CISC/CMPE 327 Software Quality Assurance

Queen's University, 2019-fall

Lecture #16 White Box Testing – Path & Data Coverage

White Box Testing

- Today we continue our look at white box testing with another code coverage method, and some data coverage methods
- We'll look at:
  - Code coverage testing:
    - **Path** coverage
  - Data coverage testing
    - Data value coverage
    - Data flow coverage
    - Data interface coverage

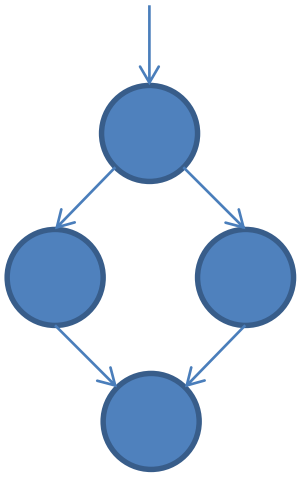
Execution Paths

- An execution path is a sequence of executed statements starting at the entry to the unit (usually the first statement) and ending at the exit from the unit (usually the last statement)
- Two paths are **independent** if there is **at least one statement on one path which is not executed on the other**
- Path analysis (also known as cyclomatic complexity* analysis) identifies all the independent paths through a unit

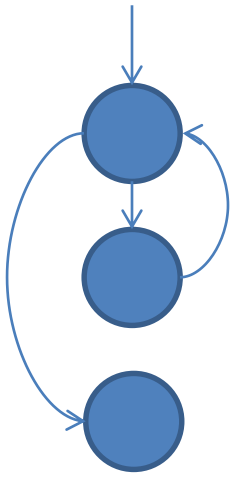
* a code metric we will look at later in the course

Execution Path Analysis

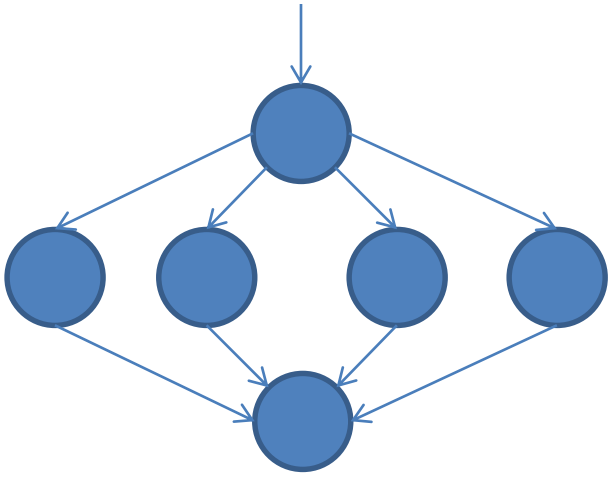
- Flow Graphs
  - It is easiest to do path analysis if we look at the execution flow graph of the program or unit
  - The flow graph shows program control flow between basic blocks



