Introduction to Computers and Programming

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Lecture 13
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Testing

- Goals of Testing
- Classification
    - Test Coverage
    - Test Technique
- Blackbox vs Whitebox
- Real bugs and software bugs

Testing

- Primary objectives
  - ***Testing*** is a process of executing a software program with the intention of finding a error
  - A good ***test case*** is one that has a high probability of finding an as-yet undiscovered error
  - A successful ***test*** is one that uncovers an as-yet undiscovered error"

(Glen Myers,"*The art of software testing"*)

- Secondary Objectives
  - Design tests that **systematically** uncover different **classes** of errors
  - Do so with a minimum of time and effort
  - Provide reliable indications of software quality

Test Techniques 1

- Classified according to the criterion used to measure the adequacy of a set of test cases:
  - **Coverage**-based testing
    - Testing requirements are specified in terms of the coverage of the product to be tested
  - **Fault**-based testing
    - Fault detecting ability of the test set determines the adequacy
  - **Error**-based testing
    - Focus on error-prone points, based on knowledge of the typical errors that people make

(Definitions)

- **Error**
  - Error is a human action that produces an incorrect result
- **Fault**
  - Consequence of an error is software containing a fault. A fault thus is the manifestion of an error
- **Failure**
  - If encountered, a fault may result in a failure
- What we observe **during testing** are **failures**

PRS

Exception handling is used to capture:

1. Errors
2. Faults
3. Failures
4. I am still sleeping …

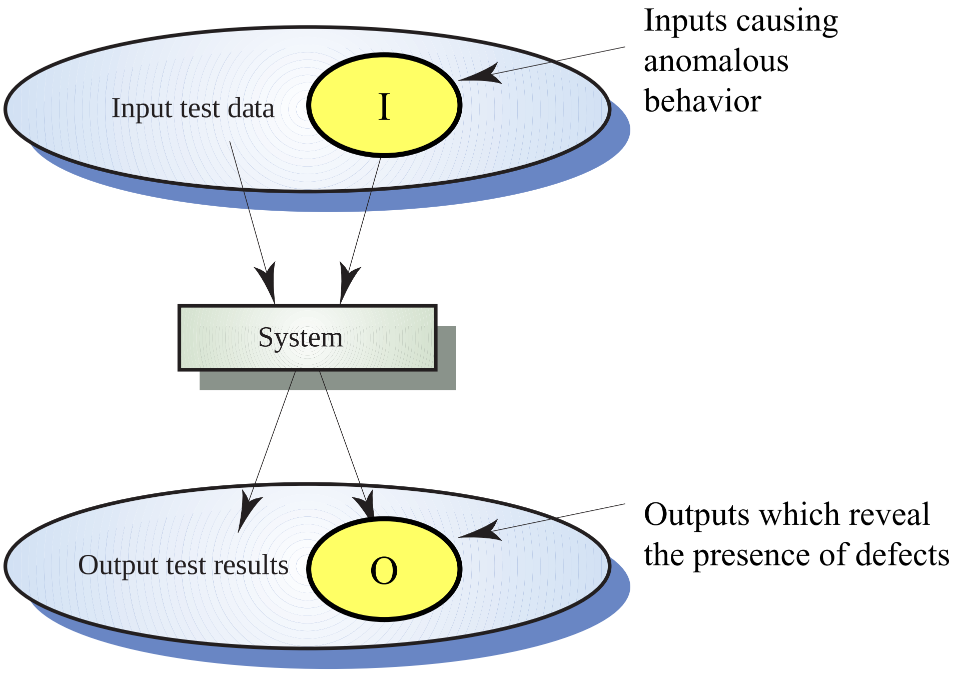
Test Techniques 2

- Or, classify test techniques based on the source of information used to derive test cases:
  - **White** (glass) **box** testing
    - Also called **structural** or program-based testing
  - **Black box** testing
    - Also called **functional** or specification-based testing

Black-Box Testing

- An approach to testing where the program is considered as a ‘black-box’
- The program test cases are based on the ***system specification***
- Test planning can begin early in the software process

