

Lab 7

Software Testing 2023

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#whoami

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GitHub Repo

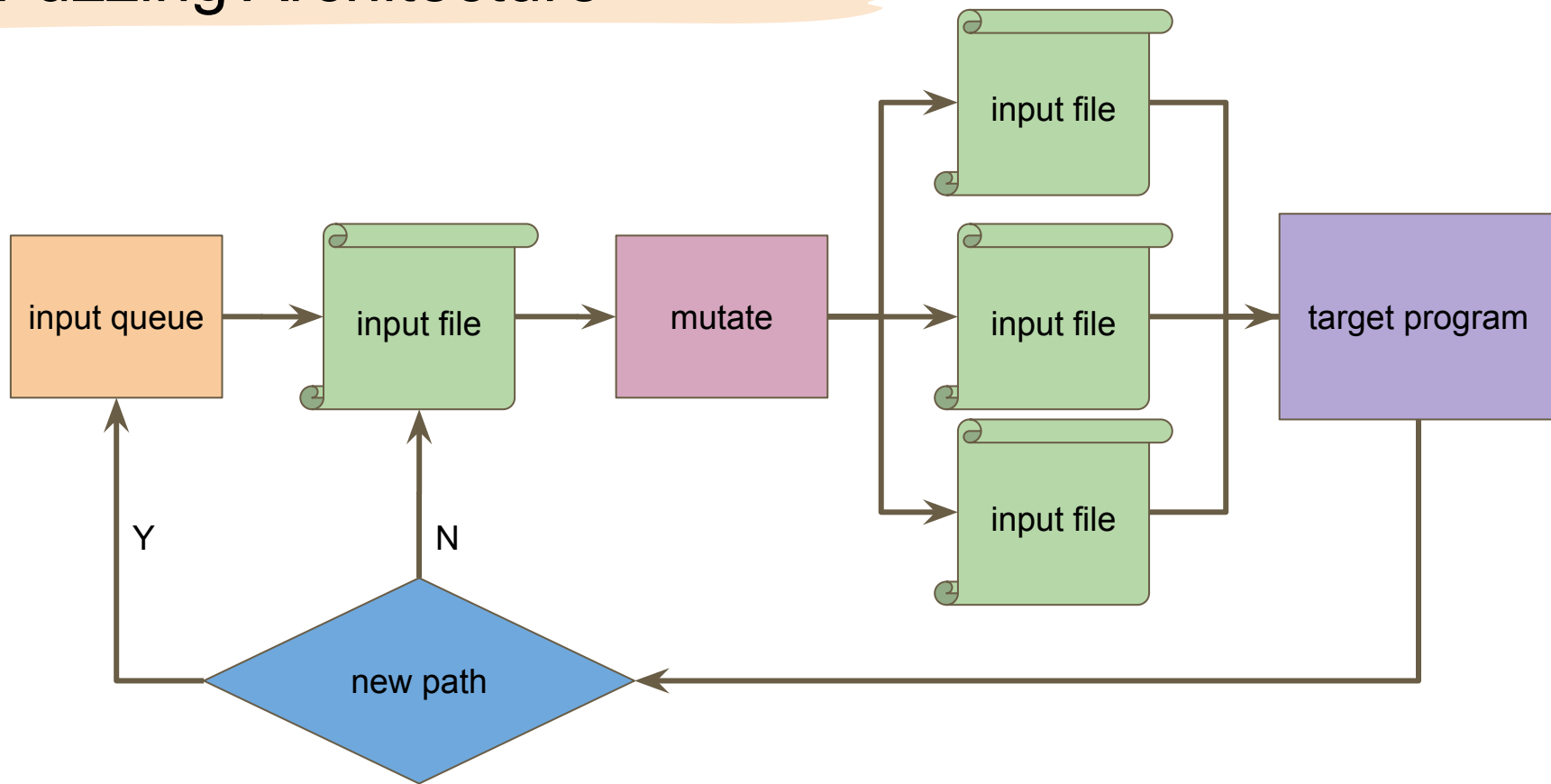
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Fuzz Testing

Traditional testing procedures

- Unit Test
 - Since it is **manual**, it is **difficult** to consider all.
 - Is there any problem with function combination?
 - Are the inputs that are not in the specification segregated?
 - Are some inputs related to internal memory config well handled?
- Can the whole program be tested automatically?

