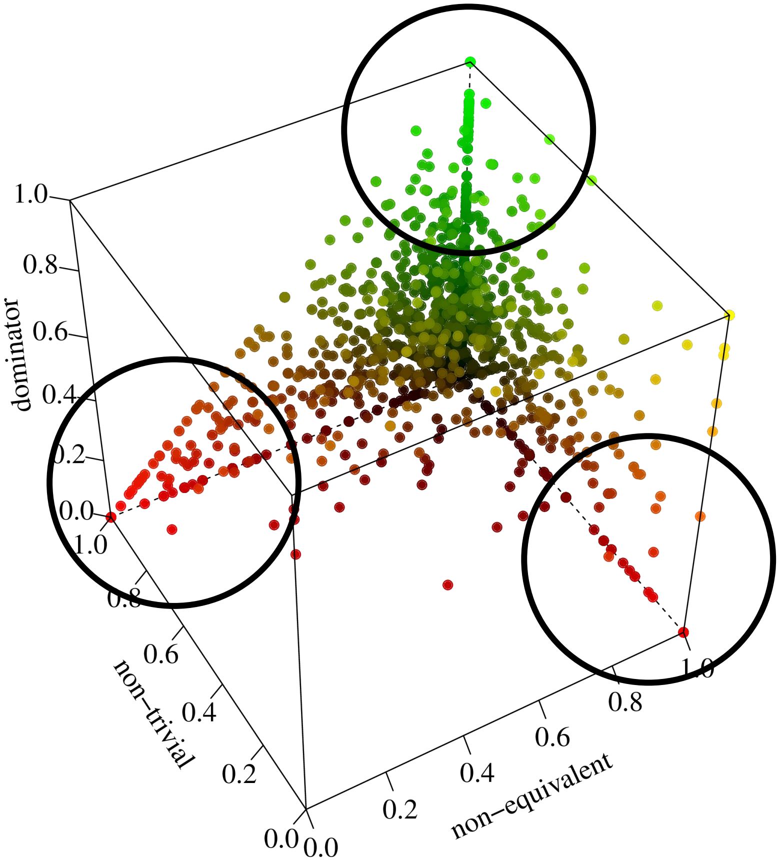
80,000 generated mutants (129 mutation operators)

http://defects4j.org

Recall the high-level goal



Expected mutant utility: context-based vs. random



Context-based selection

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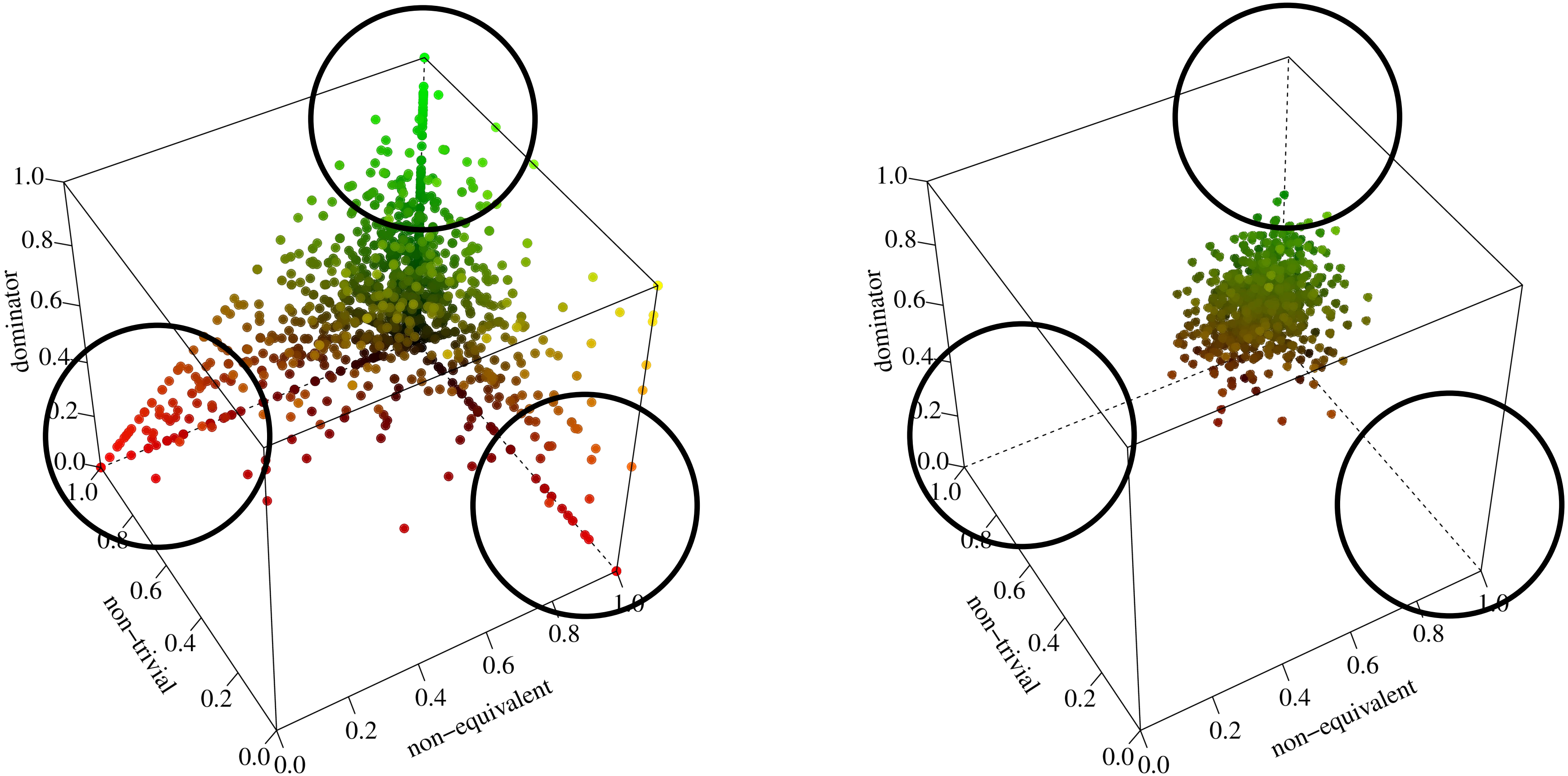


Context-based selection

Random selection

Full experimental details in the paper.