if-then-else

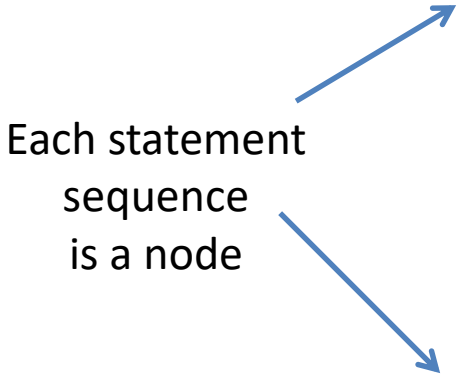


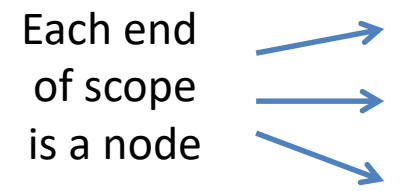
while



switch

Example: Path Analysis



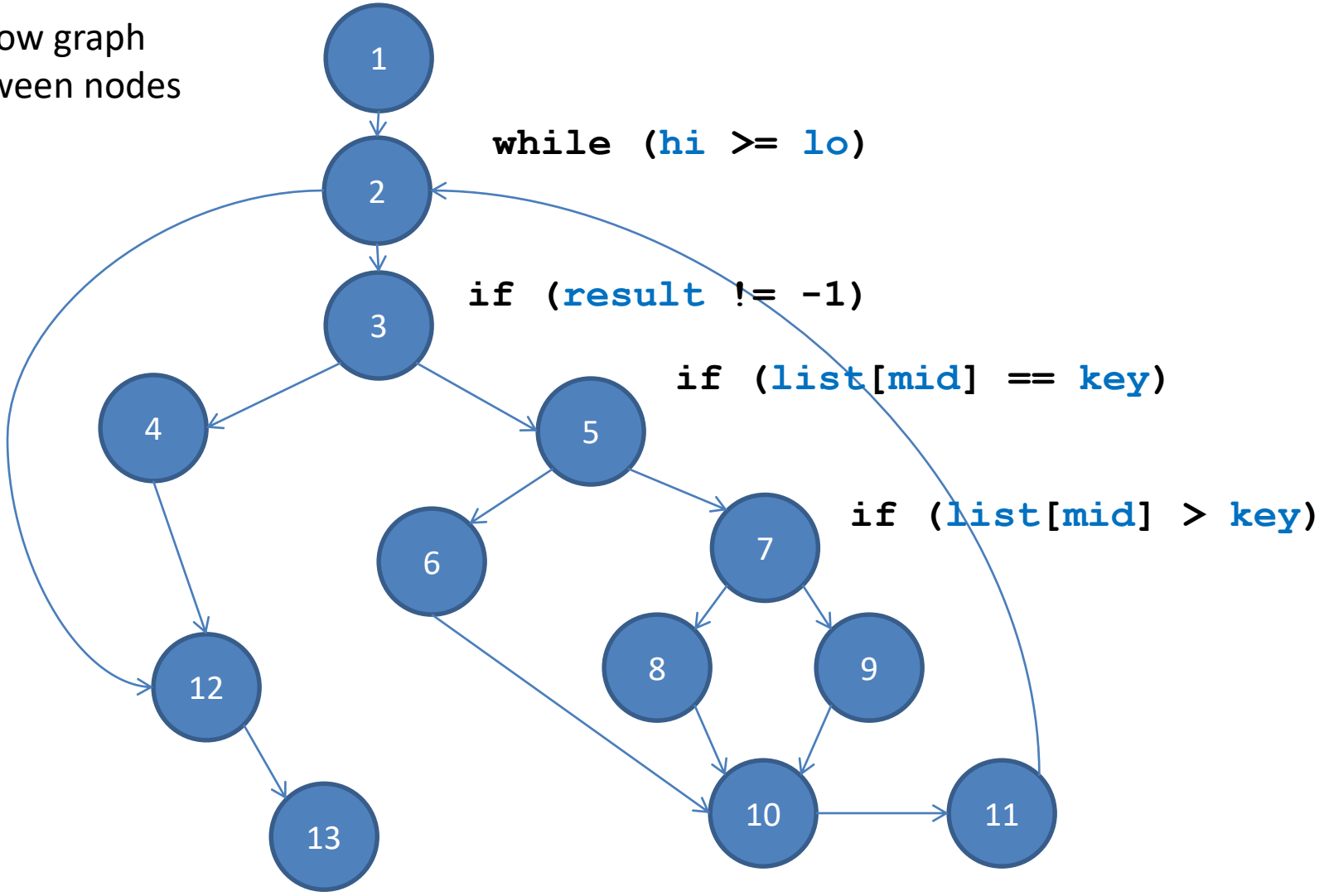



```
                static int find (int list[], int n, int key) {
                   // binary search of ordered list
1                  int lo = 0;
                   int hi = n - 1;
                   int result = -1;

2                  while (hi >= lo) {
3                     if (result != -1)
4                        break;
                      else {
5                        final int mid = (lo + hi) / 2;
                         if (list[mid] == key)
6                           result = mid;
7                        else if (list[mid] > key)
8                           hi = mid - 1;
                         else  // list[mid] < key
9                           lo = mid + 1;
10                    }
11                 }
12                 return result;
13             }
```

