GeneVis:

A Genealogical Visualization Tool for Directed Grey-box Fuzzing

Tae Eun Kim

KAIST

Background

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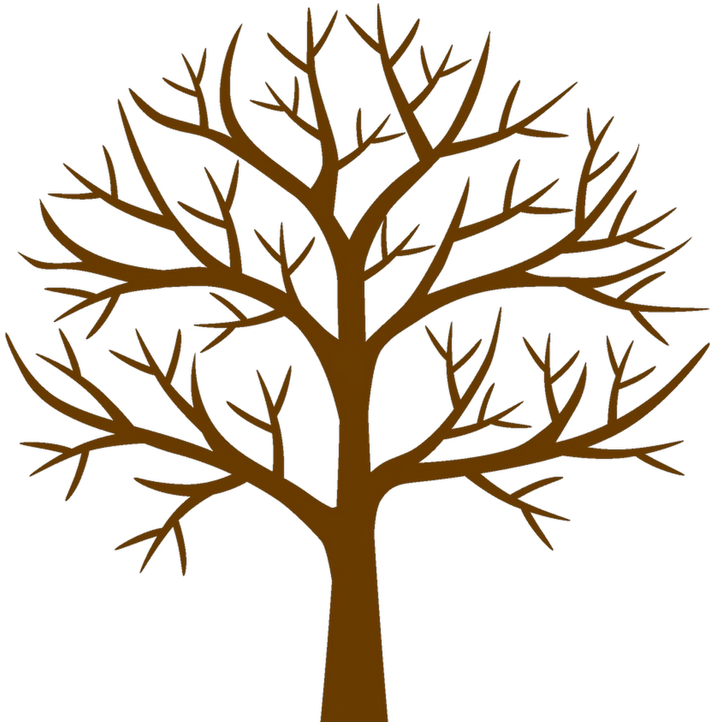

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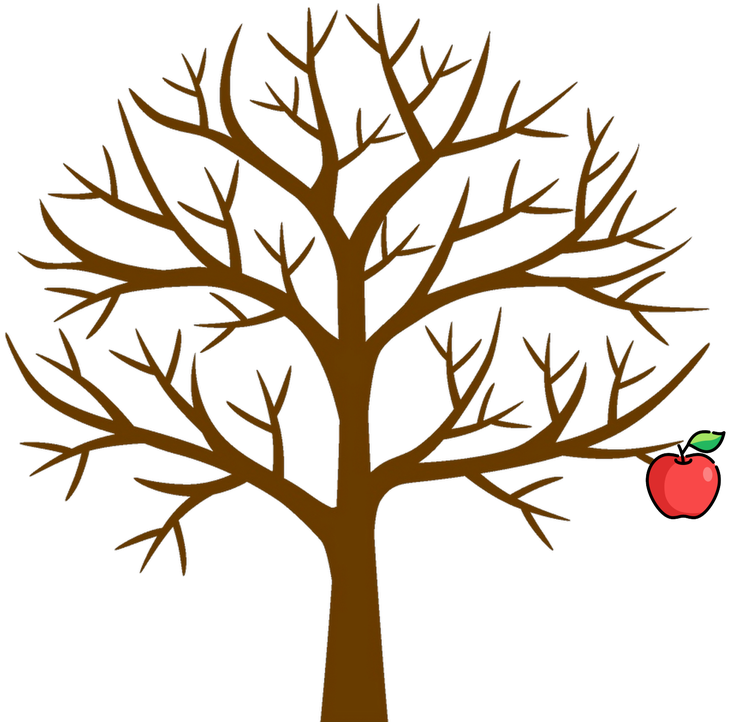

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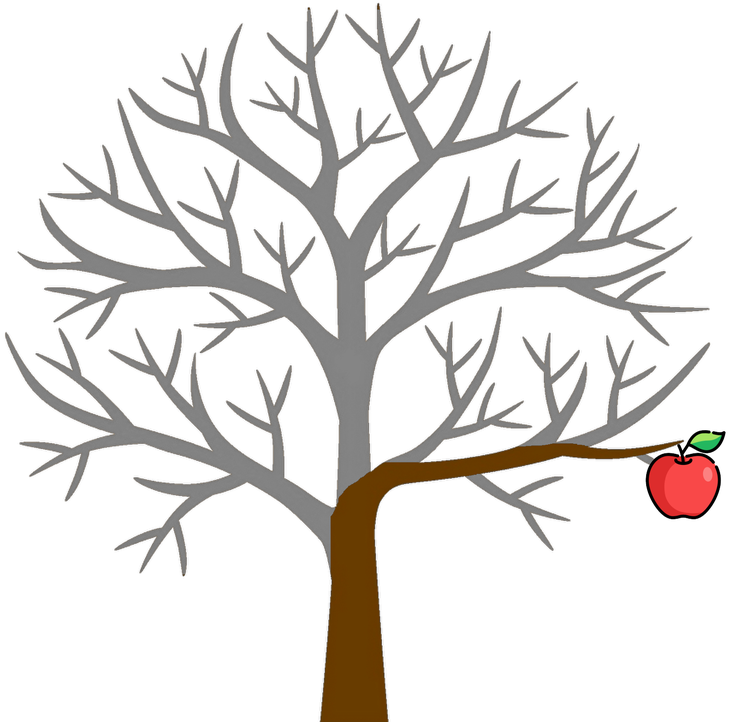

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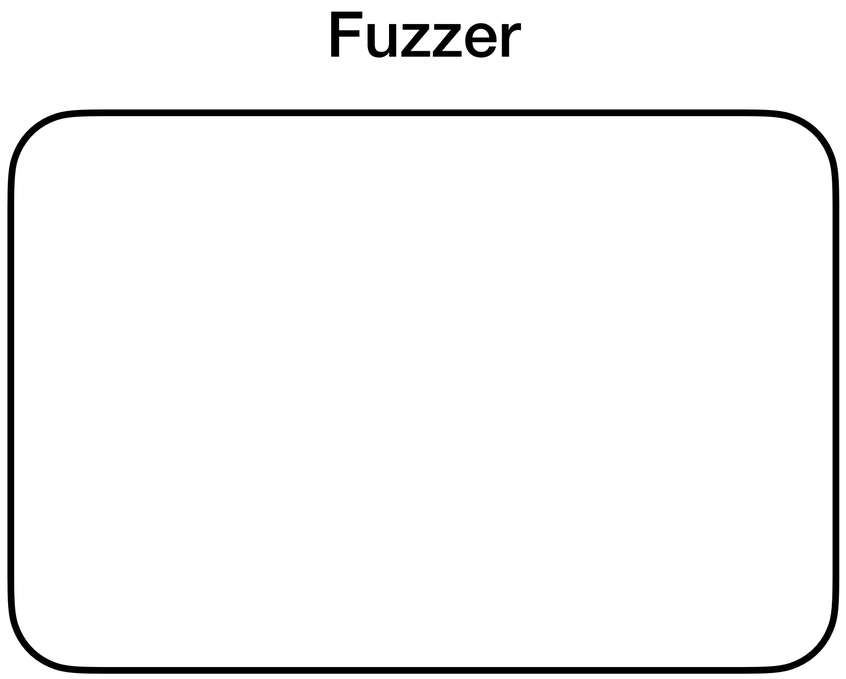

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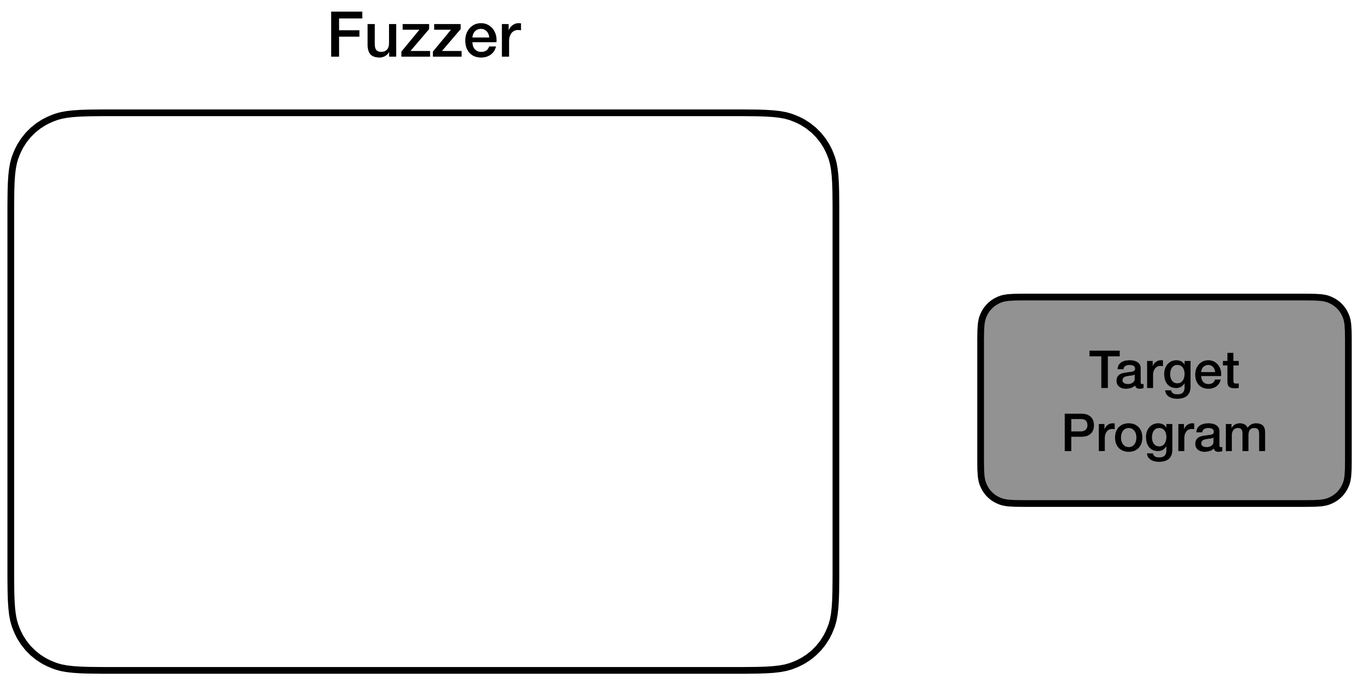

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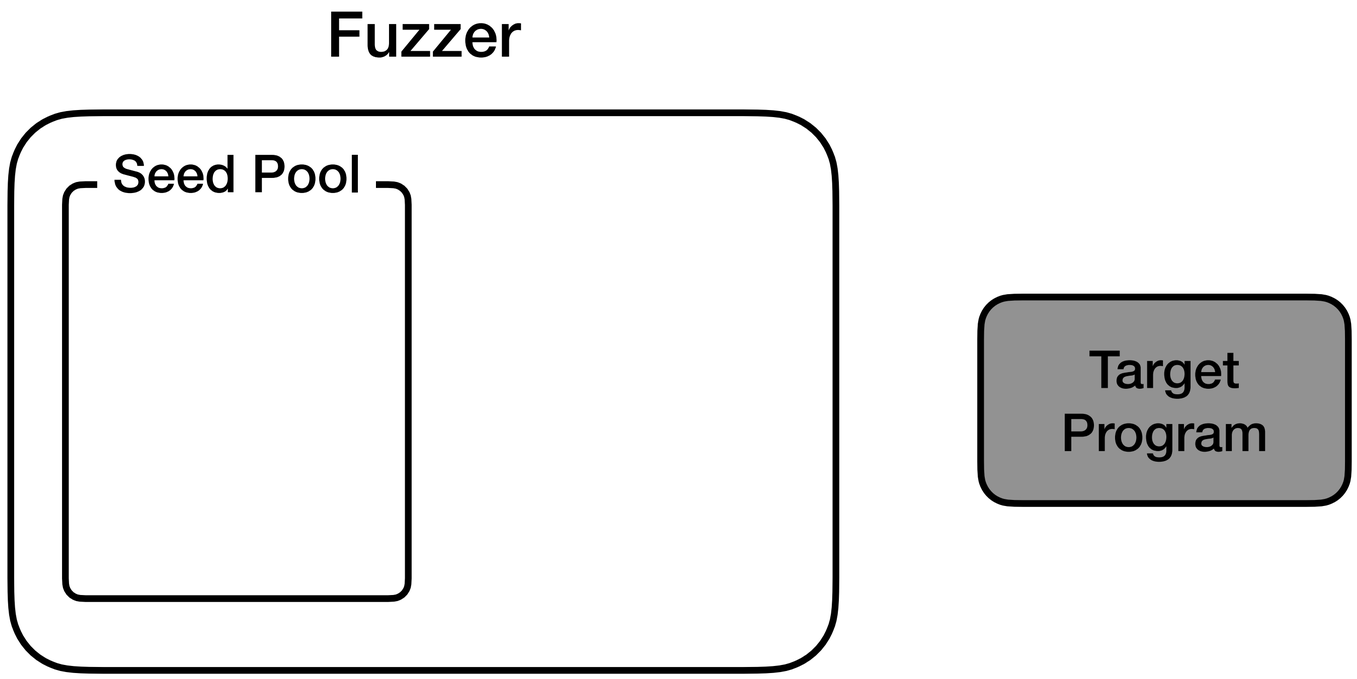

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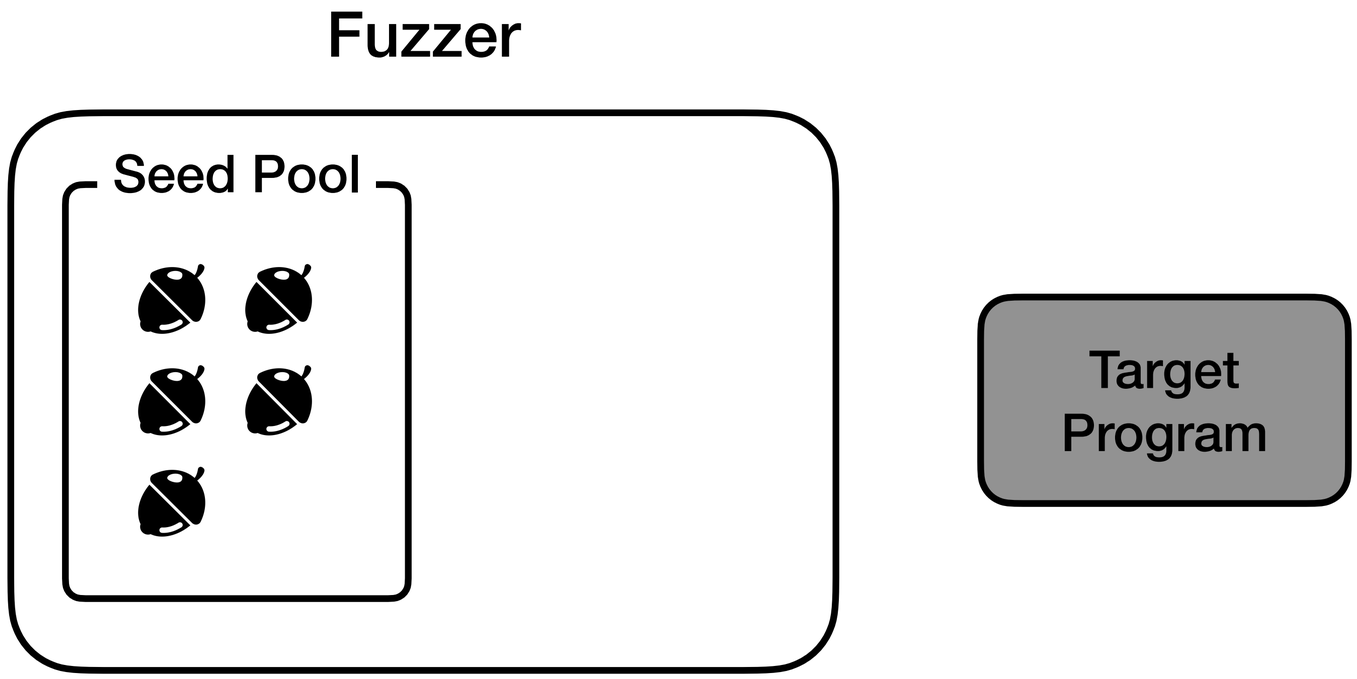