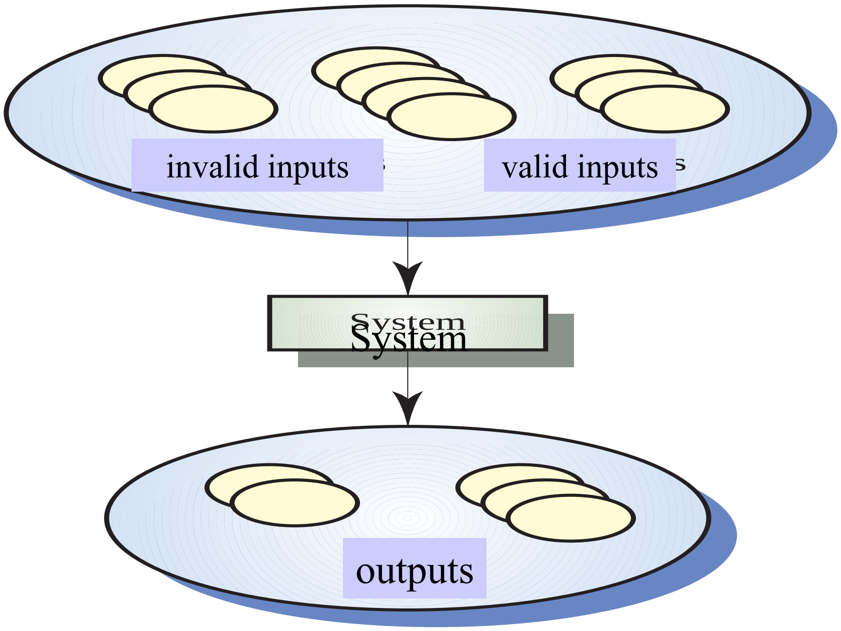
Black-Box Testing


Input test data
I
Inputs causing anomalous behavior
System
Output test results
O
Outputs which reveal the presence of defects

Equivalence Partitioning

- Input data and output results often fall into different classes where all members of a class are related
- Each of these classes is an equivalence partition where the program behaves in an equivalent way for each class member
- Test cases should be chosen from each partition

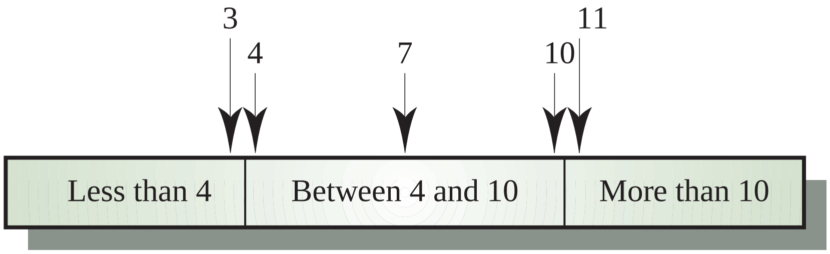
Equivalence Partitioning



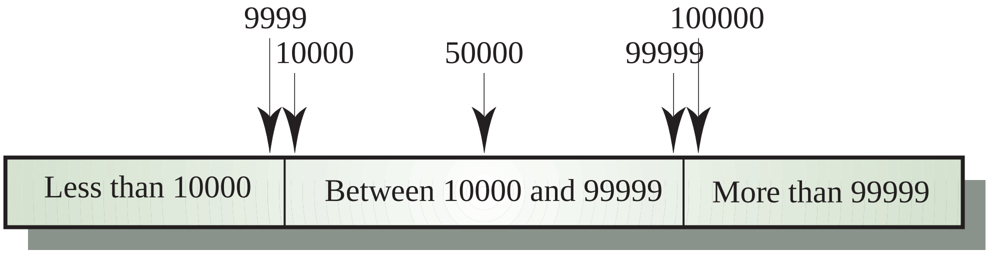
Equivalence Partitioning

- Partition system inputs and outputs into ‘equivalence sets’
  - If input is a 5-digit integer between 10,000 and 99,999 equivalence partitions are
    - <10,000
    - 10,000-99,999
    - >99,999
- Choose test cases at the boundary of these sets
  - 00000, 09999, 10000, 99999, 100000

