Testing Concepts

Lesson 4: Test Techniques

Capgemini

Lesson Objectives

To understand the following topics:

- Categories of Test Techniques
  - Choosing Test Techniques
  - Categories of Test Techniques & their Characteristics
- Black-box Test Techniques
  - Equivalence Partitioning
  - Boundary Value Analysis
  - Decision Table Testing
  - State Transition Testing
  - Use Case Testing

Lesson Objectives

- White-box Test Techniques
  - Statement Testing and Coverage
  - Decision Testing and Coverage
  - The Value of Statement and Decision Testing
- Experience-based Test Techniques
  - Error Guessing
  - Exploratory Testing
  - Checklist-based Testing

4.1 Categories of Dynamic Test Techniques

- Dynamic Testing involves working with the software, giving input values and validating the output with the expected outcome
- Dynamic Testing is performed by executing the code
- It checks for functional behavior of software system , memory/CPU usage and overall performance of the system
- Dynamic Testing focuses on whether the software product works in conformance with the business requirements
- Dynamic testing is performed at all levels of testing and it can be either black or white box testing

Categories of Dynamic Test Techniques (Cont..)

White Box Test Techniques

- Code Coverage
  - Statement Coverage
  - Decision Coverage
  - Condition Coverage
  - Loop Testing
- Code complexity
  - Cyclomatic Complexity
- Memory Leakage

Black Box Test Techniques

- Equivalence Partitioning
- Boundary Value Analysis
- Use Case / UML
- Error Guessing
- Cause-Effect Graphing
- State Transition Testing

4.1.1 Choosing Test Techniques

The choice of which test techniques to use depends on a number of factors :

- Type of component or system
- Component or system complexity
- Regulatory standards
- Customer or contractual requirements
- Risk levels & Risk types
- Test objectives
- Available documentation
- Tester knowledge and skills
- Available tools
- Time and budget
- SDLC model
- Expected use of the software
- Previous experience with using the test techniques on the component or system to be tested
- The types of defects expected in the component or system

4.1.2 Categories of Test Techniques & their Characteristics

Black-box test techniques

- It is a.k.a. behavioral/behavior-based techniques are based on an analysis of the appropriate test basis (e.g., formal requirements documents, specifications, use cases, user stories, or business processes).
- These concentrate on the inputs and outputs of the test object without reference to its internal structure.
- These techniques are applicable to both functional and nonfunctional testing.

White-box test techniques

- It is a.k.a. structural/structure-based techniques are based on an analysis of the architecture, detailed design, internal structure, or the code of the test object.
- These concentrate on the structure and processing within the test object.

Experience-based test techniques

- These leverage the experience of developers, testers and users to design, implement, and execute tests.
- These techniques are often combined with black-box and white-box test techniques.

Characteristics of Black-box Test Techniques

- Test conditions, test cases, and test data are derived from a test basis that may include software requirements, specifications, use cases, and user stories
- Test cases may be used to detect gaps between the requirements and the implementation of the requirements, as well as deviations from the requirements
- Coverage is measured based on the items tested in the test basis and the technique applied to the test basis

Characteristics of White-box Test Techniques

- Test conditions, test cases, and test data are derived from a test basis that may include code, software architecture, detailed design, or any other source of information regarding the structure of the software
- Coverage is measured based on the items tested within a selected structure (e.g., the code or interfaces)
- Specifications are often used as an additional source of information to determine the expected outcome of test cases

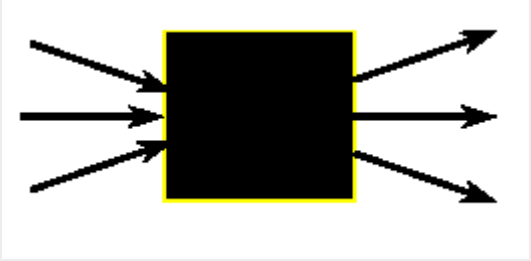
Characteristics of Experience-box Test Techniques

- Test conditions, test cases, and test data are derived from a test basis that may include knowledge and experience of testers, developers, users and other stakeholders.
- This knowledge and experience includes expected use of the software, its environment, likely defects, and the distribution of those defects

4.2 Black Box Test Techniques

- Black box is data-driven, or input/output-driven testing
- The Test Engineer is completely unconcerned about the internal behavior and structure of program
- Black box testing is also known as behavioral, functional, opaque-box and closed-box
- Black Box can be applied at different Test Levels – Unit, Subsystem and System.

Input



Output

Black Box Test Techniques

There are various techniques to perform Black box testing ;

- Equivalence Partitioning
- Boundary Value Analysis
- Decision Table Testing
- State transition testing
- Use Case Testing
- Error Guessing

4.2.1 Equivalence Partitioning

- Equivalence partitioning divides data into partitions called as equivalence classes in such a way that all the members of a given partition are expected to be processed in the same way.
- There are equivalence partitions for both valid and invalid values.
  - Valid values are values accepted by the component or system. An equivalence partition containing valid values is called a “valid equivalence partition.”
  - Invalid values are values rejected by the component or system. An equivalence partition containing invalid values is called an “invalid equivalence partition.”
- Partitions can be identified for any data element related to the test object, including inputs, outputs, internal values, time-related values (e.g., before or after an event) and for interface parameters (e.g., integrated components being tested during integration testing).
- Assumption: If one value in a group works, all will work. One from each partition is better than all from one.

