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

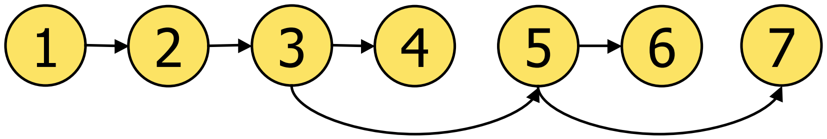
- White box testing
  - Structural testing
  - Test cases designed, selected, and ran based on structure of the source code
  - Scale: tests the nitty-gritty
  - Drawbacks: need access to source
- Black box testing
  - Specification-based testing
  - Test cases designed, selected, and ran based on specifications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

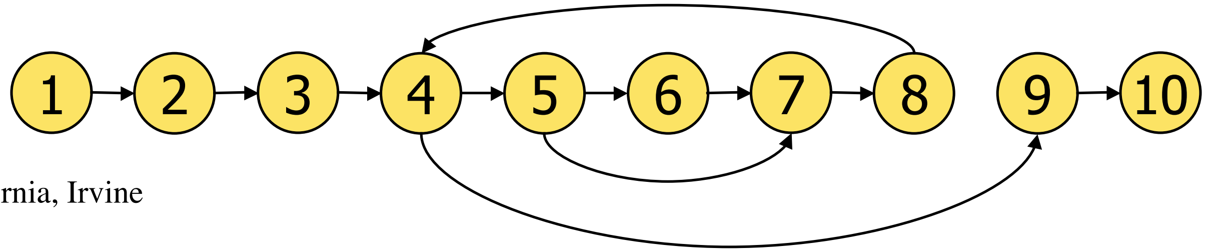
Example

```
1 Node getSecondElement() {
2    Node head = getHead();
3    if (head == null)
4       return null;
5    if (head.next == null)
6       return null;
7    return head.next.node;
8 }
```