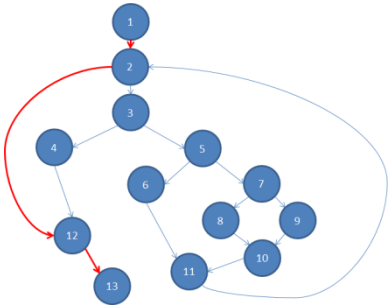
Example: Path Analysis

Flow graph between nodes

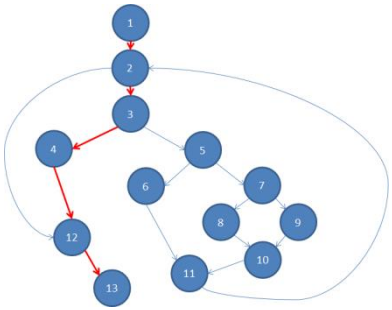


Example: Path Analysis

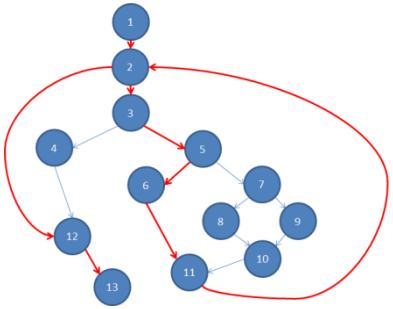
- Independent Paths
  - This program has only five independent paths (CC = 5)



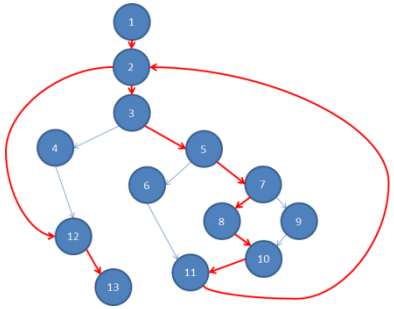
P1: 1, 2, 12, 13



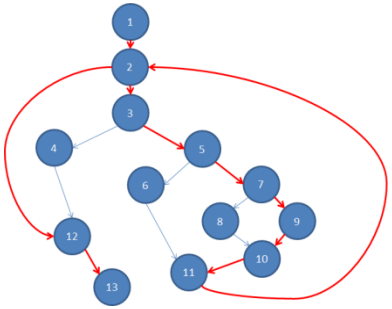
P2: 1, 2, 3, 4, 12, 13



P3: 1, 2, 3, 5, 6, 10, 11, 2, 12, 13



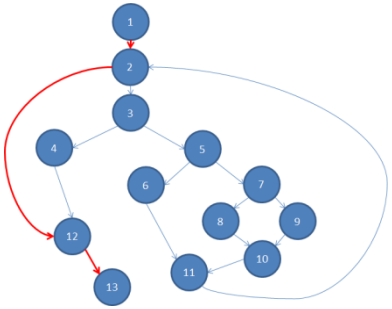
P4: 1, 2, 3, 7, 8, 10, 11, 2, 12, 13



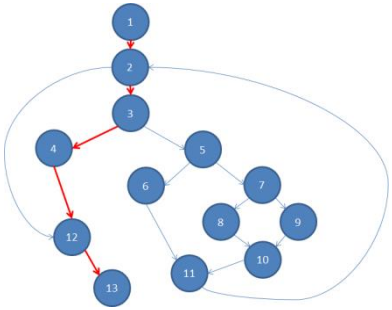
P5: 1, 2, 3, 7, 9, 10, 11, 2, 12, 13

Independent Paths

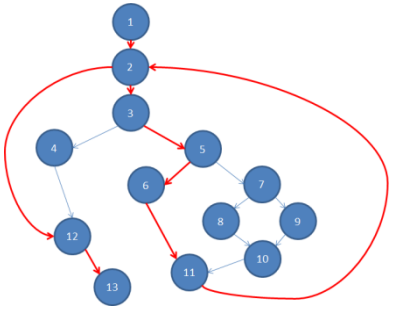
- Easiest way to find this set is to work from top-to-bottom, left-to-right to create paths