Guidelines & Examples to identify Equivalence Classes

1. If an input condition specifies a continuous range of values, there is one valid class, and two invalid classes

   E.g. The valid range of a mortgage applicant's income is $1000 - $75,000
   Valid class: {1000 > = income < = 75,000}
   Invalid classes: {income < 1000}, {income > 75,000}

2. If an input condition specifies a set of values, there is reason to believe that each is handled differently in the program.

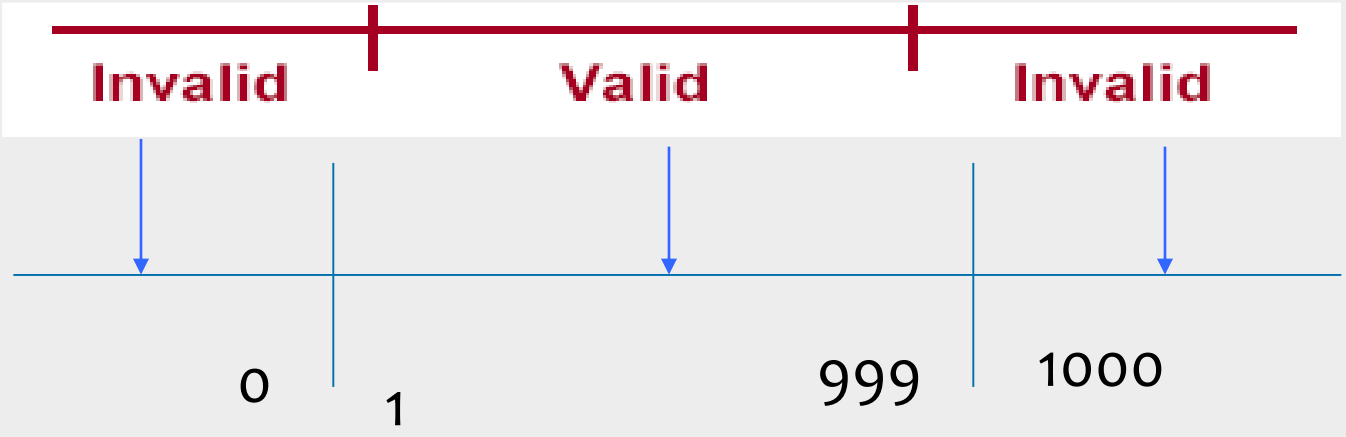
   E.g. Type of Vehicle must be Bus, Truck, Taxi). A valid equivalence class would be any one of the values and invalid class would be say Trailer or Van.

3. If a "must be" condition is required, there is one valid equivalence class and one invalid class

   E.g. The mortgage applicant must be a person
   Valid class: {person}
   Invalid classes:{corporation, ...anything else...}

Examples: Equivalence Partitioning

If an input condition specifies that a variable, say count, can take range of values(1 - 999). There is **one valid equivalence class (1 < count < 999) and two invalid equivalence classes (count < 1) & (count >999)**



4.2.2 Boundary Value Analysis

"Bugs lurk in corners and congregate at boundaries ….." *Boris Beizer*

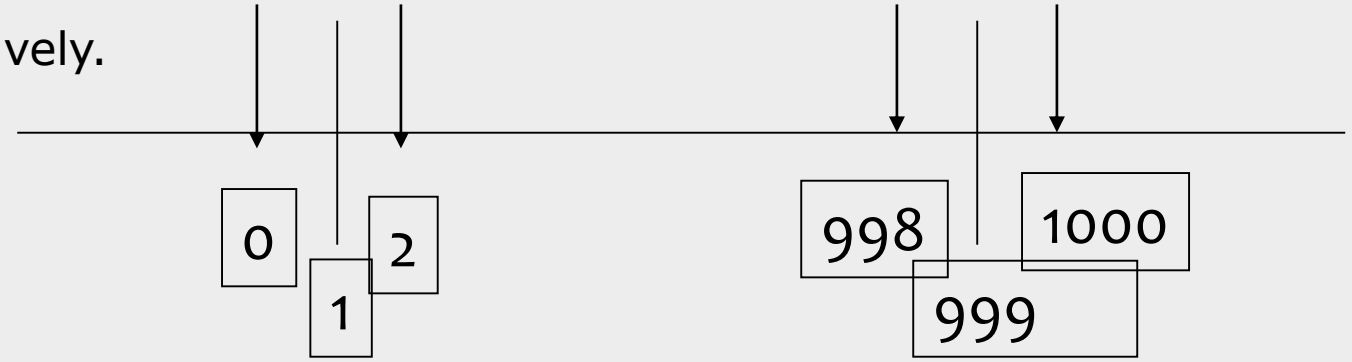
Boundary Conditions are those situations directly on, above, and beneath the edges of input equivalence classes and output equivalence classes.

