Lec11: Fuzzing

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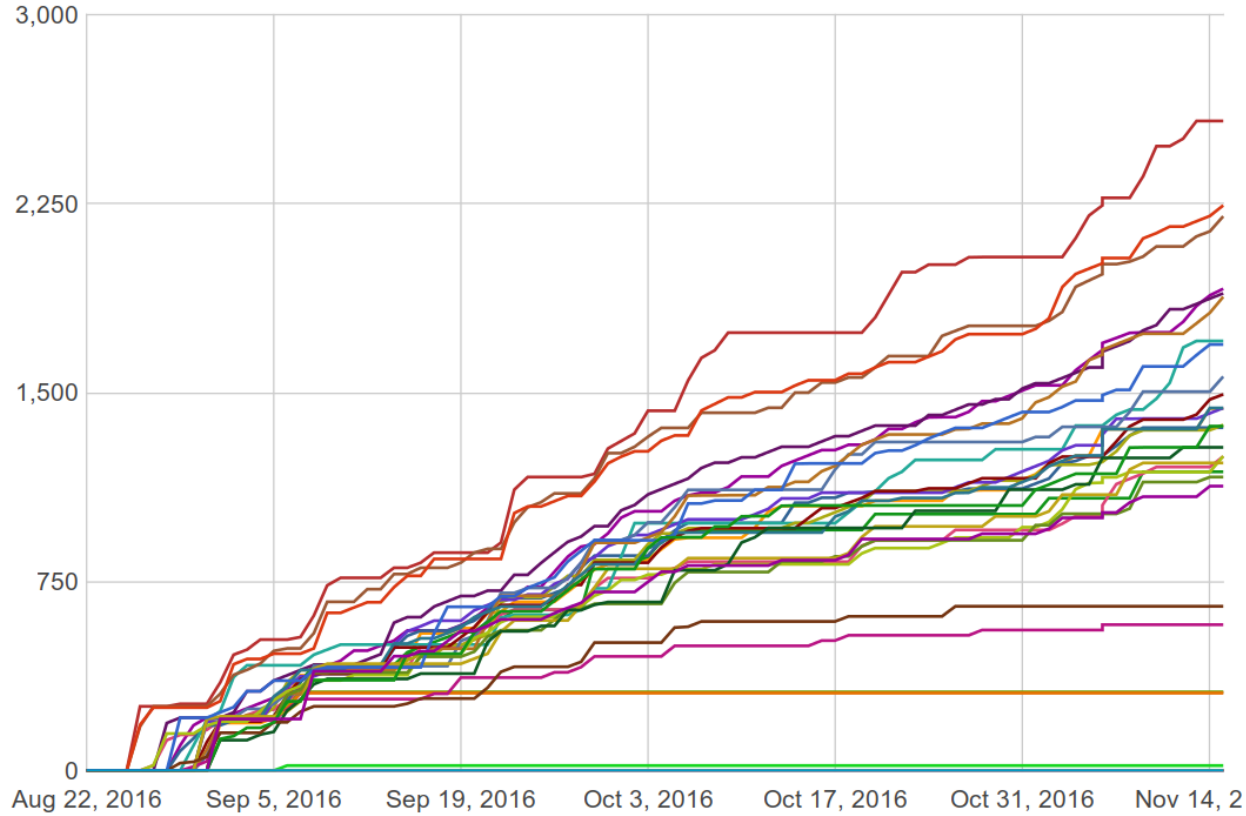
Scoreboard


3,000
2,250
1,500
750
0
Aug 22, 2016
Sep 5, 2016
Sep 19, 2016
Oct 3, 2016
Oct 17, 2016
Oct 31, 2016
Nov 14, 2

NSA Codebreaker Challenges

University	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Georgia Institute of Technology	55	45	41	31	17	4
Carnegie Mellon University	28	26	16	11	5	2
Williams College	1	1	1	1	1	1
Dakota State University	56	40	26	20	8	0
New Mexico Institute of Mining & Technology	13	13	12	11	6	0
Naval Postgraduate School	7	7	6	6	5	0
Arizona State University	22	21	12	9	3	0
University of Colorado at Colorado Springs	14	12	9	9	3	0
University of Hawaii	12	11	9	9	3	0
United States Military Academy	9	8	8	7	3	0

Administrivia

- Welcome to the last lab!
- Two options: 1) sandboxing/kernel or 2) Web exploitation
- Last lecture (Dec 2): real-world exploit (iPhone jailbreaking) + NSA Q&A
- Due: Lab04 / Lab10 / Lab11 on Dec 1
- Let you know your grade on Dec 2 in class

Today: Fuzzing

- intro
- DEMO: fuzzing

So far, focuses are more on "exploitation"

- More important question: how to find bugs?
  - often, with source code
  - but mostly, with only binary

Two Conditions

- Locating a bug (i.e., bug finding)
- Triggering the bug (i.e., reachability)

```
if (magic == 0xdeadbeef)
    memcpy(dst, src, len)
```

