2024. 05. 30. Project Final Talk

Visualizing Fuzzing Status on Def-Use Graph and its impact

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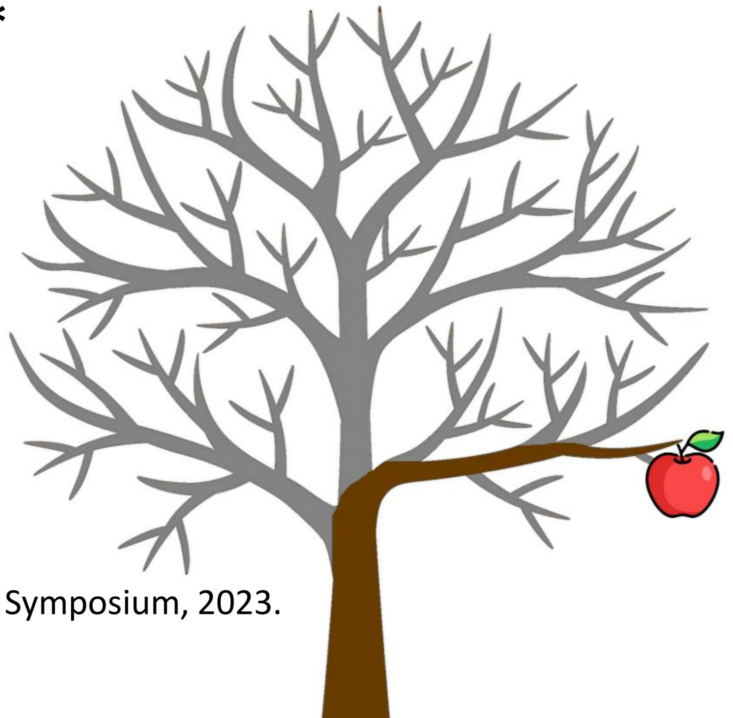
Directed Fuzzing

- **Fuzzing** Tests programs through randomly generated inputs.
  - e.g., Google's OSS Fuzz project, AFL
- **Directed fuzzing** aims to reach target location(s) of code
  - e.g., Examine recently changed code area, generate crashing input from bug report
- Reproduces bug 1.93 times faster than undirected fuzzing*
  - Undirected fuzzing: AFL, directed fuzzing: DAFL



* Tae Eun Kim et al., DAFL: Directed Grey-box Fuzzing guided by Data Dependency. USENIX Security Symposium, 2023.

Developing Fuzzing

- Performance varies based on how fuzzing guidance is given and used.

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Seed Pool
Target program

Developing Fuzzing

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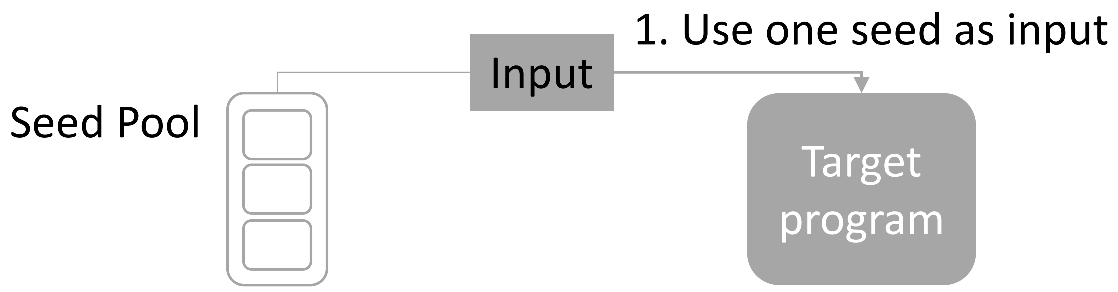

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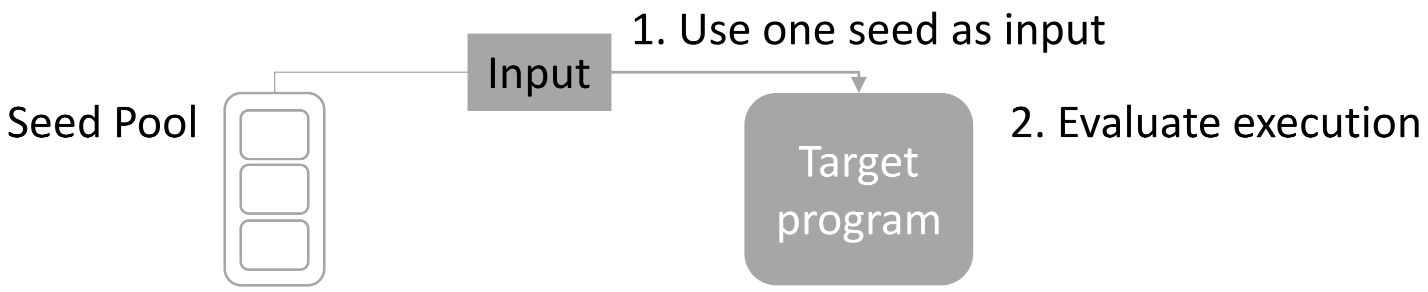

