CMPT 473
Software Testing, Reliability and Security

Random Testing

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How might this be pragmatically useful?

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} We'll discuss these more later.
The need not be random.

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Found buffer overflows (25%-33% of programs).

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- Techniques have evolved along several dimensions
  - Is an initial test suite required?
  - How are new tests generated?
  - How does the success / failure of previous tests affect test generation?
  - What kinds of bugs can be found?

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  - Even more state of the art approaches blend generation & mutation further

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  - What about binary file formats? Wire protocols?
  - Specifications may include richer information about values, structure, and dependences

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  - e.g. (https://github.com/MozillaSecurity/peach/blob/master/Pits/Files/WebVTT/vtt.xml)

```xml
<DataModel name="_Timestamp">
  <String name="Hour">
    <Hint name="NumericalString" value="true"/>
  </String>
  <String name="Seperator" value=":" token="true"/>
  <String name="Minute">
    <Hint name="NumericalString" value="true"/>
  </String>
  <String name="Period" value="." token="true"/>
  <String name="Second">
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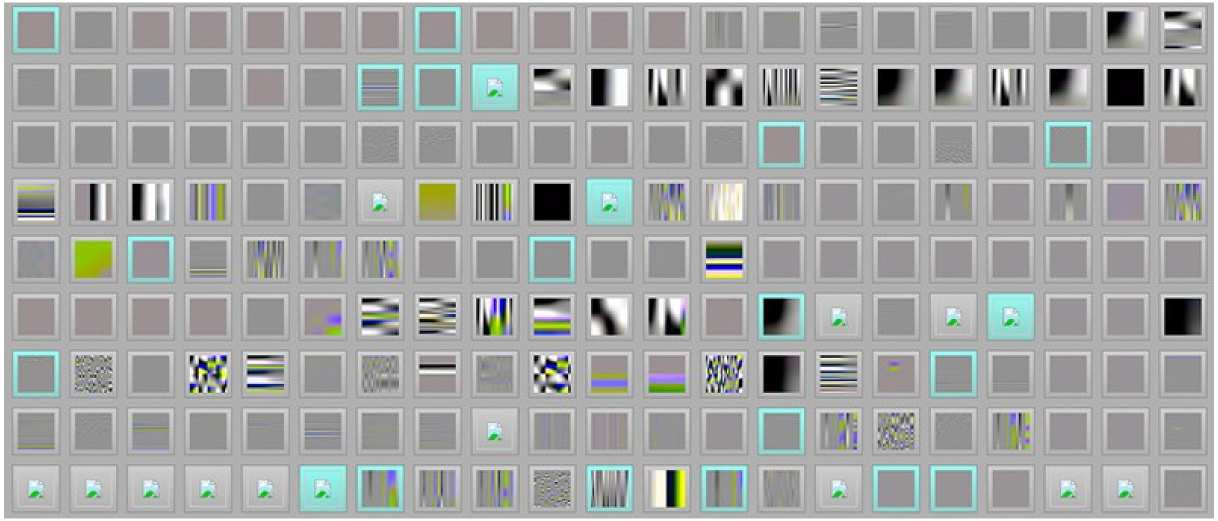
Pulling JPEGS out of thin air

[Zalewski, 2014]



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  - The power comes from the fitness heuristics
- *Coverage Guided Fuzzing* (CGF)
  - Use some notion of test coverage
  - Evolve a test suite toward more coverage

Mutational Fuzz Testing

This is just the big picture.
Many optimizations complicate
an implementation.

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S <- initial corpus
total_coverage <- {}
repeat
    for i in S:
            if sample P(i) then
                i' <- mutate(i)
                coverage <- execute(i')
                if coverage not in total_coverage:
                    S <- S and {i'}
                    total_coverage.add(coverage)
until timeout
return S
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Even simple coverage heuristics are powerful

- Let us consider just statement coverage

