定向覆盖模糊测试工具的设计与实现

毕业设计中期检查

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1. Background
   - Pre-Knowledge
   - Motivation
   - Research Status
2. Theory
3. Work
4. References

What Fuzzing is?

Defination[1]

- **Fuzzing** Fuzzing is the execution of the PUT using input(s) sampled from an input space (the “fuzz input space”) that protrudes the expected input space of the PUT.
  - PUT: Program Under Test
- **Fuzz testing** Fuzz testing is the use of fuzzing to test if a PUT violates a correctness policy.
- **Fuzzer** A fuzzer is a program that performs fuzz testing on a PUT.
- **Bug Oracle** A bug oracle is a program, perhaps as part of a fuzzer, that determines whether a given execution of the PUT violates a specific correctness policy.
- **Fuzz Configuration** A fuzz configuration of a fuzz algorithm comprises the parameter value(s) that control(s) the fuzz algorithm.
- **Seed** A seed is a (commonly well-structured) input to the PUT, used to generate test cases by modifying it.

What Fuzzing is?

Fuzz Testing

Input: $\mathbb{C}$, $\mathtt{t}_{\text{limit}}$

Output: $\mathbb{B}$ // a finite set of bugs

$\mathbb{B} \leftarrow \varnothing$

$\mathbb{C} \leftarrow \texttt{Preprocess}(\mathbb{C})$

while $\mathtt{t}_{\texttt{elapsed}} < \mathtt{t}_{\texttt{limit}} \wedge \texttt{Continue}(\mathbb{C})$ **do**

- $\texttt{conf} \leftarrow \texttt{Schedule}(\mathbb{C}, \mathtt{t}_{elapsed}, \mathtt{t}_{limit})$
- $\texttt{tcs} \leftarrow \texttt{InputGen}(conf)$
- // O_{bug} is embedded in a fuzzer
- $\mathbb{B}', \texttt{execinfos} \leftarrow \texttt{InputEval}(conf, tcs, \mathsf{O}_{bug})$
- $\mathbb{C} \leftarrow \texttt{ConfUpdate}(\mathbb{C}, conf, execinfos)$
- $\mathbb{B} \leftarrow \mathbb{B} \cup \mathbb{B}'$

return $\mathbb{B}$

Fuzzing Algorithm

Input: $\mathbb{C}$, t_{limit}
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while $t_{elapsed} < t_{limit} \wedge$ Continue($\mathbb{C}$) **do**
  conf $\leftarrow$ Schedule($\mathbb{C}$, $t_{elapsed}$, t_{limit})
  tcs $\leftarrow$ InputGen(*conf*)
  // O_{bug} is embedded in a fuzzer
  $\mathbb{B}'$, execinfos $\leftarrow$ InputEval(*conf*, *tcs*, O_{bug})
  $\mathbb{C} \leftarrow$ ConfUpdate($\mathbb{C}$, *conf*, *execinfos*)
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- $\mathbb{C}$:a set of fuzz configurations
- t_{limit}: timeout
- $\mathbb{B}$: a set of discovered bugs

Fuzzing Algorithm

```
Input: ℂ, t_limit
Output: 𝔹 // a finite set of bugs
𝔹 ← ∅
ℂ ← Preprocess(ℂ)
while t_elapsed < t_limit ∧ Continue(ℂ) do
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return 𝔹
```

$\textsc{Preprocess}(\mathbb{C}) \rightarrow \mathbb{C}$

- **Instrumentation**
  - grey-box and white-box fuzzers
  - static/dynamic(InputEval)
- **Seed Selection**
  - weed out potentially redundant configurations
- **Seed Trimming**
  - reduce the size of seeds
- **Preparing a Driver Application**
  - library Fuzzing, kernal Fuzzing

Fuzzing Algorithm

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Stop Condition

- $\mathsf{t}_{\text{elapsed}} < \mathsf{t}_{\text{limit}}$
- CONTINUE ($\mathbb{C}$)$\rightarrow$ {`True`, `False`}
  - Determine whether a new fuzz iteration should occur

