UNIT-IV

Coding

The coding is the process of transforming the design of a system into a computer language format. This coding phase of software development is concerned with software translating design specification into the source code. It is necessary to write source code & internal documentation so that conformance of the code to its specification can be easily verified.

Coding is done by the coder or programmers who are independent people than the designer. The goal is not to reduce the effort and cost of the coding phase, but to cut to the cost of a later stage. The cost of testing and maintenance can be significantly reduced with efficient coding.

Goals of Coding

To translate the design of system into a computer language format:

The coding is the process of transforming the design of a system into a computer language format, which can be executed by a computer and that perform tasks as specified by the design of operation during the design phase.

To reduce the cost of later phases:

The cost of testing and maintenance can be significantly reduced with efficient coding.

Making the program more readable:

Program should be easy to read and understand. It increases code understanding having readability and understandability as a clear objective of the coding activity can itself help in producing more maintainable software.

The Coding Standards we have to follow while coding are as follows.

- Indentation
- Inline Comments
- Use of Global
- Structured Programming

- Naming Conventions
- Errors & Exception Handling

1. **Indentation:** Proper and consistent indentation is essential in producing easy to read and maintainable programs.
   Indentation should be used to:
   - Emphasize the body of a control structure such as a loop or a select statement.
   - Emphasize the body of a conditional statement
   - Emphasize a new scope block
2. **Inline comments:** Inline comments analyze the functioning of the subroutine, or key aspects of the algorithm shall be frequently used.
3. **Rules for limiting the use of global:** These rules file what types of data can be declared global and what cannot.
4. **Structured Programming:** Structured (or Modular) Programming methods shall be used. "GOTO" statements shall not be used as they lead to "spaghetti" code, which is hard to read and maintain, except as outlined line in the FORTRAN Standards and Guidelines.
5. **Naming conventions for global variables, local variables, and constant identifiers:** A possible naming convention can be that global variable names always begin with a capital letter, local variable names are made of small letters, and constant names are always capital letters.
6. **Error return conventions and exception handling system:** Different functions in a program report the way error conditions are handled should be standard within an organization. For example, different tasks while encountering an error condition should either return a 0 or 1 consistently.

Code Review:

Code Review is a systematic examination, which can find and remove the vulnerabilities in the code such as memory leaks and buffer overflows.

- Technical reviews are well documented and use a well-defined defect detection process that includes peers and technical experts.
- This kind of review is usually performed as a peer review without management participation.
- Reviewers prepare for the review meeting and prepare a review report with a list of findings.
- Technical reviews may be quite informal or very formal and can have a number of purposes but not limited to discussion, decision making, and evaluation of alternatives, finding defects and solving technical problems.

Code reviews are quality assurance measures conducted to examine a developer's code in relation to several objectives. The primary aim of code reviews is to find code defects, but also to verify compliance with QA standards as relates to logic, structure, style, and readability. Code reviews are also indispensable to cultivating teamwork, knowledge sharing, finding new solutions, and ultimately increasing code quality. Software developers and engineers consider code reviews as the number one means of improving code quality, followed by unit testing and continuous integration

Most probably the reviews are as follows

- Informal
- Walkthrough
- Technical Review
- Inspection

Informal Review:

Unlike Formal Reviews, Informal reviews are applied multiple times during the early stages of software development process. The major difference between the formal and informal reviews is that the former follows a formal agenda, whereas the latter is conducted as per the need of the team and follows an informal agenda.

Walkthrough:

It is used to review documents with peers, managers, and fellow team members who are guided by the author of the document to gather feedback and reach a consensus.

Technical Review:

A technical review is the primary method for communicating progress, coordinating tasks, monitoring risk, and transferring products and knowledge between the team members of a project.

Inspection:

Inspections are a formal type of review that involves checking the documents thoroughly before a meeting and is carried out mostly by moderators. A meeting is then held to review the code and the design. Inspection meetings can be held both physically and virtually.