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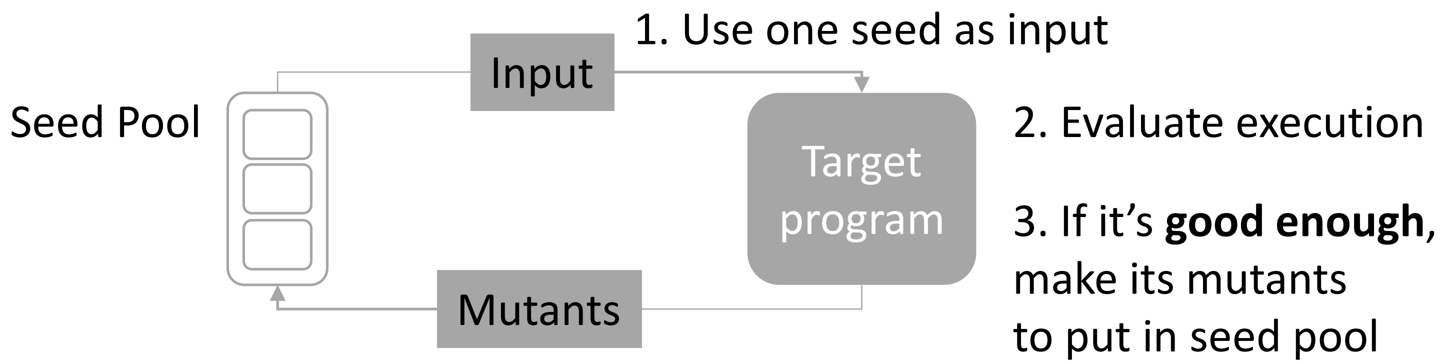

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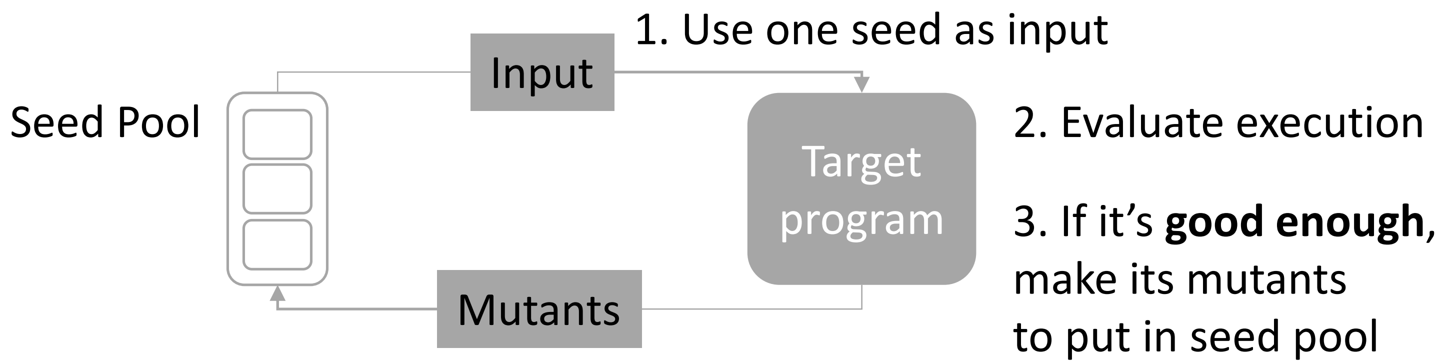

- What is the criteria for the execution to be **good enough**?

Developing Fuzzing

- For undirected **fuzzing**, increasing code coverage is considered important

```
def getSize(width, height, some_data):
if (some_data) then
   doSomething() // 1000 LoC
end if
print("Size is", width × height)
```

```
def doSomething():
if (flag == 0) then
   print(‘0’)
end if
if (flag == 1) then
   print(‘1’)
end if
…
```

Developing Fuzzing

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Developing Fuzzing

- For undirected **fuzzing**, increasing code coverage is considered important
- For **directed fuzzing**, data-flow analysis is important

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Developing Fuzzing

- For undirected **fuzzing**, increasing code coverage is considered important
- For **directed fuzzing**, data-flow analysis is important
  - Data-flow analysis is for what part of code effects data used in target line
  - In example, doSomething() does not effect data for line 5
  - Increasing code coverage of doSomething() does not affect performance

```
1:  def getSize(width, height, some_data):
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5:  print("Size is", width × height)
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width: defined at 1, used at 5

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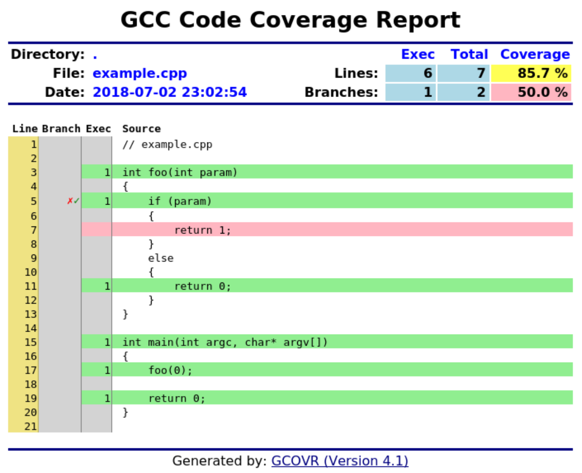
some_data: defined at 1, used at 2

Challenge 1

	Existing coverage inspectors	Need for directed fuzzing inspector
Based on	lines	basic blocks
Purpose	see where / how much are (un)covered	see how far the fuzzing reached toward target

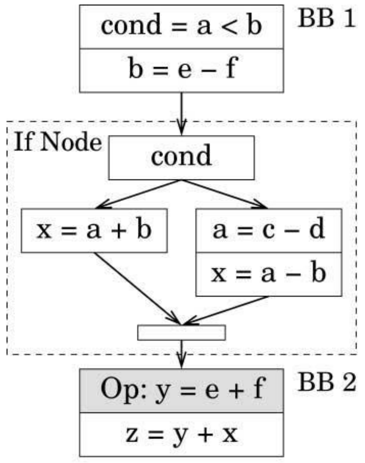


GCC Code Coverage Report

```
Directory: .                                   Exec  Total  Coverage
     File: example.cpp               Lines:       6      7    85.7 %
     Date: 2018-07-02 23:02:54    Branches:       1      2    50.0 %

