ICS 52: Introduction to Software Engineering

Winter Quarter 2004

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Lecture Notes: Testing

http://www.ics.uci.edu/~taylor/ICS_52_WQ04/syllabus.html
Two Approaches

- White box testing
  - **Structural** testing
  - Test cases designed, selected, and ran based on structure of the source code
  - Scale: tests the nitty-gritty
  - Drawbacks: need access to source

- Black box testing
  - **Specification-based** testing
  - Test cases designed, selected, and ran based on specifications
  - Scale: tests the overall system behavior
  - Drawback: less thorough
Structural Testing

- Use source code to derive test cases
  - Build a graph model of the system
    » Control flow
    » Data flow
  - State test cases in terms of graph coverage
- Choose test cases that guarantee different types of coverage
  - Node coverage
  - Edge coverage
  - Loop coverage
  - Condition coverage
  - Path coverage
Example

```java
Node getSecondElement() {
    Node head = getHead();
    if (head == null)
        return null;
    if (head.next == null)
        return null;
    return head.next.node;
}
```
Example

```
1 float homeworkAverage(float[] scores) {
2     float min = 99999;
3     float total = 0;
4     for (int i = 0; i < scores.length; i++) {
5         if (scores[i] < min)
6             min = scores[i];
7         total += scores[i];
8     }
9     total = total - min;
10    return total / (scores.length - 1);
11 }
```
Node Coverage

- Select test cases such that every node in the graph is visited
  - Also called statement coverage
    » Guarantees that every statement in the source code is executed at least once
- Selects minimal number of test cases

Test case: \{ 2 \}
Edge Coverage

- Select test cases such that every edge in the graph is visited
  - Also called branch coverage
    » Guarantees that every branch in the source code is executed at least once
- More thorough than node coverage
  - More likely to reveal logical errors

Test case: \{ 1, 2 \}
Other Coverage Criteria

- **Loop coverage**
  - Select test cases such that every loop *boundary* and *interior* is tested
    » Boundary: 0 iterations
    » Interior: 1 iteration and > 1 iterations
  - Watch out for nested loops
  - Less precise than edge coverage

- **Condition coverage**
  - Select test cases such that all conditions are tested
    » if (a > b || c > d) …
  - More precise than edge coverage
Other Coverage Criteria

◆ Path coverage
  – Select test cases such that every path in the graph is visited
  – Loops are a problem
    » 0, 1, average, max iterations
◆ Most thorough…
◆ …but is it feasible?
Challenges

- Structural testing can cover all nodes or edges without revealing obvious faults
  - No matter what input, program always returns 0
- Some nodes, edges, or loop combinations may be infeasible
  - Unreachable/unexecutable code
- “Thoroughness”
  - A test suite that guarantees edge coverage also guarantees node coverage…
  - …but it may not find as many faults as a different test suite that only guarantees node coverage
More Challenges

- Interactive programs
- Listeners or event-driven programs
- Concurrent programs
- Exceptions
- Self-modifying programs
- Mobile code
- Constructors/destructors
- Garbage collection
Specification-Based Testing

- Use specifications to derive test cases
  - Requirements
  - Design
  - Function signature
- Based on some kind of input domain
- Choose test cases that guarantee a wide range of coverage
  - Typical values
  - Boundary values
  - Special cases
  - Invalid input values
“Some Kind of Input Domain”

- Determine a basis for dividing the input domain into subdomains
  - Subdomains may overlap
- Possible bases
  - Size
  - Order
  - Structure
  - Correctness
  - Your creative thinking
- Select test cases from each subdomain
  - One test case may suffice
Example

```java
float homeworkAverage(float[] scores) {
    float min = 99999;
    float total = 0;
    for (int i = 0; i < scores.length; i++) {
        if (scores[i] < min)
            min = scores[i];
        total += scores[i];
    }
    total = total - min;
    return total / (scores.length - 1);
}
```
Possible Bases

- Array length
  - Empty array
  - One element
  - Two or three elements
  - Lots of elements

Input domain: float[]
Basis: array length

- small
- one
- large
- empty
Possible Bases

- Position of minimum score
  - Smallest element first
  - Smallest element in middle
  - Smallest element last

Input domain: float[]
Basis: position of minima
Possible Bases

- Number of minima
  - Unique minimum
  - A few minima
  - All minima

Input domain: float[]
Basis: number of minima

1 minimum
all data equal
2 minima
# Testing Matrix

<table>
<thead>
<tr>
<th>Test case (input)</th>
<th>Basis (subdomain)</th>
<th>Expected output</th>
<th>Notes</th>
</tr>
</thead>
</table>

University of California, Irvine
## homeworkAverage 1

<table>
<thead>
<tr>
<th>Test case (input)</th>
<th>Basis: Array length</th>
<th>Expected output</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Empty</td>
<td>One</td>
<td>Small</td>
</tr>
<tr>
<td>()</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(87.3)</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(90,95,85)</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(80,81,82,83,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>84,85,86,87,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>88,89,90,91)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### homeworkAverage 2

<table>
<thead>
<tr>
<th>Test case (input)</th>
<th>Basis: Position of minimum</th>
<th>Expected output</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>(80,87,88,89)</td>
<td>x</td>
<td>88.0</td>
<td></td>
</tr>
<tr>
<td>(87,88,80,89)</td>
<td>x</td>
<td>88.0</td>
<td></td>
</tr>
<tr>
<td>(99,98,0,97,96)</td>
<td>x</td>
<td>97.5</td>
<td></td>
</tr>
<tr>
<td>(87,88,89,80)</td>
<td>x</td>
<td>88.0</td>
<td></td>
</tr>
</tbody>
</table>
## Test case (input) | Basis: Number of minima | Expected output | Notes
|-------------------|------------------------|-----------------|-------
|                   | One | Several | All  |       |
| (80,87,88,89)    | x   |         |     | 88.0  |
| (87,86,86,88)    |     | x       |     | 87.0  |
| (99,98,0,97,0)   |     | x       |     | 73.5  |
| (88,88,88,88)    |     |         | x   | 88.0  |