Solution 1: Code Auditing (w/ code)

```
if ((err = SSLFreeBuffer(&hashCtx)) != 0)
    goto fail;

if ((err = ReadyHash(&SSLHashSHA1, &hashCtx)) != 0)
    goto fail;
if ((err = SSLHashSHA1.update(&hashCtx, &clientRandom)) != 0)
    goto fail;
if ((err = SSLHashSHA1.update(&hashCtx, &serverRandom)) != 0)
    goto fail;
if ((err = SSLHashSHA1.update(&hashCtx, &signedParams)) != 0)
    goto fail;
    goto fail;
if ((err = SSLHashSHA1.final(&hashCtx, &hashOut)) != 0)
    goto fail;
```

Solution 2: Static Analysis (on binary)

- Reverse Engineering (e.g., IDA)

Problem: Too Complex (e.g., browser)

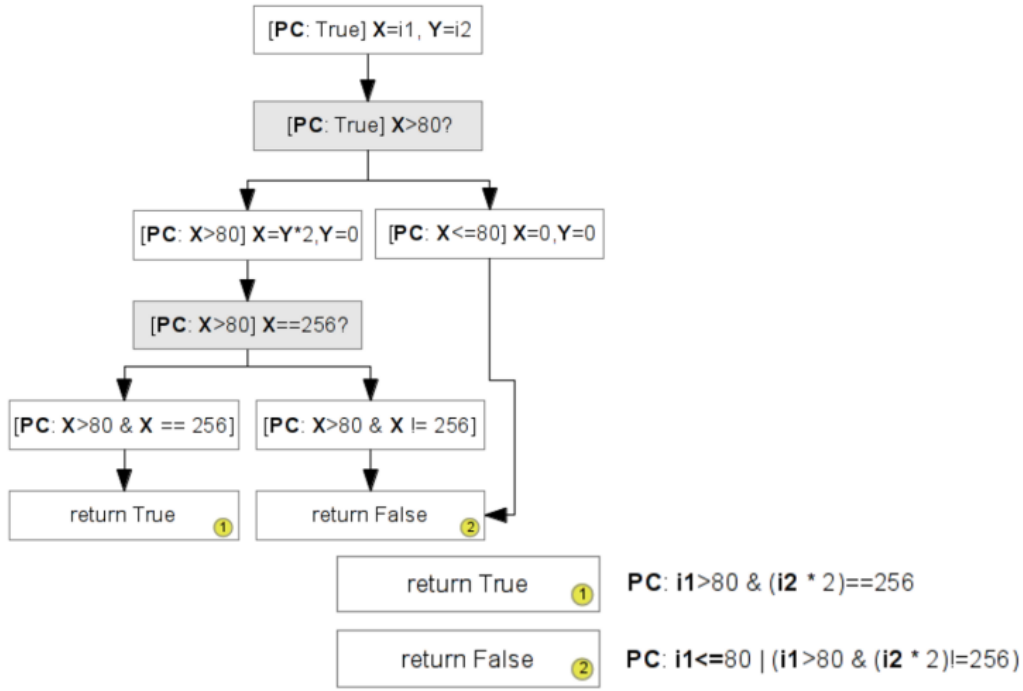
Two Popular Directions

- Symbolic Execution (also static)
- Fuzzing (dynamic)

Symbolic Execution

```
int foo(int i1, int i2)
{
    int x = i1;
    int y = i2;

    if (x > 80){
        x = y * 2;
        y = 0;
        if (x == 256)
            return True;
    }
    else{
        x = 0;
        y = 0;
    }
    /* ... */
    return False;
}
```



Problem: State Explosion

- Too many path to explore (e.g., strcmp("hello", input))
- Too huge state space (e.g., browser? OS?)
- Solving constraints is a hard problem

Today's Topic: Fuzzing

- Two key ideas
  - Reachability is given (since we are executing!)
  - Focus on quickly exploring the path/state
    - How? mutating inputs
    - How well? e.g., coverage

Example: How well fuzzing can explore all paths?

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Game Changing Fact: Speed

- In this example,
  - Symbolic execution explores/checks just two conditions
  - Fuzzing requires 256 times (by scanning values from 0 to 256)
- But, what if fuzzer is an order of magnitude faster (say, 10k times)?

Importance of High-quality Corpus

- In fact, fuzzing is really bad at exploring paths
  - e.g., if (a == 0xdeadbeef)
- So, paths should be (or mostly) given by corpus (sample inputs)
  - e.g., pdf files utilizing full features
  - but, not too many! (do not compromise your performance)
- A fuzzer will trigger the exploitable state
  - e.g., len in malloc()

AFL (American Fuzzy Lop)

- VERY well-engineered fuzzer w/ lots of heuristics

Examples of Mutation Techniques

- interest: -1, 0x8000000, 0xffff, etc
- bitflip: flipping 1,2,3,4,8,16,32 bits
- havoc: random tweak in fixed length
- extra: dictionary, etc
- etc

Key Idea: Mapping Input to State Transitions

- Input → [IPs] (problem?)