Line Branch Exec  Source
   1              // example.cpp
   2
   3           1  int foo(int param)
   4              {
   5      ✗✓   1      if (param)
   6                  {
   7                      return 1;
   8                  }
   9                  else
  10                  {
  11           1          return 0;
  12                  }
  13              }
  14
  15           1  int main(int argc, char* argv[])
  16              {
  17           1      foo(0);
  18
  19           1      return 0;
  20              }
  21
```

Generated by: GCOVR (Version 4.1)



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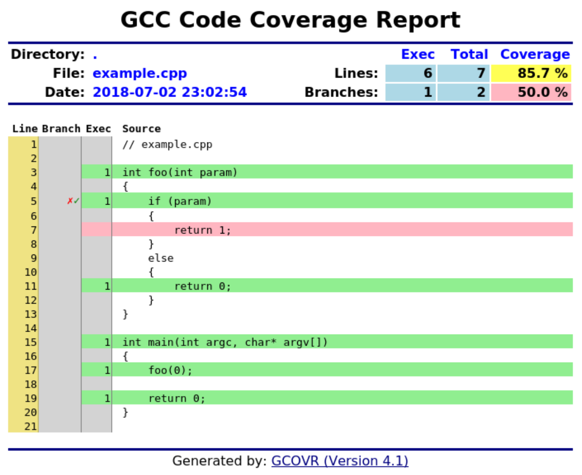

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no basic block coverage visualizer

Challenge 2

- Key aspect of directed fuzzing is **data-flow coverage**

```
1:  def getSize(width, height, some_data):
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code

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data-flow

Challenge 2

- Key aspect of directed fuzzing is **data-flow coverage**
- Visible into **def-use graph**

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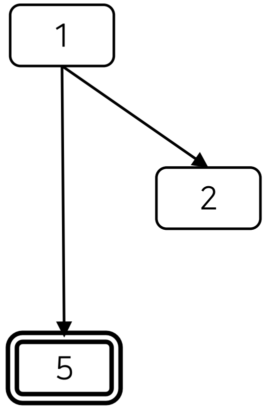

def-use graph

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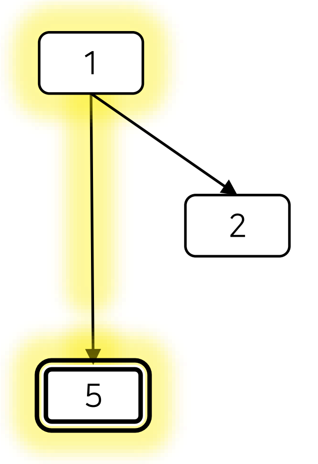

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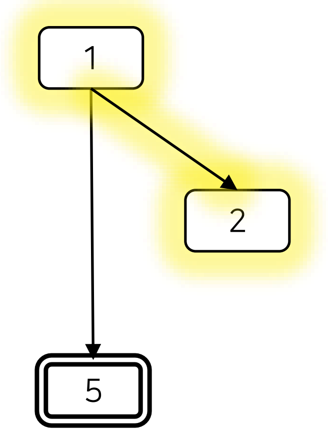

def-use graph

Challenge 2

- Key aspect of directed fuzzing is **data-flow coverage**
- Visible into **def-use graph**
- Manually traversing def-use graph alongside heat-map boosts understanding
- Not yet in the world

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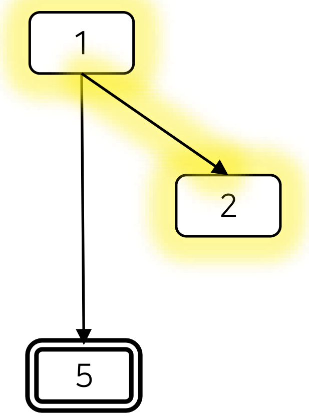


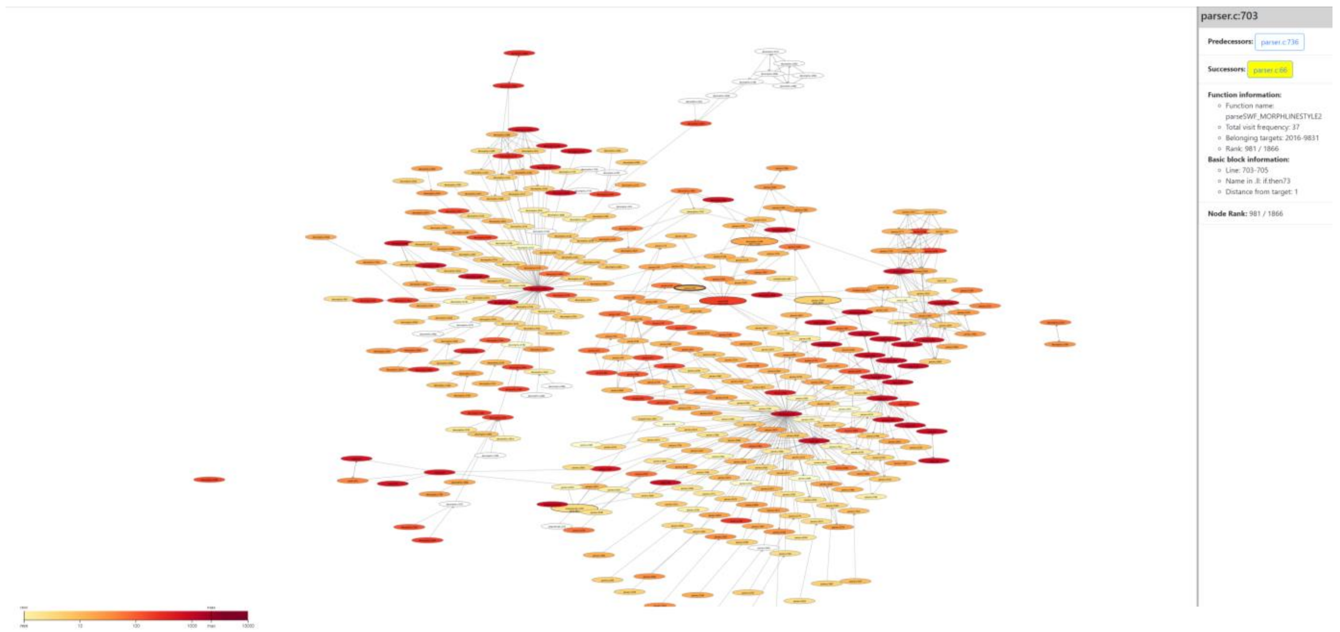
def-use graph

Our Solution

- TopViz: Def-use graph visualizer for directed fuzzing
- Tackle Challenge 1 (No basic block coverage visualizer) by a **basic-block heatmap**
- Tackle Challenge 2 (No effective def-use graph visualizer) by an **ample-info visualizer**
- Integrate that into a def-use graph visualizer with heatmap information