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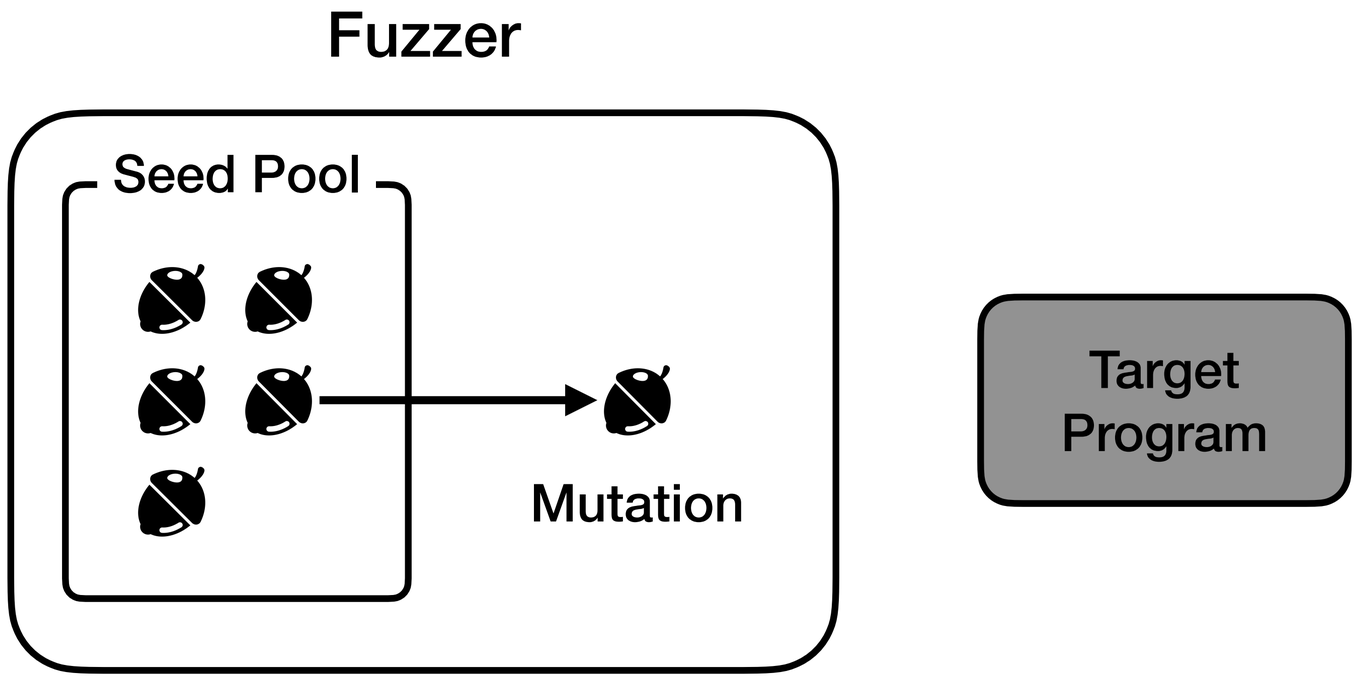

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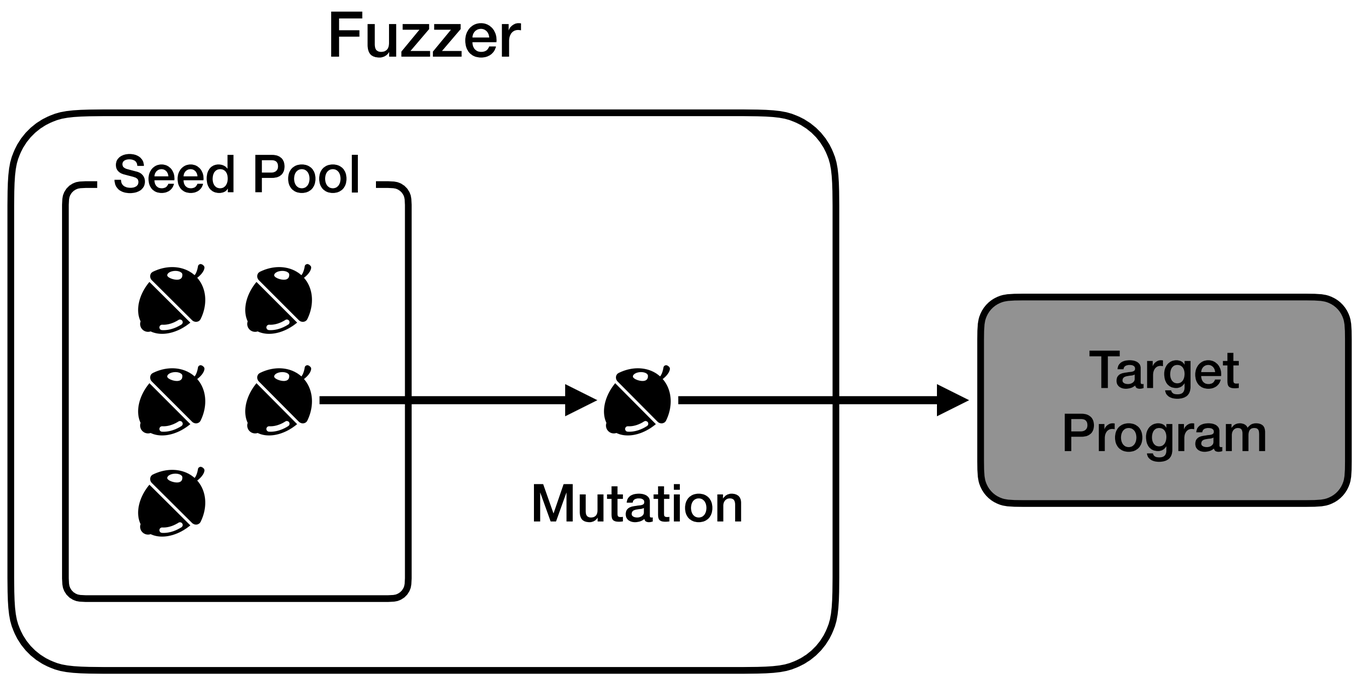

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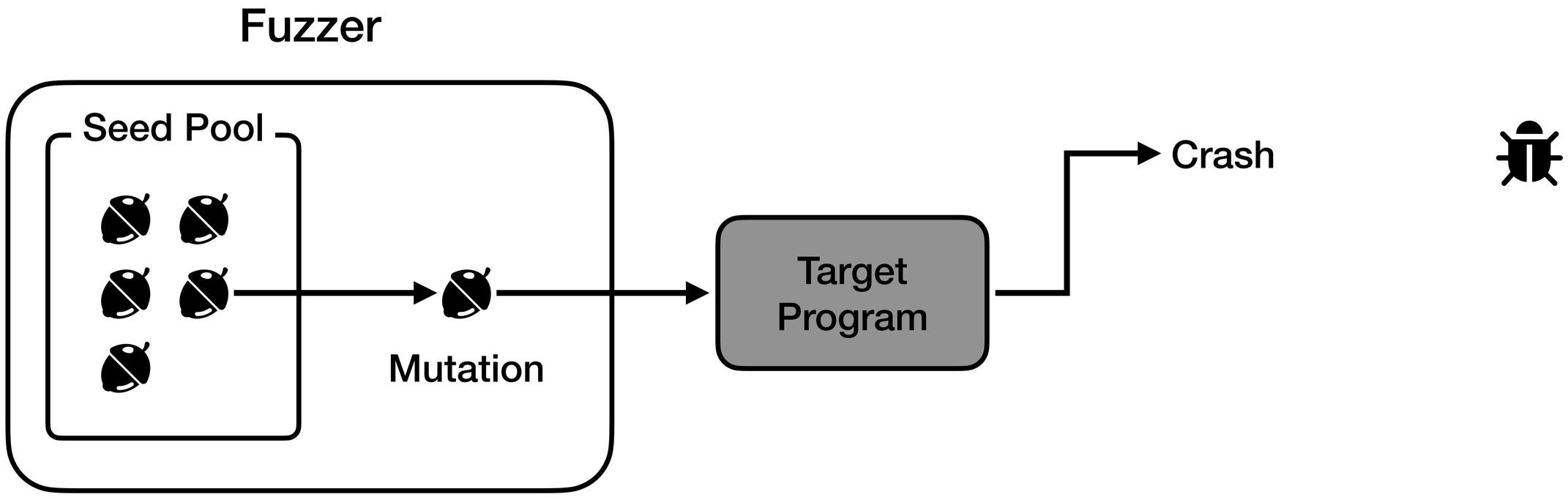

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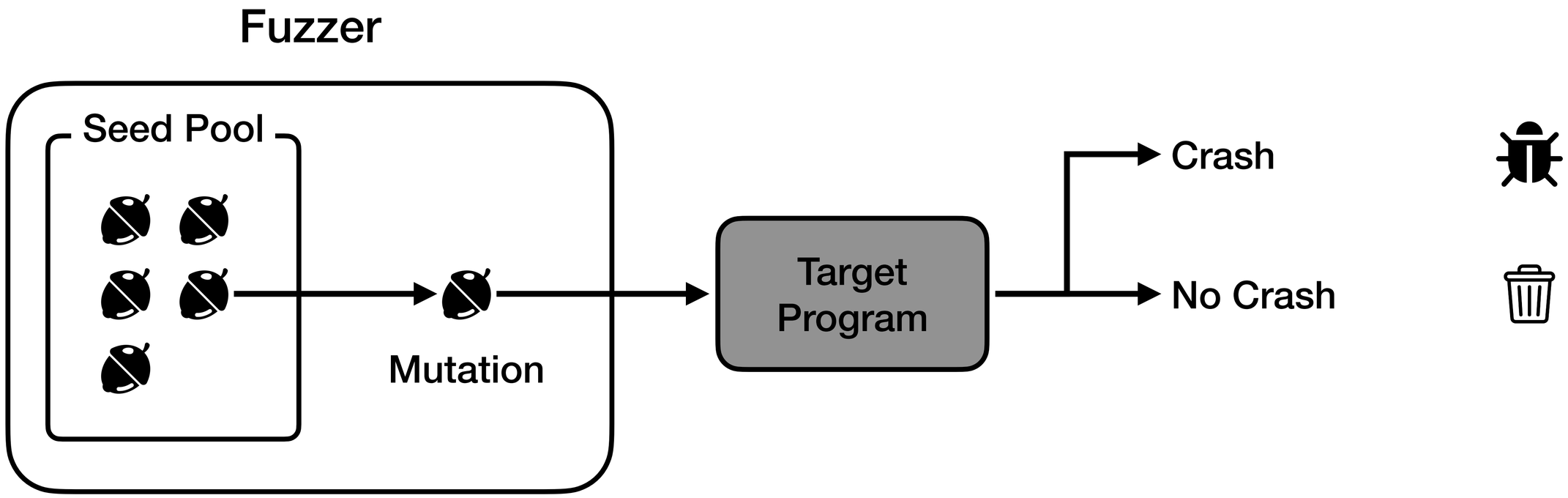

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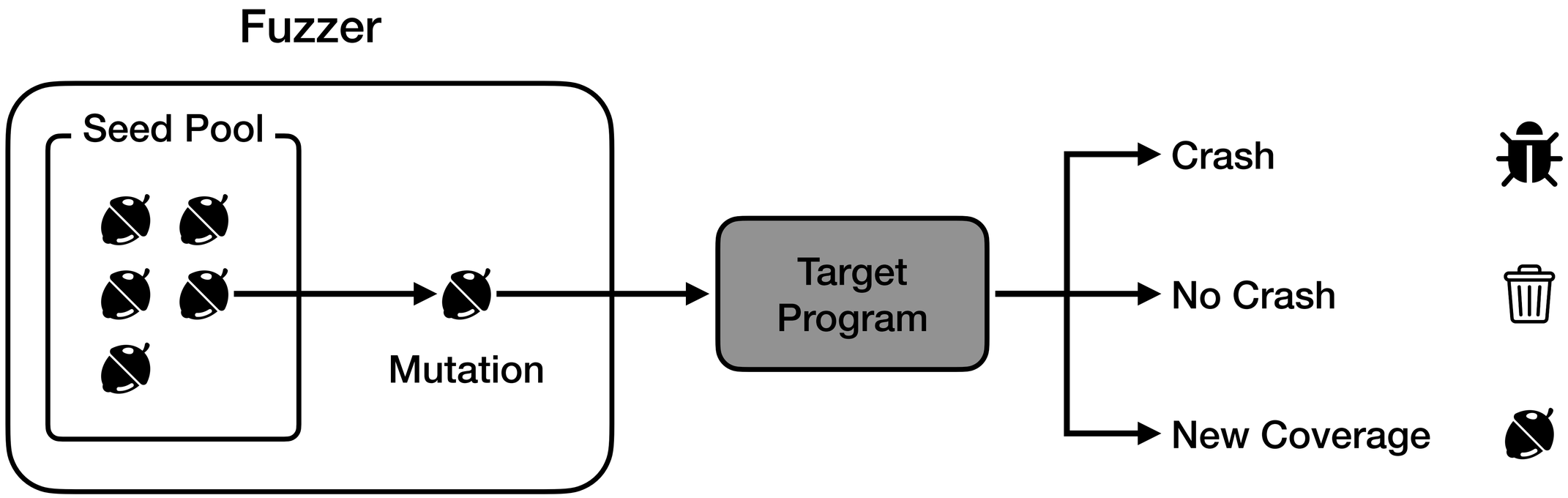

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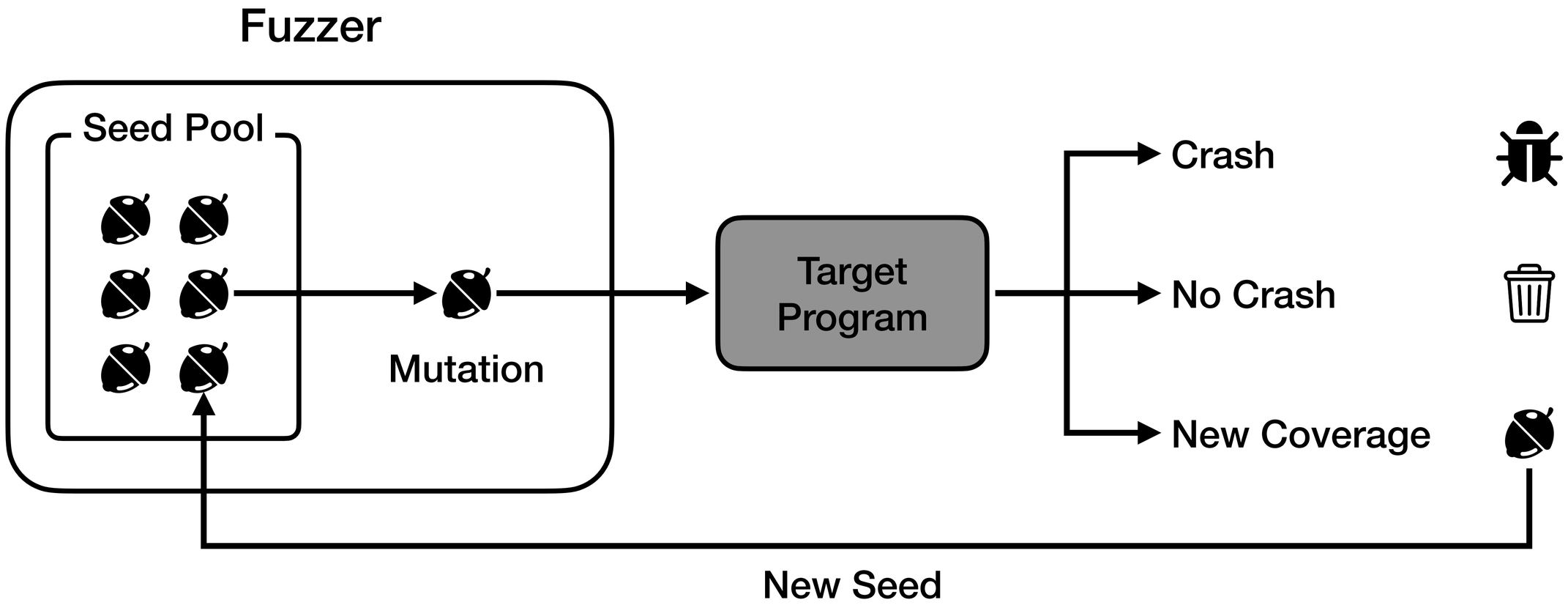