Equivalence Partitions



Input values



Input values

Search Routine Specification

```
procedure Search (Key   : Elem;
                  T     : Elem_Array;
                  Found : in out Boolean;
                  L     : in out Elem_Index)
```

Pre-Condition

```
    -- the array has at least one element
    T'First <= T'Last
```

Post-Condition

```
    -- the element is found and is referenced by L
    ( Found and T(L) = Key)
```

or

```
    -- the element is not in the array
    ( not Found and
    not (Exists I, T'First >= I <= T'Last, T (I) = Key ))
```

Testing Guidelines (Sequences)

- Test software with sequences which have only a single value
- Use sequences of different sizes in different tests
- Derive tests so that the first, middle and last elements of the sequence are accessed
- Test with sequences of zero length

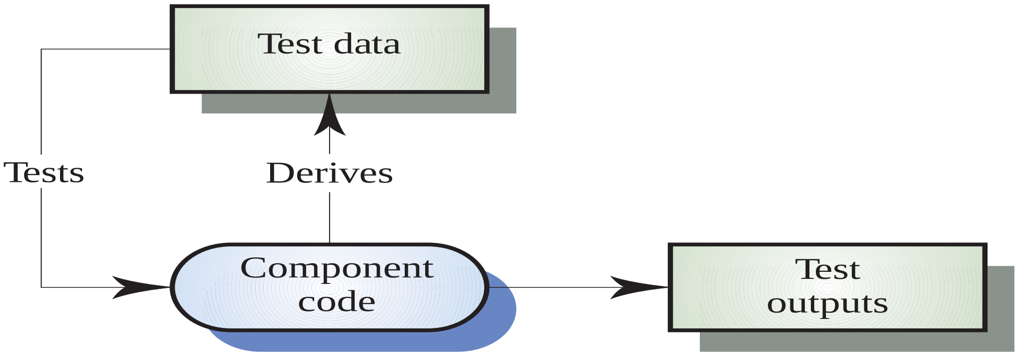
Search Routine - Input Partitions

Array	**Element**
Single value	In sequence
Single value	Not in sequence
More than 1 value	First element in sequence
More than 1 value	Last element in sequence
More than 1 value	Middle element in sequence
More than 1 value	Not in sequence

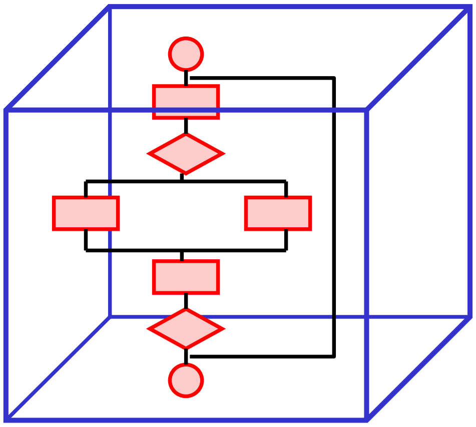
Input sequence (T)	**Key** (Key)	**Output** (Found, L)
17	17	true, 1
17	0	false, ??
17, 29, 21, 23	17	true, 1
41, 18, 9, 31, 30, 16, 45	45	true, 7
17, 18, 21, 23, 29, 41, 38	23	true, 4
21, 23, 29, 33, 38	25	false, ??

