CSE 331
SOFTWARE DESIGN & IMPLEMENTATION
TESTING II

Autumn 2011

A4

- Will be available later today
- Is a totally new assignment – by no means carefully vetted
- It's focused (again) on testing and binary search
  - This may be boring for some of you
  - I hope that the expected learning is important enough to justify this
- One of the next assignments (likely only one more, possibly two) will be a music player that accepts a textual notation for music and produces MIDI output

Midterms – Parts I and II graded

- Plan (hope?) to have them ready by Wednesday
- Key with comments is under production – released when the results are released

A4 basics

- Random test generation question from midterm
  - The randomly generated array length might not be consistent with the number of values in the array
  - The randomly generated array might not be sorted
  - Random keys are much more likely to be not found than to be found
  - There's no way to determine the oracle
- You'll write a test generation program that overcomes these issues (and produces JUnit tests)
- Generate length and then values for the test array
- Produce the randomized in a way that guarantees it is sorted – use a binary search tree (BST) to first insert the random elements and then retrieve them in sorted order
- Randomly decide to generate (for instance) 10% found keys – and then find a key in the array or find a key not in the array
- Voilà, an oracle appears (almost that easily)

A4 objectives include

- Deeper understanding of testing
- Representation invariant needed for BST
- Some focus on abstraction function
  - Related to visitor pattern for traversing BST to create sorted array
- Clean mind
  - Separate tests you generate from tests you need to test your program
  - Separate binary search (program under test) from binary search tree (implementation mechanism for your program)
  - …

White (glass, clear)-box testing

- Goals
  - Ensure test suite covers (executes) all of the program
  - Measure quality of test suite with % coverage
- Assumption
  - High coverage ⇒ few mistakes in the program
    - "If statement S hasn't been executed (covered) by any test, it might cause an error"
  - Focus on coverage, not oracles
  - Fundamentally an inadequacy property of test suites
- Focus: features not described by specification
  - Control-flow details
  - Performance optimizations
  - Alternate algorithms for different cases

White-box Motivation

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- There are some subdomains that black-box testing won't find

```
boolean[] primeTable = new boolean[CACHE_SIZE];
boolean isPrime(int x) {
  if (x>CACHE_SIZE) {
    for (int i=2; i<x/2; i++) {
      if (x%i==0) return false;
    }
    return true;
  }
  else {
    return primeTable[x];
  }
}
```

- Important transition around `x = CACHE_SIZE` that isn't visible to black-box testing (assuming `CACHE_SIZE` is `private`)

White Box Testing: Advantages

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- Finds an important class of boundaries – yields useful test cases
  - Need to check numbers on each side of `CACHE_SIZE`
    - `CACHE_SIZE-1`, `CACHE_SIZE`, `CACHE_SIZE+1`
  - If `CACHE_SIZE` is mutable, we may need to test with different `CACHE_SIZE`s
- Disadvantages?
  - Tests may have same bugs as implementation

Statement coverage

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- Test suite { `min(2,3)` }
- Good: executes every instruction
- Bad: doesn't find bug
- So, can be unsatisfying in trivial cases

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


Think of the program as a flow-chart

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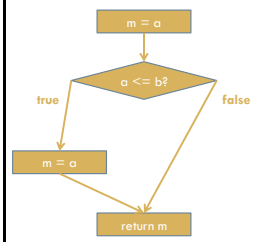
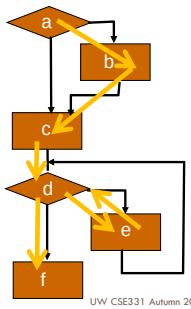



```
static int min (int a, int b) {
  int m = a;
  if (a <= b) {
    m = a;
  }
  return m;
}
```

What is missed by { `min(2,3)` }?

Edge coverage

- Covering all statements would not require edge `ac` to be covered
- Edge coverage requires all control flow graph edges to be coverage by at least one test



Edge coverage

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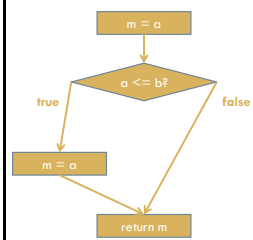


{ `min(2,3)`, `min(3,2)` }

- Doesn't increase statement coverage – still 100%
- But does increase edge coverage from 75% to 100%

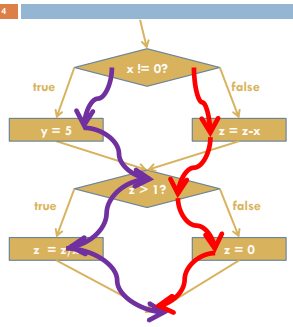
Is edge coverage enough?

- Consider this program and test suite (not exactly Java, but you can follow it)
- Make it into a flow-chart… mark executed edges

```
if x != 0
  y = 5;
else
  z = z - x;
if z > 1
  z = z / x;
else
  z = 0;
```

```
{(x = 0, z = 1)
 (x = 1, z = 3)}
```


Edge coverage: 100%




```
{(x = 0, z = 1)
 (x = 1, z = 3)}
```

What is missed?

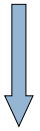
```
if x != 0
  y = 5;
else
  z = z - x;
if z > 1
  z = z / x;
else
  z = 0;
```


Path coverage

- Edge coverage is in some sense very static
- Edges can be covered without covering actual paths (sequences of edges) that the program may execute
- Not all paths in a program are always executable
- Loops complicate paths

Varieties of coverage

- Covering all of the program
  - Statement coverage
  - Edge (branch) coverage
  - *Decision coverage (not discussed)*
    - *Handling compound decisions*
  - *Loop coverage (not discussed)*
  - *Condition/Decision coverage (not discussed)*
  - Path coverage
- Limitations of coverage
  - 100% coverage is not always a reasonable target
  - High cost to approach the limit
  - Coverage is just a heuristic: we really want the revealing subdomains



increasing number of test cases (more or less)

Structural coverage: some challenges

- Interprocedural coverage
- Late binding in OO – coverage of polymorphism
- Need good tools for tracking coverage
- Higher coverage may be deceptive
- There are a family of new, automatic test generation techniques that seem to be influencing coverage-based testing

Next steps

- Assignment 4: out later today, due Wednesday November 9, 2011 at 11:59PM
- Lectures: TBA