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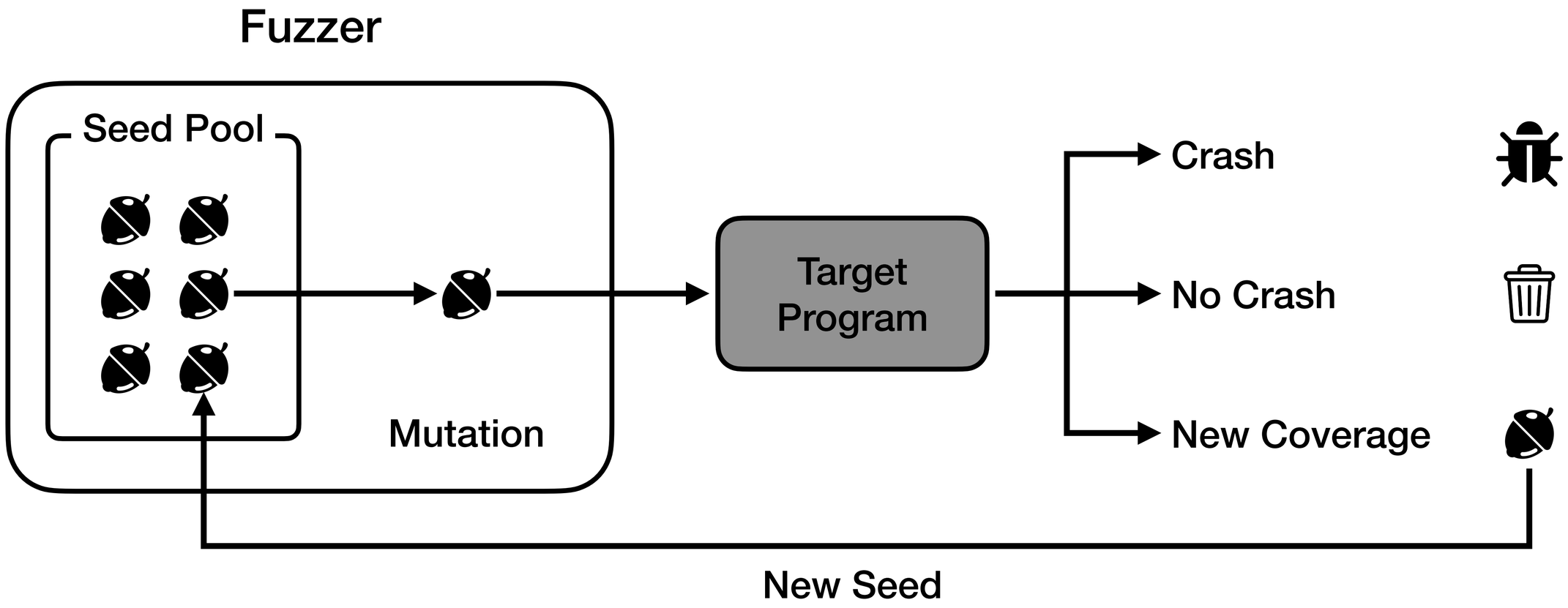

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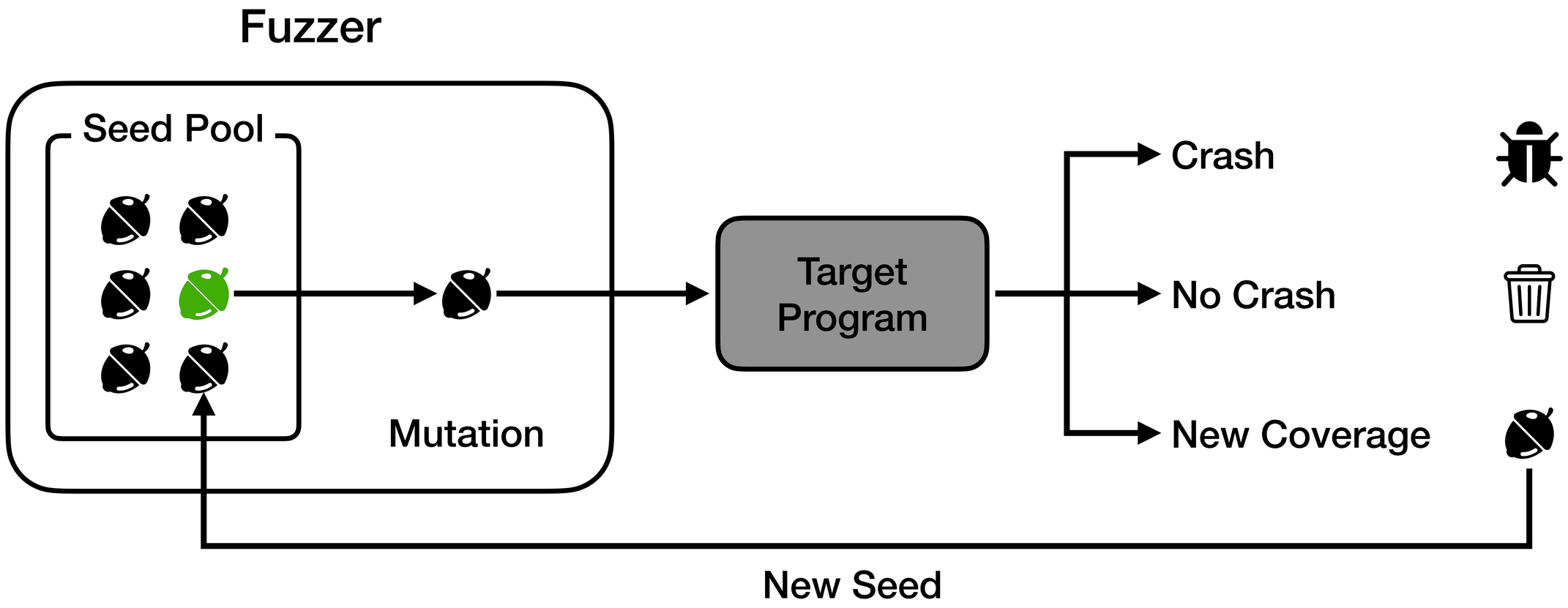

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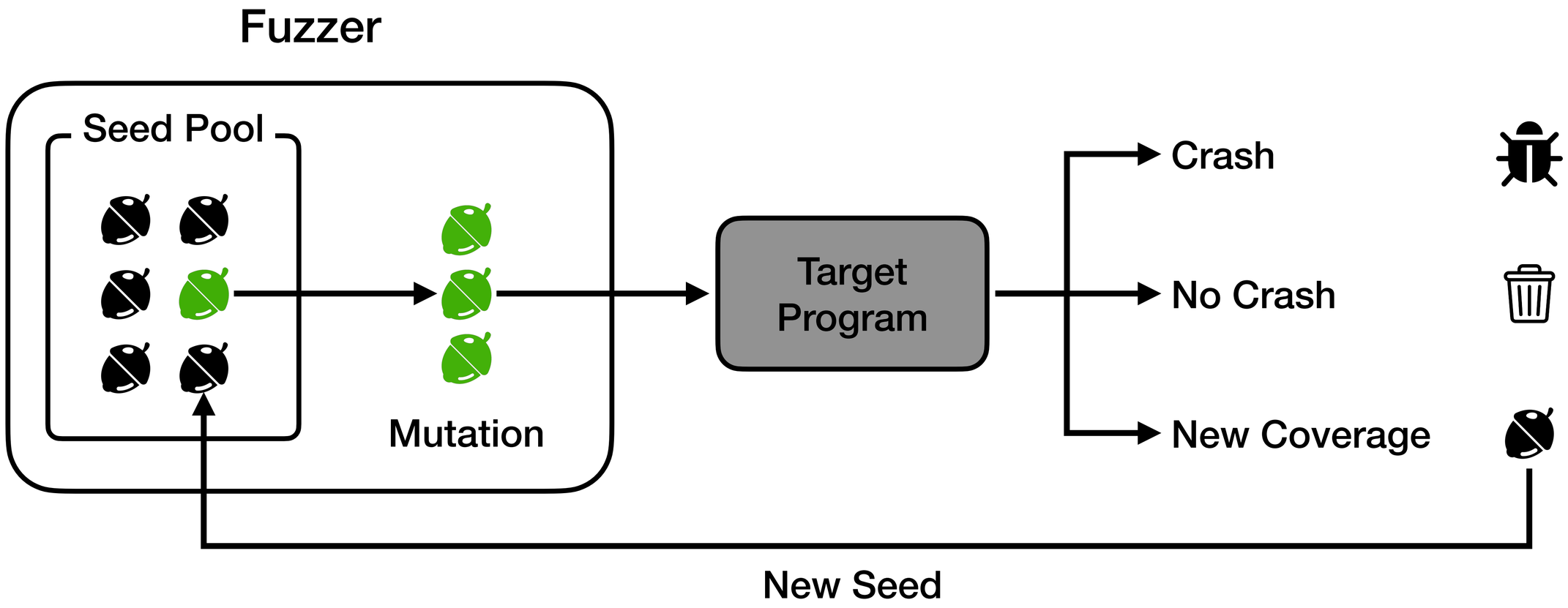

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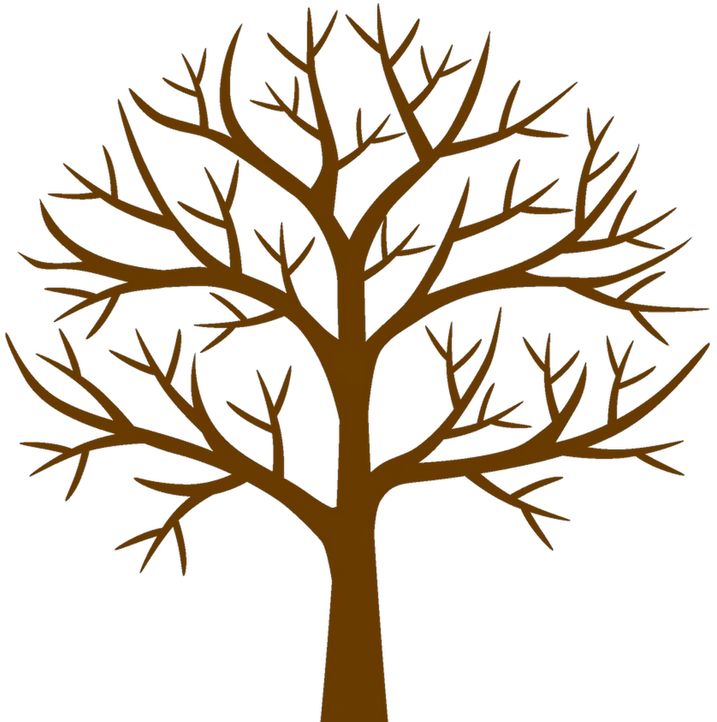

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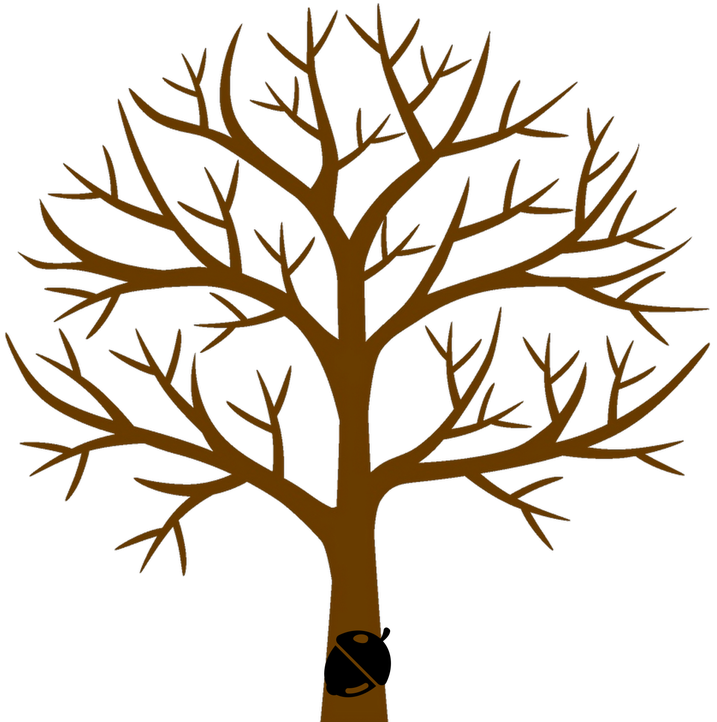

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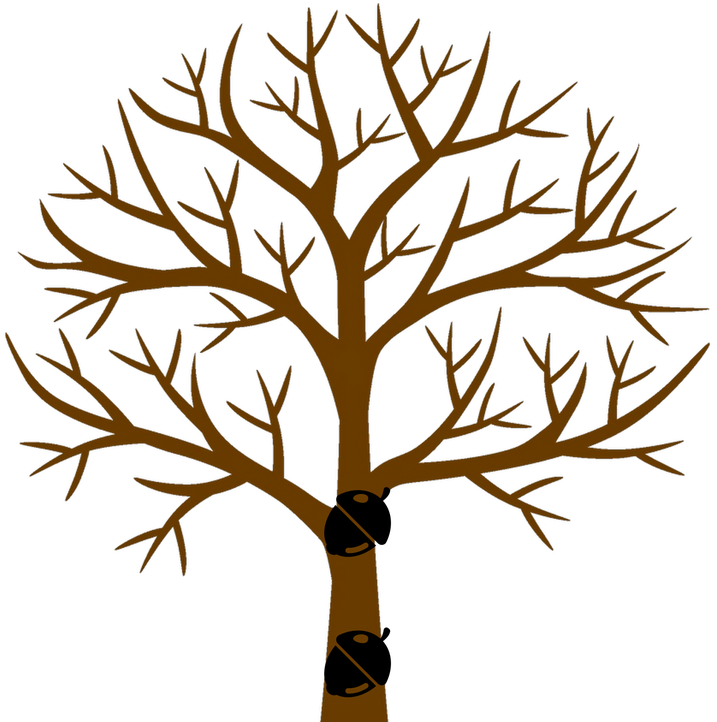

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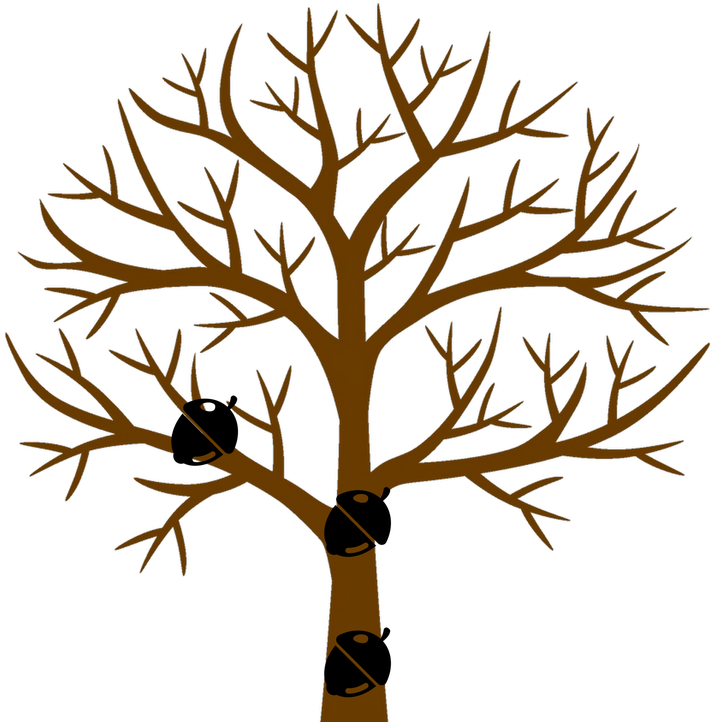

