Visualize Optimization-directed Fuzzing for Effective Optimization Testing

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IS661

Compiler’s Optimization

- Compiler optimizes the program to have lower cost
  - The optimized program must have the same semantics as the original

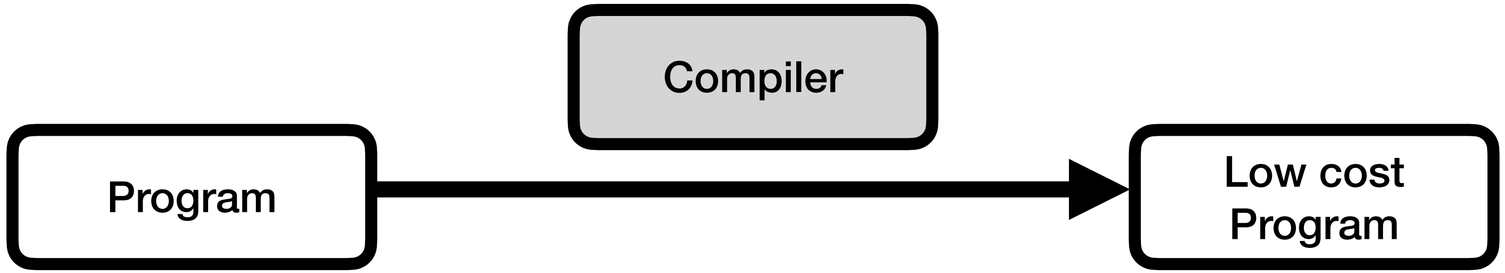
```
int foo1 (int a) {
  int temp = a + 1;
  return temp + 2;
}
```

```
int foo1 (int a) {
  return a + 3;
}
```

```
int foo2 (int a) {
  int temp = a * 4;
  return temp;
}
```

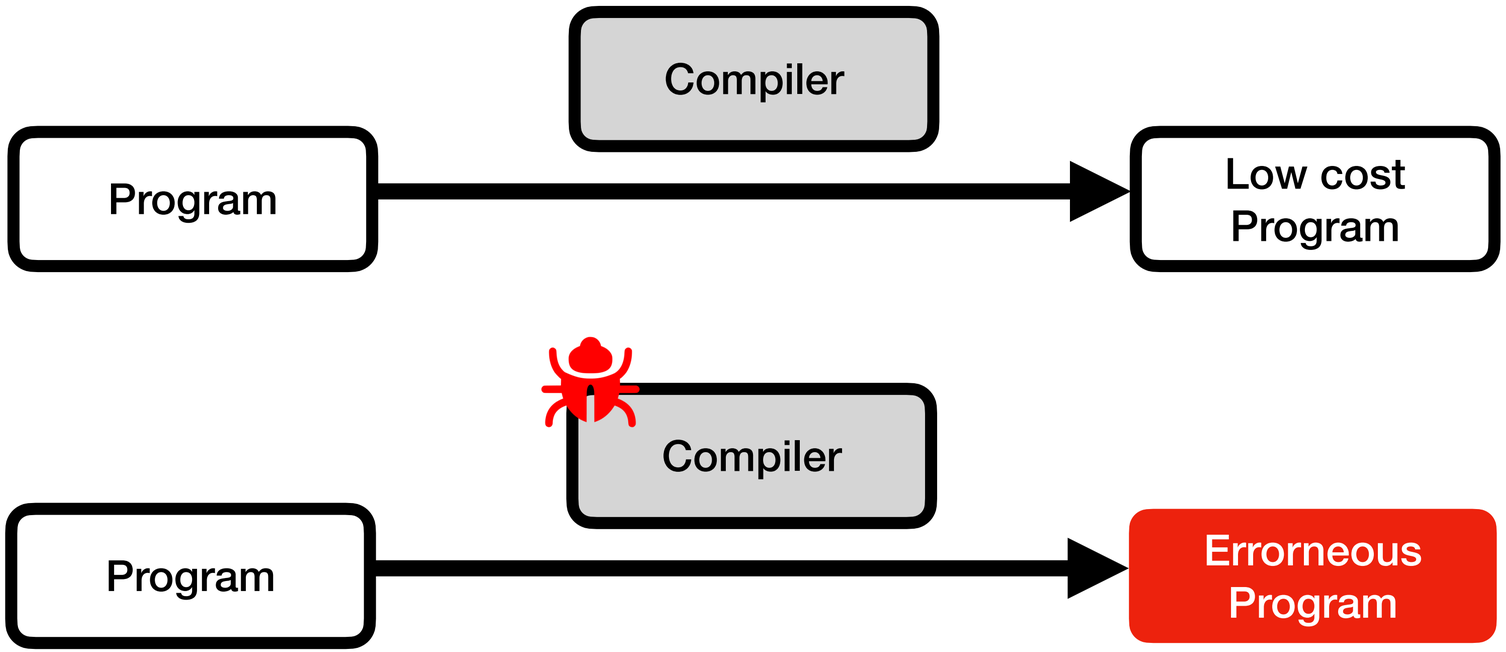
```
int foo2 (int a) {
  return a << 2;
}
```