Fuzzing Architecture



Code Coverage

- It is **difficult** to know if the input is good after mutate.
 - Currently, the most common method is based on **code coverage**.
 - Hope to cover the **uncovered** Basic Blocks.
 - Hope to cover the **more** Basic Blocks.

Instrumentation

- How to get the execution status of the program quickly?
 - Have Source Code
 - Instrumentation through compilation tools such as gcc, clang, LLVM, etc.
 - Add specific code in front of each basic block.

```
cur_location = <COMPILE_TIME_RANDOM>;  
shared_mem[cur_location ^ prev_location]++;  
prev_location = cur_location >> 1;
```

- No Source Code
 - Binary direct rewriting
 - Simulator (Qemu, Unicorn, Qiling)

Mutate

- Generate input by mutating existing files
 - **bitflip x/y** : bit flip
 - **arithmetic x/y** : adding or subtracting an integer
 - **interest x/y** : replace the bits with the data of interest
 - ex : INT_MAX , 0
 - **dictionary** : the token provided by the source user, and the token generated by automatic detection
 - **havoc** : combination of multiple mutation methods
 - **splice** : 2 seeds are spliced and havoc is performed

AFL

- Introduced by Google.
- The pioneer of coverage-guided.
- However, there have been no major updates since 2017.
 - So ...

AFL++

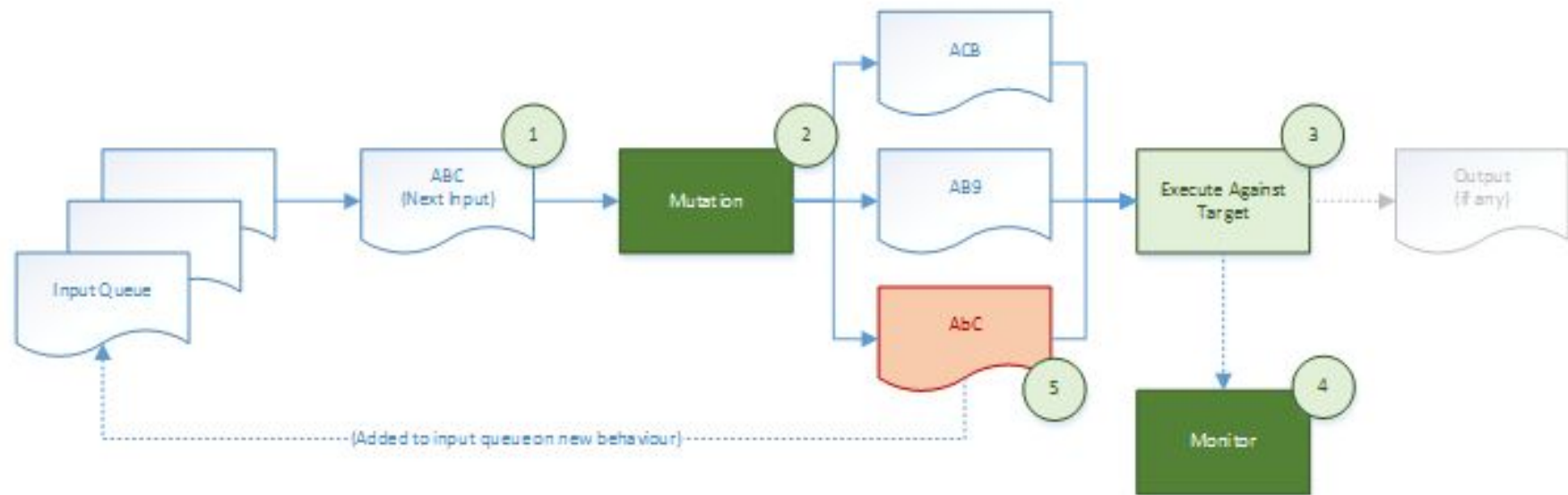
- Extensive fuzz testing community.
- Collection of quality papers and improvements.
- Continuous updates and integration of new fuzzy testing techniques.
 - example : using deep learning, new mutation techniques, etc.