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Key Idea: Mapping Input to State Transitions

- Input → [IPs] (problem?)
- Input → map[IPs % len] (problem? A→B vs B→A)
- Input → map[(prevIP >> 1 ^ curIP) % len] (problem?)
- Input → map[(rand1 >> 1 ^ rand2) % len]

Key Idea: Avoiding Redundant Paths

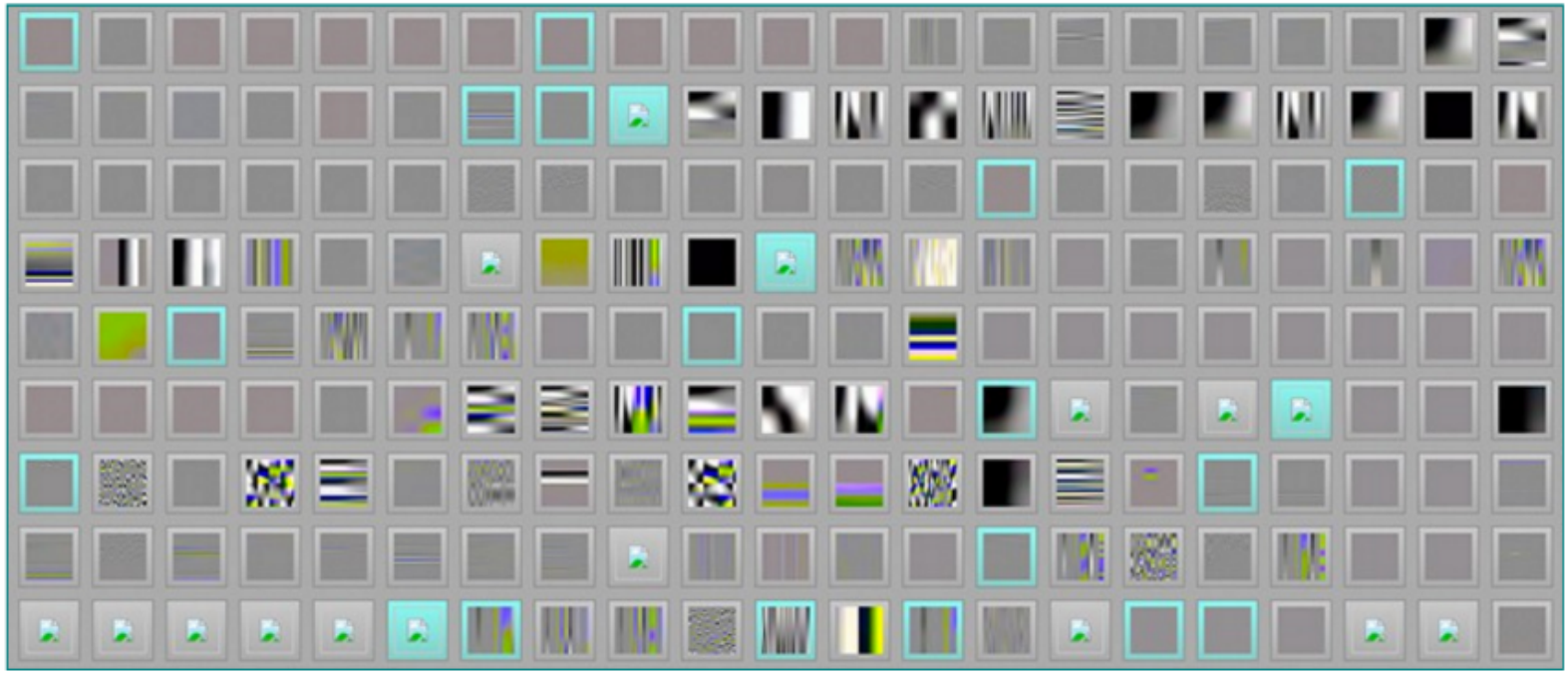
- If you see the duplicated state, throw out
  - e.g., i1 = 1, 2, 3
- If you see the new path, keep it for further exploration
  - e.g., i1 = 81

How to Create Mapping?

- Instrumentation
  - Source code → compiler (e.g., gcc, clang)
  - Binary → QEMU

```
if (block_address > elf_text_start && block_address < elf_text_end) {
  cur_location = (block_address >> 4) ^ (block_address << 8)
  shared_mem[cur_location ^ prev_location] ++;
  prev_location = cur_location >> 1;
}
```

AFL Arts



Other Types of Fuzzer

- Radamsa: syntax-aware fuzzer
- Cross-fuzz: function syntax for Javascript
- langfuzz: fuzzing program languages
- Driller: fuzzing + symbolic execution

Today's Tutorial

- In-class tutorial:
  - Fuzzing with source code
  - Fuzzing on binary
  - Fuzzing a real-world program

In-class Tutorial

```
$ git git@clone tc.gtisc.gatech.edu:seclab-pub cs6265
or
$ git pull
$ cd cs6265/lab11
$ ./init.sh

$ cd tut
$ cat README
```