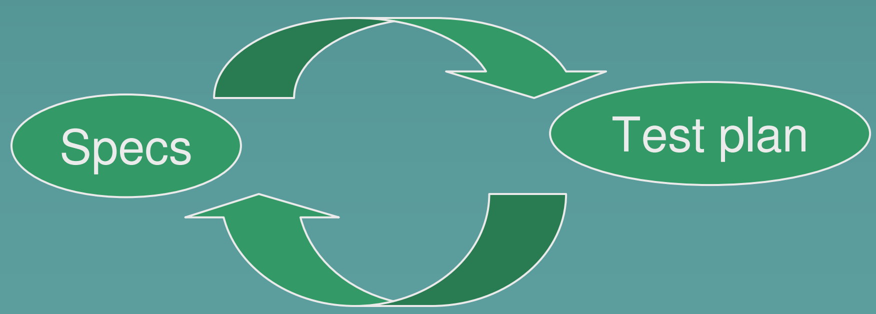
White Box Testing

Rushikesh K. Joshi
Department of Computer Science & Engineering
Indian Institute of Technology Bombay

Why Testing?

- Testing finds errors (Does not guarantee absence of bugs!)
- An early agreement upon the test plan at requirement stage is important

Test Driven Development



A Test Case

- A test case is described through the choice of inputs for the unit to be tested.
- For example, following are three different test cases to test a function int f (int x, int y) that compares two numbers and reports the maximum

Criteria	Values
– X and Y same	(10,10)
– X > Y	(10, 8)
– Y > X	(2, 25)

Important Questions

- What should be tested
- What criteria should be used to design tests?
- How to analyze the output?

Is the output of a test correct?

- Manual Validation
  - Time consuming
- Test Oracles to automatically test and validate against the expected
- The testing strategies, the test specifications and results are documented

What criteria to use?

- Should the testing be done based on externally observable behavior

OR

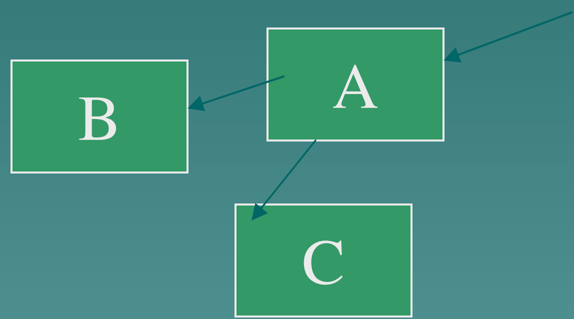
- should the code be seen to design test cases?

Black box Vs. White Box Testing

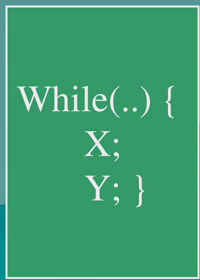
- External Vs. Internal View
  - Black box testing is based on what is required from external point of view
  - White box testing is based on an insider's view of the given artifact
    - Tester has a knowledge of code
    - Test cases are generated to test the coding structures

External Vs. Internal View

- Black box testing is based on what is required from external point of view



- White box testing is based on an insider's view of the given artifact



Black Box Testing

- Also called Functional Testing
- Test the artifact from external point of view
- Specs are used to generate test data

  - E.g. a data sorting function is tested on different sets of data
  - Data can be randomly generated based on input types

White Box Testing

- Also called Structural Testing
- Test the artifact from internal (implementation) point of view
- Cannot detect absence of features
- Coverage measures are used, e.g:
  - Statement Coverage
    - Each statement is Covered in testing
  - Branch Coverage
    - Each branch is covered (e.g. in if-then-else)
  - Path oriented testing
    - Select data such that chosen paths in the program are covered

Black Box Testing (External)

- Functional/Feature Testing
- Boundary Value Testing
- Tests for absence of features

Use of specs to generate test data

White Box Testing (Internal)

- Structural Testing
  - Internal structure used to generate test data
- Test for coverage of statements, conditional branches, paths
- Does not detect absence of features of software

Static Analysis for Testing Code

- No actual execution is done
- Check for not well formed control paths
  - Unstructured programs
  - Unreachable code
- Variable anomalies
  - Unused variables
  - Misused variables references

Statement Coverage

- Select a test suit such that each statement in the program is executed at least once
- Motivation: An error may get masked if tests do not execute parts of the program
- What is an elementary statement?

  Use of syntactic definition of language:
  - Assignment statement
  - procedural calls
  - i/o statements in conventional block structured languages

Statement coverage

- A test case may cover many statements

- One may try to minimize the number of test cases such that all the statements are still covered

An Example for Statement Coverage

```
int fib (int n) {        /* defined on n=0+ */

  if (n<2)
      return n;     ← elementary
                      statement
  else if (n>=2)
      return (fib(n-1)+fib(n-2));  ←
  elementary
  statement
}
```

Test suit: ???