Features

- **basic-block heatmap**
- **ample-info visualizer**
  - Express targets
  - Express road to target in yellow
- **good for fuzzing developer (me)**
  - Track .c code
  - Grasp block’s purpose by name



parser.c:703

Predecessors: parser.c:736

Successors: parser.c:66

Function information:
- Function name: parseSWF_MORPHLINESTYLE2
- Total visit frequency: 37
- Belonging targets: 2016-9831
- Rank: 981 / 1866

Basic block information:
- Line: 703-705
- Name in .ll: if.then73
- Distance from target: 1

Node Rank: 981 / 1866

http://elvis08.kaist.ac.kr/gun/dug/swftophp-4.7-topuzz/Topuzz/full-time/0/

Visualizer Architecture and methods

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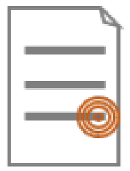

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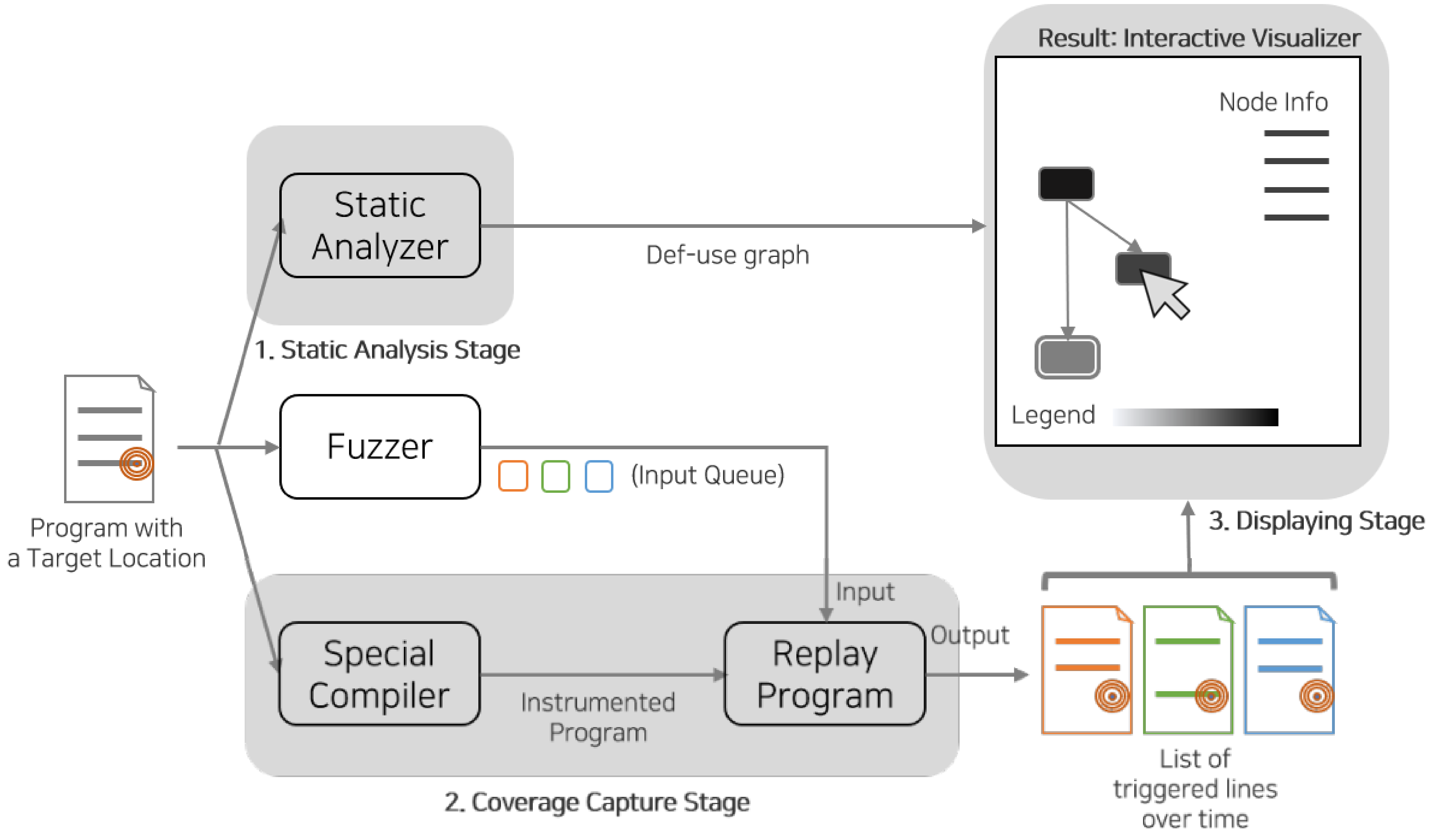