Boundary value analysis is a test case design technique that complements Equivalence partitioning but can only be used when the partition is ordered, consisting of numeric or sequential data. The minimum and maximum values (or first and last values) of a partition are its boundary values.

Test cases at the boundary of each input Includes the values at the boundary, just below the boundary and just above the boundary.

Guidelines & Examples for Boundary Value Analysis

E.g. From previous example, we have valid equivalence class as (1 < count < 999). Now, according to boundary value analysis, we need to write test cases for count=0, count=1,count=2,count=998,count=999 and count=1000 respectively.



E.g. If we have to test the function int Max(int a , int b) the Boundary Values for the arguments of the functions will be :

Arguments	Valid Values	Invalid Values
a	-32768, -32767, 32767, 32766	-32769,32768
b	-32768, -32767, 32767, 32766	-32769,32768

4.2.3 Decision Table Testing

- Decision Testing is useful for testing the implementation of system requirements that specify how different combinations of conditions result in different outcomes.
- When creating decision tables, the tester identifies conditions (often inputs) and the resulting actions (often outputs) of the system.
- These form the rows of the table, usually with the conditions at the top and the actions at the bottom.
  - Each column corresponds to a decision rule that defines a unique combination of conditions which results in the execution of the actions associated with that rule.
  - The values of the conditions and actions are usually shown as Boolean values (true or false) or can also be numbers or ranges of numbers.

Notations in Decision Tables

The common notation in decision tables is as follows:

For conditions:

- Y means the condition is true (may also be shown as T or 1)
- N means the condition is false (may also be shown as F or 0)
- — means the value of the condition doesn’t matter (may also be shown as N/A)

For actions:

- X means the action should occur (may also be shown as Y or T or 1)
- Blank means the action should not occur (may also be shown as – or N or F or 0)

Example of Decision Table

Printer troubleshooter

		Rules							
Conditions	Printer does not print	Y	Y	Y	Y	N	N	N	N
	A red light is flashing	Y	Y	N	N	Y	Y	N	N
	Printer is unrecognized	Y	N	Y	N	Y	N	Y	N
Actions	Check the power cable			X					
	Check the printer-computer cable	X		X					
	Ensure printer software is installed	X		X		X		X	
	Check/replace ink	X	X			X	X		
	Check for paper jam		X		X				

Advantages of Decision Table Testing

1. The strength of decision table testing is that it helps to identify all the important combinations of conditions, some of which might otherwise be overlooked.
2. It also helps in finding any gaps in the requirements.
3. It may be applied to all situations in which the behavior of the software depends on a combination of conditions, at any test level.