Compiler’s Optimization Bugs



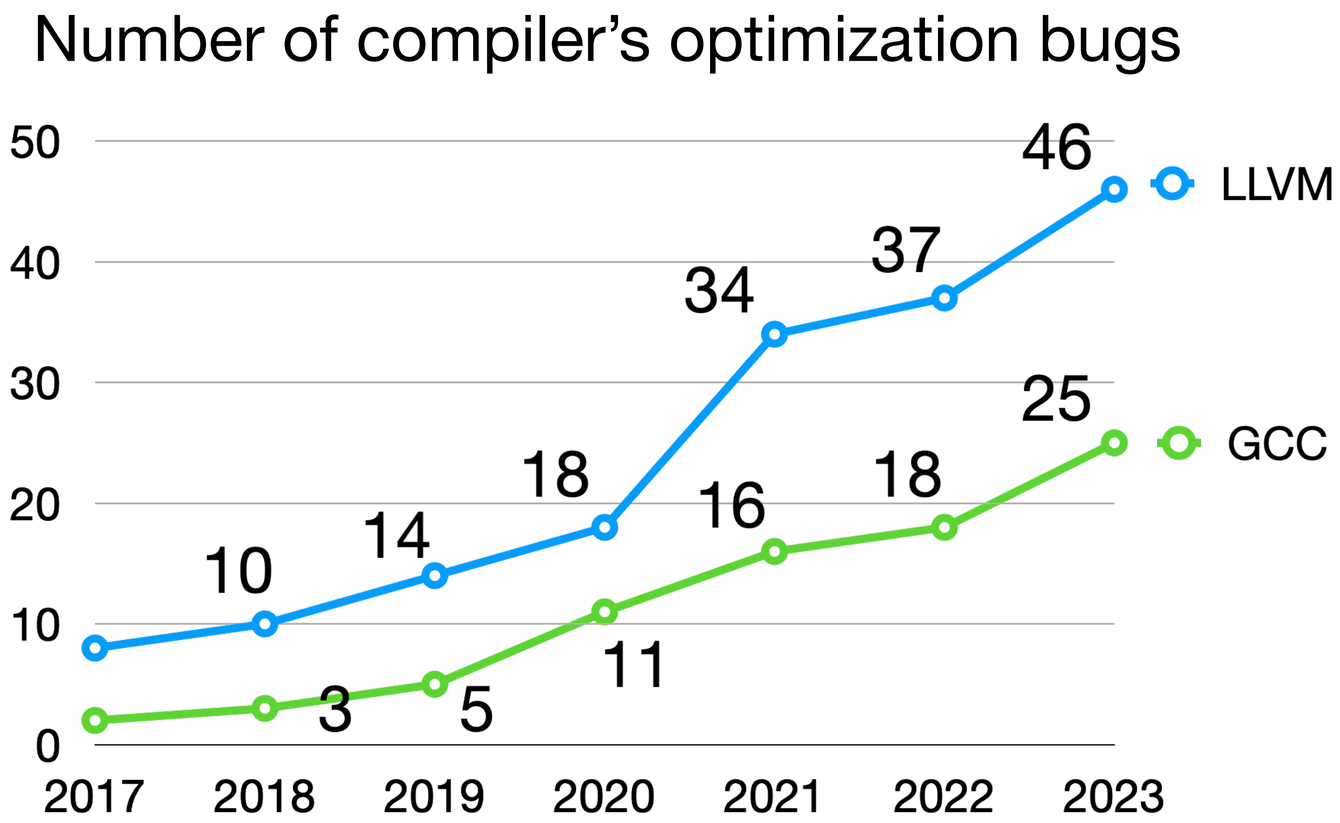
Compiler’s Optimization Bugs

- Incorrect optimization can produce erroneous programs



Compiler’s Optimization Bugs

- Compiler optimization bugs are increasing



Challenge: Compiler Optimization's Complexity

- Highly complex logic in Compiler's Optimization
  - Hard to verify optimization logic is correct
  - e.g Optimize $(X \,\&\, Y) == C \;?\; X \,|\, Y \;:\; (X \oplus Y) \,|\, C$ into $(X \oplus Y) \,|\, C : X \oplus Y$

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- large codebase
  - 175K LoC in one module of LLVM's optimization

Our Solution: Directed Fuzzing

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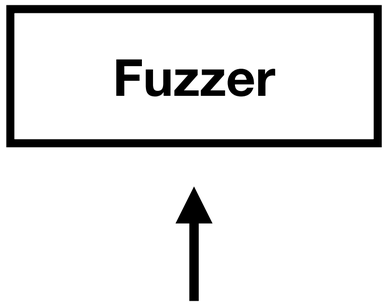
Compiler Optimization Directed Fuzzing

- Generates valid program as a compiler's input
- Appropriate guide strategy for compiler optimization

Compiler Optimization directed Fuzzer



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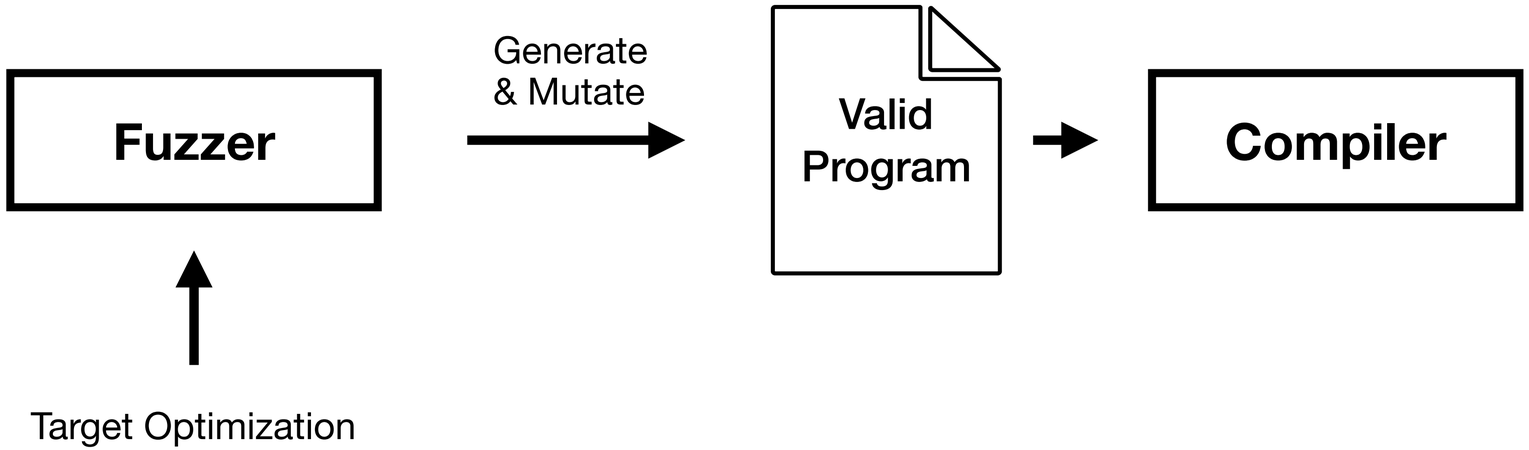

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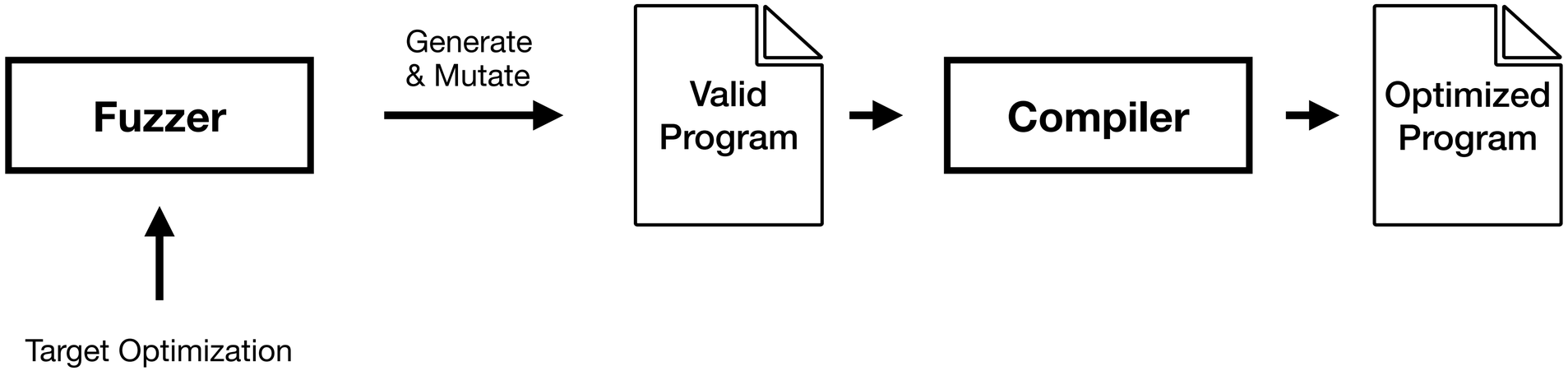