AFL

Simplifying a bit, the overall algorithm can be summed up as:

1. Load user-supplied initial test cases into the queue,
2. Take next input file from the queue,
3. Attempt to trim the test case to the smallest size that doesn't alter the measured behavior of the program,
4. Repeatedly mutate the file using a balanced and well-researched variety of traditional fuzzing strategies,
5. If any of the generated mutations resulted in a new state transition recorded by the instrumentation, add mutated output as a new entry in the queue.
6. Go to 2.



Installation on Linux

```
$ git clone https://github.com/google/AFL.git
```

```
$ cd AFL
```

```
$ make
```

```
$ sudo make install
```

Reference: [doc/INSTALL](#)

Example

libxml2

```
$ git clone https://gitlab.gnome.org/GNOME/libxml2.git
```

```
$ cd libxml2
```

```
$ ./autogen.sh
```

```
$ export CC=~/.AFL/afl-gcc
```

```
$ export CXX=~/.AFL/afl-g++
```

```
$ export AFL_USE_ASAN=1
```

```
$ ./configure --enable-shared=no
```

```
$ make
```

libxml2

```
$ mkdir -p ~/fuzz/in
```

```
$ cp xmllint ~/fuzz/libxml2
```

```
$ cp test/*.xml ~/fuzz/in/
```

Fuzzing with AFL

```
$ cd ~/fuzz
```

```
$ ~/AFL/afl-fuzz -i in/ -o out/ -m none -- ./libxml2 @@
```

Fuzzing

```
$ afl-fuzz -i in/ -o out/ -b 10 -m none -- ./target [argv1] @@ [argv2]
```

- -i dir : seed dir
- -o dir : output dir
- -b CPU_ID : bind the fuzzing process to the specified CPU core
- -m megs: memory limit for child process
- @@ : the location of the input (if NO -> stdin)

american fuzzy lop 2.57b (libxml2)

process timing		overall results
run time : 0 days, 0 hrs, 0 min, 39 sec		cycles done : 0
last new path : 0 days, 0 hrs, 0 min, 2 sec		total paths : 269
last uniq crash : none seen yet		uniq crashes : 0
last uniq hang : none seen yet		uniq hangs : 0
cycle progress	map coverage	
now processing : 0 (0.00%)	map density : 2.26% / 7.91%	
paths timed out : 0 (0.00%)	count coverage : 2.38 bits/tuple	
stage progress	findings in depth	
now trying : arith 8/8	avored paths : 38 (14.13%)	
stage execs : 3424/27.8k (12.31%)	new edges on : 132 (49.07%)	
total execs : 16.8k	total crashes : 0 (0 unique)	
exec speed : 429.7/sec	total tmouts : 0 (0 unique)	
fuzzing strategy yields	path geometry	
bit flips : 149/3280, 31/3279, 15/3277	levels : 2	
byte flips : 0/410, 12/409, 7/407	pending : 269	
arithmetics : 0/0, 0/0, 0/0	pend fav : 38	
known ints : 0/0, 0/0, 0/0	own finds : 226	
dictionary : 0/0, 0/0, 0/0	imported : n/a	
havoc : 0/0, 0/0	stability : 100.00%	
trim : 13.50%/208, 0.00%		

[cpu000: 33%]

Fuzzing - Result

- **queue/** - test cases for every distinctive execution path, plus all the starting files given by the user.
- **crashes/** - unique test cases that cause the tested program to receive a fatal signal (e.g., SIGSEGV, SIGILL, SIGABRT).
- **hangs/** - unique test cases that cause the tested program to time out. The default time limit before something is classified as a hang is the larger of 1 second and the value of the -t parameter.

Lab 7

Lab 7

- We provide a small program that converts bmp from color to grayscale.
 - Use **AFL** to find the file that can trigger the vulnerability.
 - Use **test.bmp** as initial seed.
- Please write a report named README.md/rst placed in lab07 dir in your github repo.
- The report shall contain the following information:
 - PoC: the file that can trigger the vulnerability
 - The commands (steps) that you used in this lab
 - Screenshot of AFL running (with triggered crash)
 - Screenshot of crash detail (with ASAN error report)

Lab 7

- Download target source code from: [NYCU-Software-Testing-2023/Lab07](#)