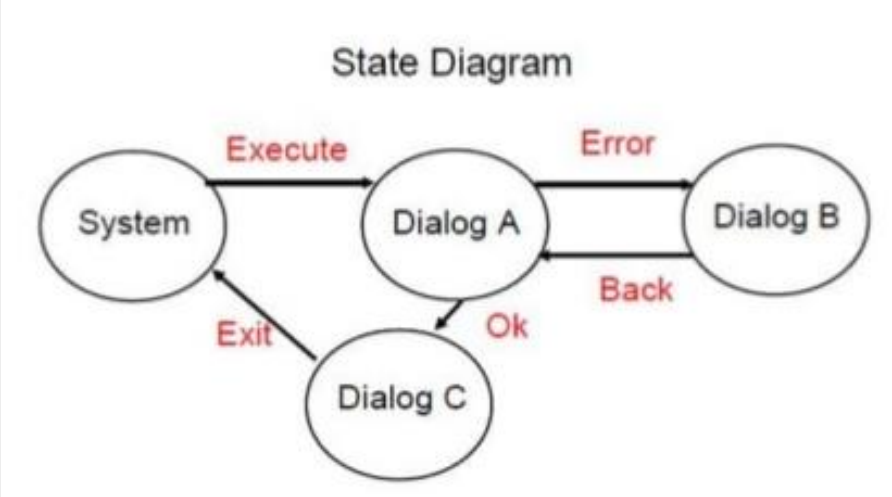
4.2.4 State Transition Testing

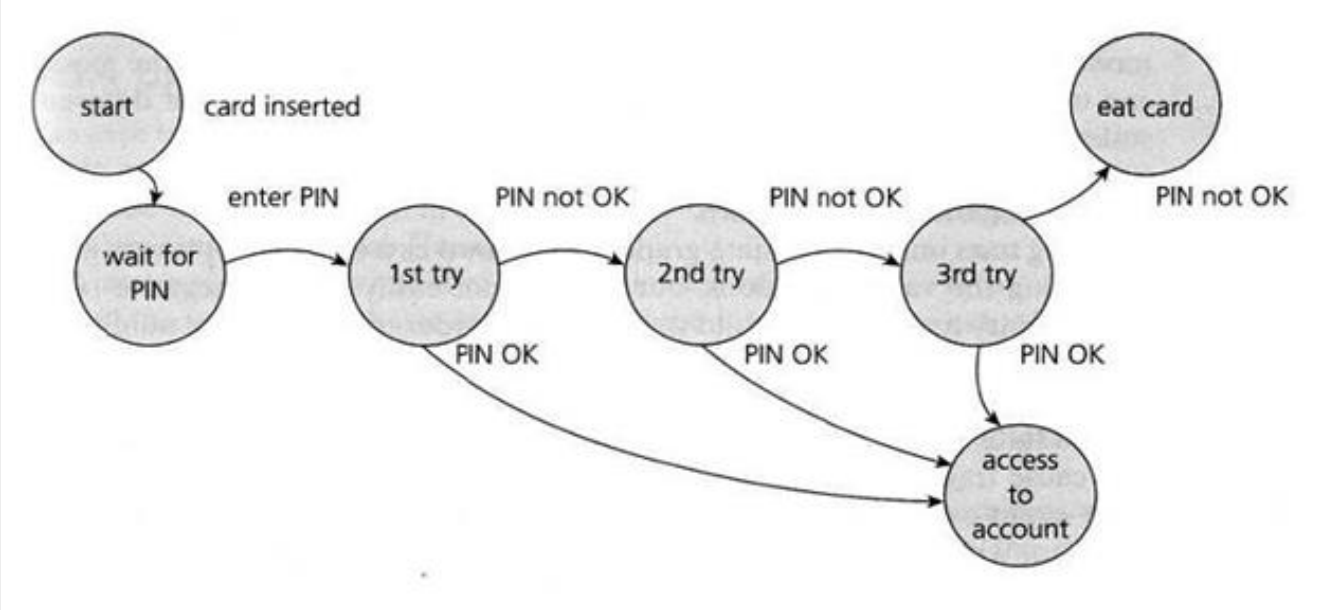
- A state transition diagram shows the possible software states, as well as how the software enters, exits, and transitions between states.
- A transition is initiated by an event (e.g., user input of a value into a field). The event results in a transition.
- If the same event can result in two or more different transitions from the same state, that event may be qualified by a guard condition.
- The state change may result in the software taking an action (e.g., outputting a calculation or error message).

Example :

- The State Transition testing is used for Menu-based application.
- The program starts with an introductory menu. As an option is selected the program changes state and displays a new menu. Eventually it displays some information , data input screen.
- Each option in each menu should be tested to validate that each selection made takes us to the state we should reach next.

Guidelines & Examples of State Transition Testing





4.2.5 Use Case Testing

- Tests can be derived from use cases, which are a specific way of designing interactions with software items, incorporating requirements for the software functions represented by the use cases.
- Use cases are associated with actors (human users, external hardware, or other components or systems) and subjects (the component or system to which the use case is applied).
- Each use case specifies some behavior that a subject can perform in collaboration with one or more actors.
- A use case can be described by interactions and activities, as well as preconditions, post conditions and natural language where appropriate.
- Interactions between the actors and the subject may result in changes to the state of the subject.

4.3 White Box Test Techniques

- White box is logic driven testing and permits Test Engineer to examine the internal structure of the program
- Examine paths in the implementation
- Make sure that each statement, decision branch, or path is tested with at least one test case.
- Desirable to use tools to analyze and track Coverage
- White box testing is also known as structural, glass-box and clear-box

There are various techniques to perform Black box testing ;

- Code Coverage
  - Statement Testing and Coverage
  - Decision Testing and Coverage
  - Condition Testing and Coverage
- Code complexity

4.3.1 Statement Coverage

Test cases must be such that all statements in the program is traversed at least once.

Example :

Consider the following snippet of code

```
void procedure(int a, int b, int x)
{
    If (a>1) && (b==0)
            { x=x/a;  }   //statement 1
     If (a==2) || (x>1)
            {  x=x+1; }  //statement 2
}
```

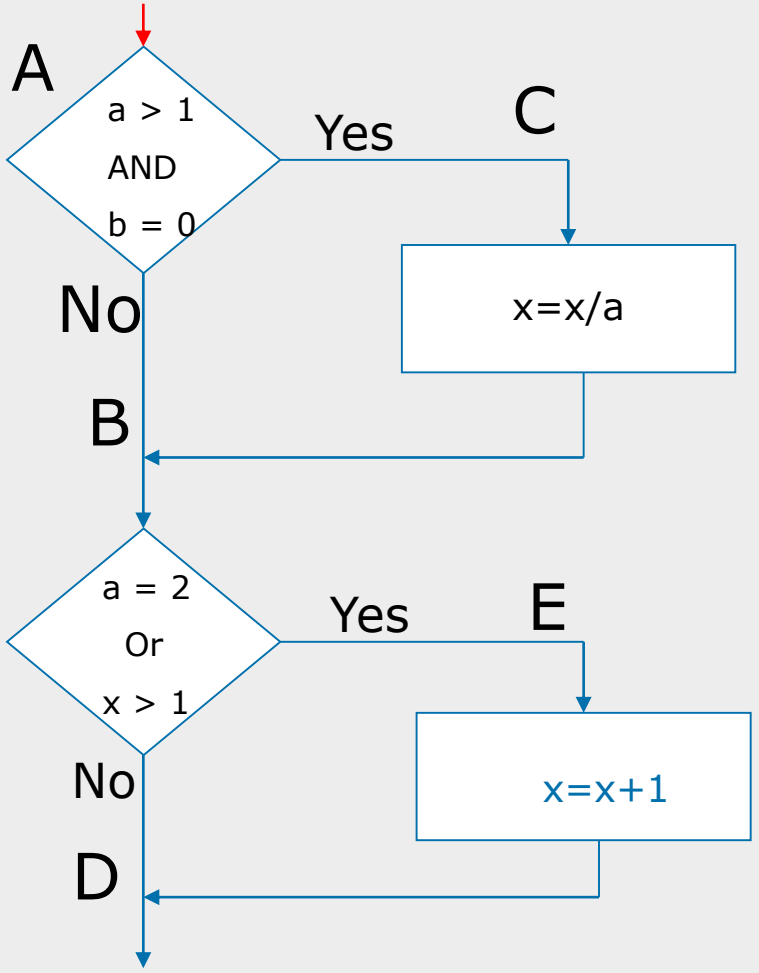
Coverage is measured as the number of statements executed by the tests divided by the total number of executable statements in the test object, normally expressed as a percentage.