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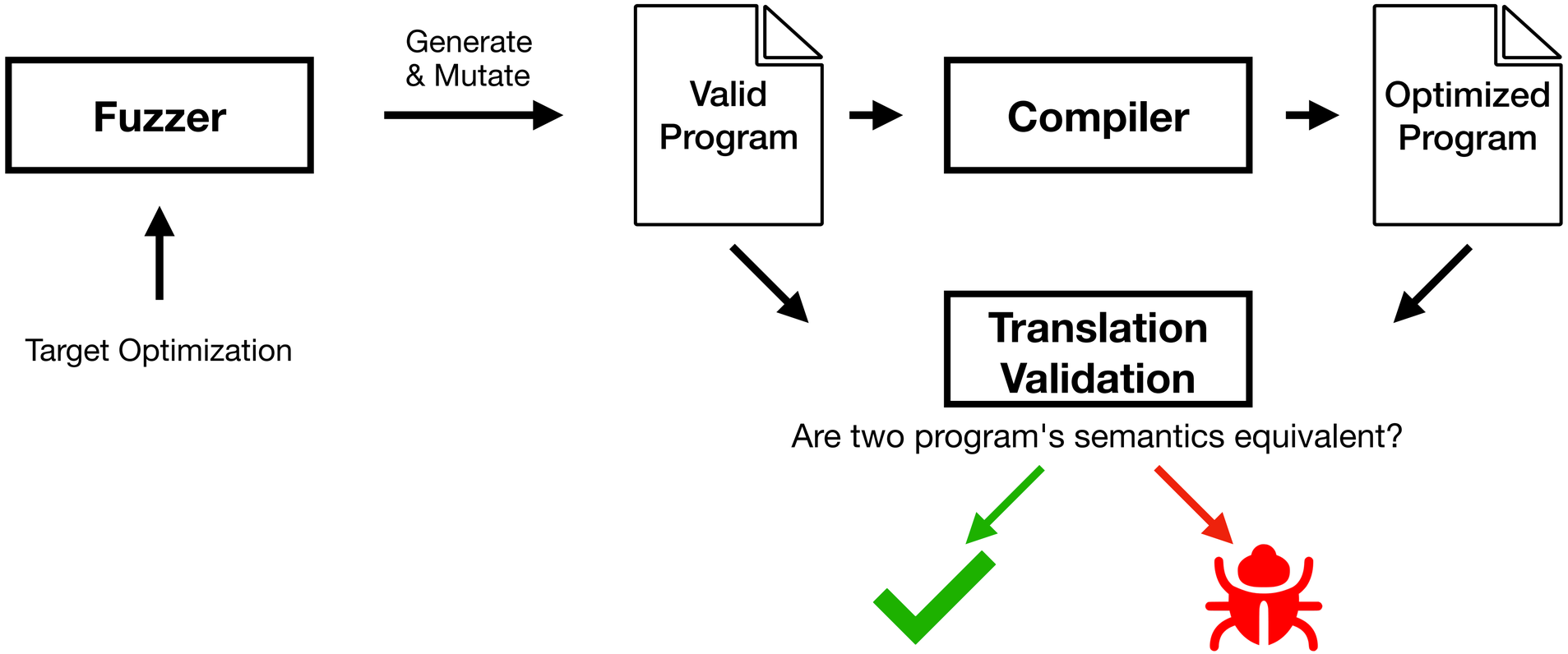

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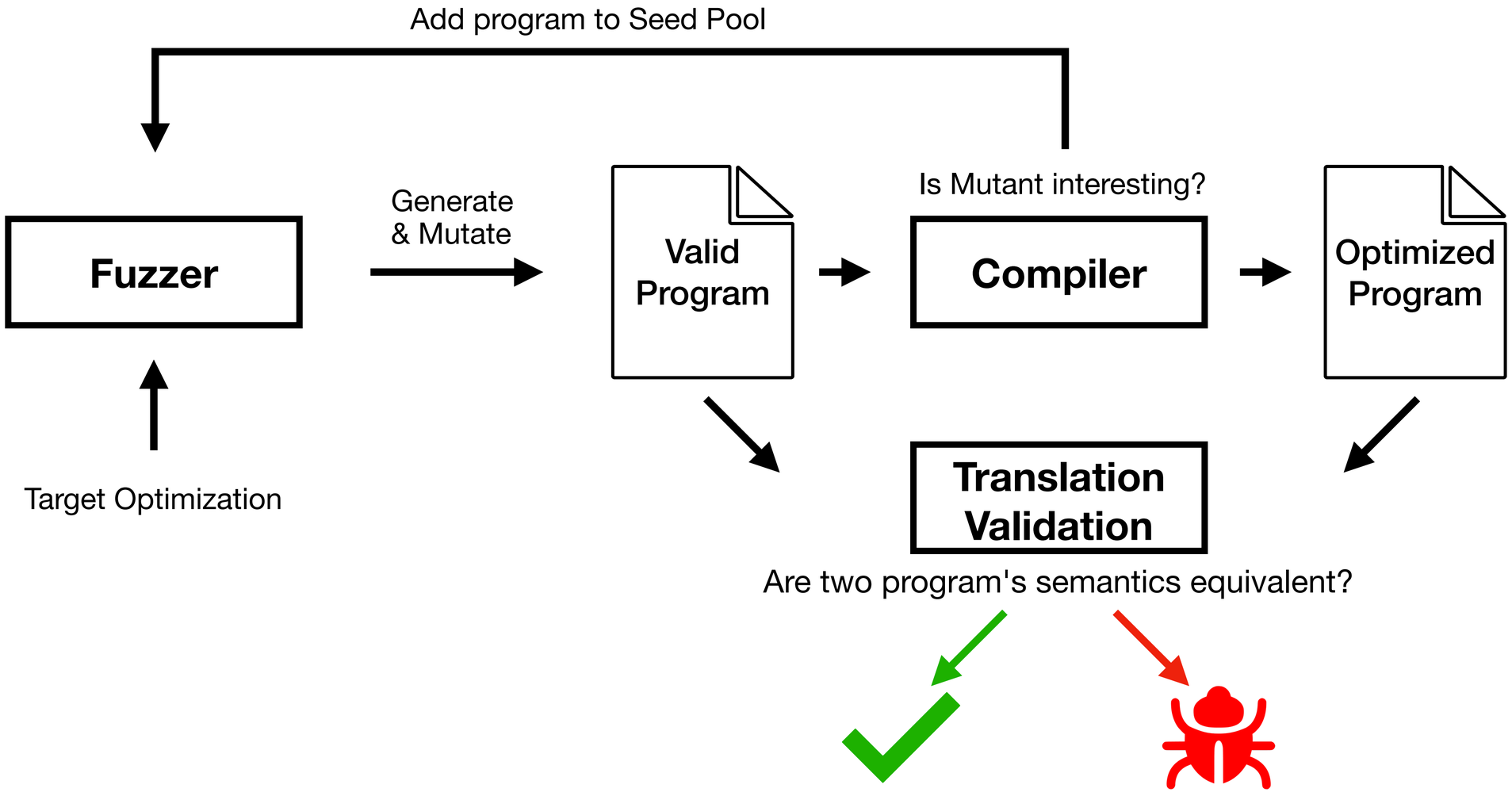