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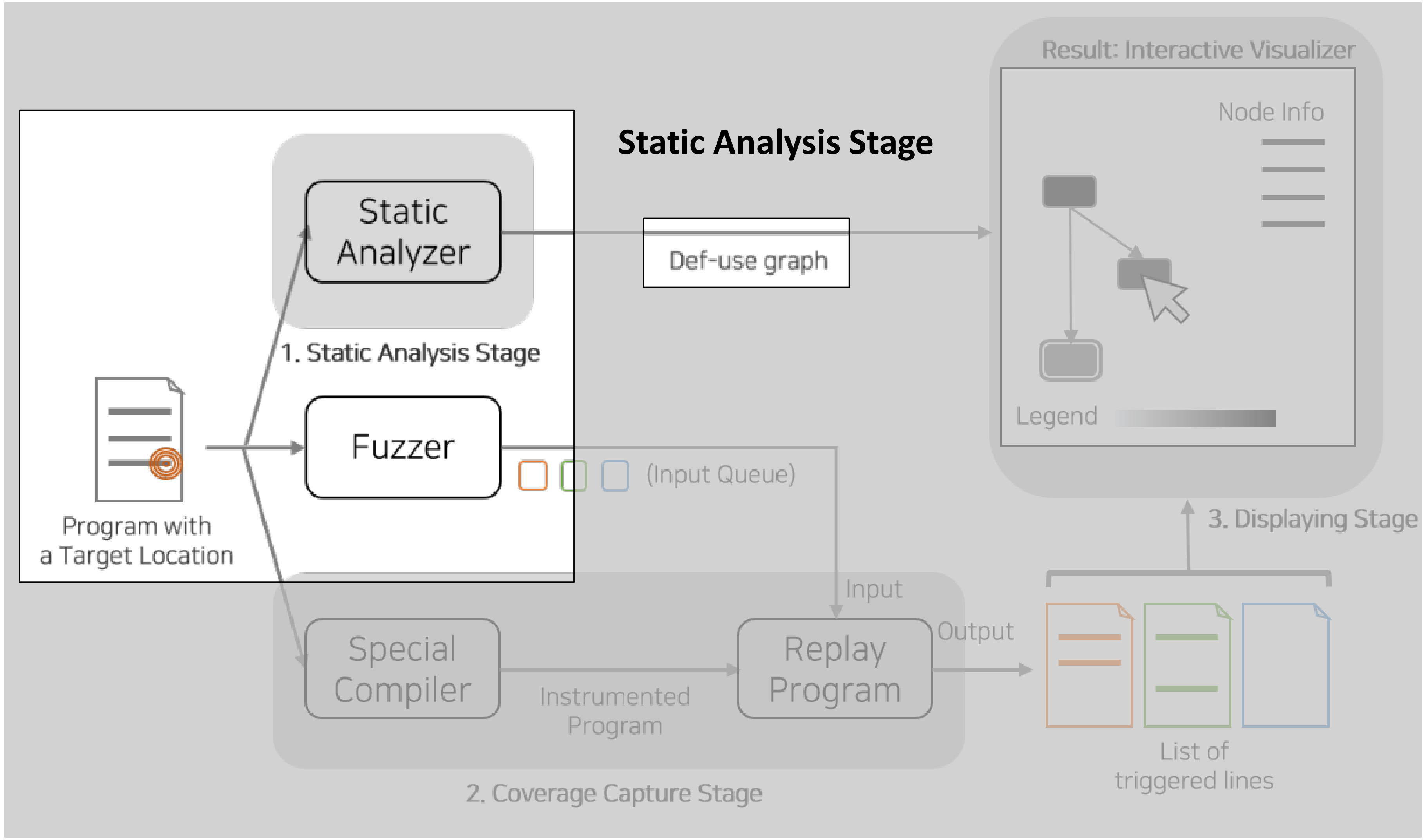

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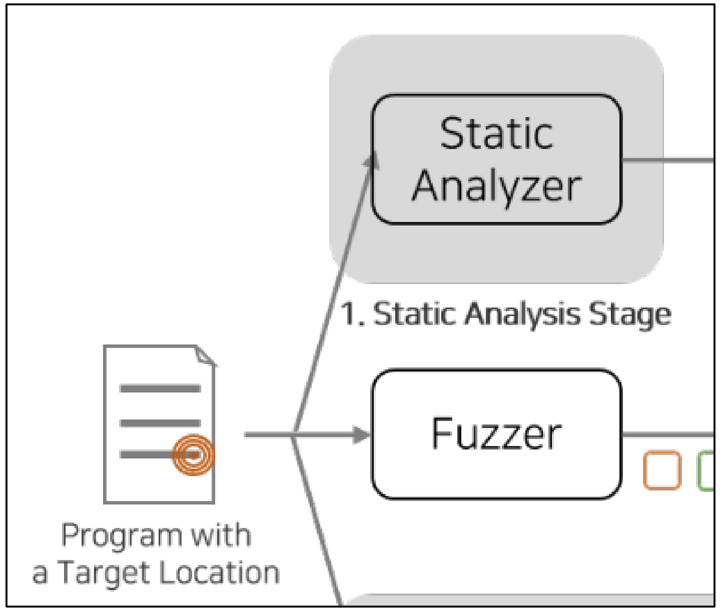
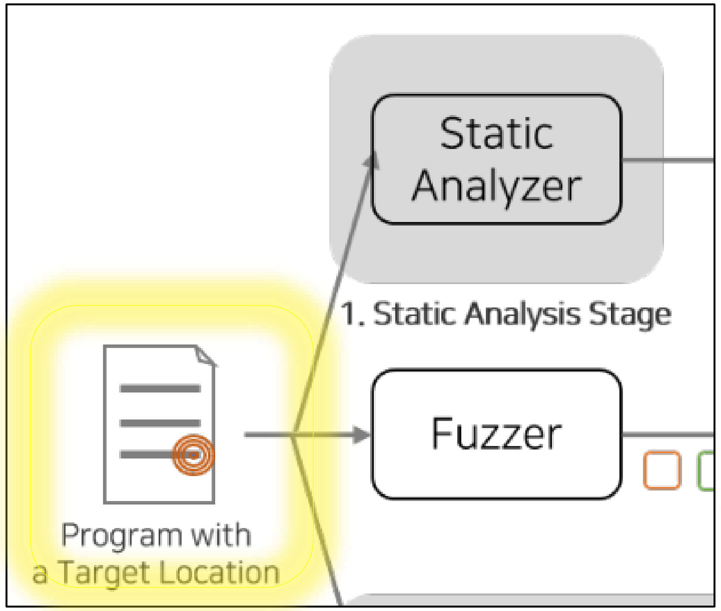