Statement Coverage

Test Case 1: a=2,b=0, x=3.

Every statement will be executed once.

One test case is sufficient to execute all the statements in the code.

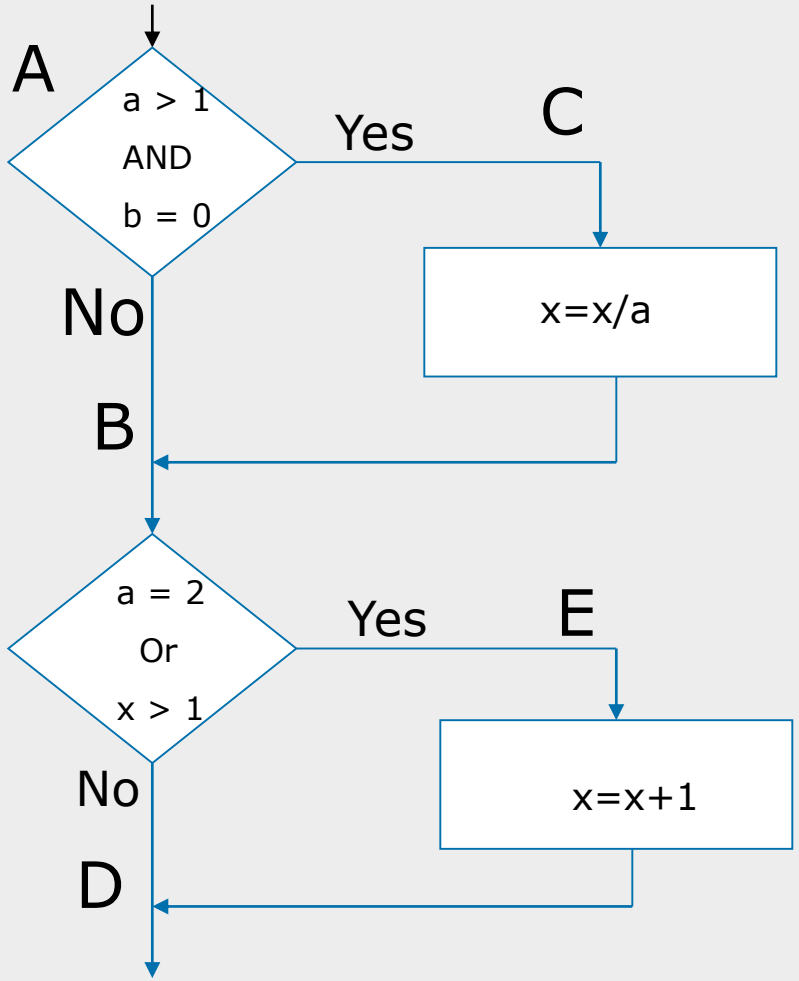


4.3.2 Decision Coverage

Test Case 1: a=2, b=0, x>1
(Decision1 is True, Decision2 is True) (Path ACE)

Test Case 2: a<=1 , b!=0, x<=1
(Decision1 is False, Decision2 is False) (Path ABD).

Two test cases are sufficient to test all decisions – every decision should be tested at least once for both TRUE and FALSE sides.



4.3.3 Value of Statement and Decision Testing

- When 100% statement coverage is achieved, it ensures that all executable statements in the code have been tested at least once, but it does not ensure that all decision logic has been tested. Statement testing provides less coverage than decision testing.
- When 100% decision coverage is achieved, it executes all decision outcomes, which includes testing the true outcome and also the false outcome, even when there is no explicit false statement (e.g., in the case of an IF statement without an else in the code).
- Statement coverage helps to find defects in code that was not exercised by other tests. Decision coverage helps to find defects in code where other tests have not taken both true and false outcomes.
- **Achieving 100% decision coverage guarantees 100% statement coverage.**

4.3.4 Condition Coverage

Test cases are written such that each condition in a decision takes on all possible outcomes at least once.