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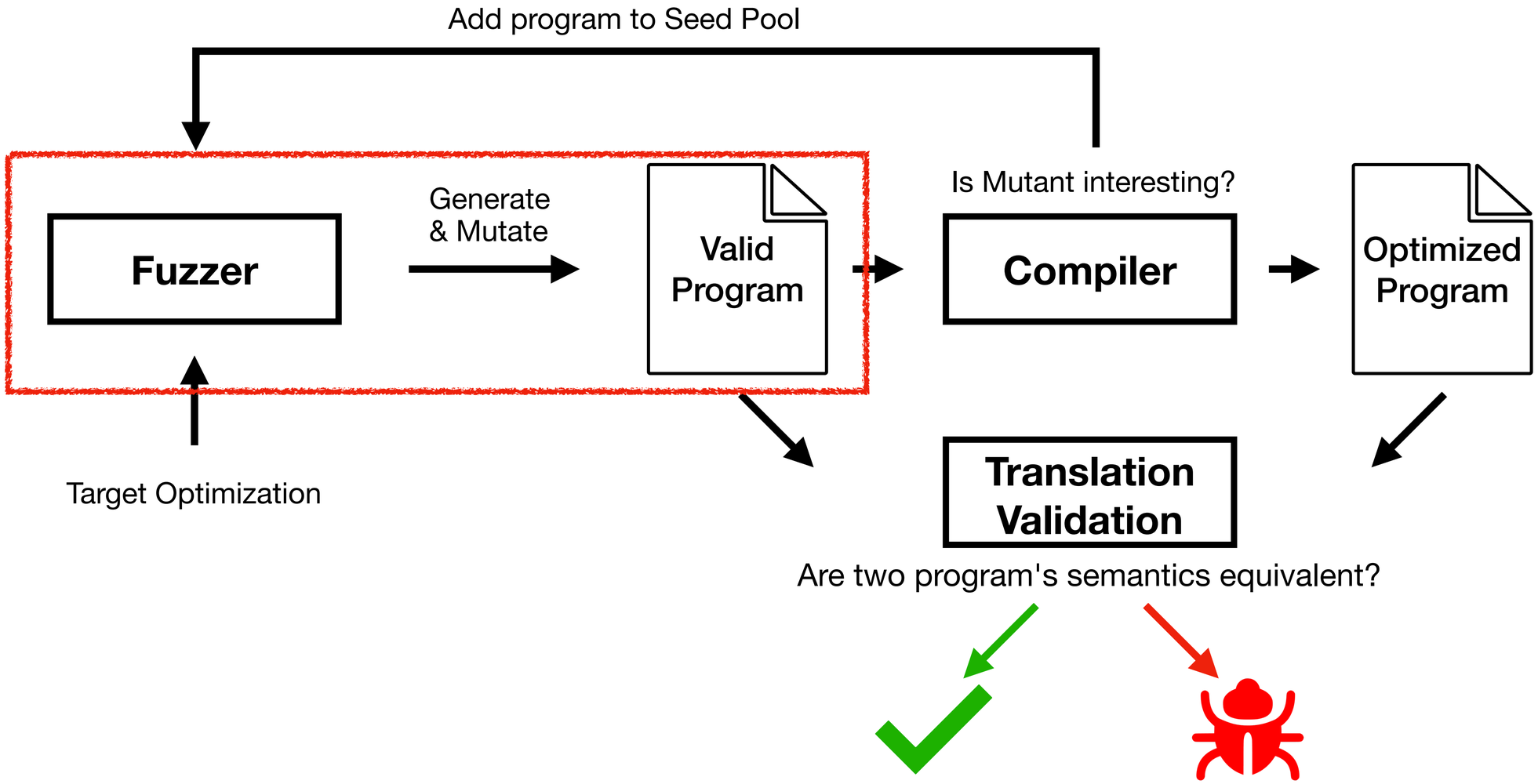

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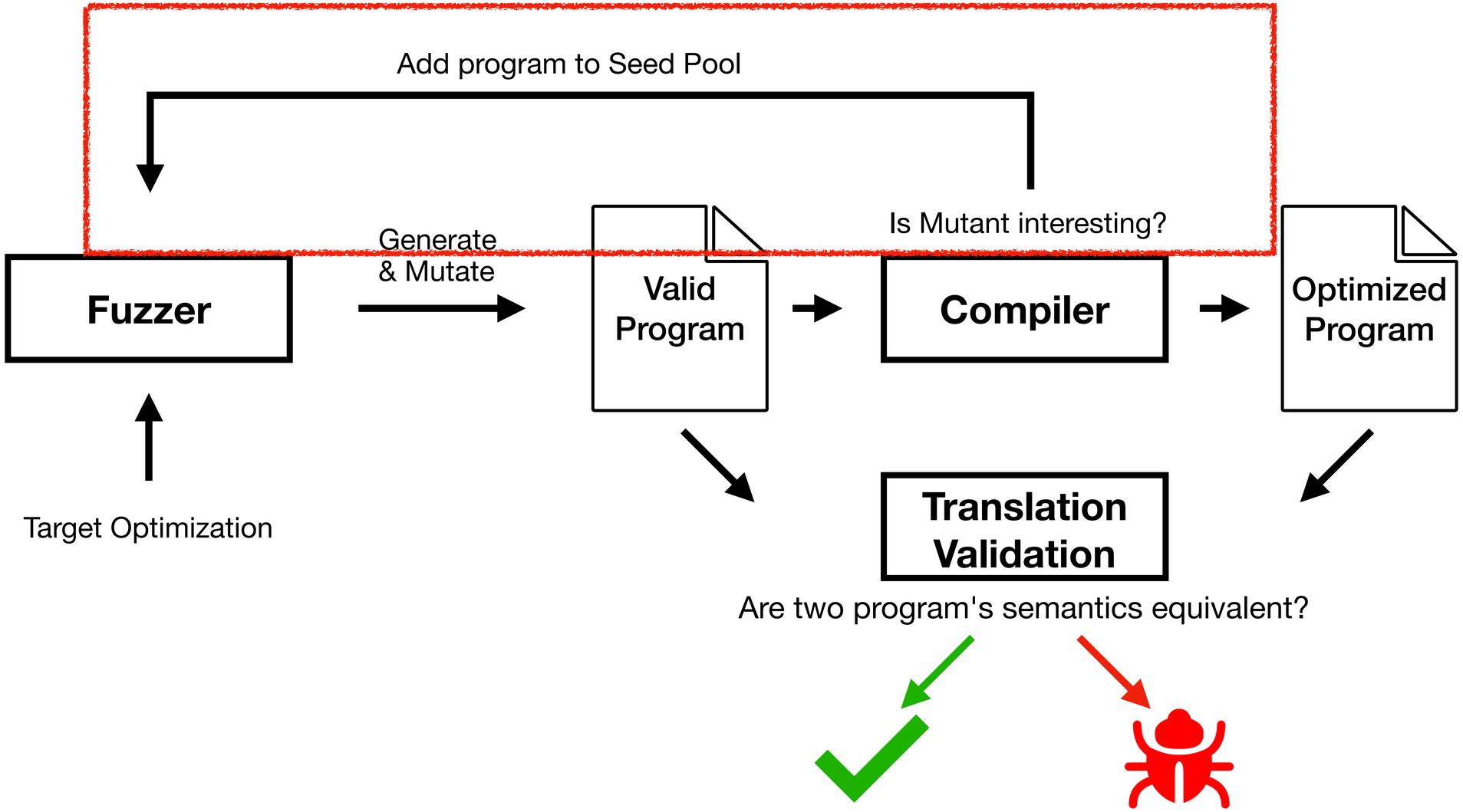

Generate Valid Program

- Mutation based input generation
  - Should make valid input (program)
  - We have several mutation strategy