White Box Testing

- Also called Structural testing
- Derivation of test cases according to program structure. Knowledge of the program is used to identify additional test cases
- Objective is to exercise all program statements



White Box Testing

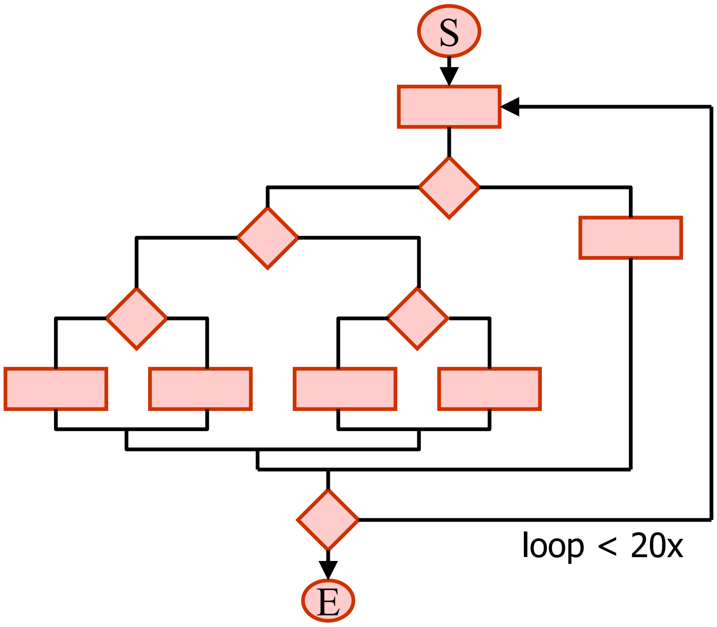


- Exercise all **independent paths** within a module at least once
- Exercise all **logical decisions** on their true and false sides
- Exercise all **loops** at their boundaries and within their operational bounds
- Exercise all **internal data** structures to assure their validity

Why White Box Testing

- Why not simply check that
  - Requirements are fulfilled?
  - Interfaces are available and working?
- Reasons for white-box testing:
  - logic errors and incorrect assumptions are inversely proportional to a path's execution probability
  - we often believe that a path is not likely to be executed; in fact, reality is often counter intuitive
  - typographical errors are random; it's likely that untested paths will contain some

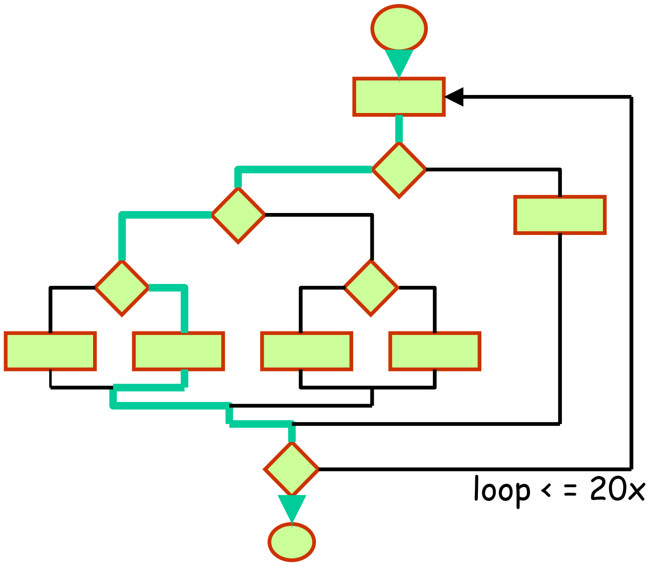
Exhaustive Testing



There are **5^{20}**=10^{14} possible paths

If we execute one test per millisecond, it would take **3,170** years to test this program