Software Documentation

Software documentation is a written piece of text that is often accompanied by a software program.

This makes the life of all the members associated with the project easier. It may contain anything from API documentation, build notes or just help content. It is a very critical process in software development.

It’s primarily an integral part of any computer code development method. Moreover, computer code practitioners are a unit typically concerned with the

worth, degree of usage, and quality of the actual documentation throughout the development and its maintenance throughout the total method.

For example, before the developments of any software product requirements are documented which is called Software Requirement Specification (SRS).

Requirement gathering is considered a stage of Software Development Life Cycle (SDLC).

Another example can be a user manual that a user refers to for installing, using, and providing maintenance to the software application/product.

Types of Software Documentation:

1. **Requirement Documentation:** It is the description of how the software shall perform and which environment setup would be appropriate to have the best out of it. These are generated while the software is under development and is supplied to the tester groups too.
2. **Architectural Documentation:** Architecture documentation is a special type of documentation that concerns the design. It contains very little code and is more focused on the components of the system, their roles, and working. It also shows the data flow throughout the system.
3. **Technical Documentation:** These contain the technical aspects of the software like API, algorithms, etc. It is prepared mostly for software developers.
4. **End-user Documentation:** As the name suggests these are made for the end user. It contains support resources for the end user.

Advantages of software documentation:

- The presence of documentation helps in keeping the track of all aspects of an application and also improves the quality of the software product.
- The main focus is based on the development, maintenance, and knowledge transfer to other developers.
- Helps development teams during development.

- Helps end-users in using the product.
- Improves overall quality of software product
- It cuts down duplicative work.
- Makes easier to understand code.
- Helps in establishing internal coordination in work.

Disadvantages of software documentation:

- The documenting code is time-consuming.
- The software development process often takes place under time pressure, due to which many times the documentation updates don't match the updated code.
- The documentation has no influence on the performance of an application.
- Documenting is not so fun; it's sometimes boring to a certain extent.

Testing:

Software testing is a process of identifying the correctness of software by considering its all attributes (Reliability, Scalability, Portability, Re-usability, Usability) and evaluating the execution of software components to find the software bugs or errors or defects.