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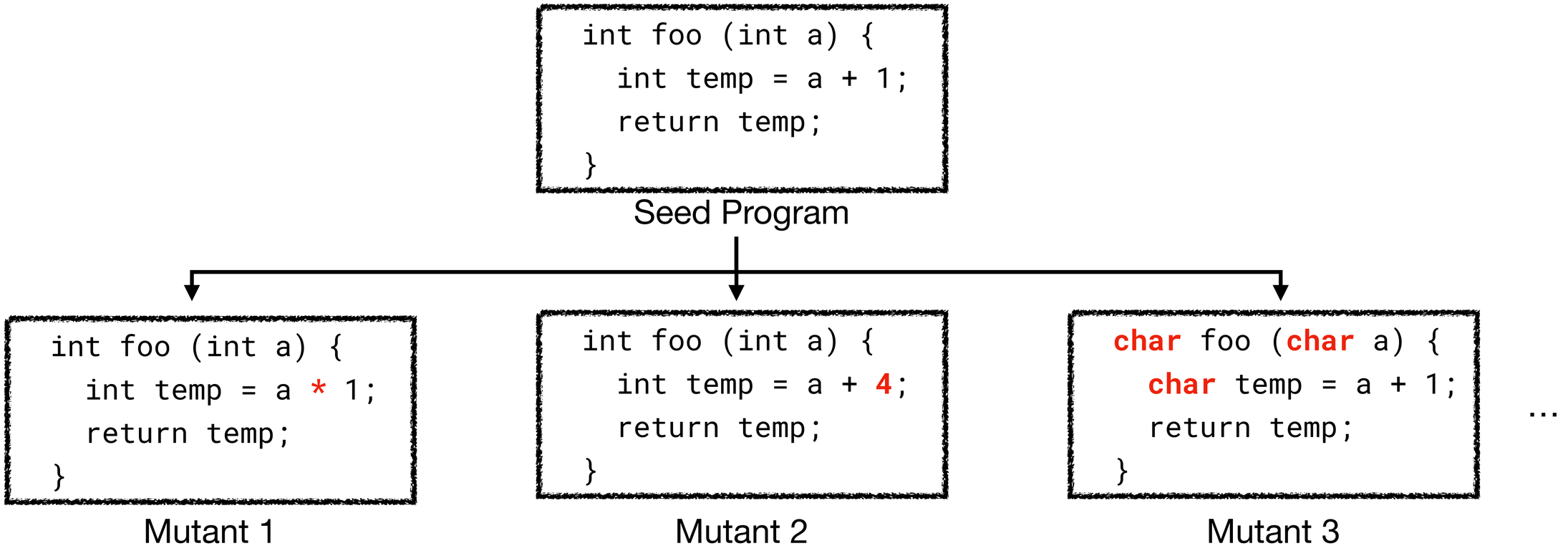
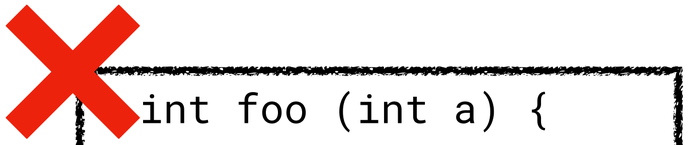


Generate Valid Pro

- Mutation not always generate valid program
  - We should handle invalid situation

```
int foo (int a) {
  int temp = a + 1;
  return temp;
}
```

Seed Program



```
int foo (int a) {
  //invalid type
  int temp = a + "1";
  return temp;
}
```

Invalid Program 1

```
int foo (int a) {
  //undefined variable
  int temp = a + b;
  return temp;
}
```

Invalid Program 2

Input Guide Strategy

- To testing target optimization, Fuzzer should generate program occurring target optimization
- The inputs generated by the fuzzer must be well-guided towards the target

Which mutant is more interesting?

How Compiler Optimization Works?