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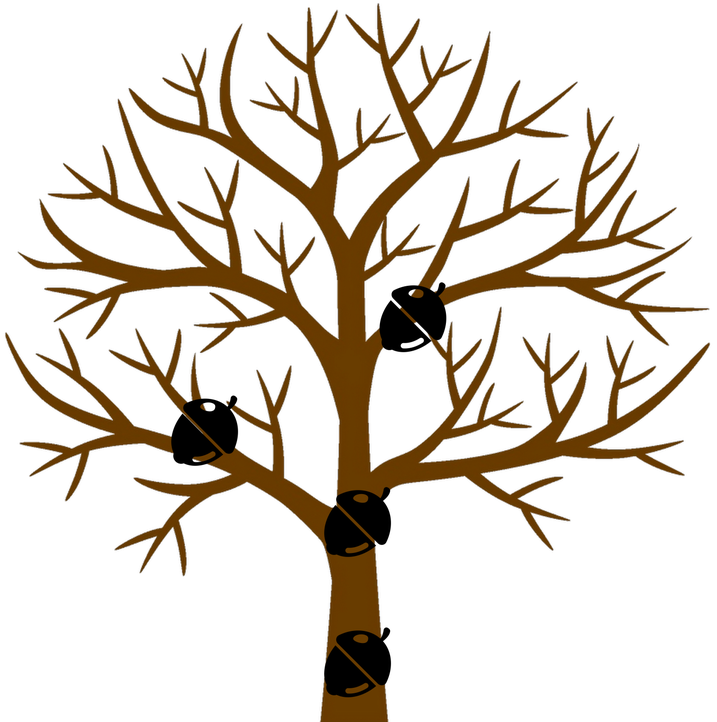

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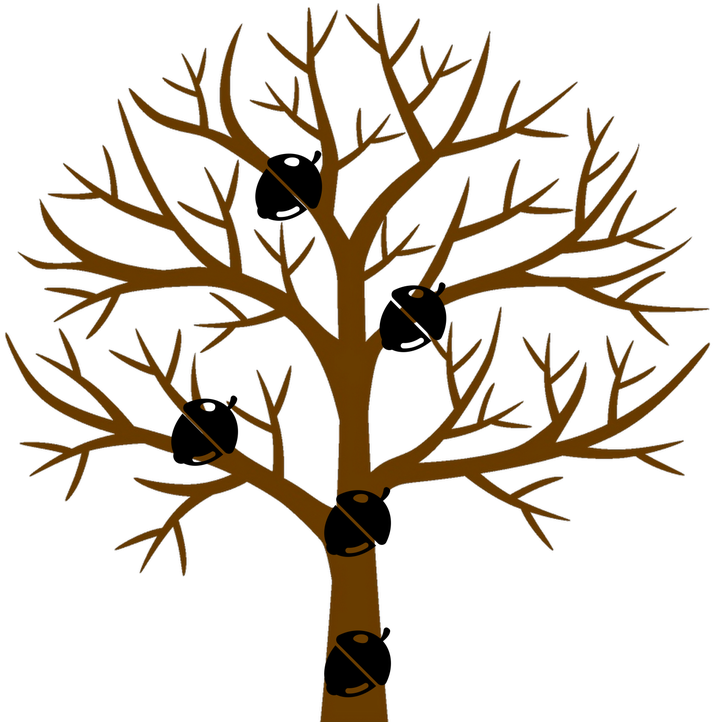

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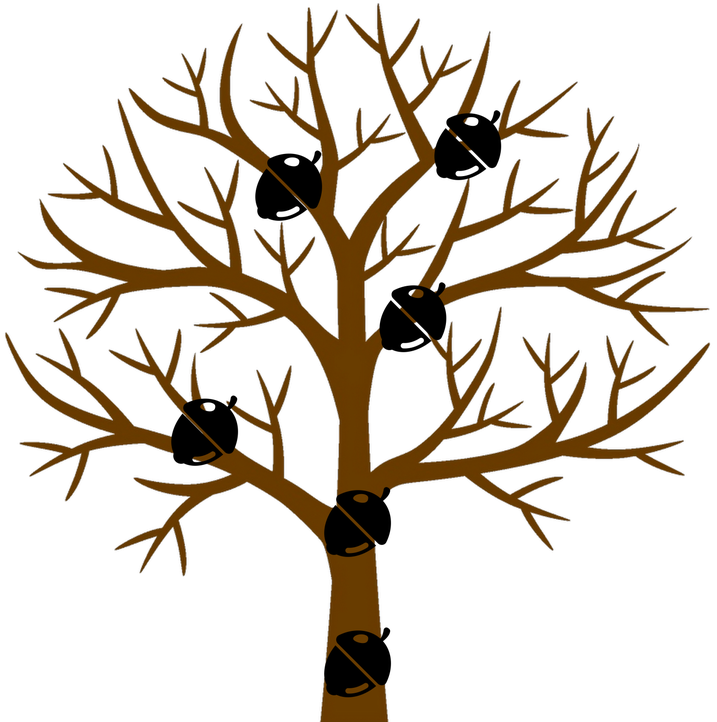

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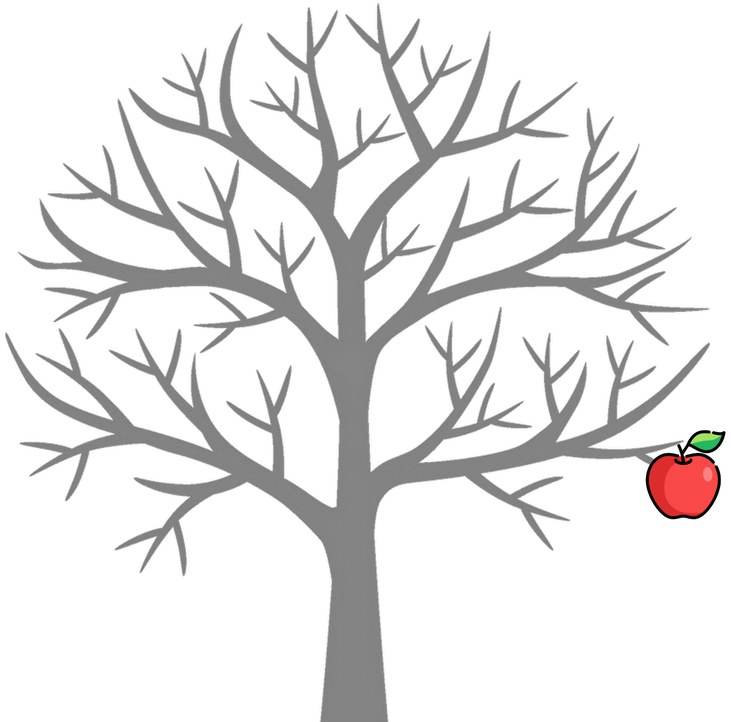

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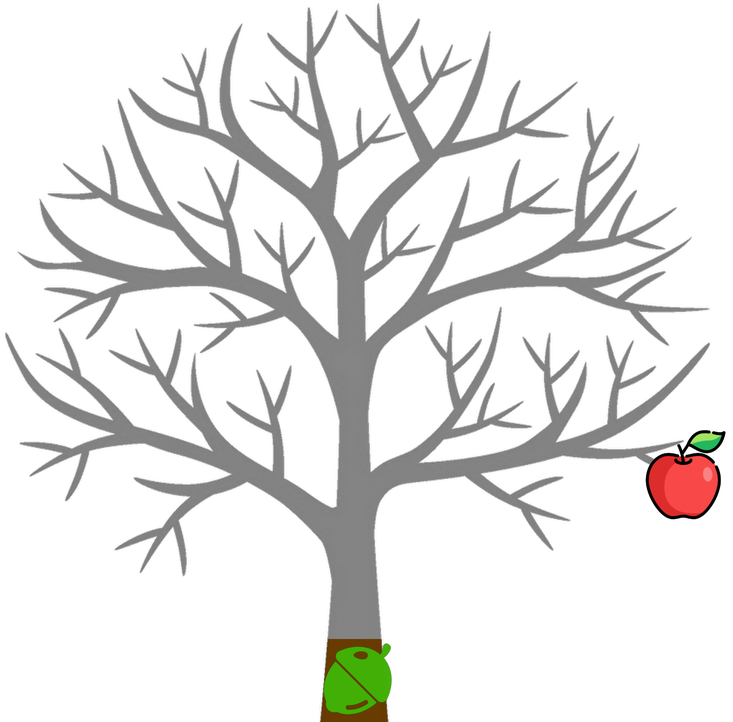

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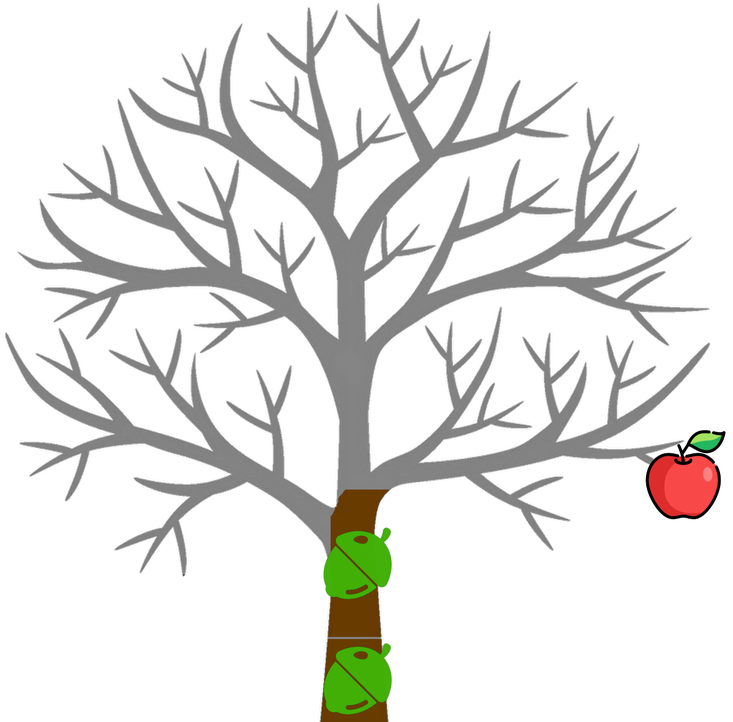

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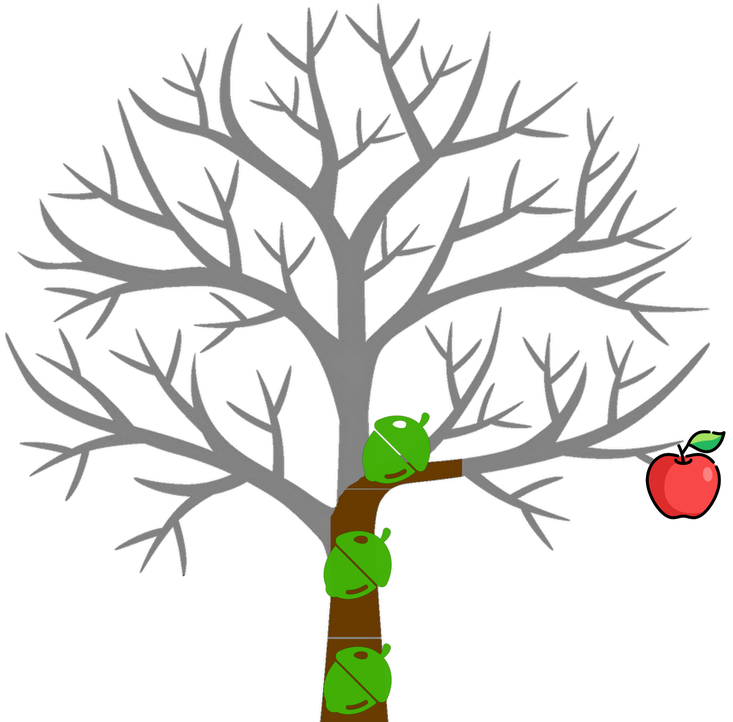

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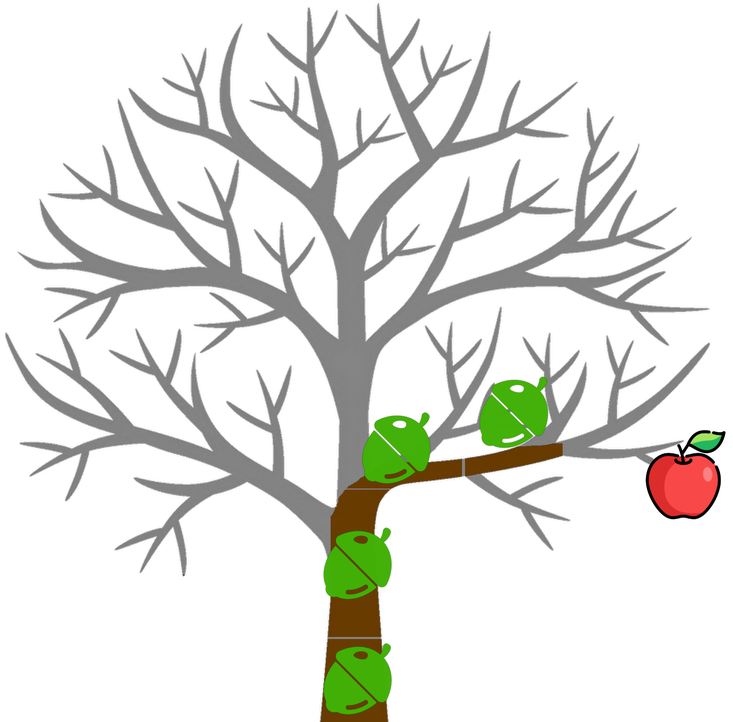

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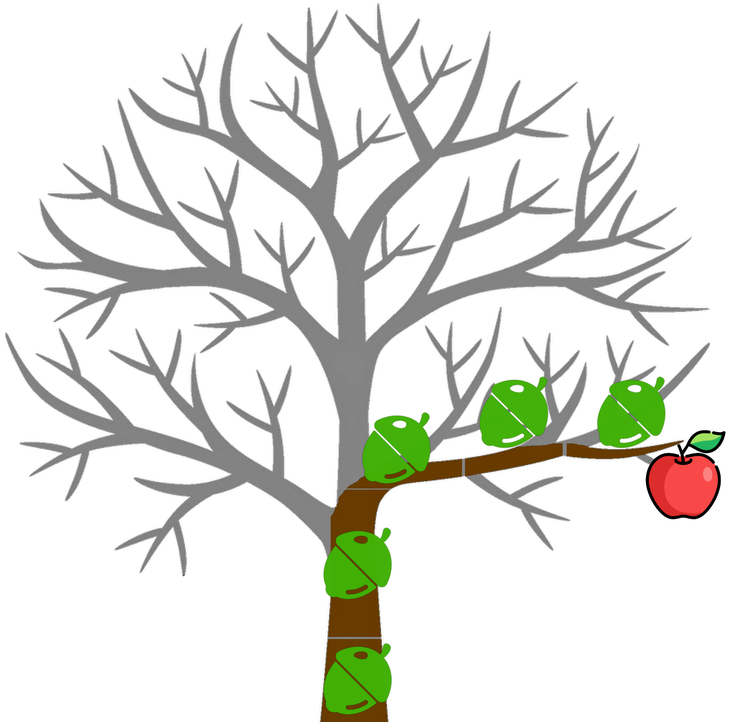

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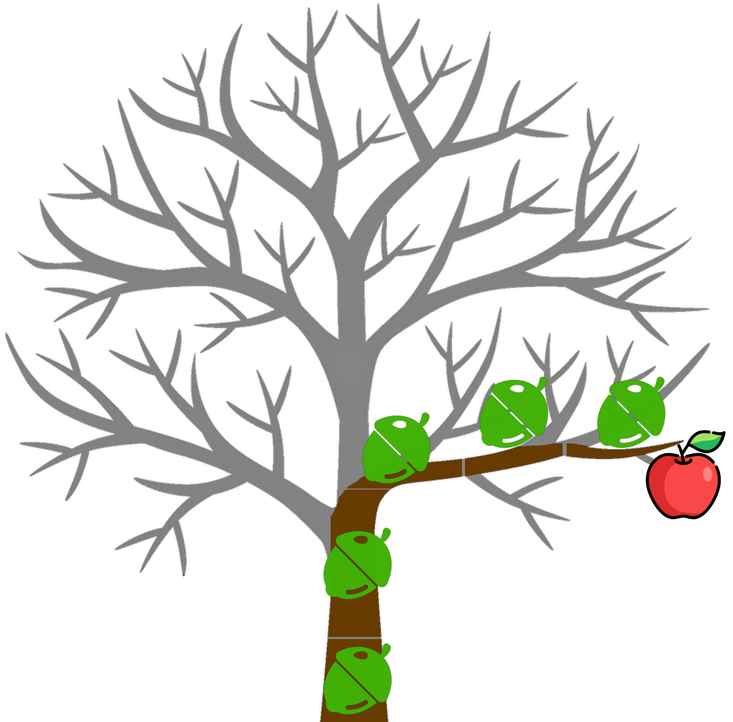
- Understanding the steps of progress is crucial



