CS261: 02/10 Scribe Notes
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# Fuzzing

**Overview of security testing and fuzz testing:**

Trying to use testing to detect bugs or vulnerabilities in a program. Similar to static analysis.
Made up of test case generation + bug oracle.
You find some way of the creating test cases -> run the program under tests -> bug oracle (tells you if the output/state is good or bad. Crashes are easy to detect and clear sign of vulnerability).

Bug Oracle:

- Does it crash? (most common)
- Any runtime monitor (bounds checking). i.e. Valgrind.

Fuzz testing: random test cast generation.

- Earliest type: random input. Usually works poorly, because there are practically infinite combinations of random bytes and odds are you won't find the appropriate sequence to trigger some behavior.
- Random mutation: take some input and then randomly mutate it. Usually looks at the output to determine if a bug was found. Decent.
- AFL (grey-box): Rather than modifying inputs randomly, do it in a smarter way. It focuses on the execution path and knows how to emphasis mutating "interesting" test cases. **Game changer**. Helped finding many safety bugs.
    - Minimization: avoids running the same path even when given different input files (if they include the same execution paths)

**Magic Bytes:**

A png file, for example, can contain validation chunks that the program checks before executing. Fuzzing is unlikely to fuzz a file to contain those.

Say we're given the two following chunk check-up schemes:

```
If (a[0] == 0xAE) {
        If (a[1] == 0x3C) {
                If (a[2] == 0x79) {
                        f() .....}}}
```

==> ~4*2^8 test cases until f() is triggered

```
If (a[0...3] == 0xAE3C7920) {
        f() {
```

==> ~2^32 test cases until f() is triggered

Could a compiler do anything to make this easier? Yes. For example, a compiler could convert method 2 to method 1.
Or, you could have coverage: anytime you make a comparison and it fails, you can count the longest prefix that has been matched. Coverage (line of code, how many bits matched)

**Checksums:**
Example code:
If (checksum(a[0...n-3]) != a[n-4...n-1])
    error()
Somewhat similar to magic bytes, but could be changed dynamically.

**Differential testing:**

- bug oracle checks if f(x) == g(x) == h(x).
- Parse(unparse(parse(s))) == parse(s)

**<u>Symbolic execution:</u>**
Similar to fuzz testing, but the test case generation is smarter:
How to do it:

- Given a path through the code: is there any input that follows that path and causes a bug?
    - z = 1/x --> assert (x != 0); z = 1/x
- Given a path through the code: is there any input that follows a different path?
    - x = inputs; v = variables; v == f(x) & PC(x,v).
    - Notice: PC is a **path constraint.** Some sort of SAT, for example.
        - v == f(x) & PC(x,v) & v == 0

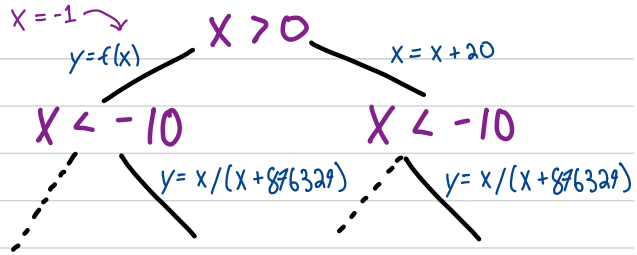
Discussion: How can it detect buffer overruns? Like array out of bounds:

- Bounds checking problem. We can use any bounds checking scheme.
- To check any vulnerability, add whatever checking scheme as assert statements, then run the symbolic executor.

# Quick discussion on the over-constraint problem and QSYM's solution

```
if X > 0
   X = X + 20
else
   y = f(x)

if X < -10
   y = X/(X+876329)
```




**Q1** Is there a divide-by-zero error in this code?

**Q2** How would a symbolic execution-like tool find it?

**a.** How would such an engine deal with f? (f is unknown/too big/binary/...)

* 5 minutes symbolically executing the example including discussion of what to do with f
  - treat as UF
  - try to model (write a spec or summarize)
  - symbolically execute inside (non modular)
  - concretize and call (and add concretization to path constraint)

**Q3** if concretize, then say we concretize X to -1 just before calling f. What happens now?

QSYM combines fuzzing with symbolic execution to catch these corner cases — but that wouldn't help here. Their goal is to explore as much of the target program as fast as possible.

**Q4** How can we fix this overconstrained issue?

**Q5** QSYM will look at a subset (specifically the last constraint). Will this work here?

How to deal with external procedure calls?
What is the overconstrained problem?
Can we select subset of constraints to solve? } start with last one
which ones and why?
what happens if we're wrong?
- our model is wrong
- we say unsat again but it actually is sat

Their contributions:
- instruction level symbolic execution
- optimistic constraint solving *
- basic block pruning