CISC/CMPE 327 Software Quality Assurance

Queen's University, 2019-fall

Lecture #15 White Box Testing - Coverage

White Box Testing

- Today we continue our look at white box testing, with emphasis on code coverage methods
- We'll look at:
  - Statement coverage
  - Basic block coverage
  - Decision coverage
  - Condition coverage
  - Branch coverage
  - Loop coverage

Code Coverage Methods

- Two kinds:
  - Statement analysis (flow independent)
  - Decision analysis (flow dependent)
- Statement analysis methods
  - Statement coverage
  - Basic block coverage
- Decision analysis methods
  - Decision coverage
  - Condition coverage
  - Loop coverage
  - Path coverage

Statement Coverage Method

- Cause every statement in the program to be executed **at least once**, giving us confidence that every statement is at least capable of executing correctly
- System: Make a test case for each statement in the program, independent of the others
  - Test must simply cause the statement to be run, ignoring its actions and sub-statements (but still must check that result of test is correct)
- Completion criterion: A test case for every statement
  - Can be checked by instrumentation injection to track statement execution coverage

Previously EVIL PARROT

```
/* Puny mortal!
   I scoff at your A1 black box testing! */
... createAccount (String number, String name) {
  evilCounter++;
  if (evilCounter == 327) {
     /* EVIL TIME */
      name = "  muahahahahaha ";
  }
  [non-evil code to write a line to the Transaction Summary]
}
```

Example: Statement Coverage

```
   // calculate numbers less than x
   //   which are divisible by y
1  int x, y;
2  x = c.readInt();
3  y = c.readInt();
4  if (y == 0)
5    c.println("y is zero");
6  else if (x == 0)
7    c.println("x is zero");
8  else
   {
9    for (int i = 1; i <= x; i++)
     {
10     if (i % y == 0)
11       c.println(i);
     }
   }
```

Example: Statement Coverage

- Statement Coverage Tests
  - We blindly make one test for each statement, analyzing which inputs are needed to cause the statement to be executed
  - Create test case for each unique set of inputs

Example: Statement Coverage

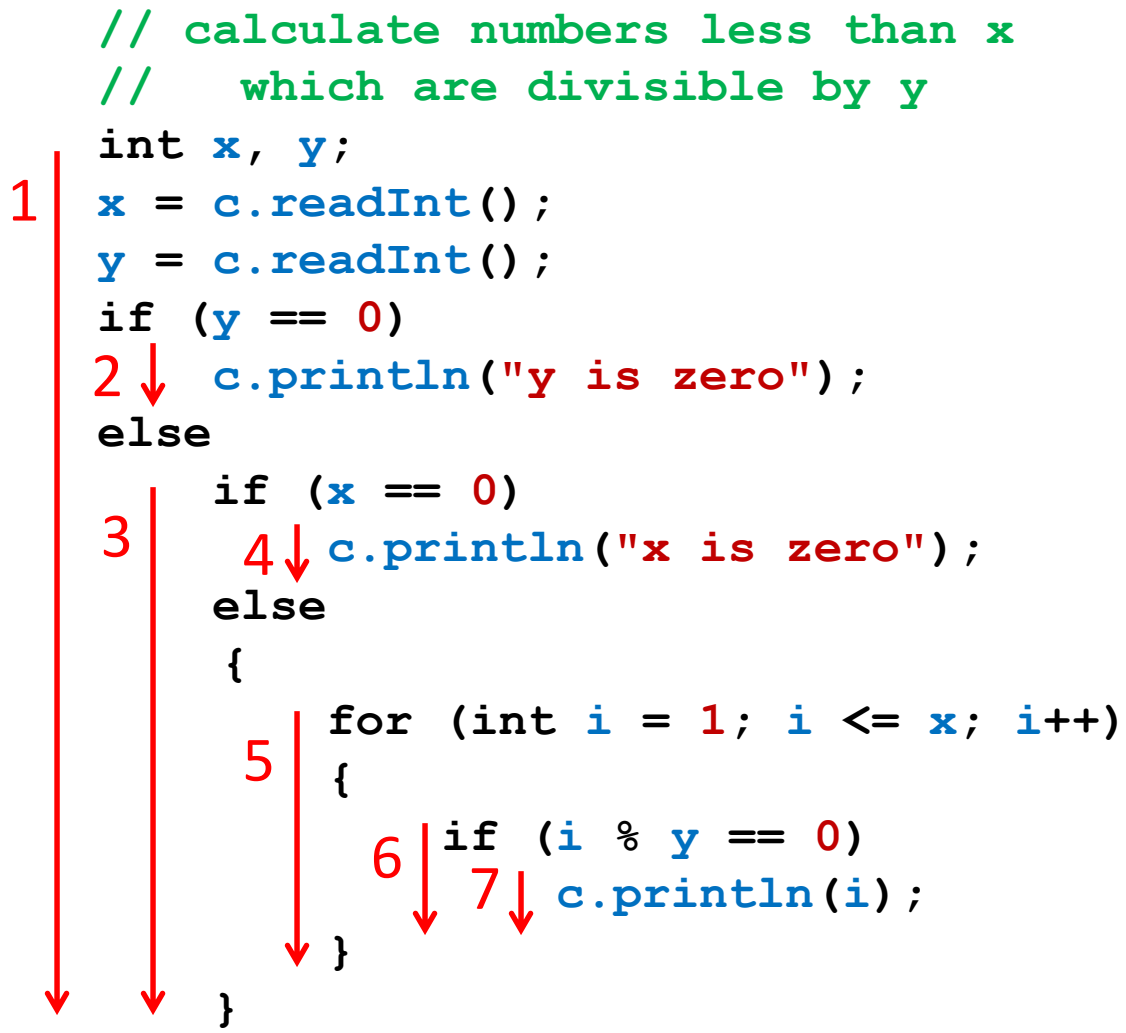
```
    // calculate numbers less than x
    //   which are divisible by y
1   int x, y;
2   x = c.readInt();
3   y = c.readInt();
4   if (y == 0)
5     c.println("y is zero");
6   else if (x == 0)
7     c.println("x is zero");
8   else
    {
9     for (int i = 1; i <= x; i++)
      {
10      if (i % y == 0)
11        c.println(i);
      }
    }
```

