CSE 331
Software Design & Implementation

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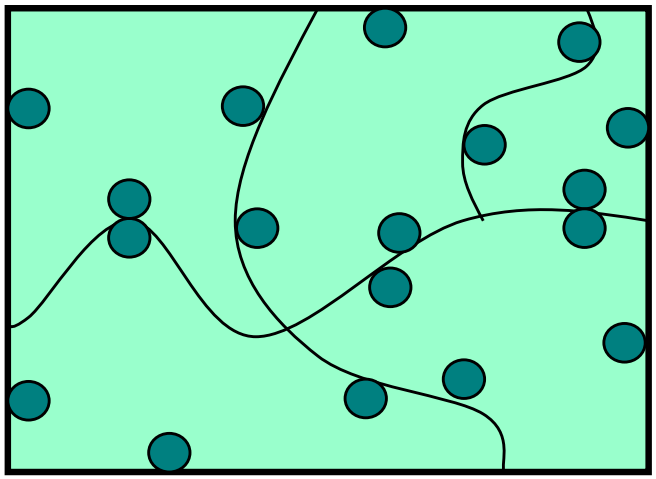
Testing

How many tests is enough?

Correct goal should use **revealing subdomains**:

- one from the middle of each subdomain
- examples along the boundaries of each subdomain



How many tests is enough?

Common goal is to achieve high **code coverage**:

- ensure test suite covers (executes) all of the program
- assess quality of test suite with % *coverage*
  - tools to measure this for you

Assumption implicit in goal:

- if high coverage, then most mistakes discovered
- **far** from perfect but widely used
- low code coverage is definitely bad

Code coverage: statement coverage

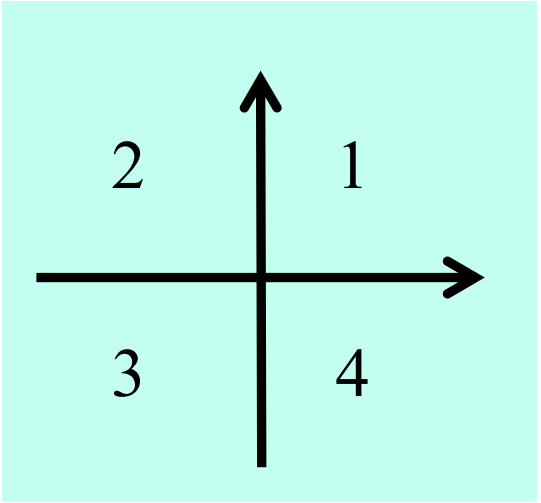
```
int min(int a, int b) {
    int r = a;
    if (a <= b) {
       r = a;
    }
    return r;
}
```

- Consider any test with $a \leq b$ (e.g., `min(1,2)`)
  - executes every instruction
  - misses the bug

- *Statement* coverage is not enough

Code coverage: branch coverage

```
int quadrant(int x, int y) {
  int ans;
  if (x >= 0)
    ans=1;
  else
    ans=2;
  if (y < 0)
    ans=4;
  return ans;
}
```



- Consider two-test suite: (2,-2) and (-2,2). Misses the bug.
- *Branch coverage* (all tests "go both ways") is not enough
  - here, *path coverage* is enough (there are 4 paths)

Code coverage: path coverage

```
int countPositive(int[] a) {
    int ans = 0;
    for (int x : a) {
      if (x > 0)
        ans = 1; // should be ans += 1;
    }
    return ans;
}
```

- Consider two-test suite: [0,0] and [1]. Misses the bug.
- Or consider one-test suite: [0,1,0]. Misses the bug.

- *Path coverage* is enough, but *no bound* on path-count!

Code coverage: what is enough?

```
int sumOfThree(int a, int b, int c) {
  return a+b;
}
```

- *Path coverage* is not enough
  - consider test suites where **`c`** is always 0

- Typically a "moot point" since path coverage is unattainable for realistic programs
  - but do not assume a tested path is correct
  - even though it is more likely correct than an untested path

- Another example: buggy **`abs`** method from earlier in lecture

Varieties of coverage

Various coverage metrics (there are more):

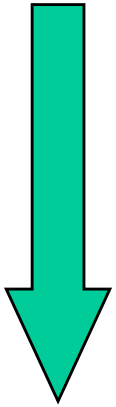
Statement coverage

Branch coverage

Loop coverage

Condition/Decision coverage

Path coverage



increasing number of test cases required (generally)

Limitations of coverage:

1. 100% coverage is not always a reasonable target
   - may be *high cost* to approach 100%
2. Coverage is *just a heuristic*
   - we really want the revealing subdomains for the errors present

Summary of Heuristics

- Split subdomains on boundaries appearing in the specification
- Split subdomains on boundaries appearing in the implementation
- Test boundaries that commonly lead to errors
- Test special cases like nulls, empty arrays, 0, etc.
- Tests to exercise every branch of the code
  - all paths would be even nicer (but not always possible)
- Test any cases that caused bugs before (to avoid regression)

On the other hand, don't confuse *volume* with *quality* of tests

- look for revealing subdomains
- want tests in every revealing subdomain not **just** lots of tests

Testing Tools

- Modern development ecosystems have built-in support for testing
- Your homework introduces you to Junit
  - standard framework for testing in Java
- Continuous integration
  - ensure tests pass **before** code is submitted
- You will see more sophisticated tools in industry
  - libraries for creating mock implementations of other modules
  - automated tools to test on every platform
  - automated tools to find severe bugs (using AI)
  - …

Testing Tips

- Write tests both **before** and **after** you write the code
  - (only clear-box tests need to come afterward)
- Be systematic: think through revealing subdomains & test **each one**
- Test your tests
  - try putting a bug in to make sure the test catches it
- Test code is different from regular code
  - changeability is less important; **correctness** is more important
  - do not write **any test code** that is not obviously correct
    - otherwise, you need to test that code too!
    - unlike in regular code, it's *okay* to repeat yourself in tests