- Nested condition statement + return optimized program

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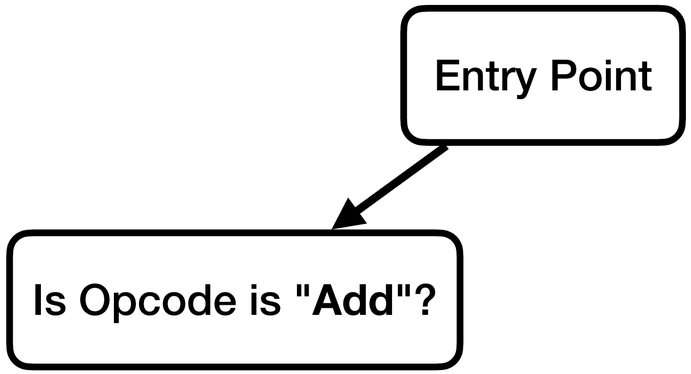
  return temp;
}
```

Input Program



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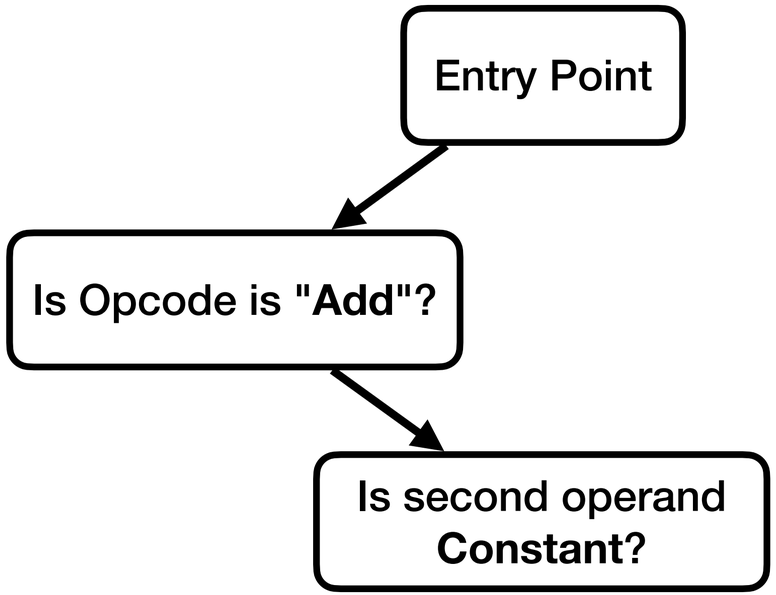

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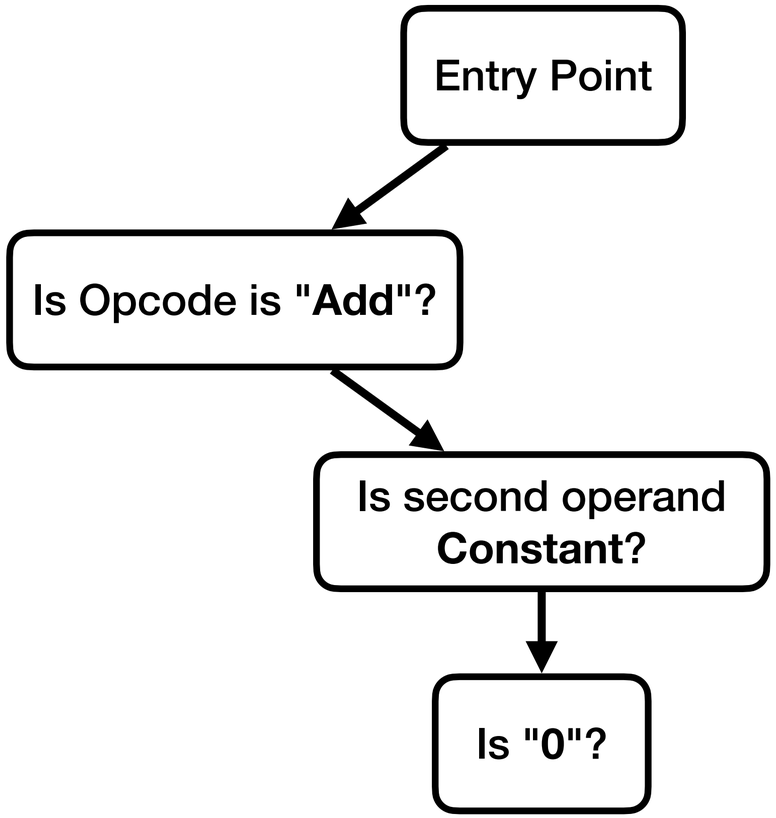

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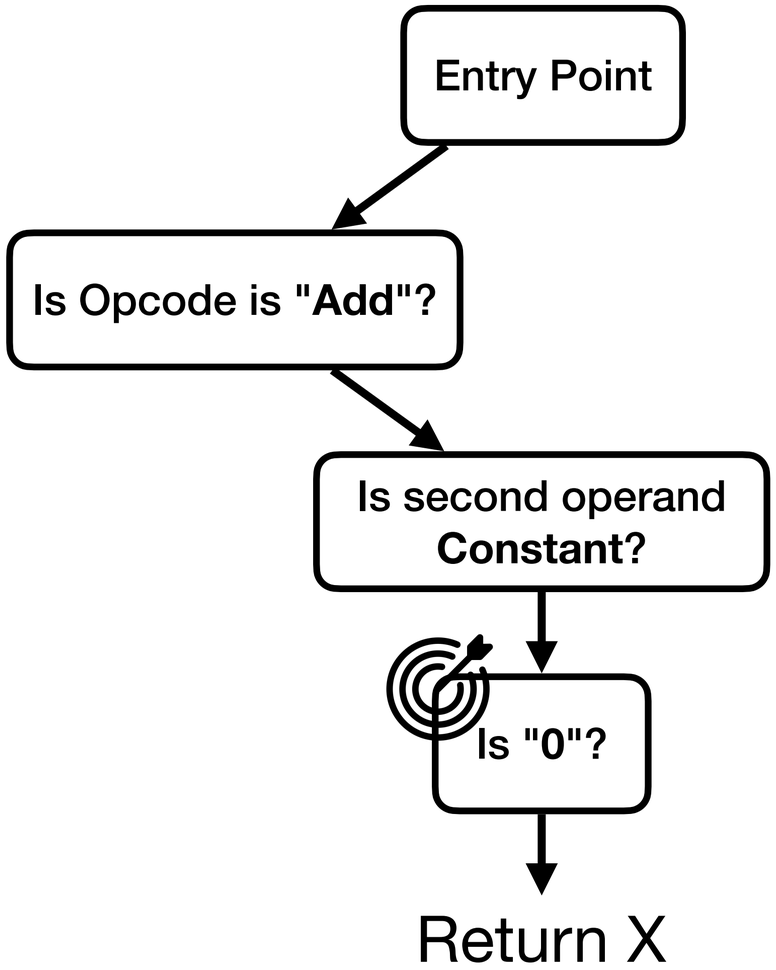

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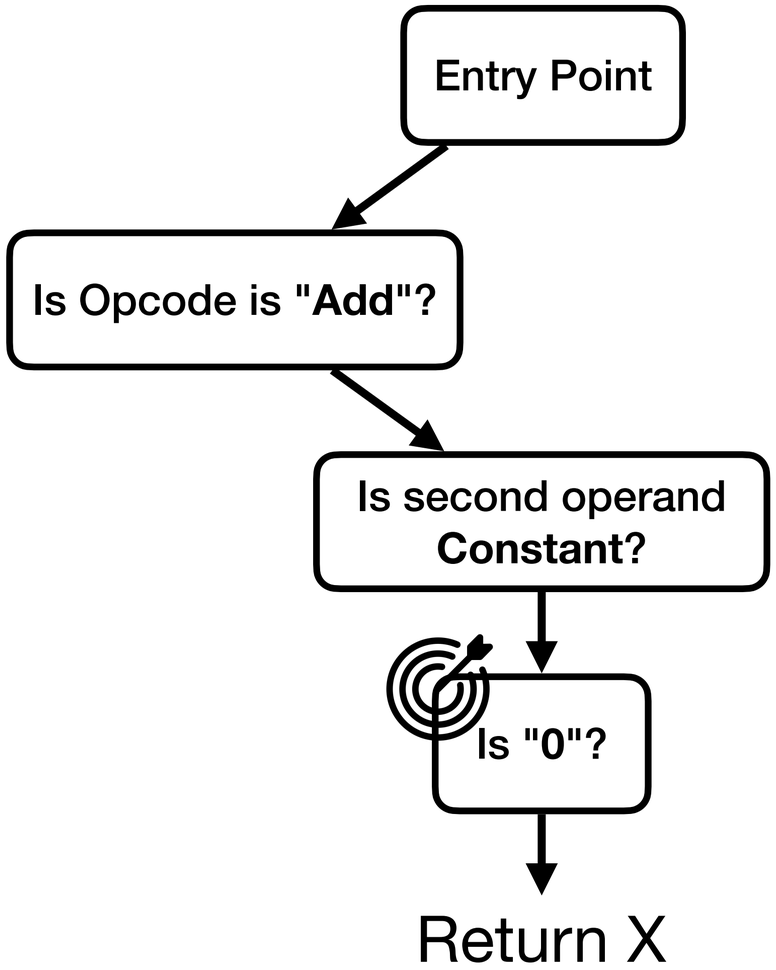
Optimized Program



Our Guide Strategy

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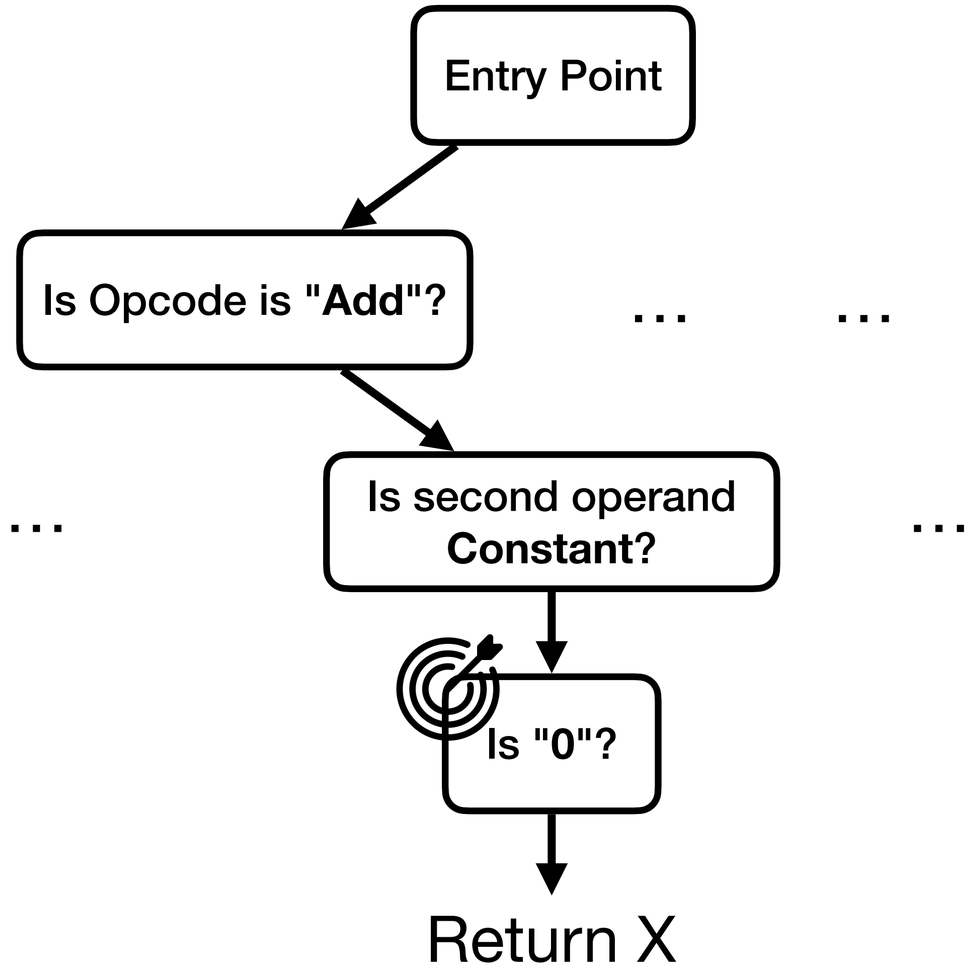
Seed Program



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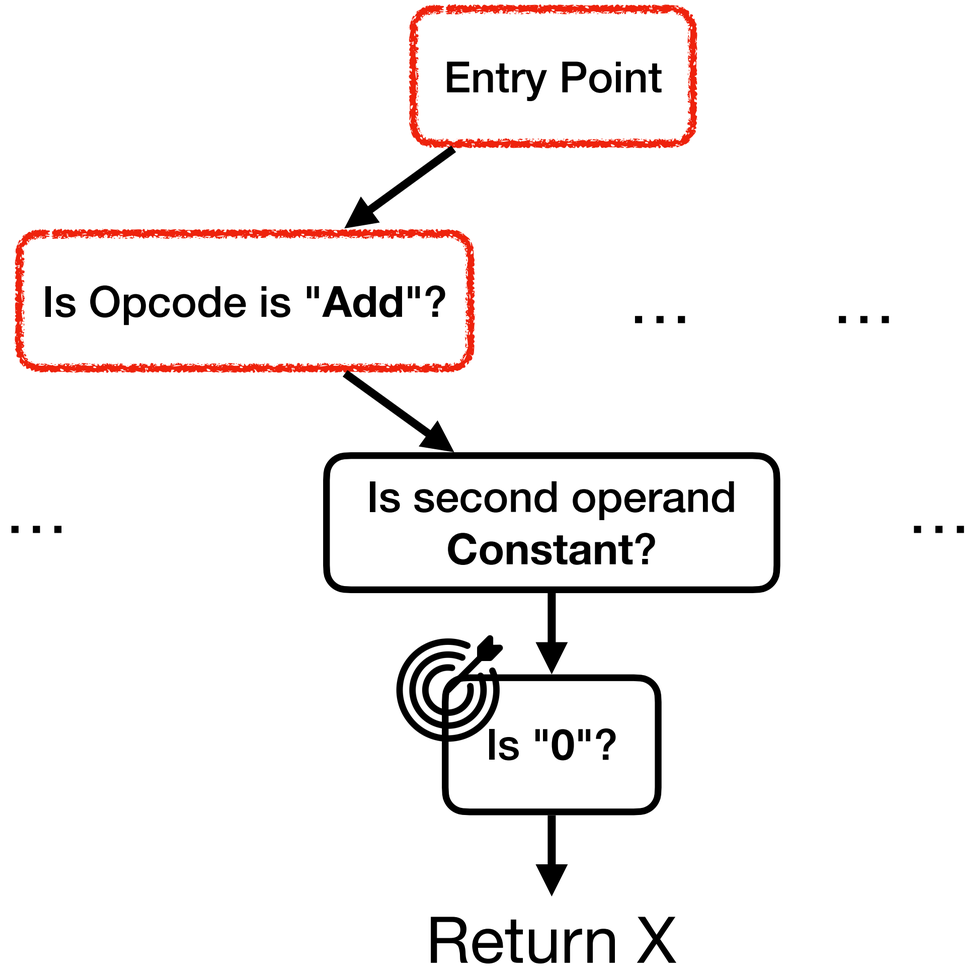

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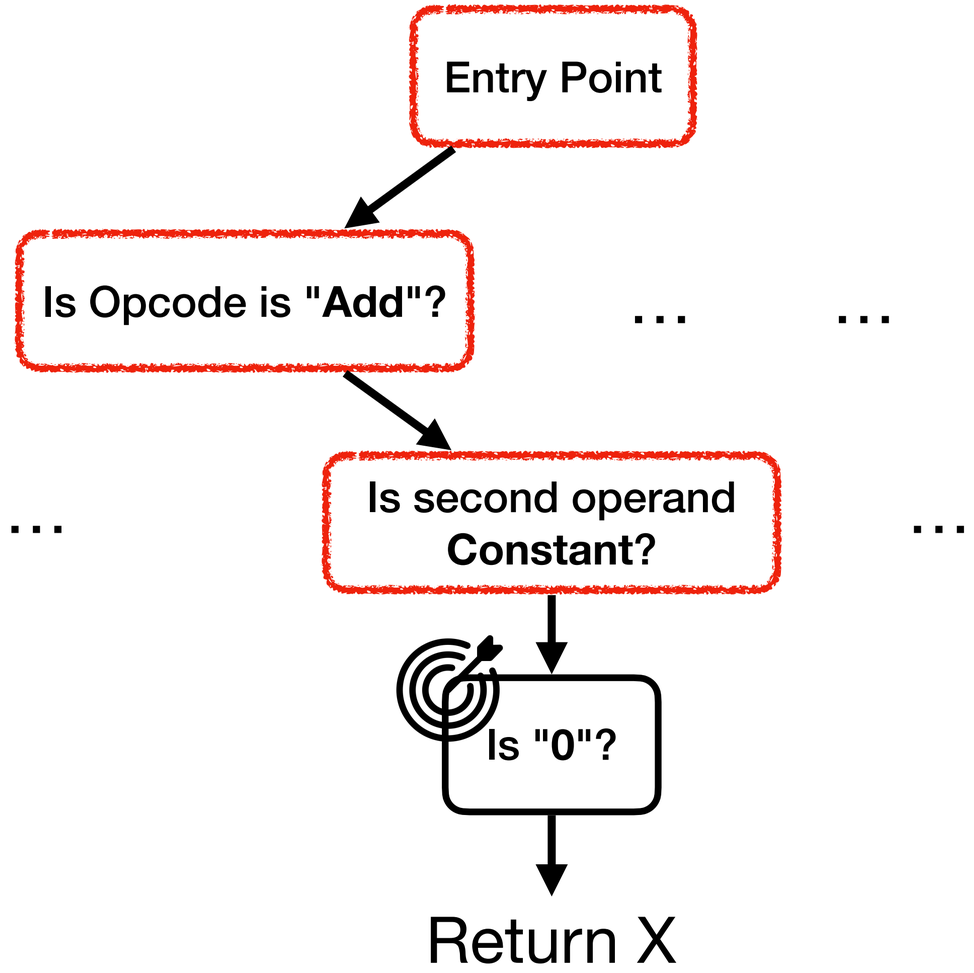

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Seed Program

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```

New Seed