An Example for Statement Coverage

```
int fib (int n) {          /* defined on n=0+ */

  if (n<2)
      return n;     ← an elementary
                      statement
  else if (n>=2)
      return (fib(n-1)+fib(n-2));  ← an
                                    elementary
                                    statement
}
```

Test suit: <n=3>,<n=1>

Observations

- Missing features are not detected
  - E.g. if number supplied is negative (n=-1), the function does not report an error
  - This test case is not needed for statement coverage criteria

- Does not cover implicit statements
  - (example on next slide)

Implicit statements

```
bool flip (bool var) {
 bool local;
   if (isTrue(var))
       local = false; ← an elementary
                         statement
   return local; ← an elementary
                   statement
}
```

Test suit: <???> sufficient to cover all statements?

Implicit statements

```
bool flip (bool var) {
 bool local;
  if (isTrue(var))
     local = false; ← an elementary
                        statement
  return local; ← an elementary
                   statement
}
```

Test suit: <var=True> sufficient to cover all statements
Error that flip does not work with <var=false> is not detected

Implicit statements

```
bool flip (bool var) {
 bool local=var;
   if (isTrue(var))
       local = false;  ← elementary
                         statement
  else { }; ← implicit else statement
  return local;  ← elementary statement
}
```

Test suit: <var=True> is **not sufficient** to cover all statements
Error that flip does not work with <var=false> will get detected with suit: <var=True>,<var=False>

Basic Path Testing

- Select test suit such that basic paths are covered
  - This guarantees that every statement gets covered

- Representations for:
  - Elementary statements: assignment, i/o, call
  - Conditional statements: If then else
  - Conditional Loops: While-do, Repeat-until
  - Sequential composition: Two sequential statements

A Sequential Composition

S1: interest = balance * (x/100);

S2: balance = balance + interest;

A Branching Statement

S1: If (employee.performance=HIGH)

S2: incentive = x;

S3: else incentive = x/2;

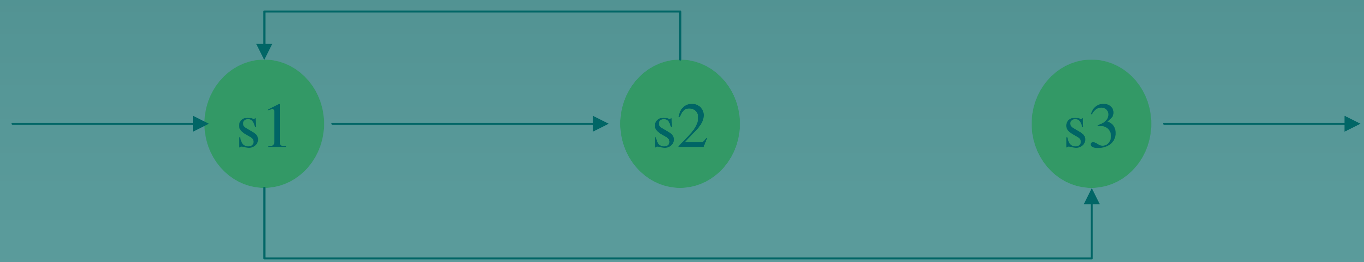
S4: Print (employee.id, incentive)

A While Statement

S1: while (!end_of_file (file))

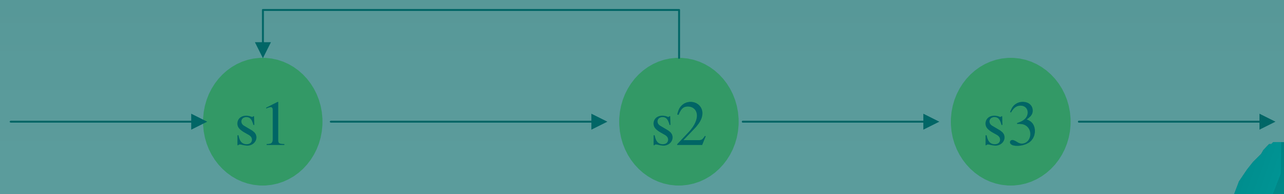
S2: read a value from file, and print it;

S3: file.close();