Selective Testing

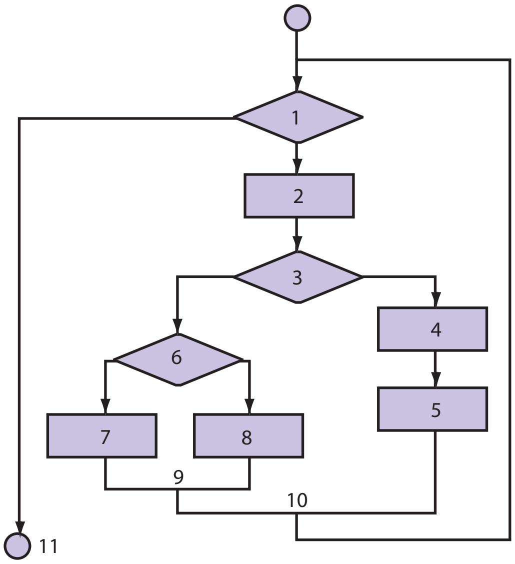


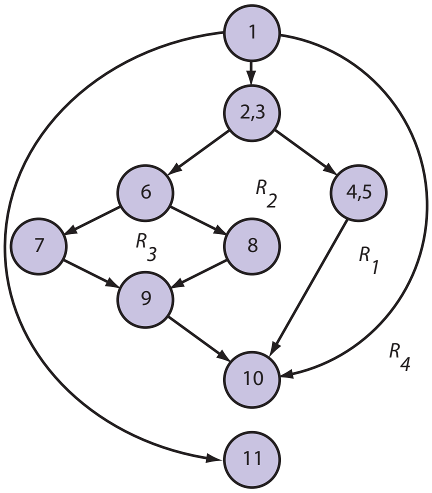
- Basis path testing
- Condition testing
- Loop testing
- Dataflow testing

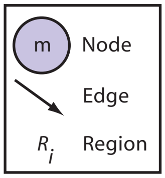
Basis Set

- **Basis set** of execution paths = **set of paths that will execute all statements** and all conditions in a program at least once
- **Cyclomatic complexity** defines the **number of independent paths** in the basis set
- Basis set is not unique
- **Goal**: Define test cases for basis set

