CMPT 473
Software Testing, Reliability and Security

Property Based Testing

Nick Sumner
wsumner@sfu.ca

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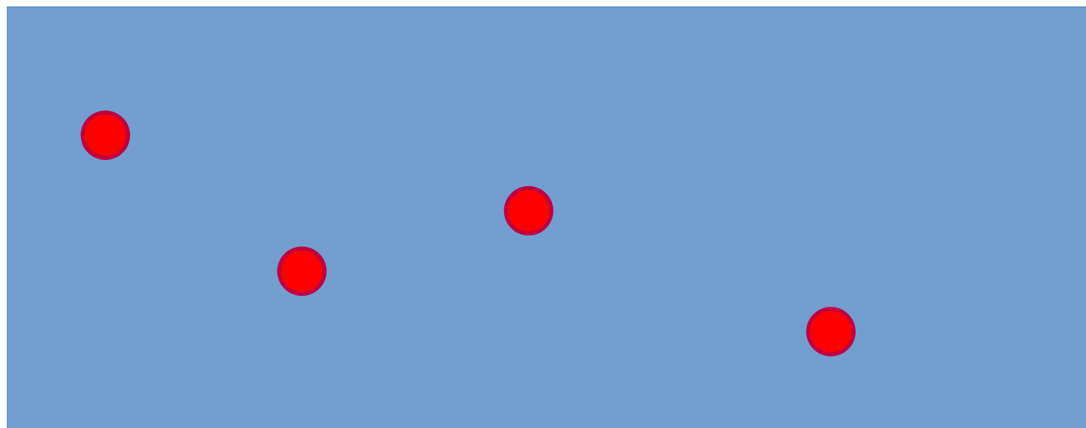

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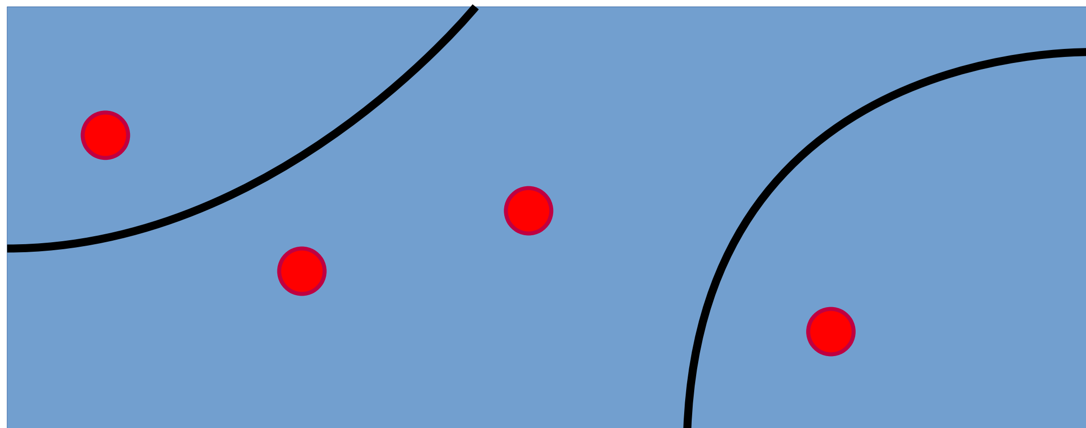

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You can already see how it relates to fuzzing & symbolic execution!

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- The emphasis is on defining (1) the scenario & (2) the oracle
- And we can use test generation strategies that we have already seen!
  - random testing
  - symbolic execution

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  - Focus *was* on generating many random tests from rich type information
  - Test case reduction was also automatically applied
  - Now includes symbolic execution as a means of generation

Property Based Testing

- Traditional testing can be seen as example based

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$$\forall x : x > 0$$

$$\forall x , y, z: \varphi(x,y,z) \rightarrow \psi(x, y, z)$$

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- For random sampling, *generators* provide ways to sample complex types
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  - Some domains may require substantial initial effort (similar to fuzzing)
- Because the process is so specification focused,
  it can also help developers understand the intent of their own code

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  - Symmetry `encode(decode(x)) == x`
  - Alternatives `bubblesort(x) == qsort(x)`
  - Induction `car(cons(head,tail)) == head`
  - Idempotence `qsort(qsort(x)) == qsort(x)`
  - Invariants `qsort(x).size() == x.size()`

Digging Deeper

- What are good properties to check for a sorting function?

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def sort(x):
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- What if we have a sort over only one field?
- The actual properties to check can be more subtle than they appear!

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  - What happens if you change an API with normal unit tests?
  - What happens with property based tests?
- Failing test cases even have test case reduction applied

In Practice: Hypothesis

- Hypothesis [https://hypothesis.works/]
  - Python, Java, …
  - Presently uses random testing
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from hypothesis import given
from hypothesis.strategies import text

@given(text())
@example('')
def test_decode_inverts_encode(s):
  assert decode(encode(s)) == s
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```
@composite
def distinct_strings_with_common_characters(draw):
  x = draw(text(), min_size=1)
  y = draw(text(alphabet=x))
  assume(x != y)
  return (x, y)
```

- A rich set of primitives is available for more complex generator needs

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  - C and C++ focused
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```
TEST(PrimePolynomial, OnlyGeneratesPrimes_NoStreaming) {
  symbolic_unsigned x, y, z;
  DeepState_Assume(x > 0);
  unsigned poly = (x * x) + x + 41;
  DeepState_Assume(y > 1);
  DeepState_Assume(z > 1);
  DeepState_Assume(y < poly);
  DeepState_Assume(z < poly);
  DeepState_Assert(poly != (y * z));
  DeepState_Assert(IsPrime(Pump(poly)));
}
```

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- By focusing more on goals rather than examples,
  it can have benefits even outside of testing
- Adoption can still require effort in defining good generators