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lrzip	4,610,069	676	44
cxxfilt	14,784,726	4,657	346
objcopy	23,562,580	5,207	177
objdump	21,022,357	5,863	175
strip	131,633	1,018	6
nm	5,976,949	2,345	69
readelf	89,493	774	1
xmllint	63,012,643	1,283	2
cjpeg	18,245,672	4,650	20
Average	17,616,357	3,031	126

1. “DAFL : Directed Grey-Box Fuzzing Guided by Data Dependency”, Kim et al., USENIX Security 2023

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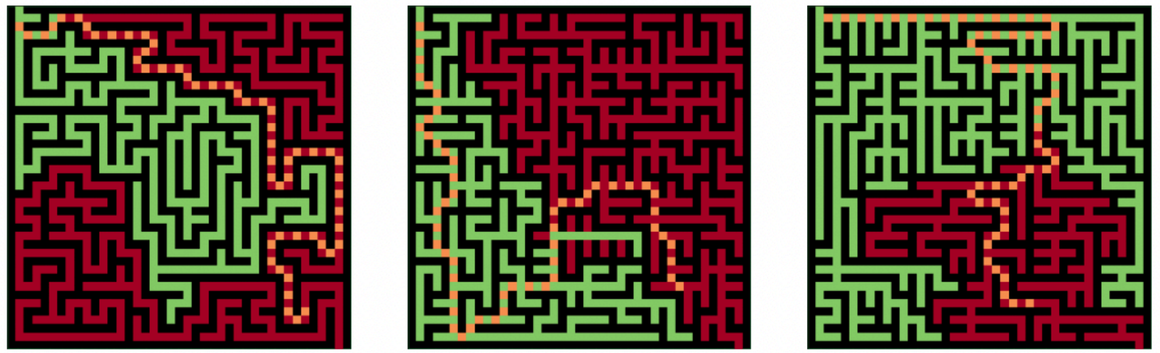

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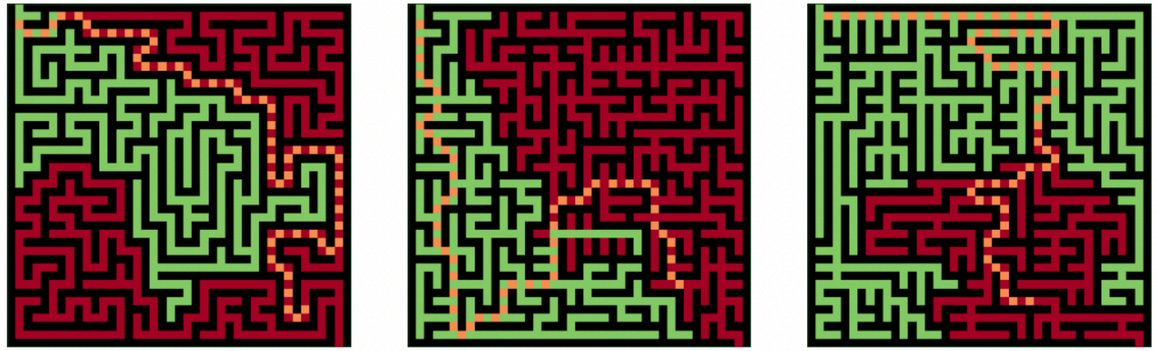

Visualization of Fuzzle[1]

LCOV - code coverage report

			Hit	Total	Coverage
Current view:	top level	**Lines:**	3270	7970	41.0 %
Test:	id:002084,src:002034,op:havoc,rep:2.lcov_info_final	**Functions:**	224	390	57.4 %
Date:	2015-05-25	**Branches:**	1778	5269	33.7 %

Directory	Line Coverage		Functions		Branches	
server	28.4 %	876 / 3080	39.5 %	49 / 124	27.0 %	541 / 2007
client	33.8 %	690 / 2039	54.9 %	39 / 71	31.5 %	397 / 1260
lib	59.8 %	1704 / 2851	69.7 %	136 / 195	42.0 %	840 / 2002

Generated by: LCOV version 1.10

Visualization of afl-cov[2]

1. "Fuzzle: Making a Puzzle for Fuzzers", Lee, Kim, and Cha, ASE 2022
2. “afl-cov - AFL Fuzzing Code Coverage”, Rash

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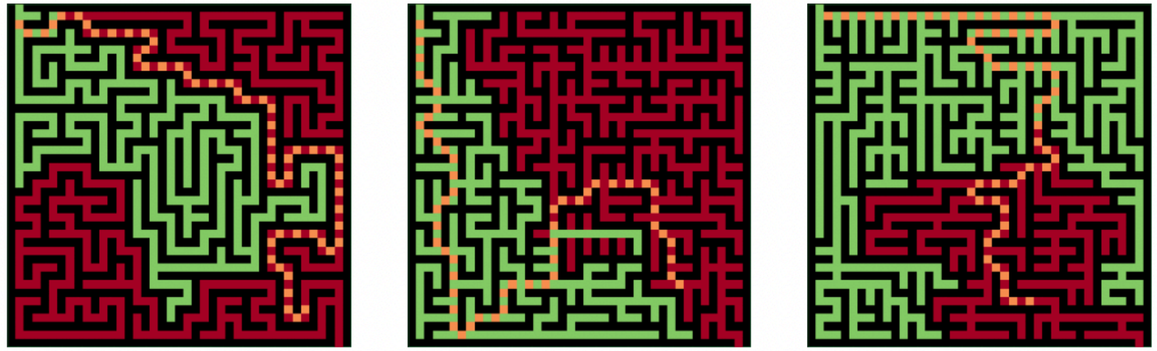
Visualization Tools

- Focused on coverage analysis



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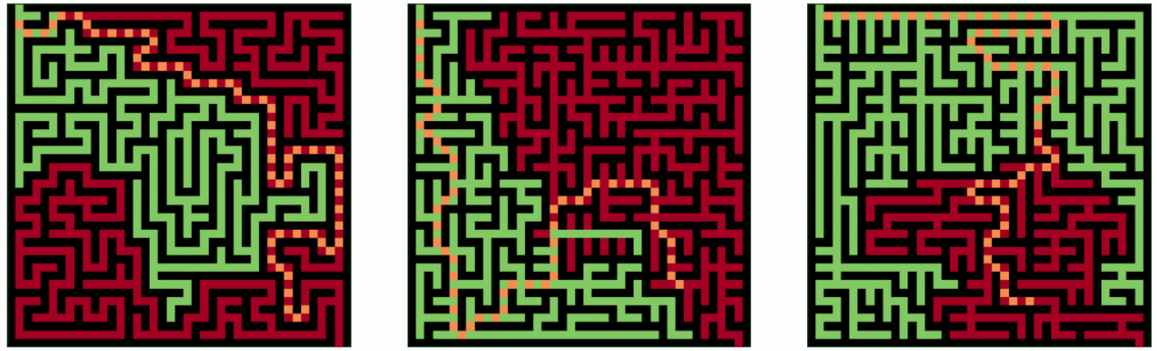
- Insufficient for directed setting



Visualization of Fuzzle[1]

LCOV - code coverage report

			Hit	Total	Coverage
Current view:	top level	**Lines:**	3270	7970	41.0 %
Test:	id:002084,src:002034,op:havoc,rep:2.lcov_info_final	**Functions:**	224	390	57.4 %
Date:	2015-05-25	**Branches:**	1778	5269	33.7 %

Directory	Line Coverage		Functions		Branches	
server	28.4 %	876 / 3080	39.5 %	49 / 124	27.0 %	541 / 2007
client	33.8 %	690 / 2039	54.9 %	39 / 71	31.5 %	397 / 1260
lib	59.8 %	1704 / 2851	69.7 %	136 / 195	42.0 %	840 / 2002

Generated by: LCOV version 1.10

Visualization of afl-cov[2]

1. "Fuzzle: Making a Puzzle for Fuzzers", Lee, Kim, and Cha, ASE 2022
2. “afl-cov - AFL Fuzzing Code Coverage”, Rash

Our Solution

Our Solution

GeneVis: Genealogical Visualization Tool

Our Solution

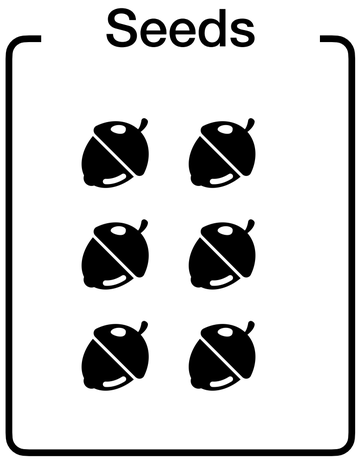
GeneVis: Genealogical Visualization Tool

- Tree structure based on the relationship between inputs

Our Solution

GeneVis: Genealogical Visualization Tool

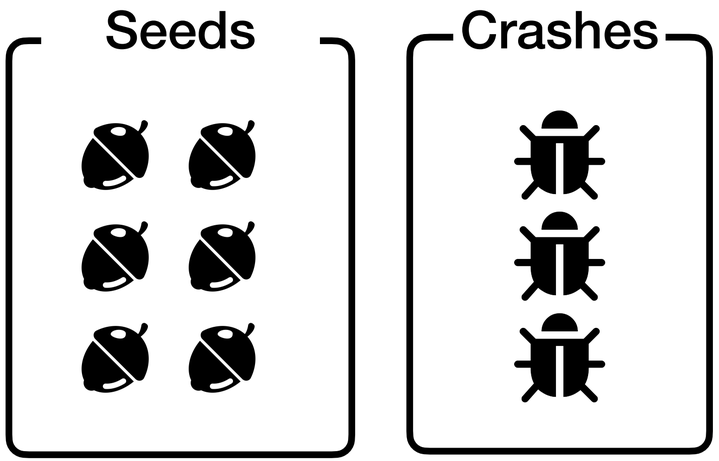
- Tree structure based on the relationship between inputs



Our Solution

GeneVis: Genealogical Visualization Tool

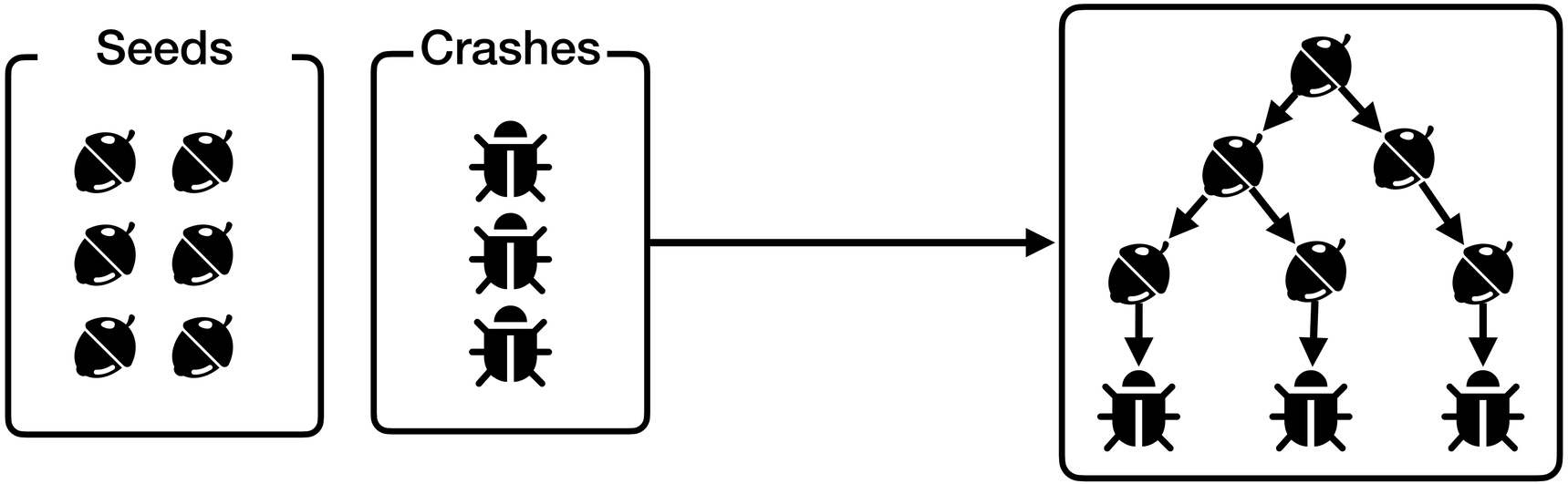
- Tree structure based on the relationship between inputs



Our Solution

GeneVis: Genealogical Visualization Tool

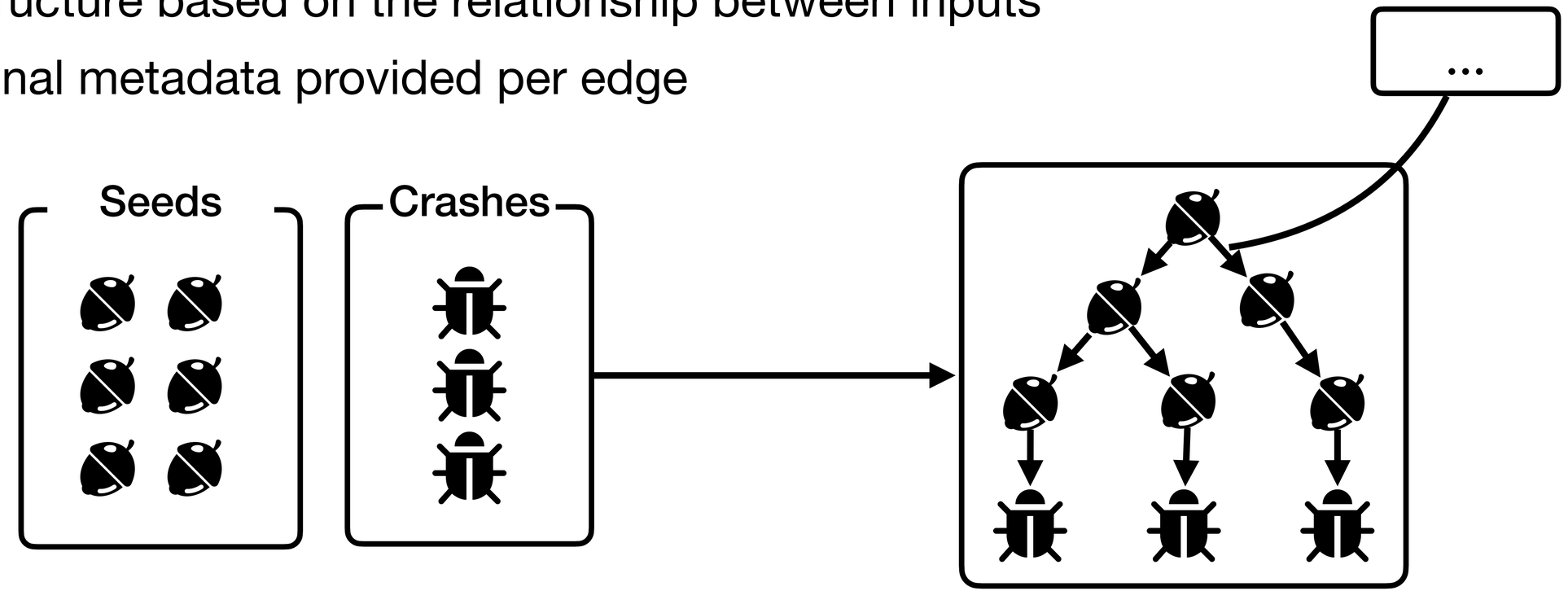
- Tree structure based on the relationship between inputs



Our Solution

GeneVis: Genealogical Visualization Tool

- Tree structure based on the relationship between inputs
- Additional metadata provided per edge