Example

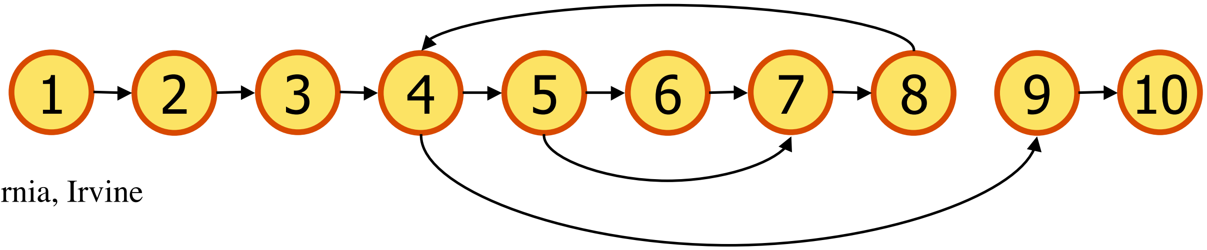
```
 1 float homeworkAverage(float[] scores) {
 2    float min = 99999;
 3    float total = 0;
 4    for (int i = 0 ; i < scores.length ; i++) {
 5       if (scores[i] < min)
 6          min = scores[i];
 7       total += scores[i];
 8    }
 9    total = total – min;
10    return total / (scores.length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

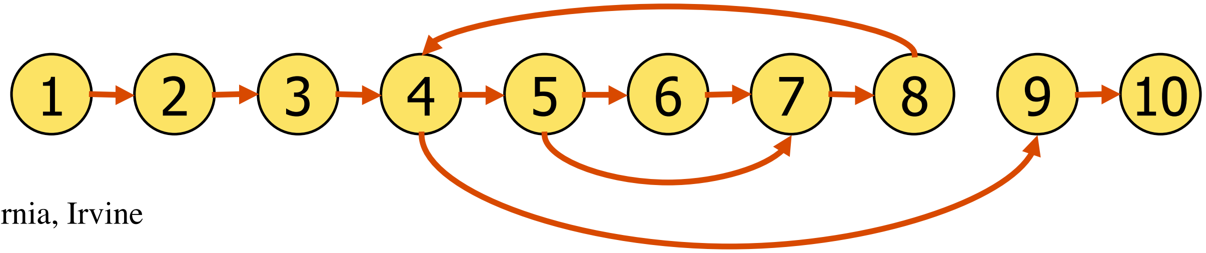
Test case: { 2 }



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 II 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”

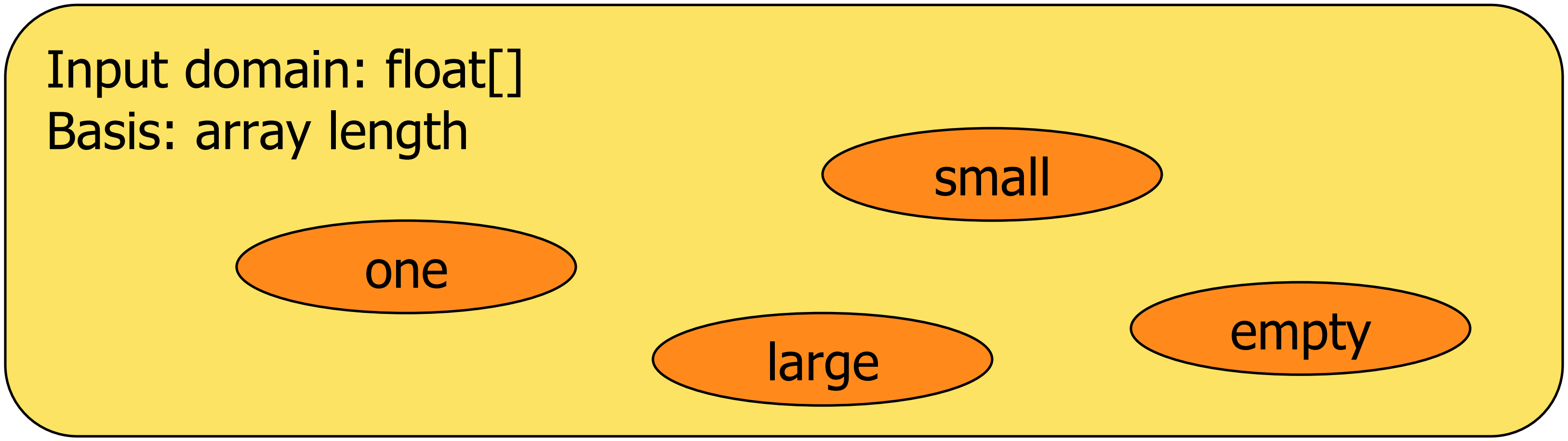
- Determine a basis for dividing the input domain into subdomains
  - Subdomains may overlap
- Possible bases
  - Size
  - Order
  - Structure
  - Correctness
  - Your creative thinking
- Select test cases from each subdomain
  - One test case may suffice

Example