```
int foo (int X, int Y) {
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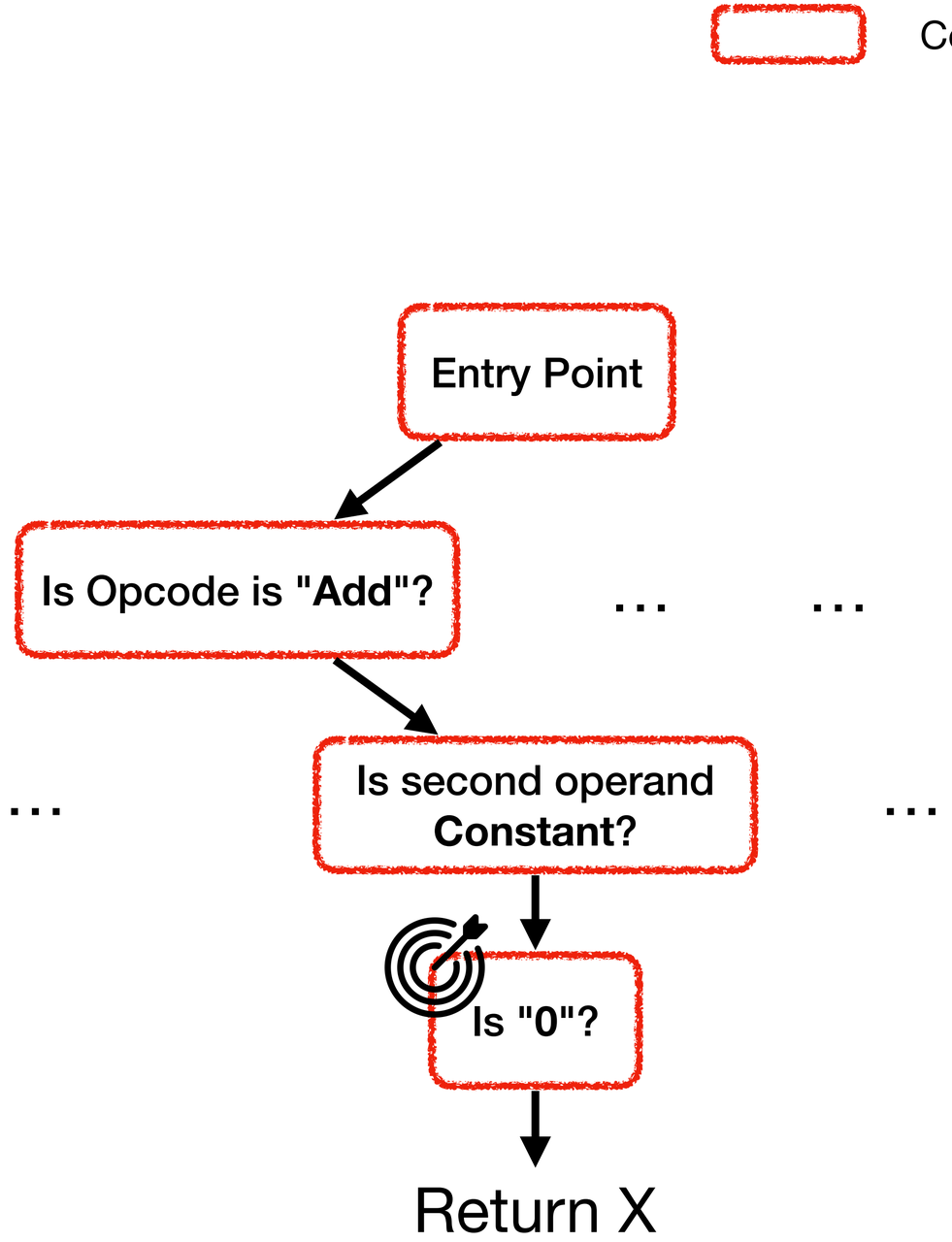