```
void
foo(char a, char b) {
  if (a > 127) {
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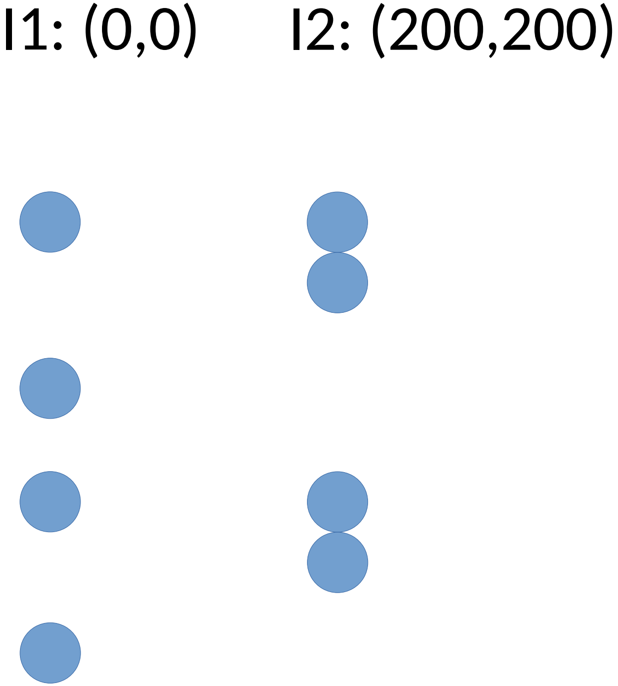

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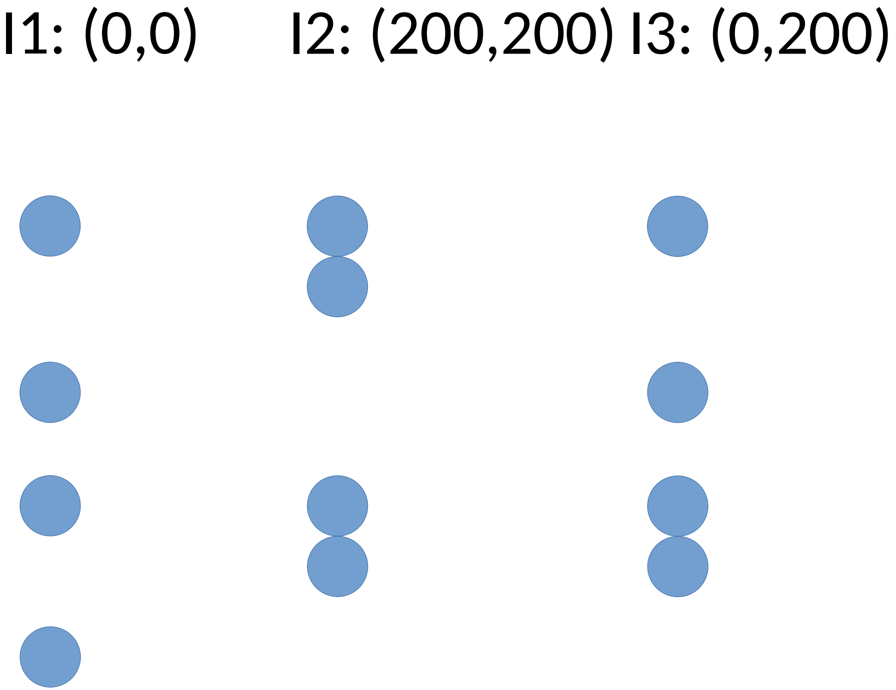

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I1: (0,0) I2: (200,200) I3: (0,200) I4: (200,0)