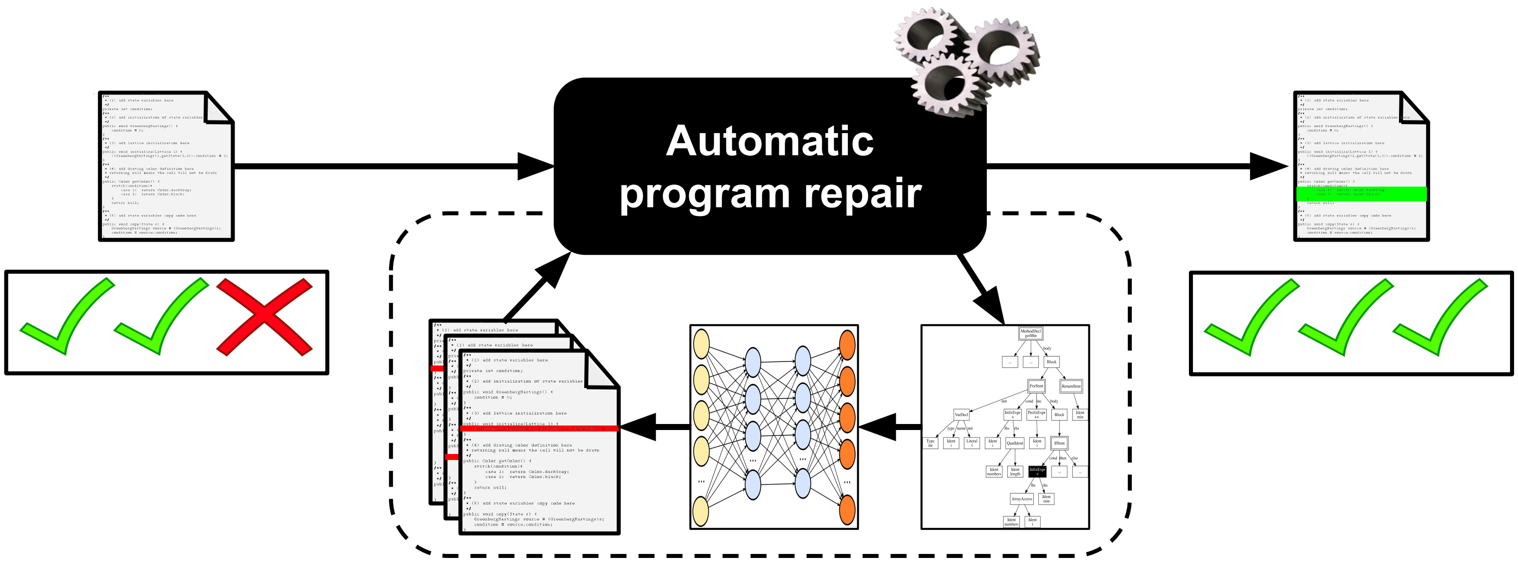
Future work: what's next?

More complex program context models

- Scope and visibility
- Control and data flow

Train effective machine learning classifiers

Integrate into downstream techniques



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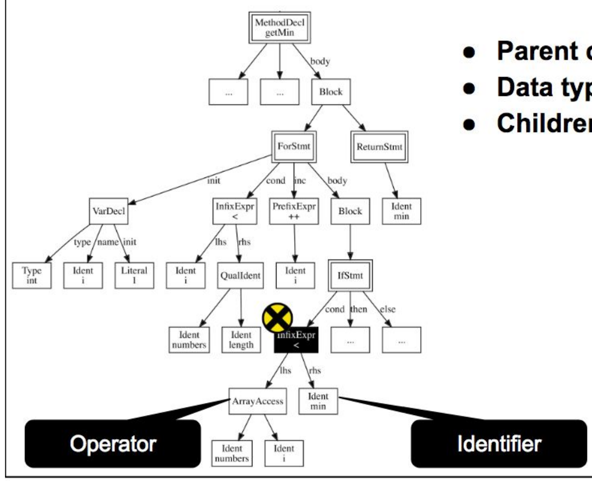

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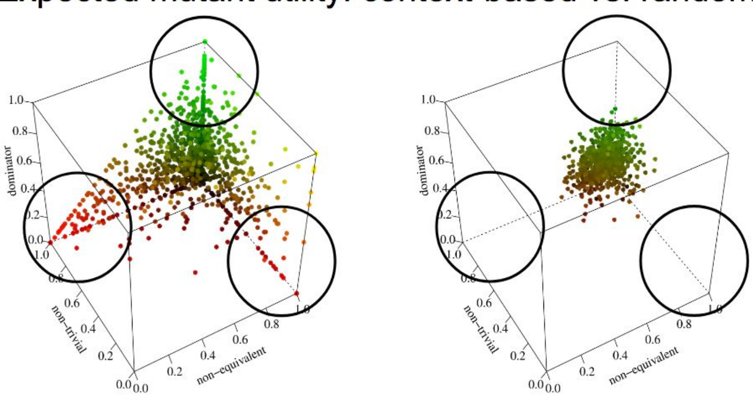

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