Fuzzing Algorithm

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SCHEDULE ($\mathbb{C}$, $t_{elapsed}$, t_{limit}) $\rightarrow$ conf

- **Function**
  - Pick important information(conf)
- **FCS Problem**
  - *exploration*:Spent time on gathering more accurate information on each configuration to inform future decisions
  - *exploitation*:Spent time on fuzzing the configurations that are currently believed to lead to more favorable outcomes

Fuzzing Algorithm

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INPUTGEN (conf) $\longrightarrow$ tcs

- **function**
  - Generate testcases
- **classification**
  - Generation-based(*Model-based*)
  - Mutation-based(*Model-less*)
  - White-box Fuzzers: symbolic execution

Fuzzing Algorithm

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InputEval (conf, tcs, O_{bug})
$\rightarrow \mathbb{B}'$, execinfos

- **Fuzzing PUT**
  - tcs
  - $\mathbb{B}'$
- **Feedback Information**
  - conf, tcs
  - execinfos (tcs,crashes,stack backtrace hash,edge coverage,etc.)

Fuzzing Algorithm

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- ConfUpdate ($\mathbb{C}$, `conf`, `execinfos`) $\rightarrow \mathbb{C}$
  - Update Fuzz Configuration(distinguishablity)
  - Seed Pool Update
- $\mathbb{B} \cup \mathbb{B}' \rightarrow \mathbb{B}$
  - Update Bugs Set

Fuzzing Algorithm

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stop condition

- $t_{elapsed} < t_{limit}$
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Classification

The amount of collected information defines the color of a fuzzer[1].

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```

- **program instrumentation**
  - static
  - dynamic
- processor traces
- system call usage
- etc.

Classification

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Program Instrumentation

- Static
  - source code
  - intermediate code
  - binary-level
- Dynamic

Classification

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```

Program Instrumentation

- Static
- Dynamic
  - dynamically-linked libraries
  - execution feedback: branch coverage, new path, etc.
  - race condition bugs: thread scheduling

Classification

Classification of Fuzzing

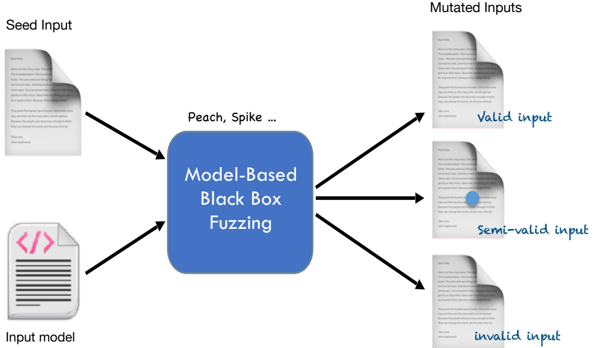
- **Black-box Fuzzing**
  - no program analysis, no feedback
- **White-box Fuzzing**
  - mostly program analysis
- **Grey-box Fuzzing**
  - no program analysis, but feedback

Why Grey-box Fuzzing ?

- Black-box Fuzzing

  Defination: techniques that do not see the internals of the PUT,and can observe only the input/output behavior of the PUT, treating it as a black-box[1].

  -No program analysis, no feedback



Why Grey-box Fuzzing ?

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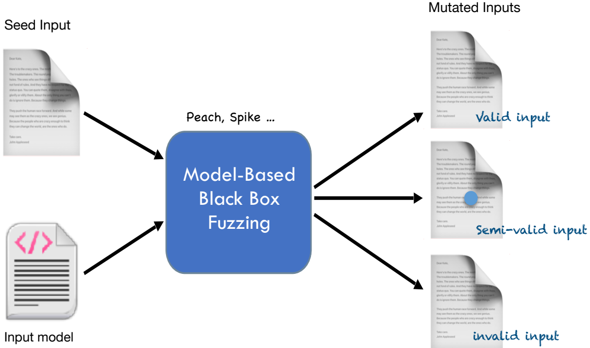


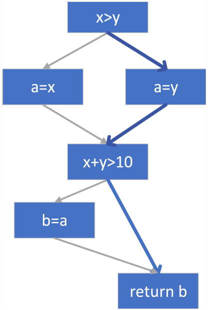
- You have no view of the PUT,but have some view of the input/output domain
- Fuzzing congfigurations are not changed according to some feedback
  - some fuzzer may add the testcases to seed pool
- Not effective

Why Grey-box Fuzzing ?