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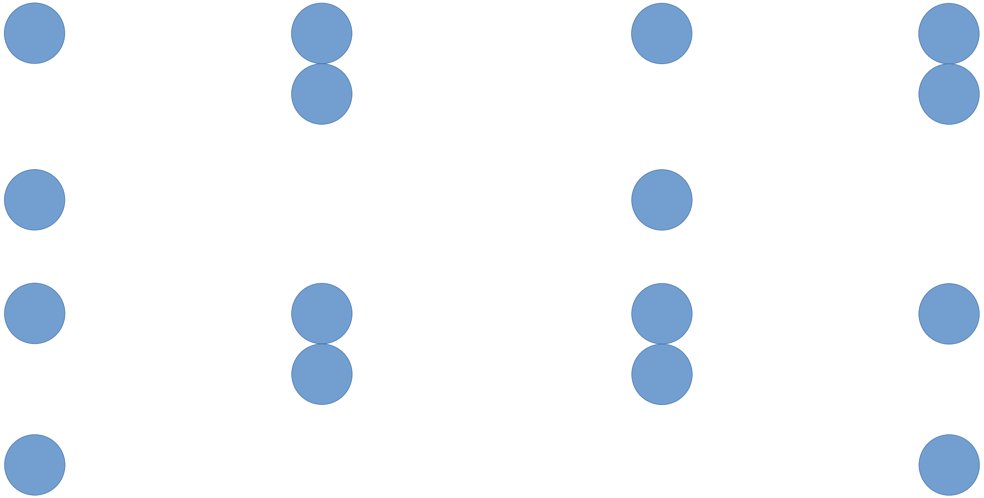

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```
void
foo(long a, long b) {
  if (a == 112358) {
    ...
  else {
    ...
  }
  if (b == 4879235) {
    ...
  } else {
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Covering both true branches
feels like finding a needle in a haystack!

What can we do?

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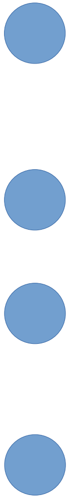

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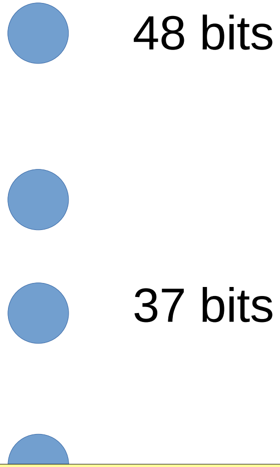

Adding notions of coverage can steer the evolution however we desire

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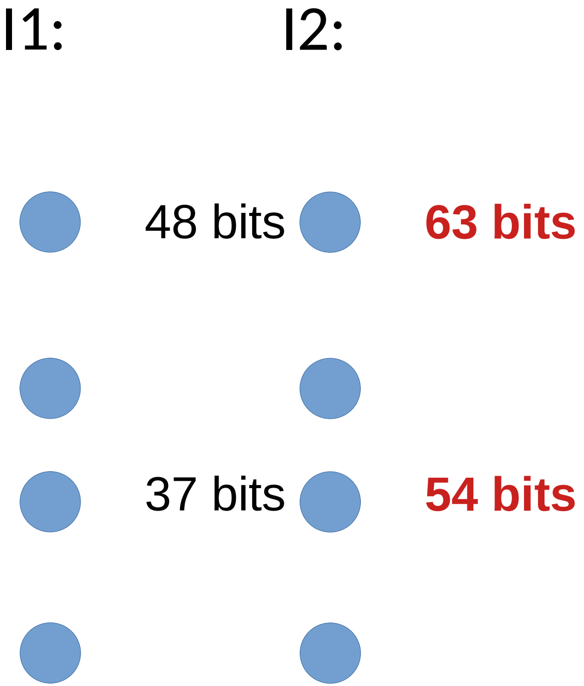