Test Case1 : a=2, b=0, x=3 (Condition1 is True,Condn2 is True)

(Path ACE)

Test Case2 : a=3, b=0, x=0

(Condn1 is True,Condn2 is False,Condn3 is False)

(Path ACD)

Test Case3 : a=1, b=0, x=3

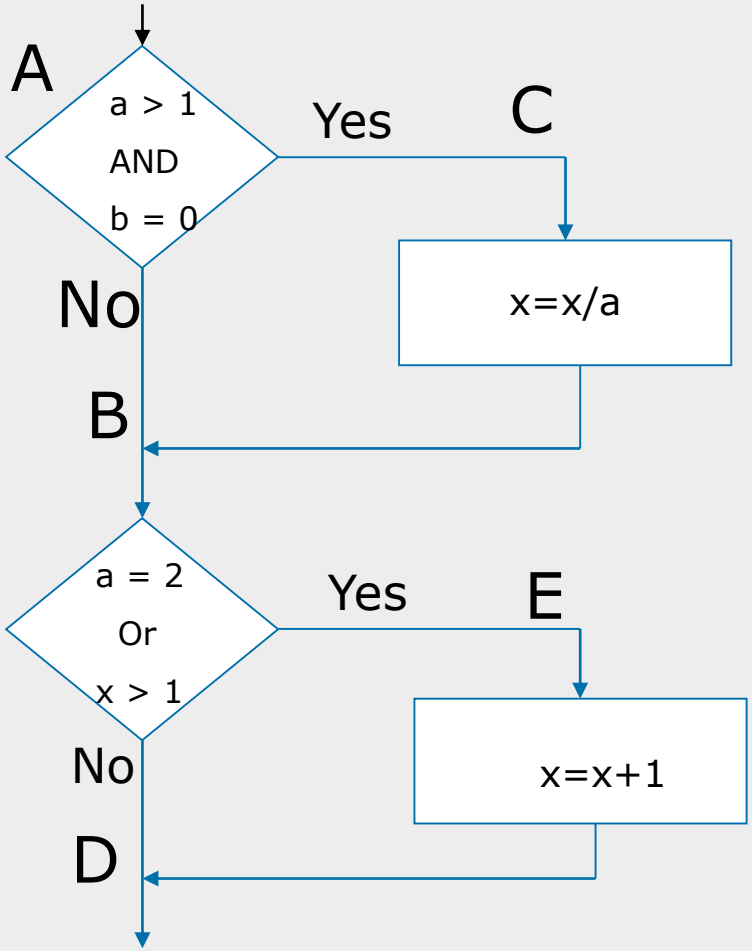
(Condition1 is False,Condition2 is True)

(Path ABE)