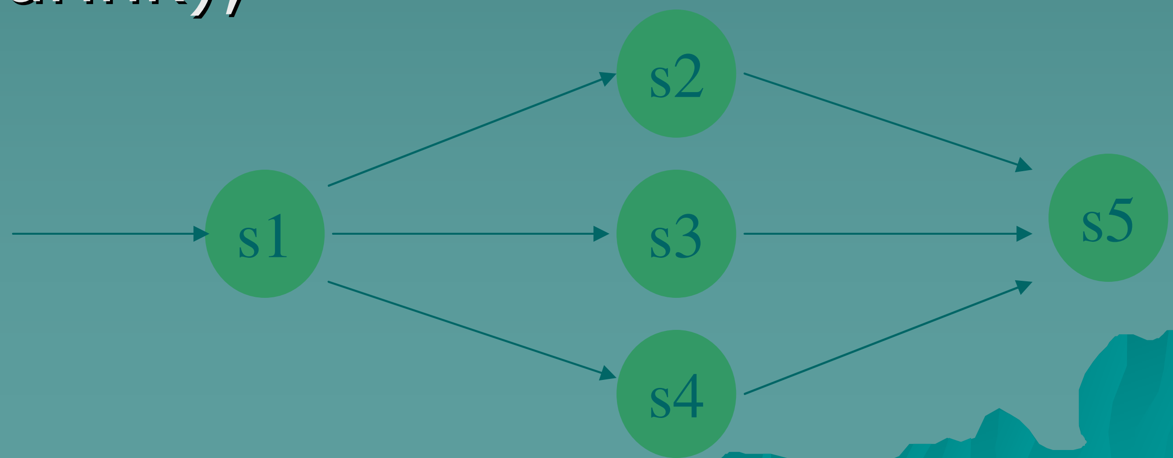
A Repeat Statement

```
A:  tmp1 = x; tmp2 = x * x; i=0;
B:  repeat
S1:     x = x + tmp;   i=i+1;
S2:  until (x == tmp2);
S3:  print (x, i);
```



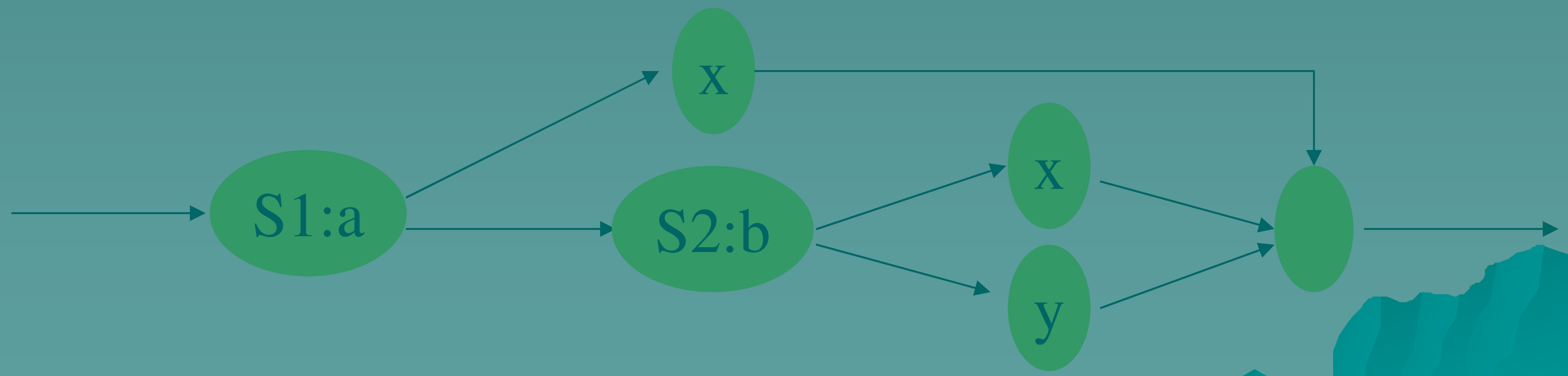
A Switch Case Statement

```
S1: switch (choice) {
S2:      case Tea: drink=prepareTea();  break;
S3:      case Coffee: drink=prepareCoffee(); break;
S4:      case Juice: drink=prepareJuice(); break;
    }
S5:  serve (drink);
```



A Compound Condition

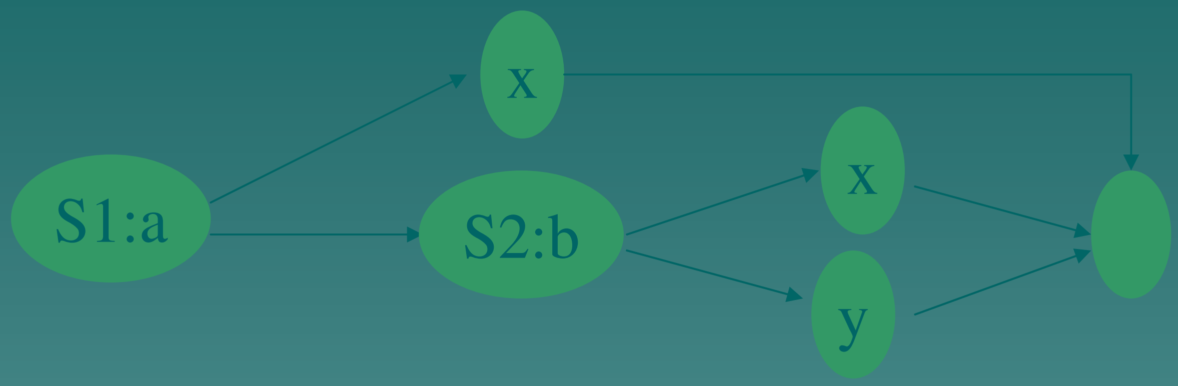
```
     If (a  OR b)
x:      do_some_thing;
     else
y:   do_something_else;
```