```
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

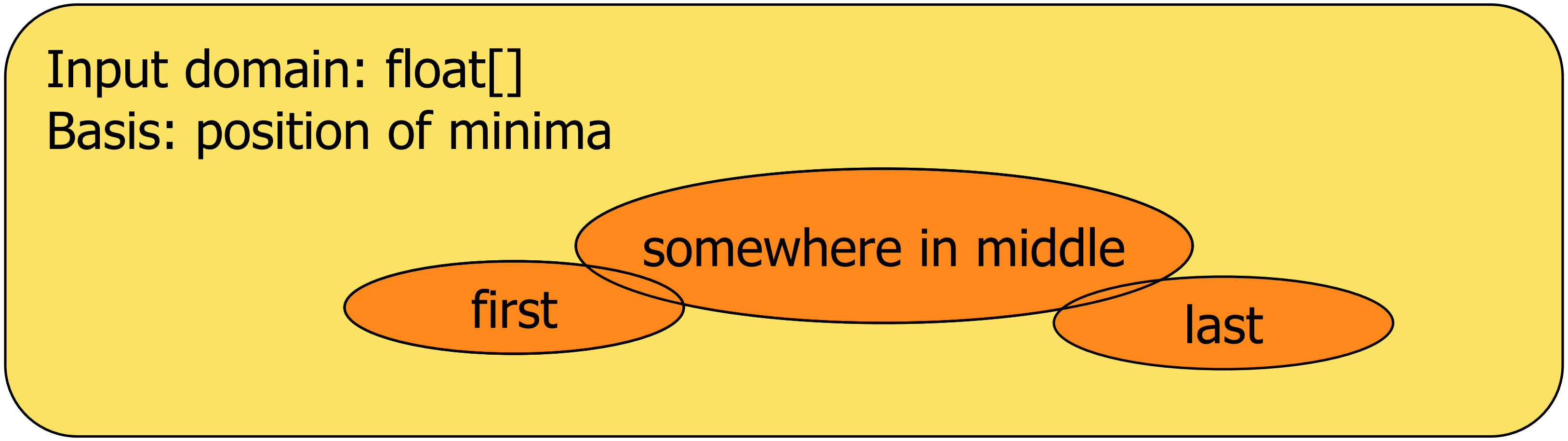
one

large

empty

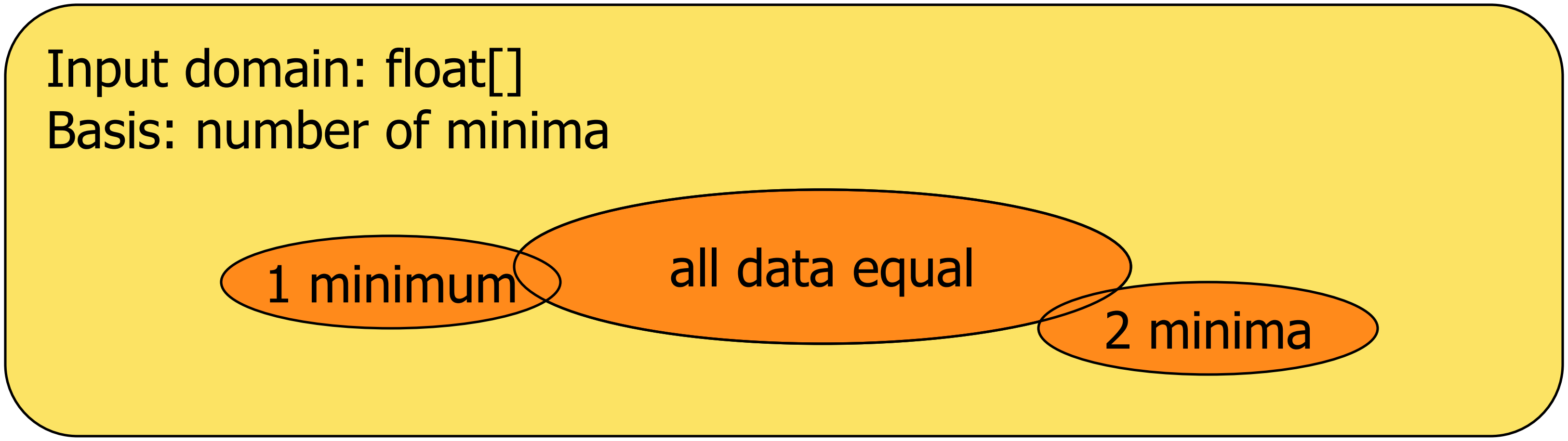
Possible Bases

- 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

Test case (input)	Basis (subdomain)	Expected output	Notes

homeworkAverage 1

Test case (input)	Basis: Array length				Expected output	Notes
	Empty	One	Small	Large		
()	x				0.0	
(87.3)		x			87.3	crashes!
(90,95,85)			x		92.5	
(80,81,82,83, 84,85,86,87, 88,89,90,91)				x	86.0	

homeworkAverage 2

Test case (input)	Basis: Position of minimum			Expected output	Notes
	First	Middle	Last		
(80,87,88,89)	x			88.0	
(87,88,80,89)		x		88.0	
(99,98,0,97,96)		x		97.5	
(87,88,89,80)			x	88.0	

homeworkAverage 3

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	