- White-box Fuzzing

  Defination: techniques that generates test cases by analyzing the internals of the PUT and the information gathered when executing the PUT[1].

  \- Requires heavy-weight program analysis and constraint solving.



Cover more paths

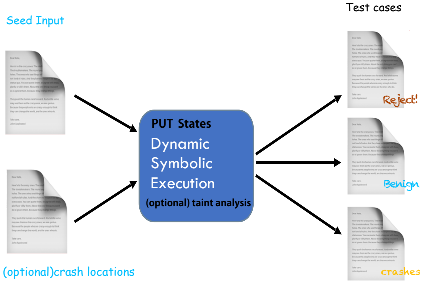
$x \le y \land x+y \le 10$

$x \le y \land \neg x+y \le 10$

$\neg x \le y$

Program Analysis

- **Symbolic Excution**
- **Constrains Satisfation**



Why Grey-box Fuzzing ?

- White-box Fuzzing

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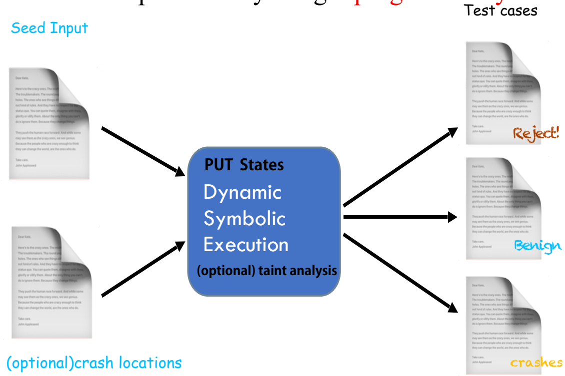


- You have the view of the PUT state(CFG,CG)
- Heavy-weight Program analysis (effective but not efficient!)

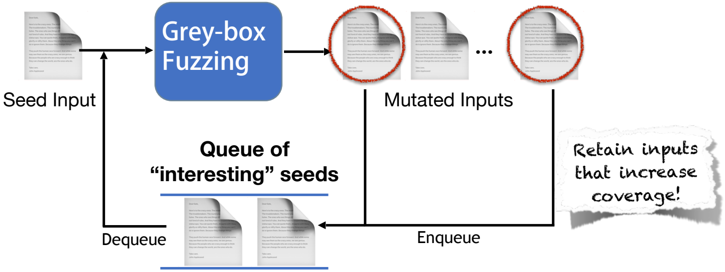
Why Grey-box Fuzzing ?

- Grey-box Fuzzing

  Defination: techniques that can obtain *some* information internal to the PUT and/or its executions to generates test cases[1].

  - Uses only lightweight instrumentation to glean some program structure

  - And coverage feedback



Why Grey-box Fuzzing ?

Grey-box Fuzzing is frequently used

- **State-of-the-art** in automated vulnerability detection
- **Extremely efficient** coverage-based input generation
  - All program analysis before/at instrumentation time.
  - Start with a seed corpus, choose a seed file, fuzz it.
  - Add to corpus only if new input increases coverage.

Why Directed Grey-box Fuzzing ?

Directed Fuzzing has many applications

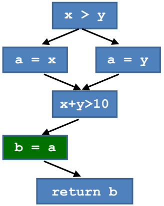
- **Patch Testing**: reach changed statements
- **Crash Reproduction**: exercise stack trace
- **SA Report Verification**: reach "dangerous" location
- **Information Flow Detection**: exercise source-sink pairs

Why Directed Grey-box Fuzzing ?

Directed Fuzzing

- **Goal:reach a specific target**
  - **Target Locations**: the line number in the source code or the virtual memory address at the binary level[2].
  - **Target Bugs**: use-after-free vulnerabilities, etc.