Static Analysis Stage

Visualizer Architecture and methods



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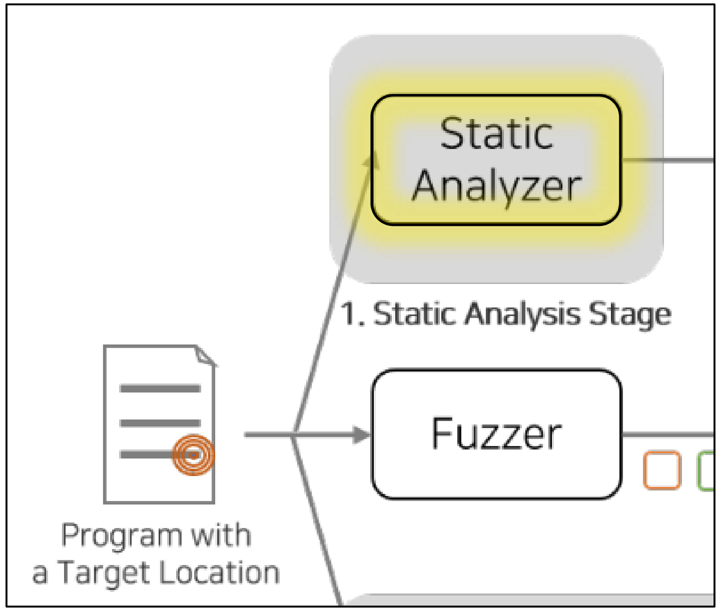

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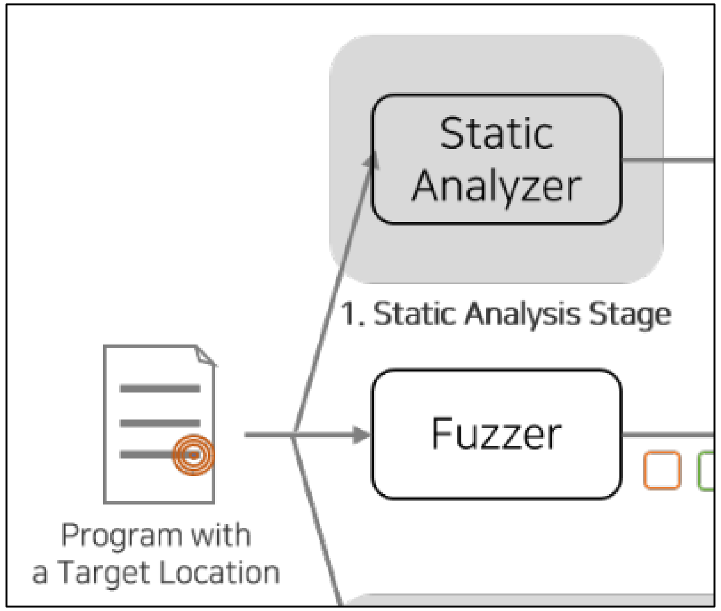

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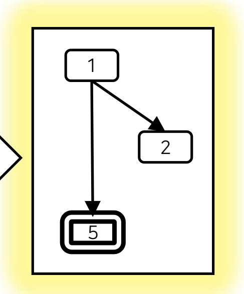

Visualizer Architecture and methods

- **How?**

Program

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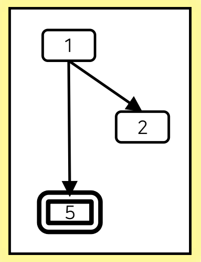
Basic-block-based graph



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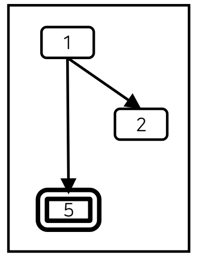

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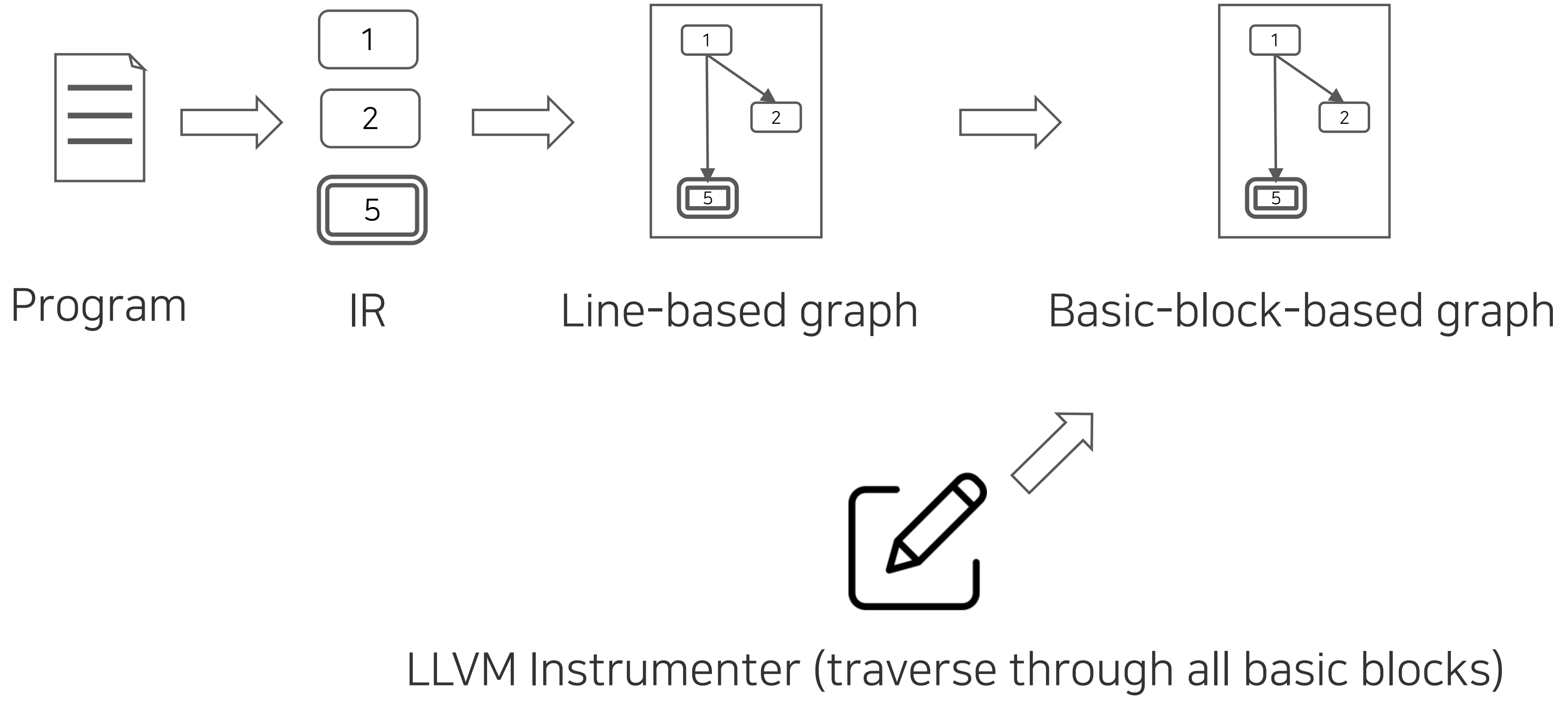