Demo

Demo

Features

Demo

Features

- Structural

Demo

Features

- Structural
  - Parent-Child relationship

Demo

Features

- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed

Demo

Features

- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed

- Metadata

Demo

Features

- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed

- Metadata
  - Coverage information

Demo

Features

- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed

- Metadata
  - Coverage information
  - Temporal information

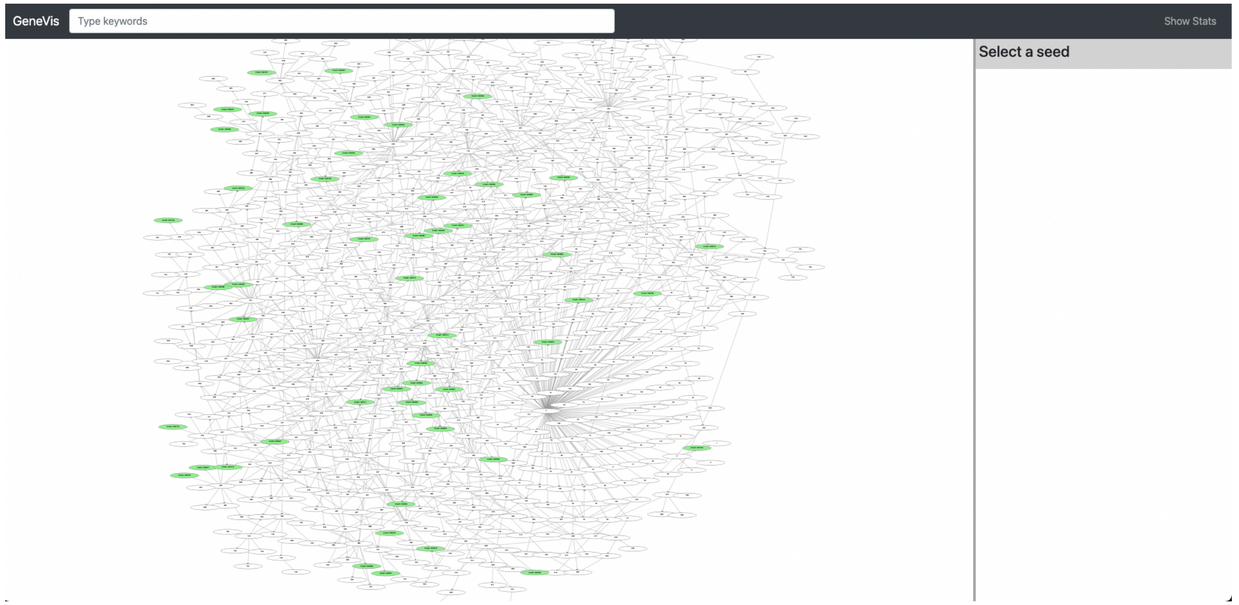
Demo

Features

- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed

- Metadata
  - Coverage information
  - Temporal information
  - Mutation information

Demo



http://elvis08.kaist.ac.kr/goodtaeeun/genevis/demo1/

Features

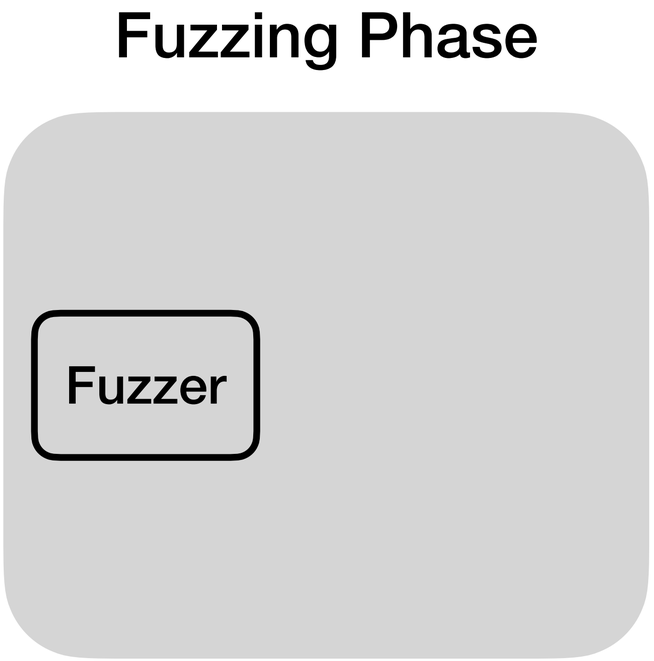
- Structural
  - Parent-Child relationship
  - Direct relationship with the initial seed
- Metadata
  - Coverage information
  - Temporal information
  - Mutation information

Overview

Overview

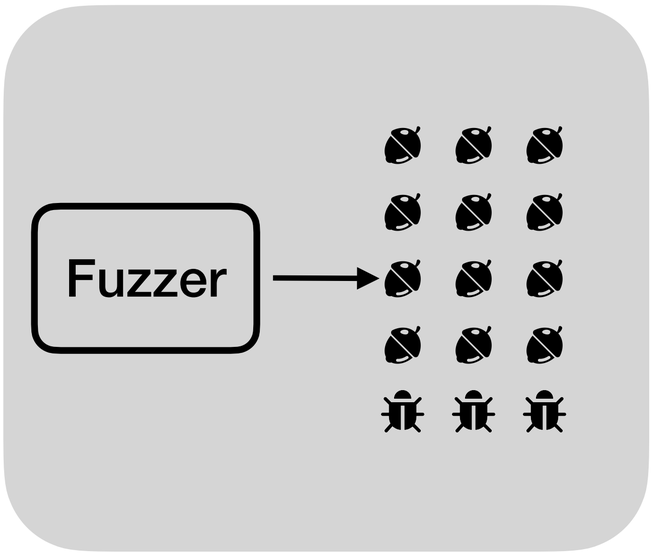
Fuzzing Phase

Overview



Overview

Fuzzing Phase



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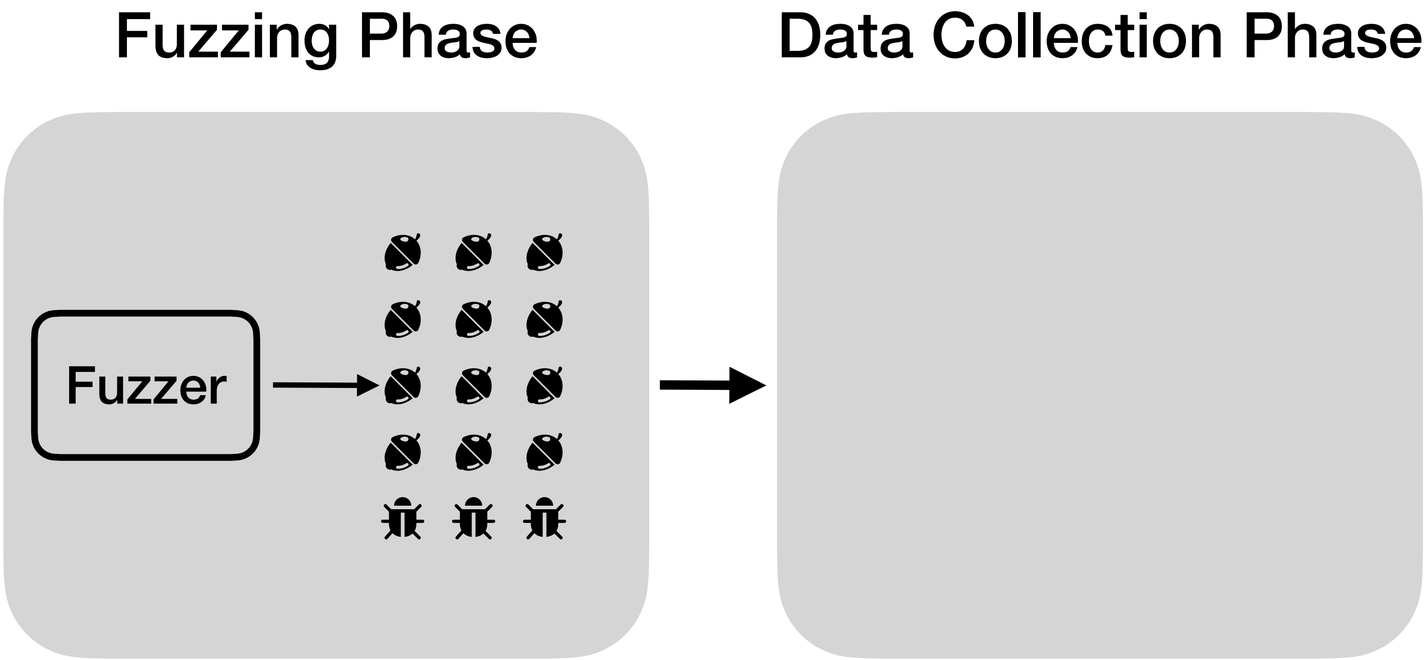

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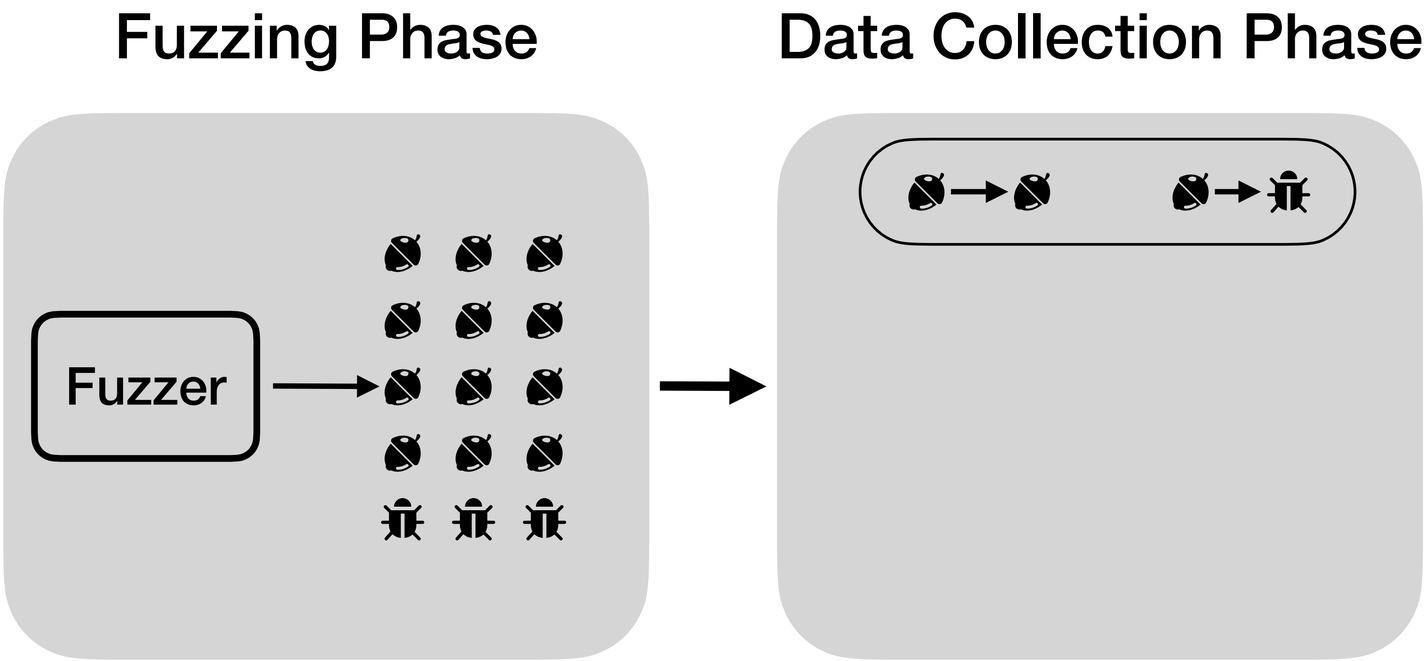

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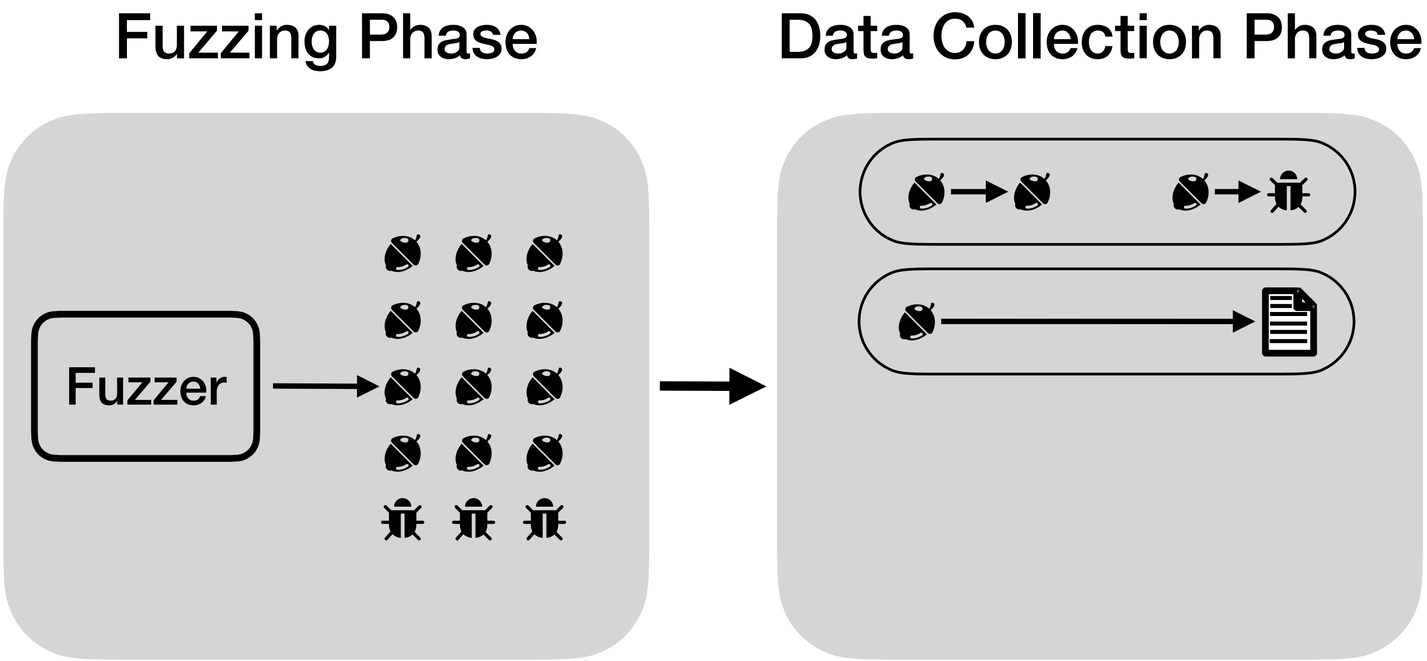

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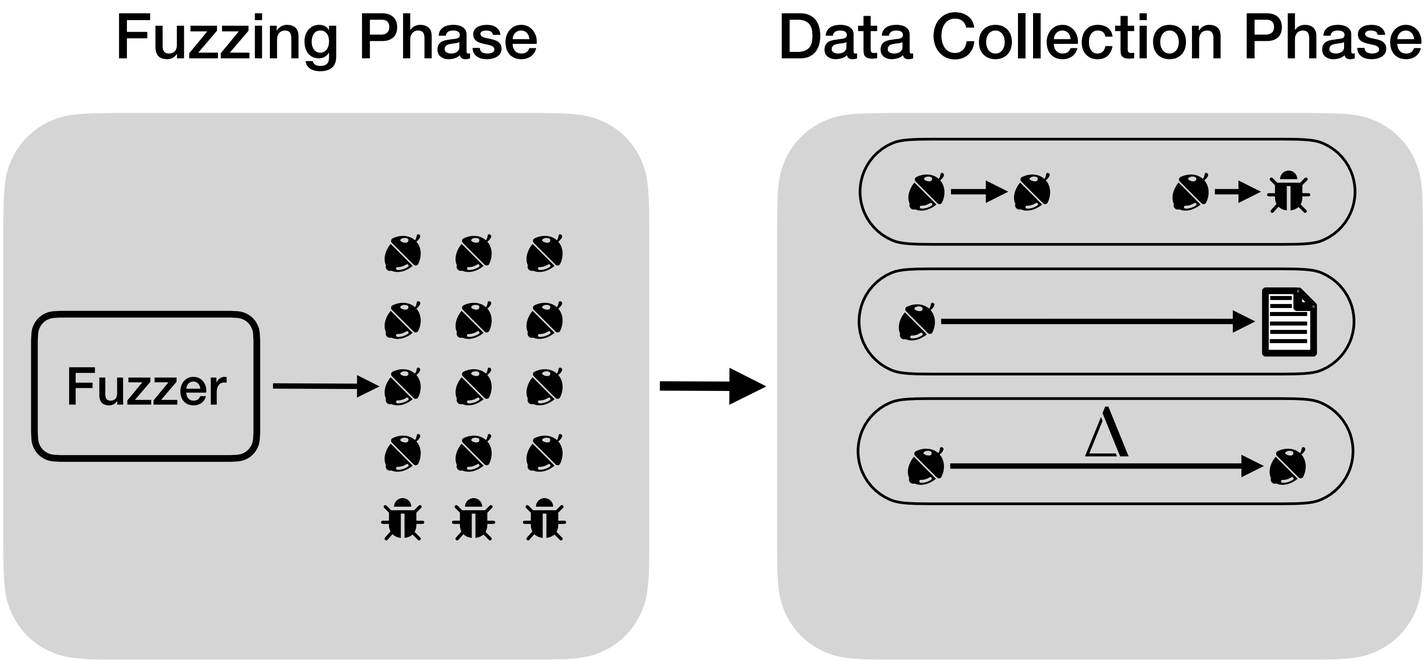