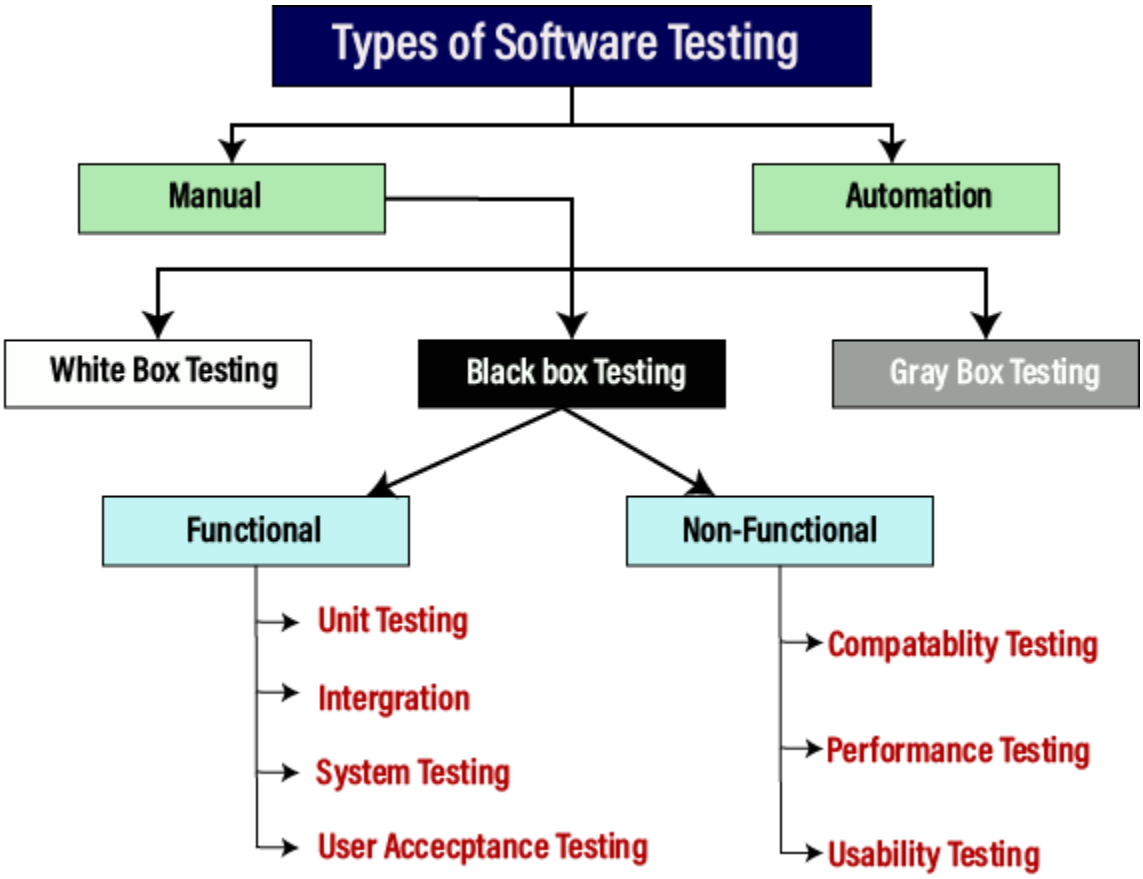
Testing is a group of techniques to determine the correctness of the application under the predefined script but, testing cannot find all the defect of application. The main intent of testing is to detect failures of the application so that failures can be discovered and corrected. It does not demonstrate that a product functions properly under all conditions but only that it is not working in some specific conditions.

Testing includes an examination of code and also the execution of code in various environments, conditions as well as all the examining aspects of the code. In the current scenario of software development, a testing team may be separate from the

development team so that Information derived from testing can be used to correct the process of software development.

Types of Testing:

The various types of testing available in the market are as follows.



Manual testing

Manual testing is a software testing process in which test cases are executed manually without using any automated tool. All test cases executed by the tester manually according to the end user's perspective. It ensures whether the application is working, as mentioned in the requirement document or not. Test cases are planned and implemented to complete almost 100 percent of the software application. Test case reports are also generated manually.

The process of checking the functionality of an application as per the customer needs without taking any help of automation tools is known as manual testing. While performing the manual testing on any application, we do not need any

specific knowledge of any testing tool, rather than have a proper understanding of the product so we can easily prepare the test document.

Manual Testing is one of the most fundamental testing processes as it can find both visible and hidden defects of the software. The difference between expected output and output, given by the software, is defined as a defect. The developer fixed the defects and handed it to the tester for retesting.

Manual testing is mandatory for every newly developed software before automated testing. This testing requires great efforts and time, but it gives the surety of bug-free software. Manual Testing requires knowledge of manual testing techniques but not of any automated testing tool.

Need of Manual Testing:

Whenever an application comes into the market, and it is unstable or having a bug or issues or creating a problem while end-users are using it.

If we don't want to face these kinds of problems, we need to perform one round of testing to make the application bug free and stable and deliver a quality product to the client, because if the application is bug free, the end-user will use the application more conveniently.

If the test engineer does manual testing, he/she can test the application as an end-user perspective and get more familiar with the product, which helps them to write the correct test cases of the application and give the quick feedback of the application.

Manual testing can be further divided into three types of testing, which are as follows:

- **White box testing**
- **Black box testing**
- **Gray box testing**

White box Testing:

white box testing which also known as glass box is **testing, structural testing, clear box testing, open box testing and transparent box testing**. It tests internal coding and infrastructure of a software focus on checking of predefined inputs against expected and desired outputs. It is based on inner workings of an application and revolves around internal structure testing. In this type of testing programming skills are required to design test cases. The primary goal of white box testing is to focus on the flow of inputs and outputs through the software and strengthening the security of the software.