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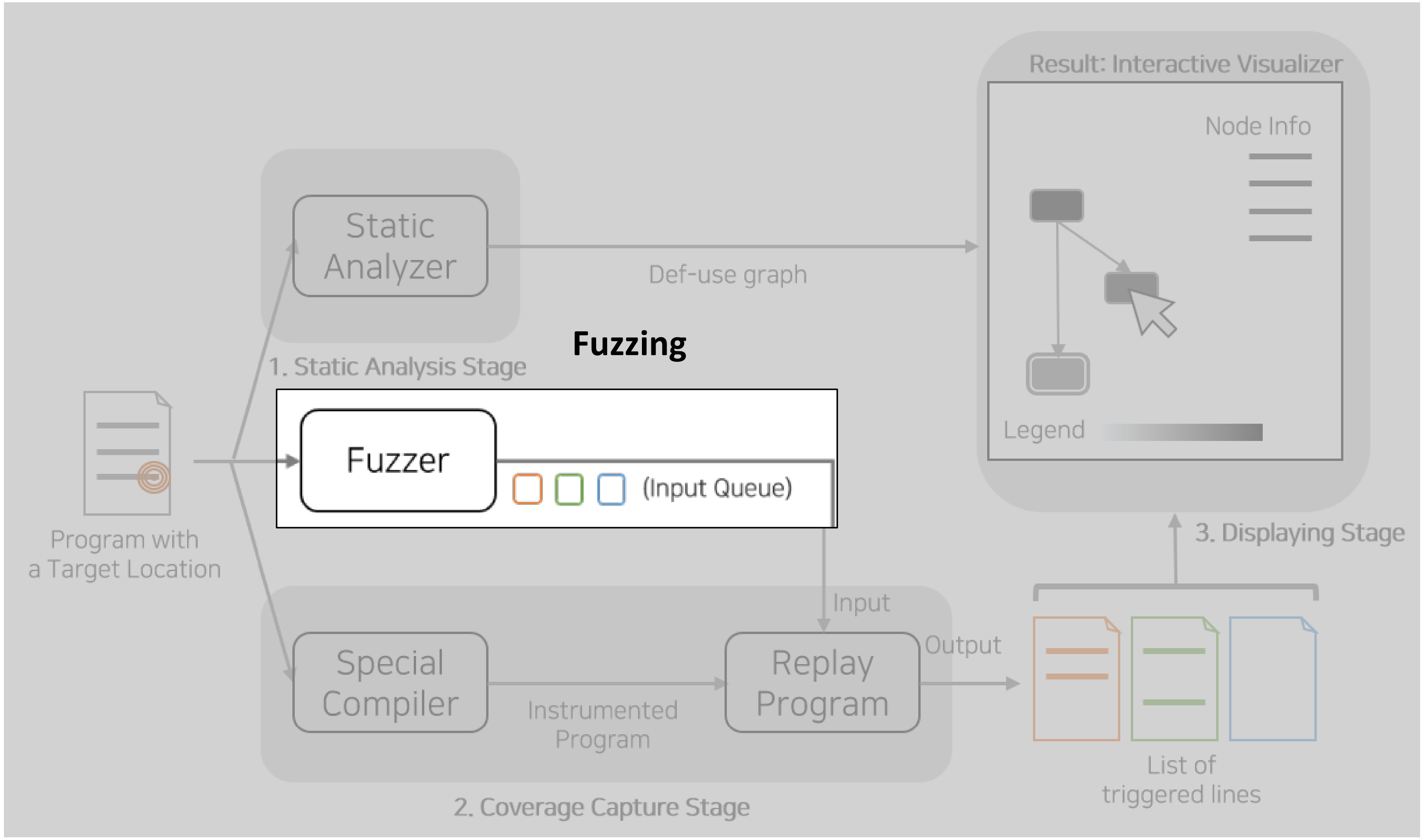

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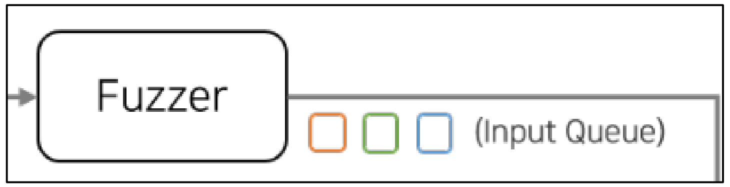
Fuzzing