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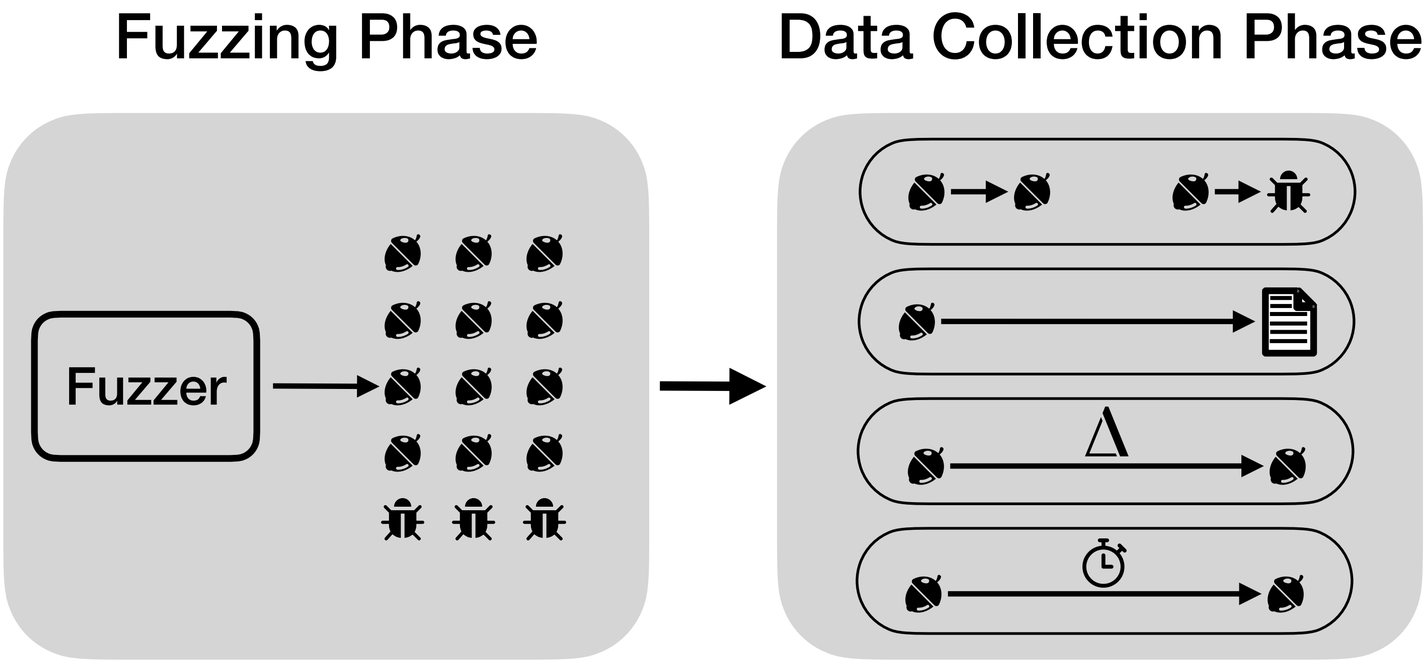
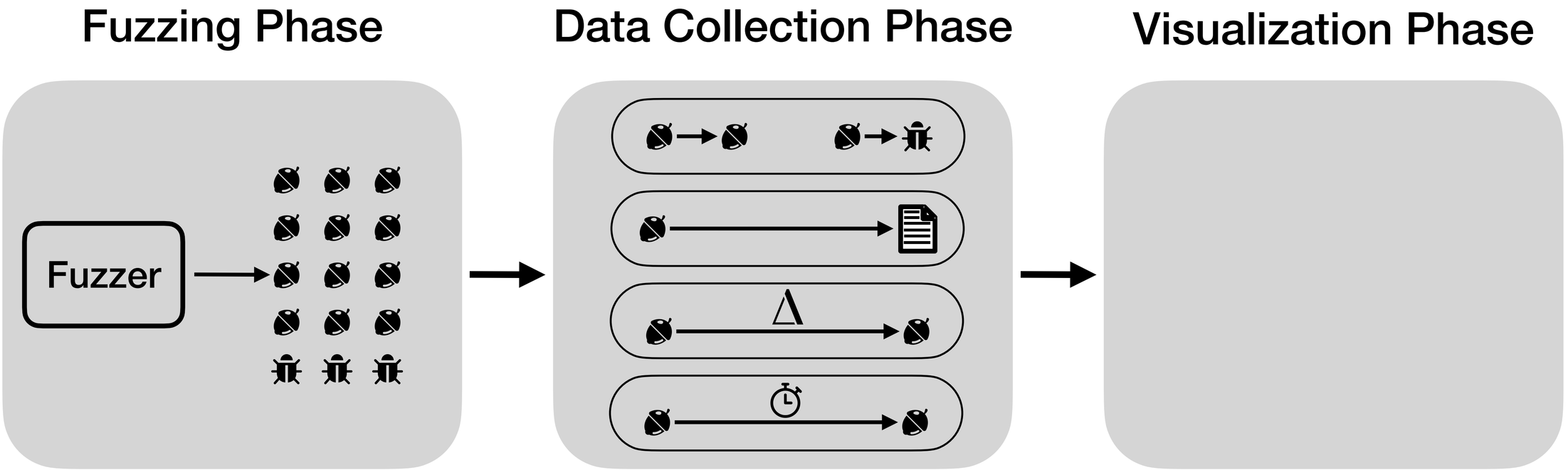
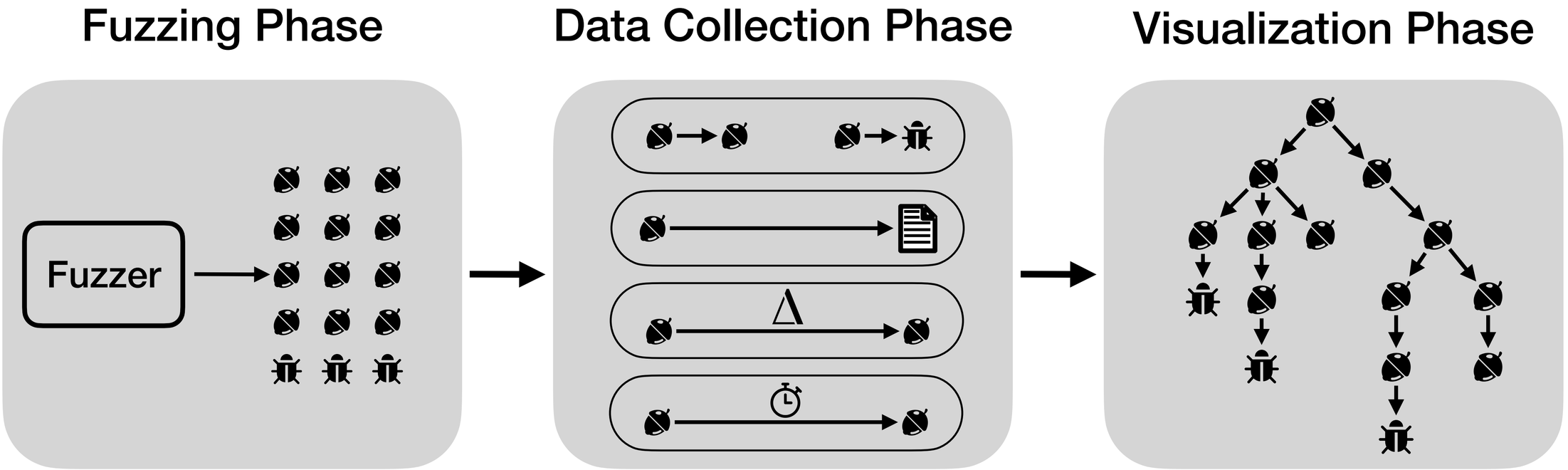


Overview


Fuzzing Phase
Data Collection Phase
Visualization Phase
Fuzzer

Overview


Fuzzing Phase
Data Collection Phase
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Fuzzer
Δ

Key Challenges

Key Challenges

Data Collection

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Data Collection

- Structure of genealogical tree

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- Structure of genealogical tree
- Metadata to enhance analysis

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- Must be **compatible**

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Visualization

Key Challenges

Data Collection

- Structure of genealogical tree
- Metadata to enhance analysis
- Must be **compatible**

Visualization

- Graphical visualization of collected data

Key Challenges

Data Collection

- Structure of genealogical tree
- Metadata to enhance analysis
- Must be **compatible**

Visualization

- Graphical visualization of collected data
- Must be **scalable** and **interactive**

Data Collection

Data Collection

Objectives

Data Collection

Objectives

- Structure of the genealogical tree

Data Collection

Objectives

- Structure of the genealogical tree
  - **Parent-child** relationships between inputs

Data Collection

Objectives

- Structure of the genealogical tree
  - **Parent-child** relationships between inputs
- Other metadata

Data Collection

Objectives

- Structure of the genealogical tree
  - **Parent-child** relationships between inputs
- Other metadata
  - **What** was the progress?

Data Collection

Objectives

- Structure of the genealogical tree
  - **Parent-child** relationships between inputs
- Other metadata
  - **What** was the progress?
  - **How** was the progress made?

Data Collection

Objectives

- Structure of the genealogical tree
  - **Parent-child** relationships between inputs
- Other metadata
  - **What** was the progress?
  - **How** was the progress made?
  - How **difficult** was the progress?

Data Collection

Parent-child relationships between inputs

Data Collection

Parent-child relationships between inputs

- Naming convention of AFL

Data Collection

Parent-child relationships between inputs

- Naming convention of AFL
  - “id:000027,src:000021,op:havoc,rep:2”

Data Collection

Parent-child relationships between inputs

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  - Input “000027” has input “000021” as a parent

Data Collection

Parent-child relationships between inputs

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Data Collection

Parent-child relationships between inputs

- Naming convention of AFL
  - “id:000027,src:000021,op:havoc,rep:2”
  - Input “000027” has input “000021” as a parent

- Compatible with 11 out of 14 state-of-the-art Directed Grey-box Fuzzers

Data Collection

Metadata per edge

Data Collection

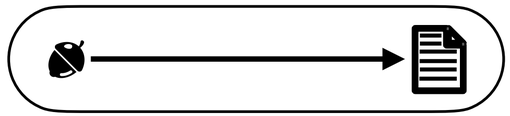
Metadata per edge

- **What** was the progress?

Data Collection

Metadata per edge

- **What** was the progress?
  - Coverage



Collecting Coverage

Collecting Coverage

Visualization for Directed Fuzzing

Collecting Coverage

Visualization for Directed Fuzzing

- Not all coverage matters

Collecting Coverage

Visualization for Directed Fuzzing

- Not all coverage matters
- Not all seeds cover new lines

Collecting Coverage

Visualization for Directed Fuzzing

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Coverage with respect to the target

Collecting Coverage

Visualization for Directed Fuzzing

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Coverage with respect to the target

- Target function reachability

Collecting Coverage

Visualization for Directed Fuzzing

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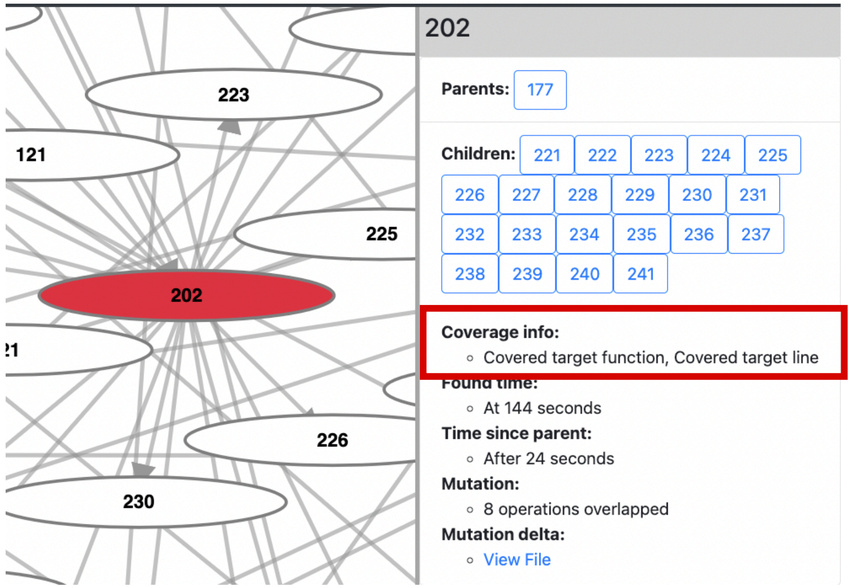
Coverage with respect to the target

- Target function reachability
- Target line reachability

Collecting Coverage



Visualization for Directed Fuzzing

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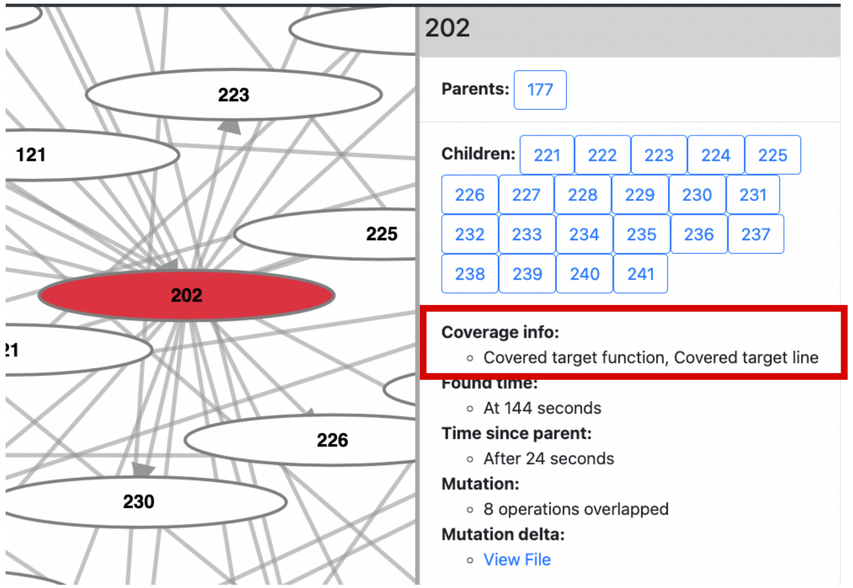

