Structural (White Box) Testing

Slides from Prof. Ghosh and Prof. France

White box testing criteria

- **Statement coverage criterion**: Select a test set T such that executing program P for each t in T results in each elementary statement of P being executed at least once.
- **Edge-coverage criterion**: Select a test set T such that executing P for each t in T results in each edge of P's control graph being traversed at least once.
- **Condition-coverage criterion**: Select a test set T such that executing P for each t in T results in each edge of P's control graph being traversed at least once and all possible values of the constituents of compound conditions being exercised at least once.
- **Path-coverage criterion**: Select a test set T such that executing P for each t in T results in all paths leading from the initial to the final node of P's control graph being traversed.

Statement coverage example

```
1.  read(x);
2.  read(y);
3.  if x > 0 then
4.      write("1");
5.  else
6.      write("2");
7.  end if;
8.  If y > 0 then
9.      write("3");
10. else
11.     write("4");
12. end if;
```

Input domains for statement coverage
D1: {x>0}
D2:{x<=0}
D3: {y>0}
D4:{y<=0}

How did we get these domains?
Ans: from the branch conditions.

Statement coverage weakness

```
1. if x < 0
   then
2.    x := -x;
3. end if;
4. z:=x;
```

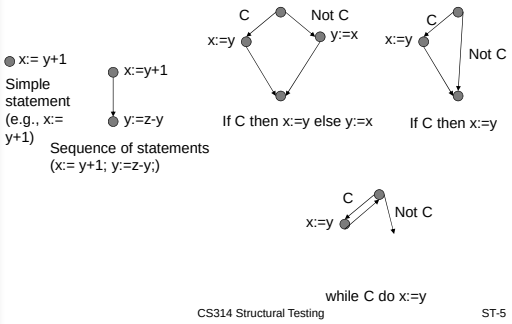
Program is intended to change negative numbers to positive number and leave positive numbers unchanged, and then assign to z

Input domains for statement coverage
D1: {x<0}

Weakness: does not cover the case when x >= 0.

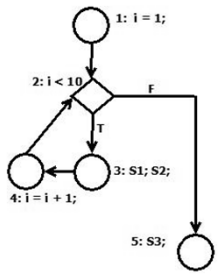
A test set that satisfies the **edge-coverage criterion** will cover the case when x>=0.

Control Flow Graph examples



For Loop Control Flow Graph

```
for (int i = 1;  i < 10;  i = i + 1) {
   s1;
   s2;
}
s3;
```



Edge coverage

1. if x < 0 then
2. x := -x;
3. end if;
4. z:=x;

Input domains for edge coverage
D1: {x<0}
D2: {x >= 0}

Condition coverage vs. edge coverage criterion

```
found:= false; counter:= 1;
while (not found) and (counter < num_items) loop
    if table(counter) = desired_elem then
        found := true;
    end if;
    counter := counter + 1;
end loop;
If found then
    write("element found");
else
    write("element does not exist");
end if;
```


Edge criterion test set weakness

A test set for the program on previous slide:
- A table with no items
- A table with three items, the second being the desired element.

The above satisfies the edge coverage criterion but fails to uncover the error in the condition of the while loop (< instead of <=)

The coverage criterion can be used to uncover this error.

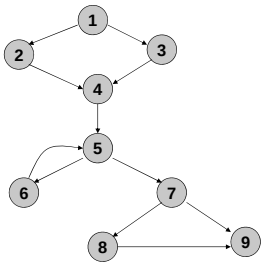
Checking condition coverage using control graphs

- You can use control graphs to check condition coverage if you can rewrite as an equivalent program that uses only conditions with single clauses
- Not as straightforward as you may think to do this!

Code finds the value of x^y

```
1. scanf(x, y); if(y < 0)
2.     pow = 0 – y;
3. else pow = y;
4. z = 1.0;
5. while(pow != 0)
6.   { z = z * x; pow = pow – 1;}
7. if ( y < 0 )
8.    z = 1.0/z;
9. printf(z);
```


Control Flow Graph



Problems with branch coverage

- What if a decision has many conditions (using *and*, *or*)
- Decision may evaluate to true or false without actually exercising all the conditions

```
int check (int x) {
  if ((x >= 5) && (x <= 200))
    return TRUE;
  return FALSE;
}
```

Test inputs:
x = 5:
x = -5:

Error (should be 100)

Rewrite of search program?

```
found:= false; counter:= 1;
while (not found) loop
  if (counter < num_items) then
     if table(counter) = desired_elem then
          found := true;
     end if;
     counter := counter + 1;
  else
     break;
end loop;
If found then
     write("element found");
else
     write("element does not exist");
end if;
```


Edge coverage weakness

```
if x not = 0 then
   y:=5;
else
   z:=z-x;
end if;
if z > 1 then
   z:=z/x;
else
   z:=0;
end if;
```

The following test set satisfies the edge criterion:
{<x=0,z=1>,<x=1,z=3>}

It does not uncover the division by 0 fault.

A test set that uncovers the fault is given below:
{<x=0,z=3>,<x=1,z=1>}

Solution?

- Require all individual conditions to evaluate to true and false
- Problem:
  - Even if individual conditions evaluate to true and false, the decision may not get both true and false values
- Solution:
  - Require both decision / condition coverage!!

White-box testing summary

- Tests what a program does
- Can catch only "commission" faults; cannot catch omission faults
  - Black box testing can be used to catch omission faults.
- It is not always possible to select test sets that satisfy criterion
  - E.g., unreachable statements in code makes it impossible to satisfy statement coverage criterion

Testing Limitations

- If our testing results in:
  - 100% statement coverage,
  - 100% branch coverage,
  - 100% condition coverage,

The program may still have hidden faults.
Why?