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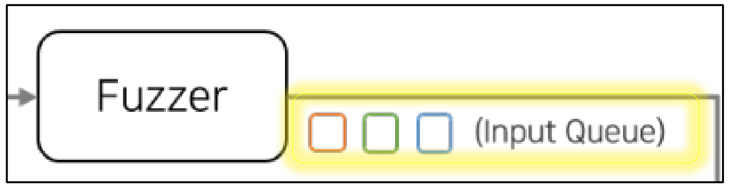

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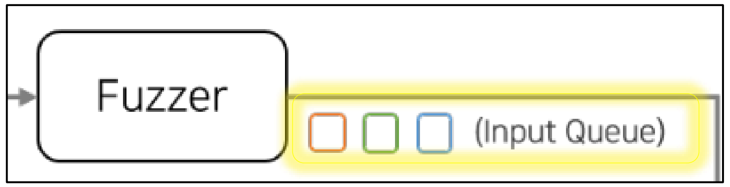

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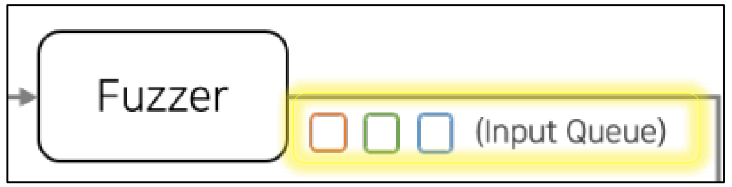


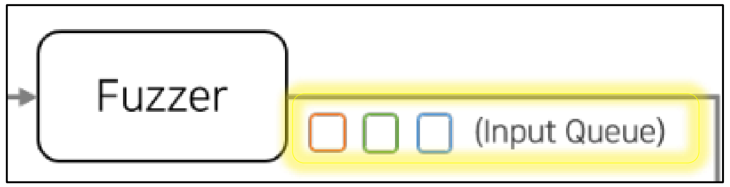
compatible with any fuzzing tools

easily usable standalone module

Visualizer Architecture and methods

- **Why?**
- We snatch the input queue to reproduce coverage in a separate binary

Fuzzing



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Visualizer Architecture and methods

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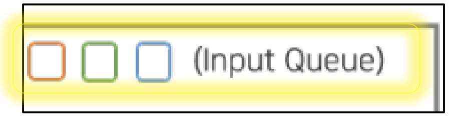
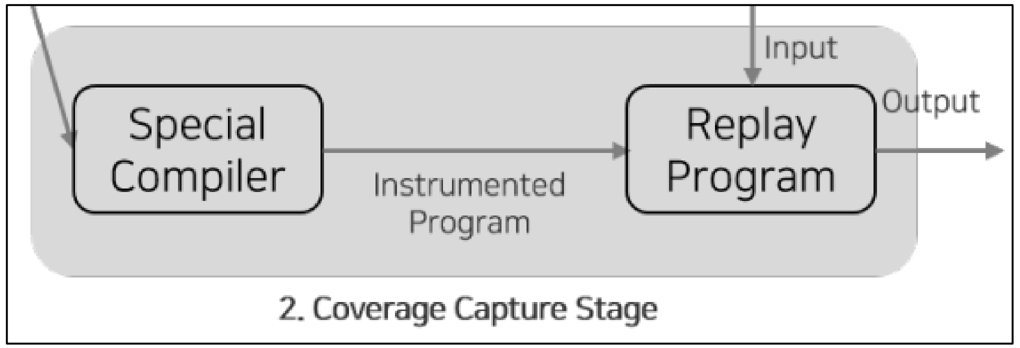
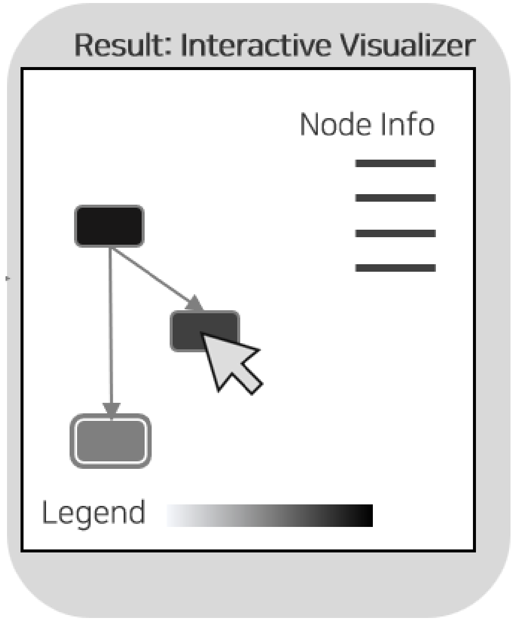
2. Coverage Capture Stage





Visualizer Architecture and methods

- **3. Visualizing**
- Our interest
  - How far was the node from any target?
  - Did lagging target node get less visit?
  - How did the fuzzing setting change basic block coverage?
- Visualization results
  - Gives distance and routes to target
  - Easily understandable



Result

- TopViz **helps developing** directed fuzzing by..
  - tracking data-flow to target location.
  - **clear**, interactive frequency chart and parent/child buttons.
- TopViz is **first** to aid directed fuzzing research.
- TopViz is compatible with..
  - **any** fuzzing tools.
  - **any** target programs with open source code.

Future works

- **Time bar to see hourly status**
- Visualize time axis to help establish dynamic heuristic

- **Chart to compare basic blocks hit-rate per fuzzing setting**
- Easy to know the contribution of new-setted fuzzing

Conclusion

- This research builds a brand-new visualization tool, **TopViz**.
- TopViz **helps developing** directed fuzzing by..
  - tracking data-flow to target location.
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