SE 2AA4, CS 2ME3 (Introduction to Software Development)

Winter 2018

32 White Box Testing Continued (Ch. 6) DRAFT

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December 15, 2017

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- Administrative details
- White box testing
  - Edge coverage
  - Condition coverage
  - Path coverage

Administrative Details

TBD

Theoretical Foundations Of Testing: Definitions

- P (program), D (input domain), R (output domain)
  - P: D $\rightarrow$ R (may be partial)
- Correctness defined by OR $\subseteq$ D $\times$ R
  - P(d) correct if $\langle$ d, P(d) $\rangle \in$ OR
  - P correct if all P(d) are correct
- Failure
  - P(d) is not correct
  - May be undefined (error state) or may be the wrong result
- Error (Defect)
  - Anything that may cause a failure
    - Typing mistake
    - Programmer forgot to test "x=0"
- Fault
  - Incorrect intermediate state entered by program

Definitions Questions

- A test case t is an element of D or R?
- A test set T is a finite subset of D or R?
- How would we define whether a test is successful?
- How would we define whether a test set is successful?

Definitions Continued

- Test case t: An element of D
- Test set T: A finite subset of D
- Test is successful if P(t) is correct
- Test set successful if P correct for all t in T

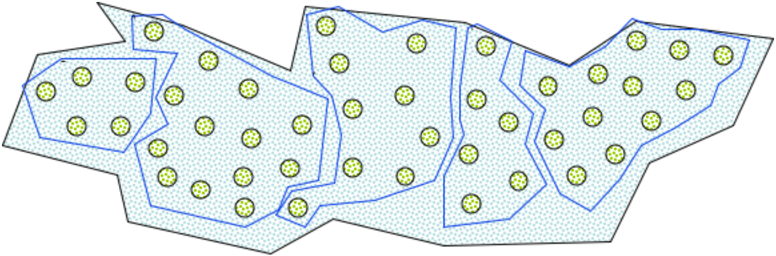
Theoretical Foundations of Testing

- Desire a test set T that is a finite subset of D that will uncover all errors
- Determining and ideal T leads to several undecideable problems
- No algorithm exists:
  - To state if a test set will uncover all possible errors
  - To derive a test set that would prove program correctness
  - To determine whether suitable input exists to guarantee execution of a given statement in a given program
  - etc.

Empirical Testing

- Need to introduce empirical testing principles and heuristics as a compromise between the impossible and the inadequate
- Find a strategy to select significant test cases
- Significant means the test cases have a high potential of uncovering the presence of errors

Complete-Coverage Principle



White-box Testing

- Intuitively, after running your test suites, what percentage of the lines of code in your program should be exercised?

White-box Coverage Testing

- (In)adequacy criteria - if significant parts of the program structure are not tested, testing is inadequate
- Control flow coverage criteria
  - Statement coverage
  - Edge coverage
  - Condition coverage
  - Path coverage

Statement-Coverage Criterion

- Select a test set T such that every elementary statement in P is executed at least once by some d in T
- An input datum executes many statements - try to minimize the number of test cases still preserving the desired coverage

Example

```
read (x); read (y);
if x > 0 then
        write ("1");
else
        write ("2");
end if;
if y > 0 then
        write ("3");
else
        write ("4");
end if;
```

How would you write a test case?

What is the minimum number of test cases?

Example

```
read (x); read (y);
if x > 0 then
        write ("1");
else
        write ("2");
end if;
if y > 0 then
        write ("3");
else
        write ("4");
end if;
```

{<x = 2, y = -3>, <x = - 13, y = 51>, <x = 97, y = 17>, <x = - 1, y = - 1>} covers all statements

{<x = - 13, y = 51>, <x = 2, y = - 3>} is minimal

Weakness of the Criterion

```
if x < 0 then
        x := -x;
end if;
z := x;
```

{<x=-3>} covers all statements. Why is this not enough?

Weakness of the Criterion

```
if x < 0 then
        x := -x;
end if;
z := x;
```

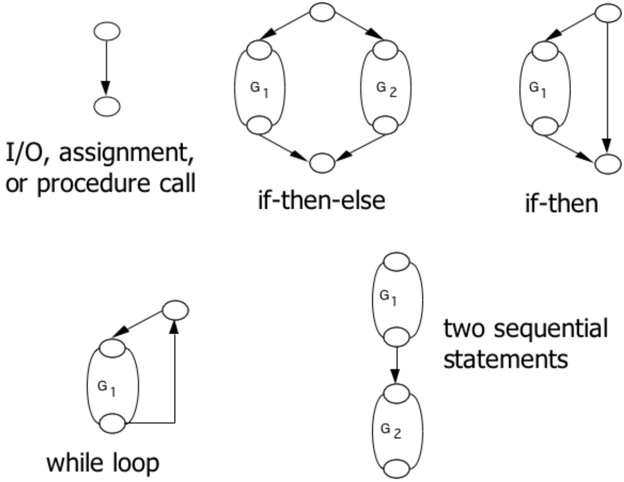
{<x=-3} covers all statements

it does not exercise the case when x is positive and the then branch is not entered