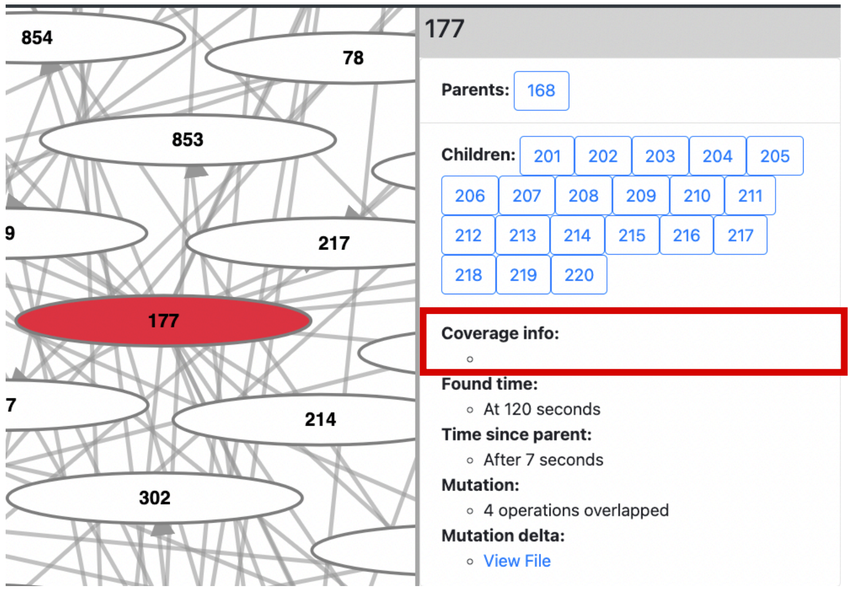

Collecting Coverage

Visualization for Directed Fuzzing

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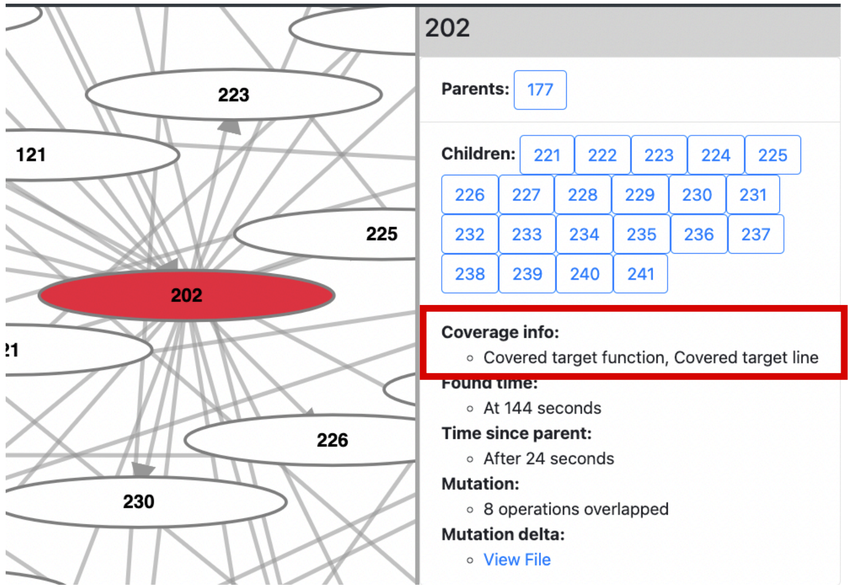
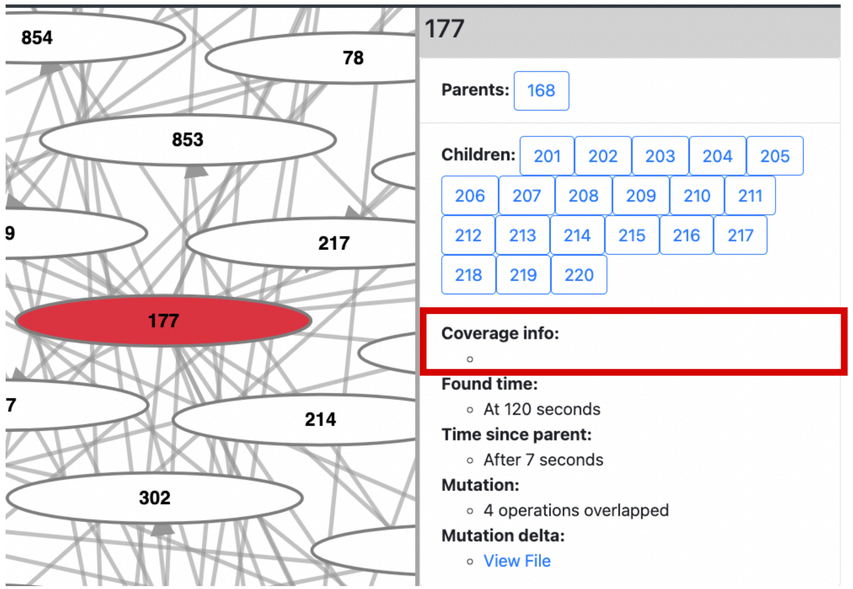
Coverage with respect to the target

- Target function reachability
- Target line reachability

Instrumented binary

- Instrumented with LLVM compiler pass

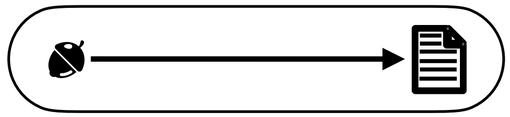




Data Collection

Metadata per edge

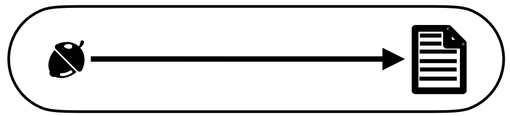
- **What** was the progress?
  - Coverage of target function/line



Data Collection

Metadata per edge

- **What** was the progress?
  - Coverage of target function/line
- **How** was the progress made?



Data Collection

Metadata per edge

- **What** was the progress?
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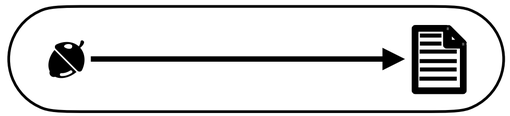
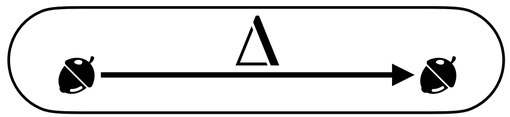
- **How** was the progress made?
  - Mutation delta between parent-child inputs





Collecting Mutation information

Mutation Information

Collecting Mutation information

Mutation Information

- The intensity of the mutation: # of applied mutations

Collecting Mutation information

Mutation Information

- The intensity of the mutation: # of applied mutations
- Diff between parent and child seeds

Collecting Mutation information

Mutation Information

- The intensity of the mutation: # of applied mutations
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  - Too large, thus provided as a link to a file

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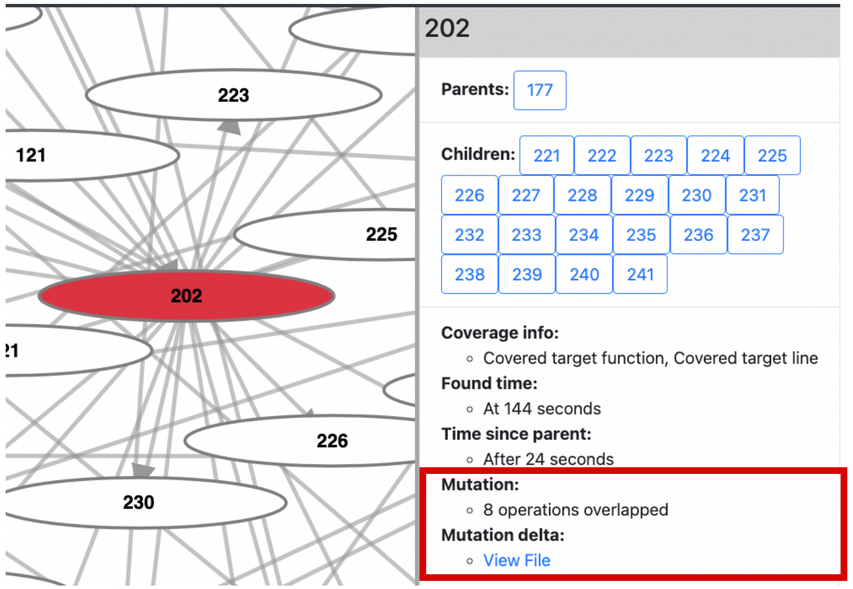

Collecting Mutation information

Mutation Information

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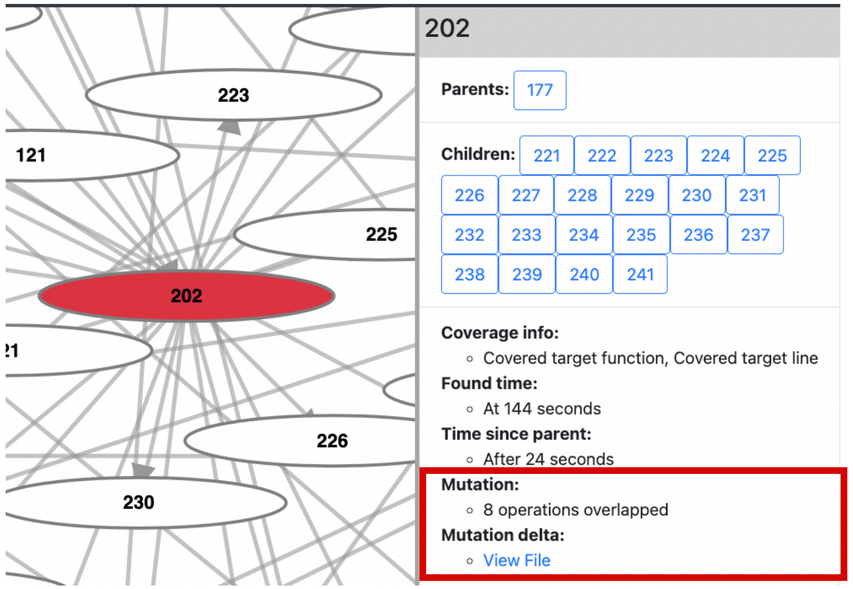


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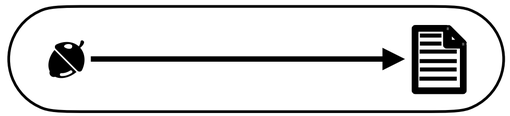
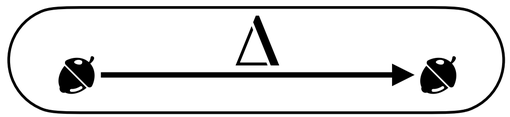
  f6
  02
-00 20
+a6 ab
  4e
  f8
  93
@@ -251,7 +251,7 @@
  03
  12
  34
-4d
+40
  34
  56
  00
```

Data Collection

Metadata per edge

- **What** was the progress?
  - Coverage of target function/line
- **How** was the progress made?
  - Mutation delta between parent-child inputs





Data Collection

Metadata per edge

- **What** was the progress?
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- **How** was the progress made?
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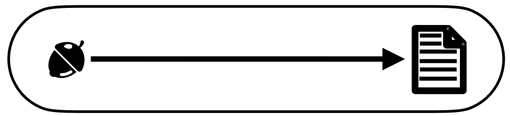
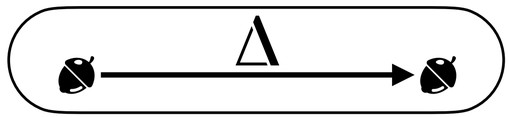
- How **difficult** was the progress?





Data Collection

Metadata per edge

- **What** was the progress?
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- **How** was the progress made?
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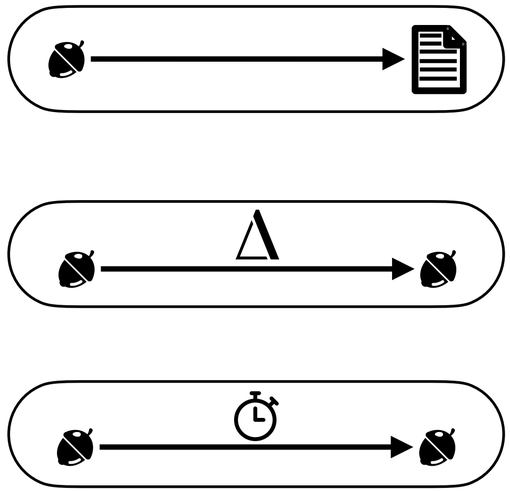
- How **difficult** was the progress?
  - Generation time delta between parent-child inputs



Collecting Time Log

Collecting Time Log

Post-process the generated inputs

Collecting Time Log

Post-process the generated inputs

- After fuzzing, inspect the output directory

Collecting Time Log

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Absolute & Relative time information

Collecting Time Log

Post-process the generated inputs

- After fuzzing, inspect the output directory

Absolute & Relative time information

- Found time

Collecting Time Log

Post-process the generated inputs

- After fuzzing, inspect the output directory

Absolute & Relative time information

- Found time
- Time since parent was found

Collecting Time Log

Post-process the generated inputs

- After fuzzing, inspect the output directory

Absolute & Relative time information

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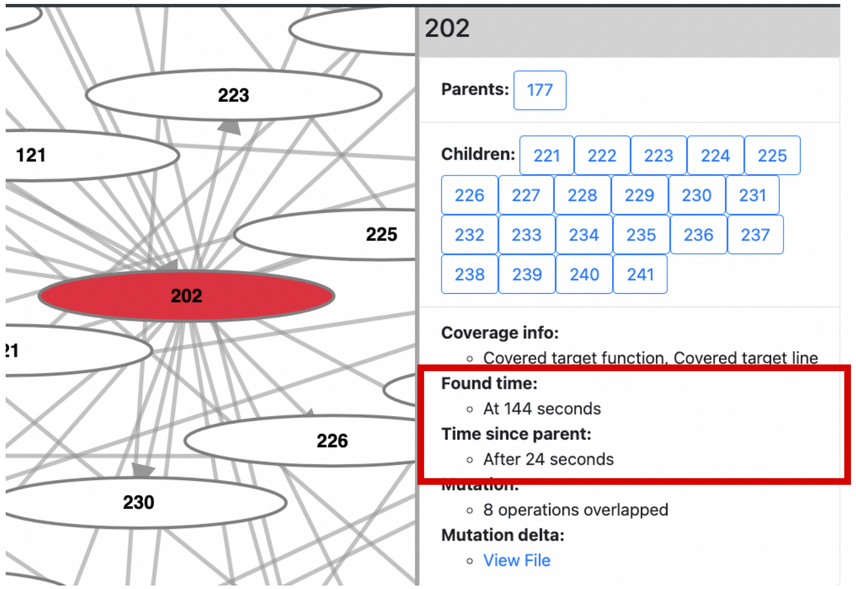

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Metadata per edge

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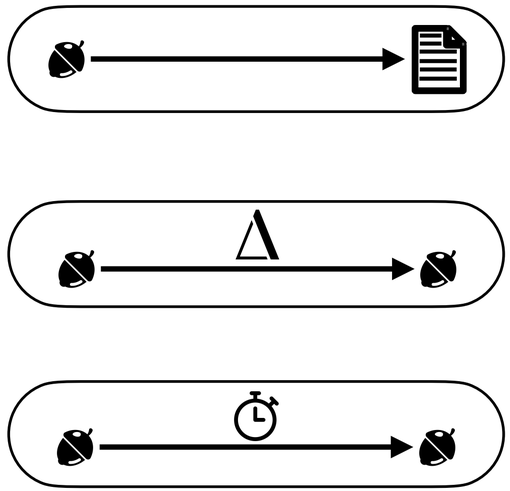

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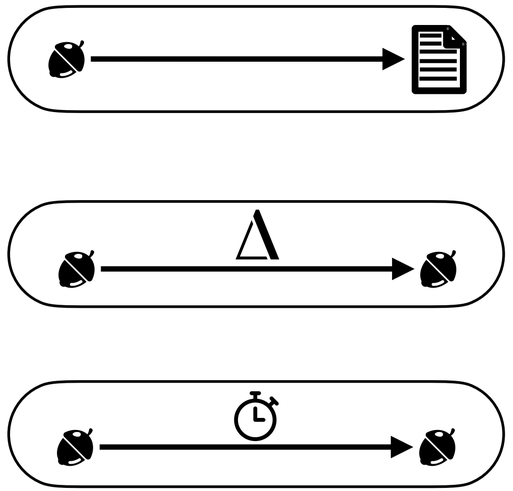
- How **difficult** was the progress?
  - Generation time delta between parent-child inputs



- Independent from fuzzer implementation

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D3: Data visualization library

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- **Scalable**

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  - Zoom in/out, toggle, traversing the graph

Implementation

- **Coverage Instrumentation**
  - LLVM compiler pass

- **Data Parsing**
  - Python and Bash script

- **Visualization**
  - JavaScript, D3 library

Results

Results

GeneVis: Genealogical Visualization Tool for Directed Grey-box Fuzzers

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Future Works

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Coverage Information

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- More fine-grained coverage information

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Mutation Information

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- Identify the critical part of the mutation that caused the progress

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- More fine-grained coverage information

Mutation Information

- Identify the critical part of the mutation that caused the progress
- Connect mutation to the impacted program location

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  - Open up the opportunity to further improve the field of Directed Grey-box Fuzzing