Stmt	x input	y input	Test	x	y
1	0	0	T1	0	0
2	0	0			
3	0	0			
4	0	0			
5	0	0			
6	0	1	T2	0	1
7	0	1			
8	1	1	T3	1	1
9	1	1			
10	1	1			
11	1	1			

Basic Block Coverage

- Cause every basic block (indivisible sequence of statements) to be executed at least once
  - Usually generates fewer tests
- System: Identify basic blocks by code analysis, design test case for each basic block
  - Sequence of statements in a row, ignoring sub-statements, such that if first is executed then following are all executed
- Completion criterion: A test case for every basic block
  - Can be checked by instrumentation injection to track statement execution coverage

Example: Basic Block Coverage



Example: Basic Block Coverage

- Basic Block Coverage Tests
  - We make one test for each block, analyzing which inputs are needed to cause the block to be entered
  - Create test case for each unique set of inputs

```
// calculate numbers less than x
//   which are divisible by y
int x, y;
x = c.readInt();
y = c.readInt();
if (y == 0)
    c.println("y is zero");
else
    if (x == 0)
        c.println("x is zero");
    else
    {
        for (int i = 1; i <= x; i++)
        {
            if (i % y == 0)
                c.println(i);
        }
    }
```

Block	x input	y input	Test	x	y
1	0	0	T1	0	0
2	0	0			
3	0	1	T2	0	1
4	0	1			
5	1	1	T3	1	1
6	1	1			
7	1	1			

Decision Coverage

- Decision (Branch) Coverage Method
  - Causes every decision (if, switch, while, etc.) in the program to be made both ways (or every possible way for switch)
  - System: Design a test case to exercise each decision in the program each way (true/false)
  - Completion criterion: A test case for each side of each decision
    - Can be checked by instrumentation injection to track branches taken in execution

Example: Decision Coverage

```
        // calculate numbers less than x
        //   which are divisible by y
        int x, y;
        x = c.readInt();
        y = c.readInt();
1       if (y == 0)
            c.println("y is zero");
        else
2           if (x == 0)
                c.println("x is zero");
            else
            {
                for (int i = 1; i <= x; i++)
                {
3                   if (i % y == 0)
                        c.println(i);
                }
            }
```

Example: Decision Coverage

- Decision Coverage Tests
  - We make one test for each side of each decision

```
   // calculate numbers less than x
   //   which are divisible by y
   int x, y;
   x = c.readInt();
   y = c.readInt();
1  if (y == 0)
      c.println("y is zero");
   else
2     if (x == 0)
         c.println("x is zero");
      else
      {
         for (int i = 1; i <= x; i++)
         {
3           if (i % y == 0)
               c.println(i);
         }
      }
```

Decision	x input	y input	Test	x	y
1: true	0	0	T1	0	0
1: false	0	1	T2	0	1
2: true	0	1			
2: false	1	1	T3	1	1
3: true	1	1			
3: false	2	3	T4	2	3

Condition Coverage

- Like decision coverage, but causes every condition to be exercised both ways (true/false)
- A condition is any true/false sub-expression in a decision
  - Example: if ((x == 1 || y > 2) && z < 3)
  - Requires separate condition coverage tests for each of:
    - x == 1 true / false
    - y > 2 true / false
    - z < 3 true / false
- More effective than simple decision coverage since exercises the different entry preconditions for each branch selected

Loop Coverage

- Most programs* do their real work in do, while, and for loops
- This method makes tests to exercise each loop in the program in four different states:
  - execute body zero times (do not enter loop)
  - execute body once (do not repeat)
  - execute body twice (repeat once)
  - execute body many times (repeat more than once)

* in non-functional languages

Loop Coverage

- Usually used as an enhancement of a statement, block, decision, or condition coverage method
- System: Devise test cases to exercise each loop with zero, one, two, and many repetitions
- Completion criterion: A test for each of these cases for each loop
  - Can be verified using instrumentation injection in the code

Example: Loop Coverage

```
// calculate numbers less than x
//   which are divisible by y
int x, y;
x = c.readInt();
y = c.readInt();
if (y == 0)
    c.println("y is zero");
else if (x == 0)
    c.println("x is zero");
else
{
    for (int i = 1; i <= x; i++)
    {
        if (i % y == 0)
            c.println(i);
    }
}
```

Loop Body	x	y
zero times	-1	1
once	1	1
twice	2	1
many times	10	1

Instrumentation Injection

```
// calculate numbers less than x
//   which are divisible by y
int x, y;
x = c.readInt();
y = c.readInt();
if (y == 0)
    c.println("y is zero");
else if (x == 0)
    c.println("x is zero");
else
{
    for (int i = 1; i <= x; i++)
    {
        if (i % y == 0)
            c.println(i);
    }
}
```

Summary

- White Box Testing
  - Code coverage methods
    - Statement analysis methods (statement, basic block coverage)
    - Decision analysis methods (decision, condition, loop coverage)
- Next time
  - More code coverage methods: path coverage
  - Data coverage methods