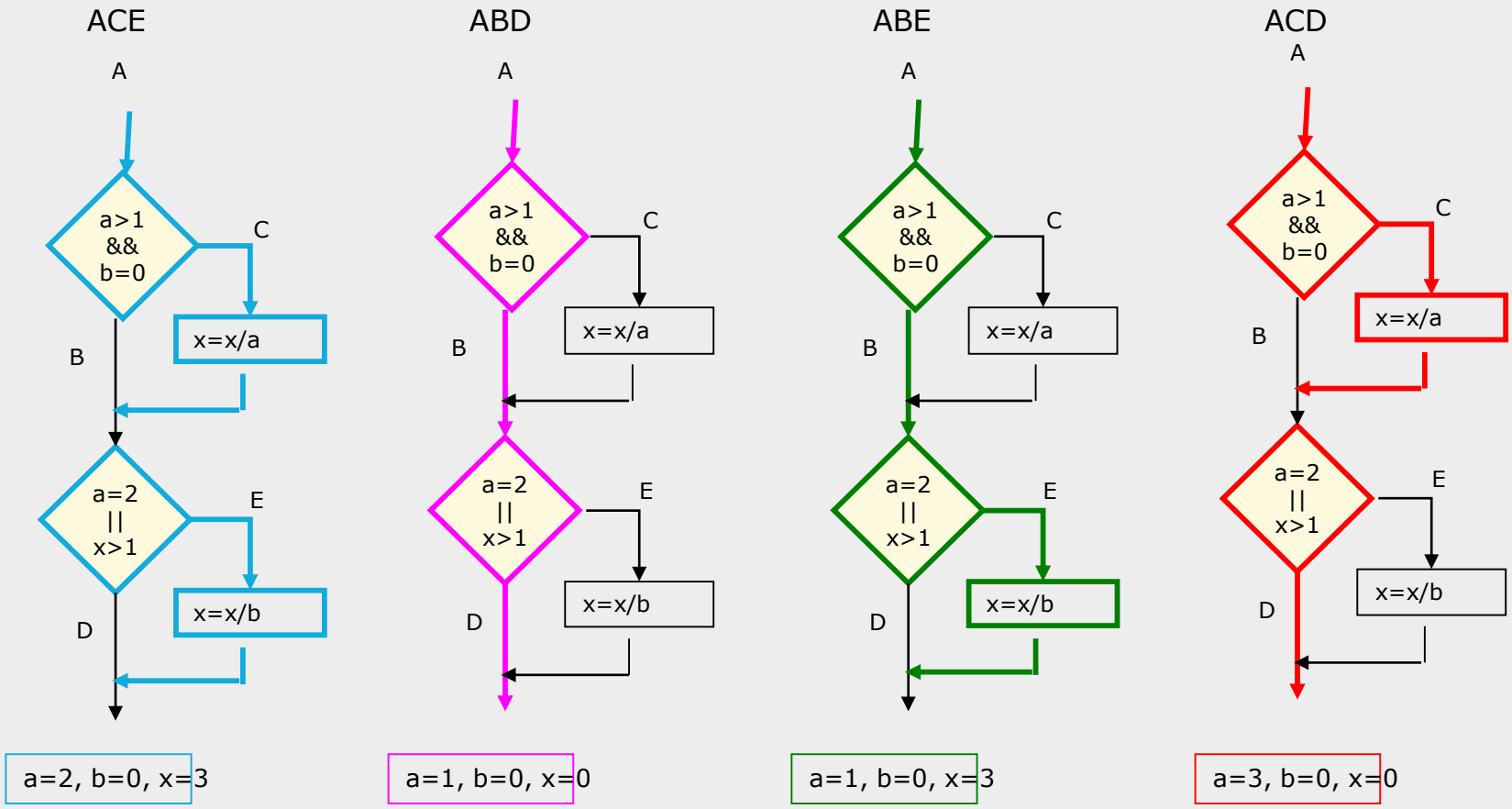
Test Case4: a=1, b=1, x=1

(Condition1 is False,Condition2 is False)

(Path ABD)



Condition Coverage



a=2, b=0, x=3

a=1, b=0, x=0

a=1, b=0, x=3

a=3, b=0, x=0

Cyclomatic Complexity

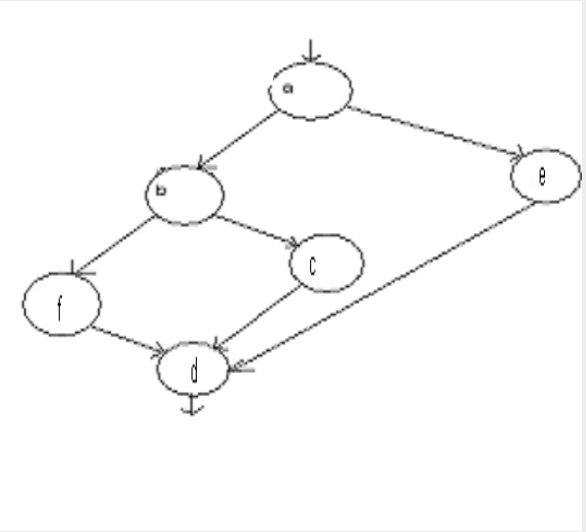
- Cyclomatic Complexity (Code Complexity) is a software metric that provides a quantitative measure of logical complexity of a program
- When Used in the context of the basis path testing method, value for cyclomatic complexity defines number of independent paths in basis set of a program
- Also provides an upper bound for the number of tests that must be conducted to ensure that all statements have been executed at least once
- Cyclomatic complexity is often referred to simply as program complexity, or as McCabe's complexity

Calculating Cyclomatic Complexity

- The cyclomatic complexity of a software module is calculated from a flow graph of the module , when used in context of the basis path testing method
- Cyclomatic Complexity V(G) is calculated one of the three ways:
  - V(G) = E - N + 2 , where E is the number of edges and N = the number of nodes of the graph
  - V(G) = P+1, where P is the number of predicate nodes
  - V(G) = R , where number of region in the graph

Calculating Cyclomatic Complexity : Example

In the given figure a and b are predicate nodes



1. Cyclomatic Complexity, V(G) for a flow Graph G is V(G) = E – N + 2
   E = Number of Edges in the graph (7 in the above figure)
   N = number of flow graph Nodes (6)
   R = number of Regions (3)
   Hence V(G) = 7-6+2 = 3
2. V(G) can also be calculated as V(G) = P+1, where P is the number of predicate nodes. Here V(G) = 2+1 = 3
3. Also V(G) can be calculated as V(G) = R hence V(G) = 3

4.4 Experience-based Test Techniques

- When applying experience-based test techniques, the test cases are derived from the tester's skill and intuition, and their experience with similar applications and technologies.
- These techniques can be helpful in identifying tests that were not easily identified by other more systematic techniques.
- Depending on the tester's approach and experience, these techniques may achieve widely varying degrees of coverage and effectiveness.
- Coverage can be difficult to assess and may not be measurable with these techniques.

Commonly used experience-based techniques are

- Error Guessing
- Exploratory Testing
- Checklist-based Testing

4.4.1 Error Guessing

It is an ad hoc approach

Error guessing is a technique used to anticipate the occurrence of mistakes, defects, and failures, based on the tester's knowledge, including:

- How the application has worked in the past
- What types of mistakes the developers tend to make
- Failures that have occurred in other applications

A methodical approach to the error guessing technique is to create a list of possible mistakes, defects, and failures, and design tests that will expose those failures and the defects that caused them.