Flow Graph Notation



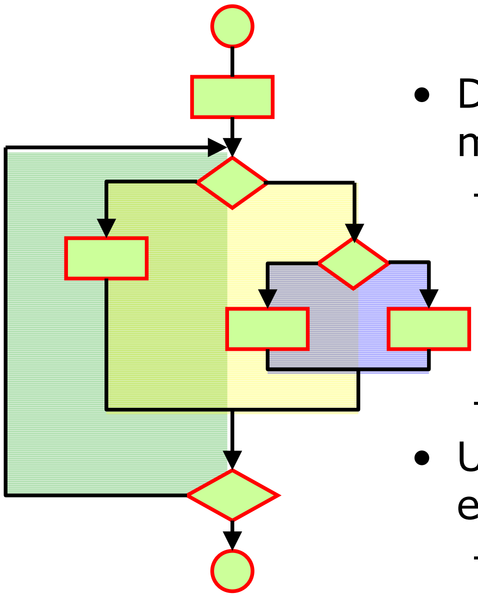




Graph Cyclomatic Number V(G) = e - n + 1

Cyclomatic Complexity CV(G) = V(G) + 1

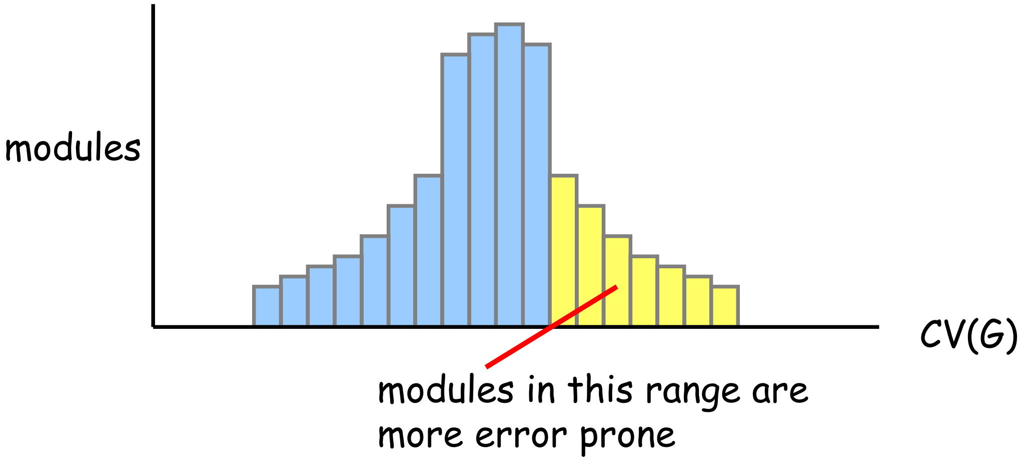
Basis Path Testing



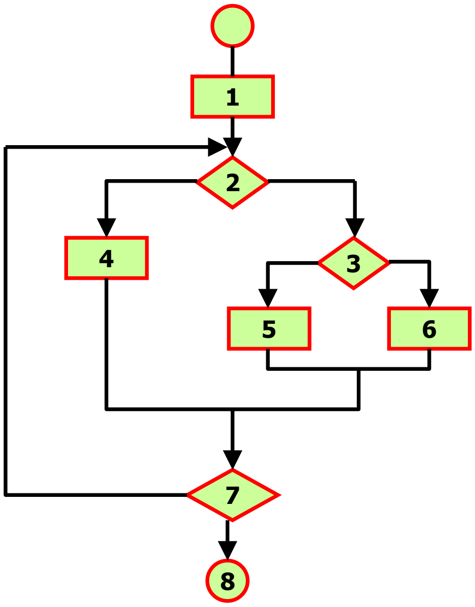
- Derive a logical complexity measure
  - Cyclomatic complexity CV(G)
    - Number of **simple decisions** +1 (compound decisions have to be split)
    - Number of **enclosed areas**+1 (uses flow-graph notation)
  - In this case, CV(G) = 4
- Use CV(G) to define a basis set of execution paths
  - CV(G) provides an lower bound of tests that must be executed to guarantee coverage of all programs

Cyclomatic Complexity

A number of industry studies have indicated that the higher CV(G), the higher the probability of errors.



Basis Path Testing



CV(G) = 4

There are four paths

Path 1:	1,2,3,6,7,8
Path 2:	1,2,3,5,7,8
Path 3:	1,2,4,7,8
Path 4:	1,2,4,7,2…7,8

We derive test cases to exercise these paths

Selective Testing

- Basis path testing
- Condition testing
- Loop testing
- Dataflow testing

Condition Testing

- Exercises each logical condition in a program module
- Possible conditions:
  - **Simple** condition:
    - Boolean variable (T or F)
    - Relational expression (a<b)
  - **Compound** condition:
    - Composed of several simple conditions ((a=b) and (c>d))

Condition Testing Methods

- **Branch** testing:
  - Each branch of each condition needs to be exercised at least once
- **Domain** testing:
  - Relational expression a<b:
    - 3 tests: a<b, a=b, a>b
  - Boolean expression with n variables
    - 2^n tests required

Selective Testing

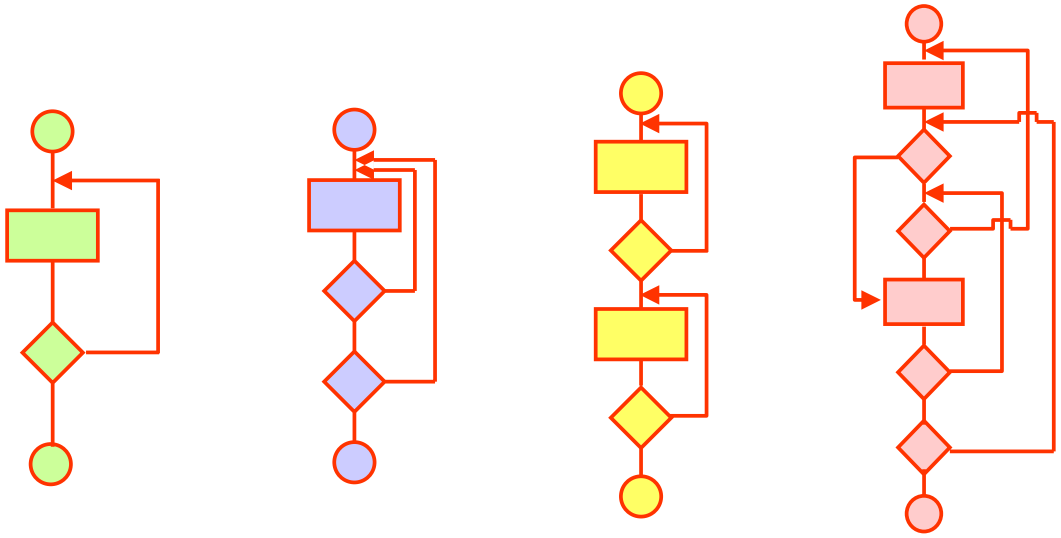
- Basis path testing
- Condition testing
- Loop testing
- Dataflow testing