Cyclomatic Complexity

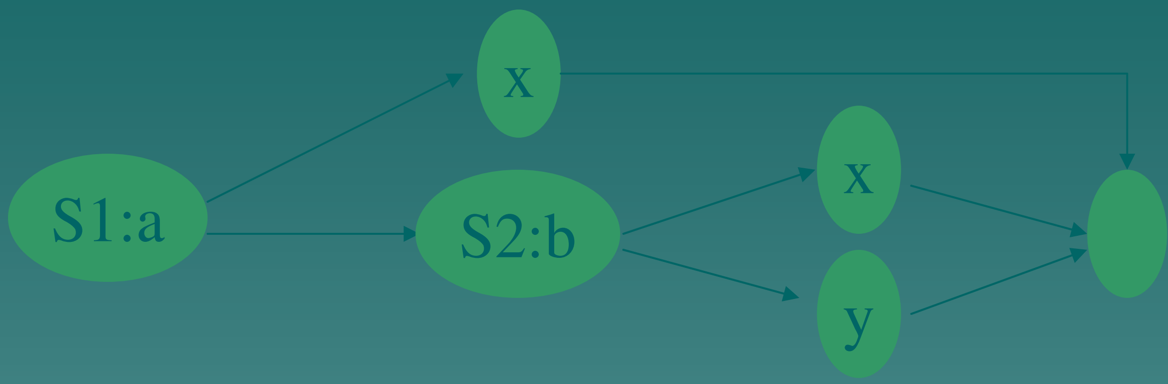
- No. of independent paths in the basis set
- Upper bound on no. of test that must be conducted
  - to ensure all statements get covered at least once
- =No. of regions (count outer region also)
- =No. of predicate nodes + 1
- =No. of edges – no. of vertices + 2

Cyclomatic Complexity Example



- =No. of regions (count outer region also): 3
- =No. of predicate nodes + 1: 2+1= 3
- =No. of edges – no. of vertices + 2 = 7-6+2=3
- i.e. basis set has 3 paths

Cyclomatic Complexity Example



- The 3 independent paths in basis set
  - a is found to be true
  - a is not found to be true, but b is found to be true
  - a is not found to be true, b is also not true

Test suite: <a=true, b=false>, <a=false, b=true>, <a=false, b=false> to test

→ If (a or b) then x else y;

Condition Testing

- Simple conditions
  - Boolean variable
  - Relational operator (<, >, <=, ==, >=)
- Compound conditions
  - Composition of 2 or more conditions with Boolean operators (&&, ||, !)
- Error could occur due to
  - wrong variable values
  - Wrong choice of operators
  - Wrong expression inside conditions
  - Parenthesis problems

Condition Testing Strategies

- Branch testing:
  - Test for true and false for C
  - Every simple condition in C is executed at least once
- Domain Testing:
  - Boolean expression with n variables
    - Test for all possible 2^n values
  - Relational operators
    - For a R b:
      - test for a less than b
      - a greater than b
      - a equal to b.

Data Flow Testing Strategies

- Selection of paths according to data definition and usage

- DEF(S) = {D| statement S contains definition of D}
- USE(S) = {D| statement S contains use of D}

- DU chain of variable X: [X,S,S'] such that
  - X is in DEF(S);
  - X is in USE (S');
  - Definition of X in statement S is live at statement S'
    - The definition is not overridden by another definition)
- A strategy: cover all DU chains at least once

Mutation Testing

- Change the program code a bit
- Test this mutant
- If the test does not generate a detectable error, the test case is not enough
  - Test once more and continue thus with mutation testing

Exercise: Try different strategies on the below program, make a few errors and try the tests again

```
 AwardGrades (List L) {
1. int current=0;
2.        while (current<L.size) {
3.                if  (L [current].marks < 35)
                          L[current].grade='F';
                  else
4.                      if  (L [current].marks <50)
5.                          L [current].grade='D';
                      else
6.                          if  (L [current].marks <70)
7.                                  L [current].grade='C';
                           else
8.                                if  (L [current].marks <90)
9.                                  L [current].grade='B';
                               else
10.                                 L[current].grade='A';
11.              current=current+1;
         }
 }
```