How to Improve Our Fuzzing Process?

- **Better Mutation**
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- **Effective Guide Performance**
  - Fuzzer should efficiently make IR that raise target optimization
  - Fuzzer should guide mutations towards target optimization well

Research Goal: Visualize Our Fuzzer

- **Visualize**
  - "A computer should make both calculations and **graphs**"*

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  - Graphically represent the attempt rates and success rates of each mutation

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Research Goal: Visualize Our Fuzzer

- **Visualize**
  - "A computer should make both calculations and **graphs**"*
- **Mutation Statistics**
  - Graphically represent the attempt rates and success rates of each mutation
- **Conditional Statement Tree Heat Map**
  - Measuring guide performance by displaying the coverage in a heatmap

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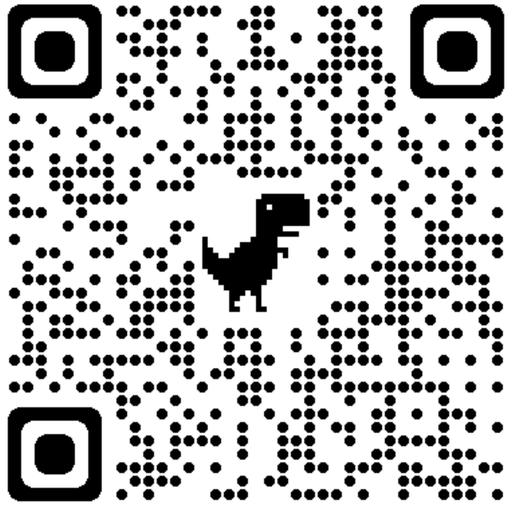
Demo



http://143.248.41.84:8000/index.html

Use School WiFi or KVPN

Mobile Available

Details

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- Code snippet of the node (conditional statement)

Impacts

Easy Understanding

Entire visualization on **one** screen

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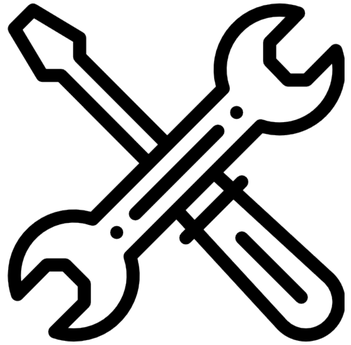
Maintenance



Found **3** bugs in our Fuzzer Implementation

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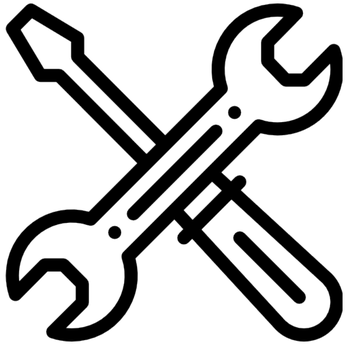

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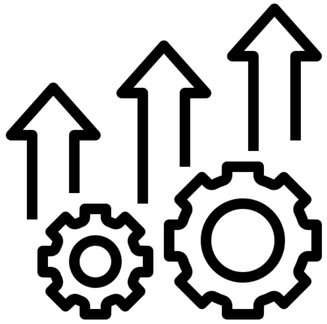
Improvement



Easy understanding of the current performance of our fuzzer

Future Works

- Display the seeds that covered the target node
- Naturally rendering the heatmap changes over time
- More useful features when improving the fuzzer