Loop Testing

- Loops are the cornerstone of every program
- Loops can lead to non-terminating programs
- Loop testing focuses exclusively on the validity of loop constructs

```
while X < 20 loop
  do something
end loop;
```

Loop Testing



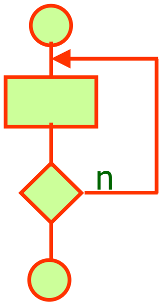
simple loop

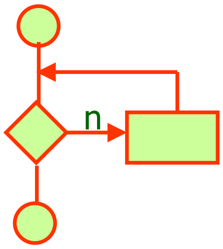
nested loops

concatenated loops

unstructured loops

Testing Simple Loops

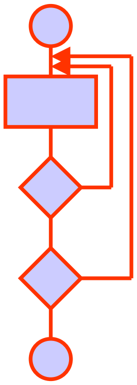




- Minimum conditions - simple loops
  - **skip** the loop entirely
  - only **one pass** through the loop
  - **two passes** through the loop
  - **m passes** through the loop m < n
  - **(n-1)**, **n**, and **(n+1) passes** through the loop

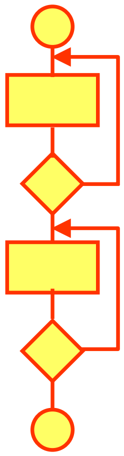
n = maximum number of allowable passes

Testing Nested Loops



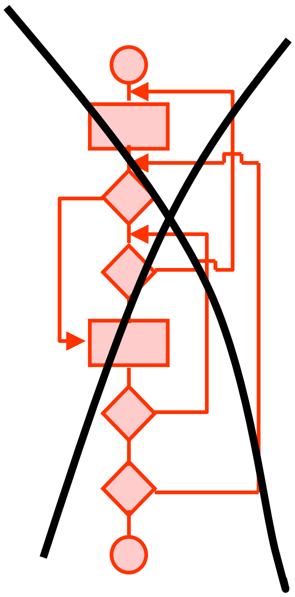
- Just extending simple loop testing
  - number of tests grows geometrically
- Reduce the number of tests:
  - start at the innermost loop; set all other loops to minimum values
  - conduct simple loop test; add out-of-range or excluded values
  - work outwards while keeping inner nested loops to typical values
  - continue until all loops have been tested

Testing Concatenated Loops



- Loops are independent of each other:
  - Use simple-loop approach
- Loops depend on each other:
  - Use nested-loop approach

Testing Unstructured Loops

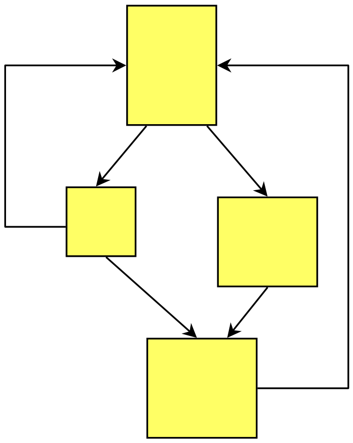


Bad Programming!

Selective Testing

- Basis path testing
- Condition testing
- Loop testing
- Dataflow testing

Dataflow Testing



- Partition the program into pieces of code with a single entry/exit point
- For each piece find which variables are set/used
- Various covering criteria:
  - For all set-use pairs
  - For all set to some use