Edge-Coverage Criterion

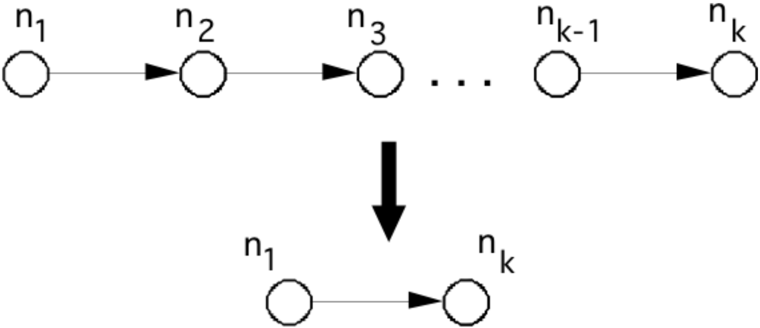
- Select a test set T such that every edge (branch) of the control flow is exercised at least once by some d in T
- This requires formalizing the concept of the control graph and how to construct it
  - Edges represent statements
  - Nodes at the ends of an edge represent entry into the statement and exit

Control Graph Construction Rules



Simplification

A sequence of edges can be collapsed into just one edge



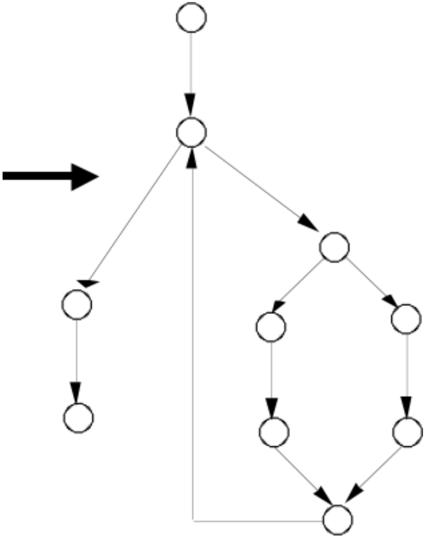
Example: Euclid's Algorithm

```
begin
        read (x); read (y);
        while x ≠ y loop
                if x > y then
                        x := x - y;
                else
                        y := y - x;
                end if;
        end loop;
        gcd : = x;
end;
```

Draw the control flow graph

Example: Euclid's Algorithm

```
begin
        read (x); read (y);
        while x ≠ y loop
                if x > y then
                        x := x - y;
                else
                        y := y - x;
                end if;
        end loop;
        gcd : = x;
end;
```



Weakness

```
found := false; counter := 1;
while (not found) and counter < number_of_items loop
        if table (counter) = desired_element then
                found := true;
        end if;
        counter := counter + 1;
end loop;
if found then
        write ("the desired element is in the table");
else
        write ("the desired element is not in the table");
end if;
```

test cases: (1) empty table, (2) table with 3 items, second of which is the item to look for

Weakness

```
found := false; counter := 1;
while (not found) and counter < number_of_items loop
        if table (counter) = desired_element then
                found := true;
        end if;
        counter := counter + 1;
end loop;
if found then
        write ("the desired element is in the table");
else
        write ("the desired element is not in the table");
end if;
```

test cases: (1) empty table, (2) table with 3 items, second of which is the item to look for

Do not discover the error ($<$ instead of $\leq$)

```
if c1 and c2 then
    st;
else
    sf;

// equivalent to

if c1 then
    if c2 then
        st;
    else
        sf;
else
    sf;
```

Condition-Coverage Criterion

- Select a test set T such that every edge of P's control flow is traversed and all possible values of the constituents of compound conditions are exercised at least once
- This criterion is finer than edge coverage

Weakness

```
if x ≠ 0 then
        y := 5;
else
        z := z - x;
end if;
if z > 1 then
        z := z / x;
else
        z := 0;
end if;
```

{<x = 0, z = 1>, <x = 1, z = 3>} causes the execution of all edges, but fails to expose the risk of a division by zero

Path-Coverage Criterion

- Select a test set T that traverses all paths from the initial to the final node of Ps control flow
- It is finer than the previous kinds of coverage
- However, number of paths may be too large, or even infinite (see while loops)
- Loops
  - Zero times (or minimum number of times)
  - Maximum times
  - Average number of times

The Infeasibility Problem

- Syntactically indicated behaviours (statements, edges, etc.) are often impossible
- Unreachable code, infeasible edges, paths, etc.
- Adequacy criteria may be impossible to satisfy
  - Manual justification for omitting each impossible test case
  - Adequacy "scores" based on coverage - example 95 % statement coverage

Further Problem

- What if the code omits the implementation of some part of the specification?
- White box test cases derived from the code will ignore that part of the specification!