- **DSE:classical constraint satisfaction problem**
  - uses program analysis and constraint solving to generate inputs that systematically and effectively explore the state space of feasible paths[3].
  - **Program analysis** to identify **program paths** that reach given program locations.
  - **Symbolic Execution** to derive **path conditions** for any of the identified paths.
  - **Constraint Solving** to find an input

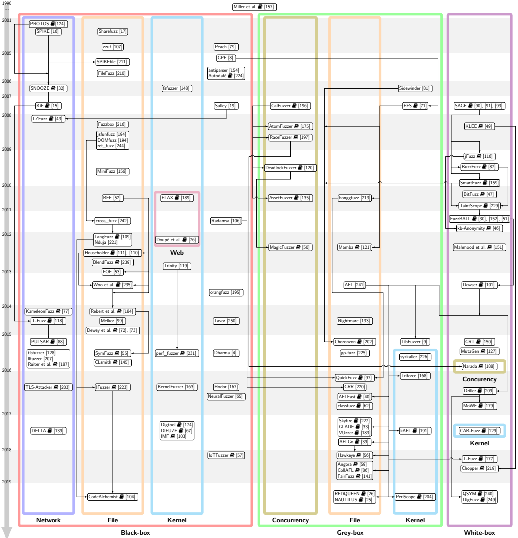


$$\varphi_1 = (x>y) \land (x+y>10)$$
$$\varphi_2 = \neg(x>y) \land (x+y>10)$$

Why Directed Grey-box Fuzzing ?

- **Effectiveness comes at the cost of efficiency**
- **Heavy-weight program analysis**

Genealogy tracing significant fuzzers' lineage[1]



[1] paper[1]-Figure1

Representative Work

- **AFLGo(2017)**[4]
- **Hawkeye(2018)**[5]
- **Github Repository**:awesome-directed-fuzzing
  `https://github.com/strongcourage/awesome-directed-fuzzing`

OverView

Algorithm

Directed Grey-box Fuzzing

```
Input: 𝕊 // a finite set of seeds
Input: 𝕋 // a finite set of targer sits
Output: 𝕊′ // a finite set of buggy seeds
𝕊′ ← ∅
SeedQueue ← 𝕊
Graphs ← GraphExt(Code)
BBdistance ← DisCalcu(𝕋, Graphs)
while true do
    s ← Dequeue(SeedQueue)
    e ← AssinEnergy(s, t_elapsed, BBdistance)
    for i ← 1 to e do
        s′ ← Mutation(s)
        trace ← Execution(s′)
        if s′ crashes then 𝕊′ ← 𝕊′ ∪ s′
        if IsIntersting(s′) then
            distance ← SeedEva(trace, BBdistance)
            SeedQueue ← SortInser(distance, s′, SeedQueue)
    if Siganl then break
return 𝕊′
```

[1] MANÈS V J, HAN H, HAN C, et al. The art, science, and engineering of fuzzing: A survey[J]. IEEE Transactions on Software Engineering, 2019, 47(11) : 2312 – 2331.

[2] WANG P, ZHOU X, LU K, et al. The Progress, Challenges, and Perspectives of Directed Greybox Fuzzing[EB]. arXiv, 2022.

[3] MA K-K, YIT PHANG K, FOSTER J S, et al. Directed symbolic execution[C] // Static Analysis: 18th International Symposium, SAS 2011, Venice, Italy, September 14-16, 2011. Proceedings 18. 2011 : 95 – 111.

[4] BÖHME M, PHAM V-T, NGUYEN M-D, et al. Directed Greybox Fuzzing[C/OL] // Proceedings of the 2017 ACM SIGSAC Conference on Computer and Communications Security. Dallas Texas USA : ACM, 2017 : 2329 – 2344. http://dx.doi.org/10.1145/3133956.3134020.

[5] CHEN H, XUE Y, LI Y, et al. Hawkeye: Towards a Desired Directed Grey-Box Fuzzer[C/OL] // Proceedings of the 2018 ACM SIGSAC Conference on Computer and Communications Security. Toronto Canada : ACM, 2018 : 2095 – 2108. http://dx.doi.org/10.1145/3243734.3243849.

Thanks!