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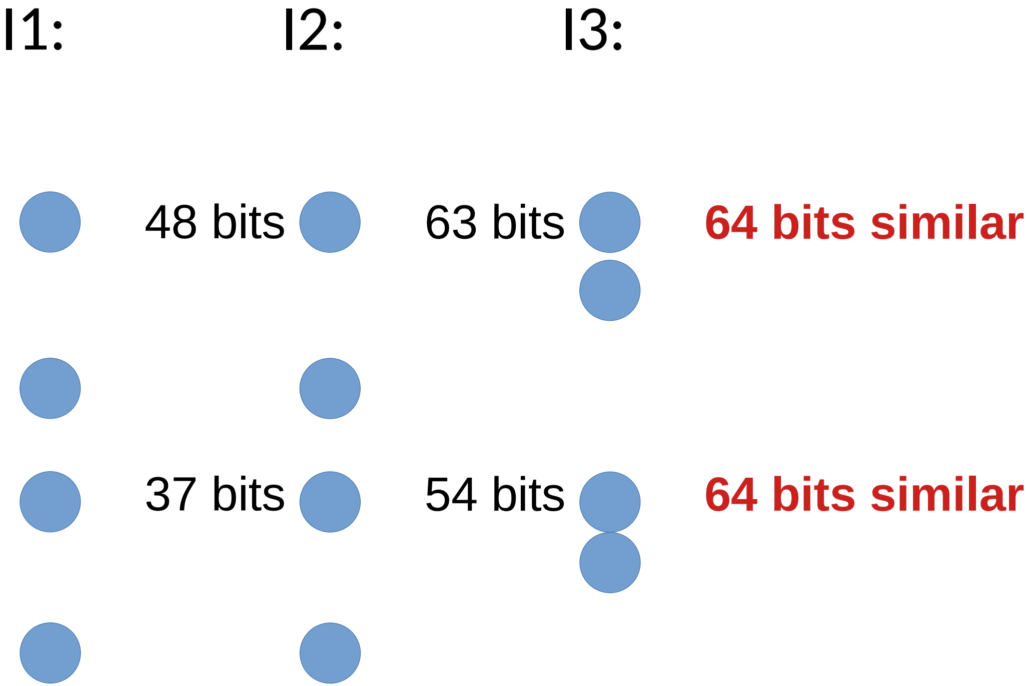

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    ...
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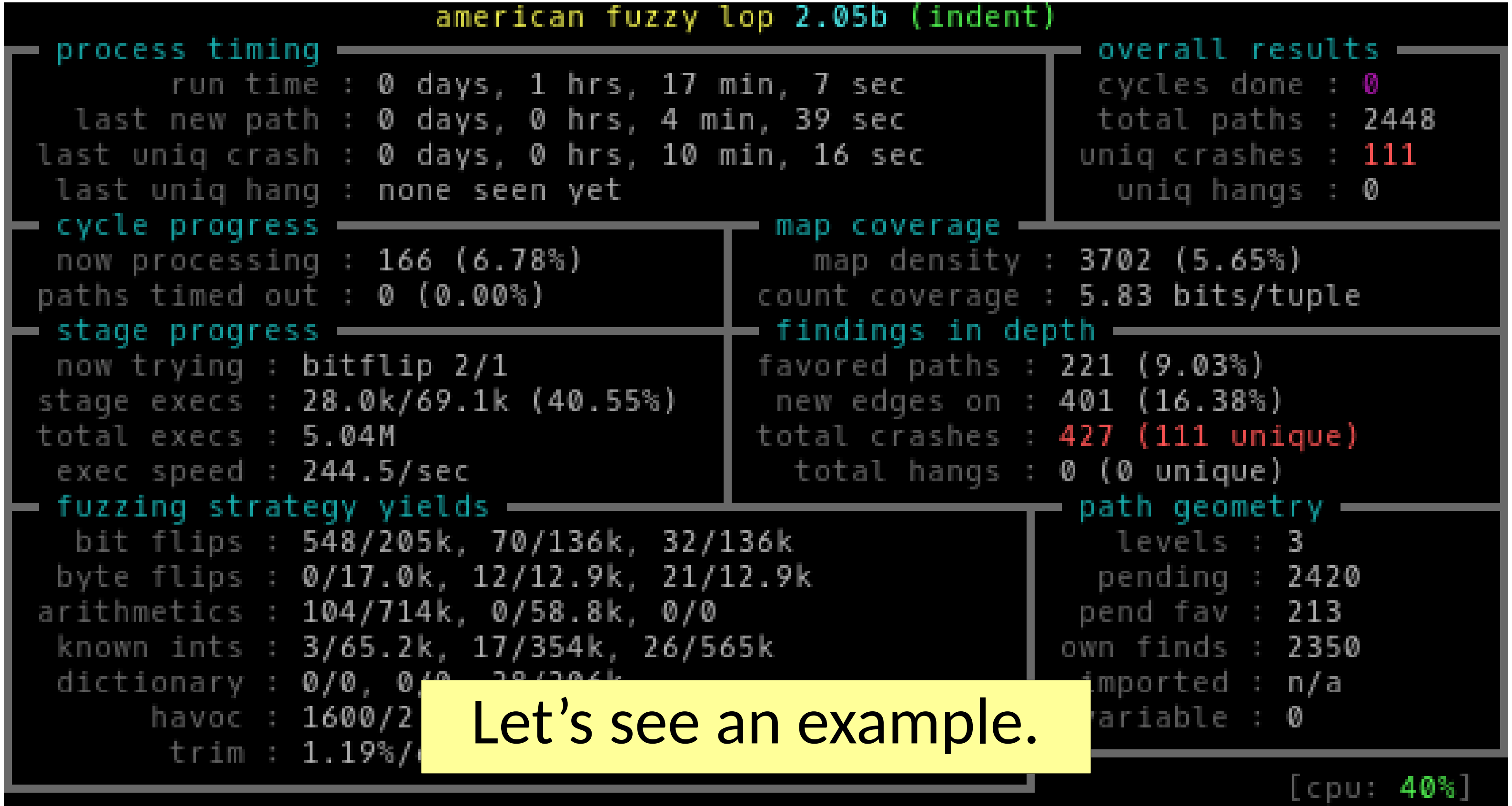
American Fuzzy Lop