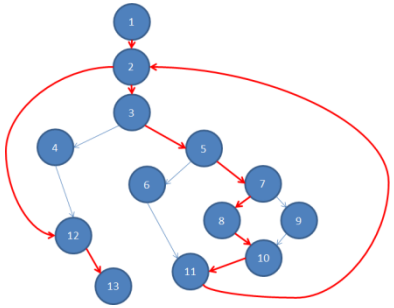
P1: 1, 2, 12, 13



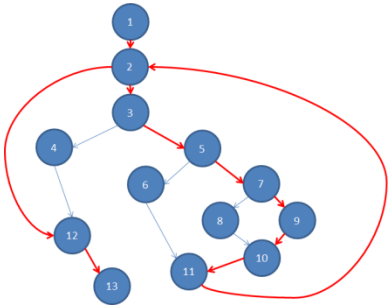
P2: 1, 2, 3, 4, 12, 13



P3: 1, 2, 3, 5, 6, 11, 2, 12, 13



P4: 1, 2, 3, 7, 8, 10, 11, 2, 12, 13



P5: 1, 2, 3, 7, 9, 10, 11, 2, 12, 13

Independent Paths

		x < 0	**x >= 0**
1	if (x < 0)		
2	y -= 1;	yes	no
3	else		
4	y += 2;	no	yes
5	if (x < 0)		
6	y -= 3;	yes	no
7	else		
8	y += 5;	no	yes

Not “semantically independent” paths.
1, 2, 5, 7, 8 is an independent path, though impossible
(2 only hit if $x < 0$, 8 only hit if $x \geq 0$)

Path Coverage Testing

- System: Make one test case for each independent path analyzing which inputs are needed to exercise the path
- Completion criterion: A test for each path
- Test creation is easy once paths have been identified

Path	list[]	n	key
P1	(empty)	0	0
P2	1 2 3 4	4	0
P3	1 2 3 4	4	1
P4	1 2 3 4	4	4
P5	1 2 3 4	4	2

Path Coverage Testing

- Advantages
  - Covers all basic blocks:
    does all of basic block testing
  - Covers all conditions:
    does all of decision/condition testing
  - Does all of both, but with fewer tests!
  - Automatable
- Disadvantages
  - Does not take data complexity into account at all
    (also a disadvantage of basic block coverage and condition coverage)

Path Coverage Testing

- Disadvantage Example
  - These fragments have the same outcome and should be tested the same way, but the one on the left gets five tests whereas the one on the right gets only one

```
// control-centric solution
switch (n) {
    case 1:
        s = "One"; break;
    case 2:
        s = "Two"; break;
    case 3:
        s = "Three"; break;
    case 4:
        s = "Four"; break;
    case 5:
        s = "Five"; break;
}
```

```
// data-centric solution
String[] numbers =
    {"One", "Two",
     "Three", "Four”,
     "Five"};

s = numbers[n-1];
```

White Box Data Coverage

- **Data coverage methods** explicitly try to cover the data aspects of the program code, rather than the control aspects
- Three kinds: data value coverage, data flow coverage, data interface coverage

White Box Data Coverage

- System: Identify critical variables, analyze code to find the different values or sets of values each can take on, partition and design tests to cover
- Completion criterion:
  Test for each value partition

Data Path Coverage

- System: Identify output variables, analyze code to find data flow paths that affect their value (technically called slices)
- Completion criterion: Test for each data flow path to output
- Much like control path testing, but additionally identifies data-centric paths

Data Path Coverage

- For example, if we look at a program slice for the variable sum, we can eliminate portions of the source that do not affect the value of sum

```
int i;
int sum = 0;
int product = 1;
for (i = 0; i < n; i++) {
  sum = sum + i;
  product = product * i;
}
```

```
int i;
int sum = 0;
// line not in slice
for (i = 0; i < n; i++) {
  sum = sum + i;
  // line not in slice
}
```

Data Interface Coverage

- System: Identify unit's interface input variables, analyze code to find classes of values that cause different code behaviours, partition and test
- Completion criterion:
  Test for each input value partition
- Really just like black box input partitioning again, but with added advantages of ability to analyze code when creating partitions

Summary

- White Box Testing
  - Code coverage methods:
    - Decision analysis methods: path coverage
  - Data coverage methods:
    - Data value coverage, flow coverage, interface coverage
- Next Time
  - Mutation testing