Lab 7

Build & fuzz with AFL

```
$ cd Lab07
```

```
$ export CC=~/.AFL/afl-gcc
```

```
$ export AFL_USE_ASAN=1
```

```
$ make
```

```
$ mkdir in
```

```
$ cp test.bmp in/
```

```
$ ~/.AFL/afl-fuzz -i in -o out -m none -- ./bmpgrayscale @@ a.bmp
```

Lab 7

```
$ ./bmpgrayscale out/crashes/id:000000* a.bmp
```

Example Output

american fuzzy lop 2.57b (target)

process timing

run time : 0 days, 0 hrs, 0 min, 16 sec
last new path : 0 days, 0 hrs, 0 min, 3 sec
last uniq crash : none seen yet
last uniq hang : none seen yet

cycle progress

now processing : 0 (0.00%)
paths timed out : 0 (0.00%)

stage progress

now trying : bitflip 2/1
stage execs : 1936/3279 (59.04%)
total execs : 7137
exec speed : 423.9/sec

fuzzing strategy yields

bit flips : 149/3280, 0/0, 0/0
byte flips : 0/0, 0/0, 0/0
arithmetics : 0/0, 0/0, 0/0
known ints : 0/0, 0/0, 0/0
dictionary : 0/0, 0/0, 0/0
havoc : 0/0, 0/0
trim : 13.50%/208, n/a

map coverage

map density : 2.26% / 7.79%
count coverage : 2.36 bits/tuple

findings in depth

favorable paths : 38 (17.76%)
new edges on : 104 (48.60%)
total crashes : 0 (0 unique)
total tmouts : 0 (0 unique)

overall results

cycles done : 0
total paths : 214
uniq crashes : 0
uniq hangs : 0

path geometry

levels : 2
pending : 214
pend fav : 38
own finds : 171
imported : n/a
stability : 100.00%

[cpu000: 35%]

```

oceane@lab547 ~/N/Lab07 (main)> ./bmpgrayscale out/crashes/id:000000* a.bmp
[WIDTH]: 285
[HEIGHT]: 301
[PADDING]: 1
=====
==1047564==ERROR: AddressSanitizer: negative-size-param: (size=-1)
  #0 0x7f91c4439c87 in __interceptor_memset ../../../../src/libsanitizer/sanitizer_common/sanitizer_common_interceptors.inc:799
  #1 0x563ad456da11 in bmpConvert /home/oceane/NYCU-Software-Testing-2023/Lab07/bmpgrayscale.c:41
  #2 0x563ad456d47c in main /home/oceane/NYCU-Software-Testing-2023/Lab07/bmpgrayscale.c:62
  #3 0x7f91c4029d8f in __libc_start_call_main ../sysdeps/nptl/libc_start_call_main.h:58
  #4 0x7f91c4029e3f in __libc_start_main_impl ../csu/libc-start.c:392
  #5 0x563ad456d524 in _start (/home/oceane/NYCU-Software-Testing-2023/Lab07/bmpgrayscale+0x1524)

Address 0x7ffc1a3088b0 is located in stack of thread T0 at offset 48 in frame
  #0 0x563ad456d5ff in bmpConvert /home/oceane/NYCU-Software-Testing-2023/Lab07/bmpgrayscale.c:6

This frame has 2 object(s):
  [48, 51) 'pixel' (line 7) <== Memory access at offset 48 is inside this variable
  [64, 118) 'header' (line 8)
HINT: this may be a false positive if your program uses some custom stack unwind mechanism, swapcontext or vfork
(longjmp and C++ exceptions *are* supported)
SUMMARY: AddressSanitizer: negative-size-param ../../../../src/libsanitizer/sanitizer_common/sanitizer_common_interceptors.inc:799 in __interceptor_memset
==1047564==ABORTING

```

Submission

Submission

- Please submit your Github repo `<student_id>-ST-2023` (1) commit URL to E3
- Please submit your URL as link
- commit URL
 - refer to Lab 1 submission

Reference

Reference

- <https://github.com/google/AFL>
- <https://afl-1.readthedocs.io/en/latest/>
- <https://github.com/AFLplusplus/AFLplusplus>
- https://aflplus.plus/docs/technical_details/
- https://aflplus.plus/docs/tutorials/libxml2_tutorial/