- (AFL) is one commonly used fuzzer that was supported by Google



Let’s see an example.

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- Metamorphic Testing
  - Identify key properties that enable correct results to be known relative to mutations (e.g. graphics drivers, machine learning, …)

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- Making use of nuanced oracles can be challenging in practice
- It can be most effective at a whole program or single function level

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  - Generate a sequence of such operations randomly to explore API behavior

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  - Generate a sequence of such operations randomly to explore API behavior
  - Use coverage feedback again to guide the process

Feedback Directed Random Testing

- In practice, *input* fuzzing may not apply
  - What if the thing we want to test is an API rather than a program?
  - What if it is an object oriented API?
- It can be preferable to generate some other model of behavior
- Feedback Directed Random Testing
  - Consider a unit test with *Arranging*, *Acting*, and *Asserting*
  - Generate a sequence of such operations randomly to explore API behavior
  - Use coverage feedback again to guide the process
- Available through such tools as Randoop, GRT, …

Feedback Directed Random Testing

```
TEST(...,...) {
  Triangle t{1,1,1};













}
```

Feedback Directed Random Testing

```
TEST(...,...) {

}
```

```
TEST(...,...) {
  Triangle t{1,1,1};
  t.isEquilateral();

}
```

Feedback Directed Random Testing

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TEST(...,...) {
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TEST(...,...) {
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```

```
TEST(...,...) {
  Triangle t{1,1,1};
  t.isEquilateral();
  Triangle t2{1,2,1};
}
```

Feedback Directed Random Testing

```
TEST(...,...) {
  TEST(...,...) {
    TEST(...,...) {
      TEST(...,...) {
        Triangle t{1,1,1};
        t.isEquilateral();
        Triangle t2{1,2,1};
        t2.contains(t1);
      }
    }
  }
}
```

Feedback Directed Random Testing

```
TEST(...,...) {
  TEST(...,...) {
    TEST(...,...) {
      TEST(...,...) {
        TEST(...,...) {
          Triangle t{1,1,1};
          t.isEquilateral();
          Triangle t2{1,2,1};
          t2.contains(t1);
          ...
        }
      }
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  }
}
```

Challenges in Feedback Directed Random Testing

- What notions of coverage are good?
  - Sometimes a sequence extension does not add value

Challenges in Feedback Directed Random Testing

- What notions of coverage are good?
  - Sometimes a sequence extension does not add value
- Oracles, again
  - Simple contracts & exceptions are easy
  - Invariant violation?
  - Near invariants?
  - Alternate schedules?

Summary

- Random testing strategies provide a means of continuous testing

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- Random testing strategies provide a means of continuous testing
- They can be surprisingly effective in practice
- Effective application to a specific problem may require tailoring a tool