Example :

Suppose we have to test the login screen of an application. An experienced test engineer may immediately see if the password typed in the password field can be copied to a text field which may cause a breach in the security of the application.

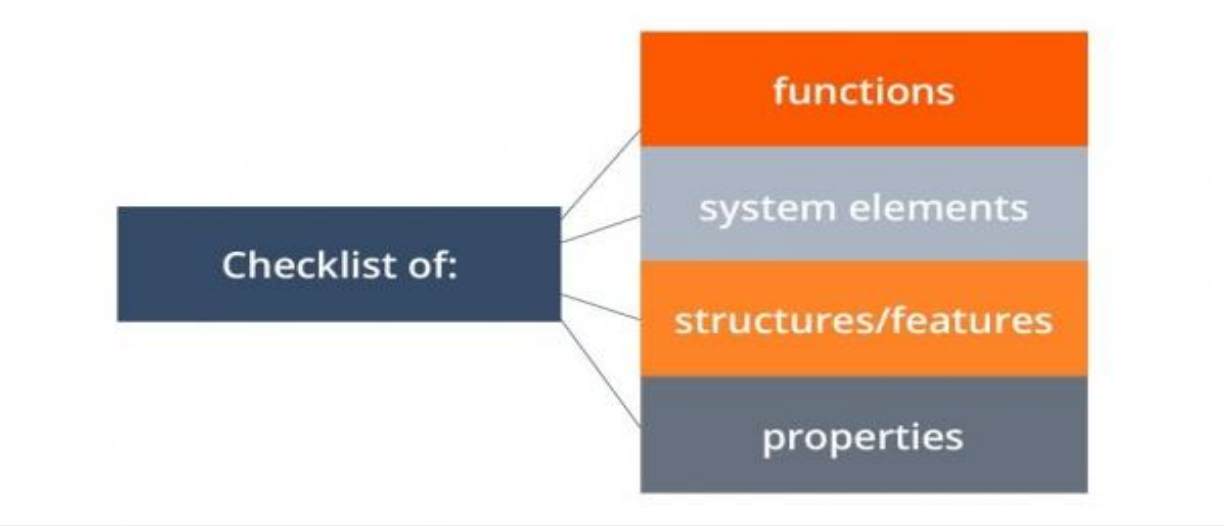
4.4.2 Exploratory Testing

- In exploratory testing, informal (not pre-defined) tests are designed, executed, logged, and evaluated dynamically during test execution.
- The test results are used to learn more about the component or system, and to create tests for the areas that may need more testing.
- Exploratory testing is sometimes conducted using session-based testing to structure the activity.
- Exploratory testing is most useful when there are few or inadequate specifications or significant time pressure on testing.
- Exploratory testing is also useful to complement other more formal testing techniques. Exploratory testing is strongly associated with reactive test strategies (see section 5.2.2). Exploratory testing can incorporate the use of other black-box, white-box, and experience-based techniques.

4.4.3 Checklist-based Testing

- In checklist-based testing, testers design, implement, and execute tests to cover test conditions found in a checklist.
- As part of analysis, testers create a new checklist or expand an existing checklist, but testers may also use an existing checklist without modification.
- Such checklists can be built based on experience, knowledge about what is important for the user, or an understanding of why and how software fails.
- Checklists can be created to support various test types, including functional and non-functional testing.
- In the absence of detailed test cases, checklist-based testing can provide guidelines and a degree of consistency.
- As these are high-level lists, some variability in the actual testing is likely to occur, resulting in potentially greater coverage but less repeatability.

Commonly used Testing Checklists



Advantages of using checklists in testing

- Flexibility.
- Easy to create.
- Analyzing the results.
- Team integration.
- Deadlines control.
- Test case reusability can help in cutting down costs incurred in missing out on important testing aspects.
- innovative testing strategy can be added in the testing checklist.

Difficulties of using checklists in testing

- Different interpretation
- Difficulty in Test results reproducibility
- “Holes” in coverage.
- Item overlap.
- Reporting problems.

Summary

In this lesson, you have learnt:

- The test case techniques discussed so far need to be combined to form overall strategy
- Each technique contributes a set of useful test cases, but none of them by itself contributes a thorough set of test cases

Review Question

Question 1: For calculating cyclomatic complexity, flow graph is mapped into corresponding flow chart

- Option: True / False

Question 2: How many minimum test cases required to test a simple loop?

Question 3: Incorrect form of logic coverage is :

- Statement coverage
- Pole coverage
- Condition coverage
- Path coverage

Question 4: One test condition will have _____ test cases.

Review Question

Question 5: For Agile development model conventional testing approach is followed.

- Option: True / False

Question 6: A test case is a set of _____, _____, and _____ developed for a particular objective.

Question 7: An input field takes the year of birth between 1900 and 2004. State the boundary values for testing this field.

- 0, 1900,2004,2005
- 1900, 2004
- 1899, 1900, 2004, 2005
- 1899, 1900, 1901, 2003, 2004, 2005

Review Question: Match the Following

1. Code coverage	A. Flow graph
2. Interface errors	B. Loop testing
3. Code complexity	C. Black box testing
	D. Flow chart
	E. Condition testing
	F. White box testing