The term 'white box' is used because of the internal perspective of the system. The clear box or white box or transparent box name denote the ability to see through the software's outer shell into its inner workings.

Developers do white box testing. In this, the developer will test every line of the code of the program. The developers perform the White-box testing and then send the application or the software to the testing team, where they will perform the black box testing and verify the application along with the requirements and identify the bugs and sends it to the developer.

The developer fixes the bugs and does one round of white box testing and sends it to the testing team. Here, fixing the bugs implies that the bug is deleted, and the particular feature is working fine on the application.

Here, the test engineers will not include in fixing the defects for the following reasons:

- Fixing the bug might interrupt the other features. Therefore, the test engineer should always find the bugs, and developers should still be doing the bug fixes.
- If the test engineers spend most of the time fixing the defects, then they may be unable to find the other bugs in the application.

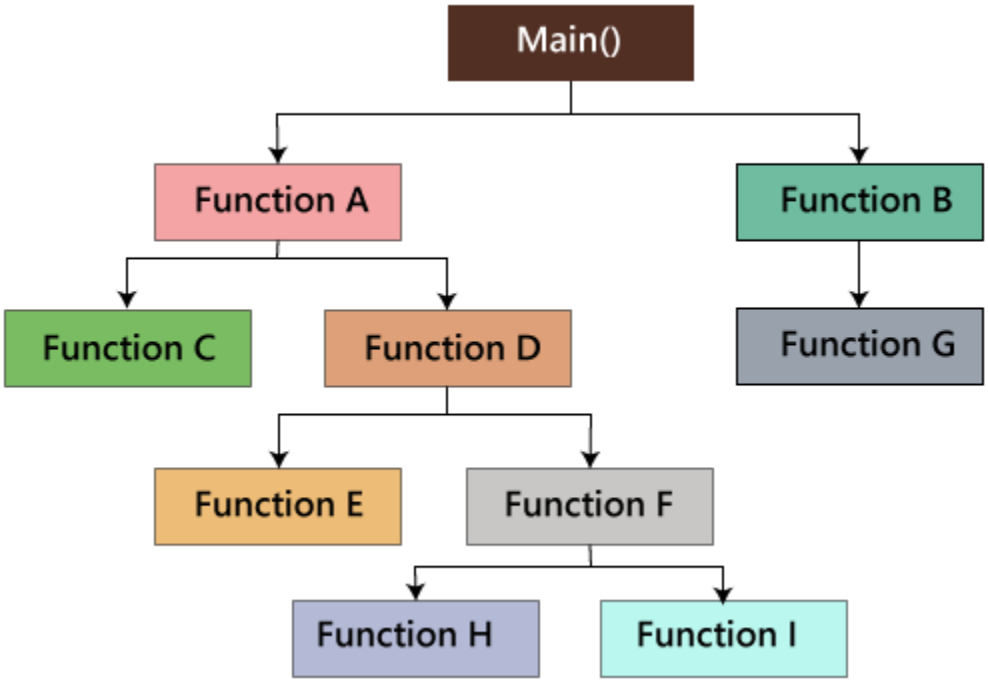
The white box testing contains various tests, which are as follows:

- Path testing

- Loop testing
- Condition testing
- Testing based on the memory perspective
- Test performance of the program

Path testing

In the path testing, we will write the flow graphs and test all independent paths. Here writing the flow graph implies that flow graphs are representing the flow of the program and also show how every program is added with one another as we can see in the below image:



And test all the independent paths implies that suppose a path from main() to function G, first set the parameters and test if the program is correct in that particular path, and in the same way test all other paths and fix the bugs.

Loop testing

In the loop testing, we will test the loops such as while, for, and do-while, etc. and also check for ending condition if working correctly and if the size of the conditions is enough.

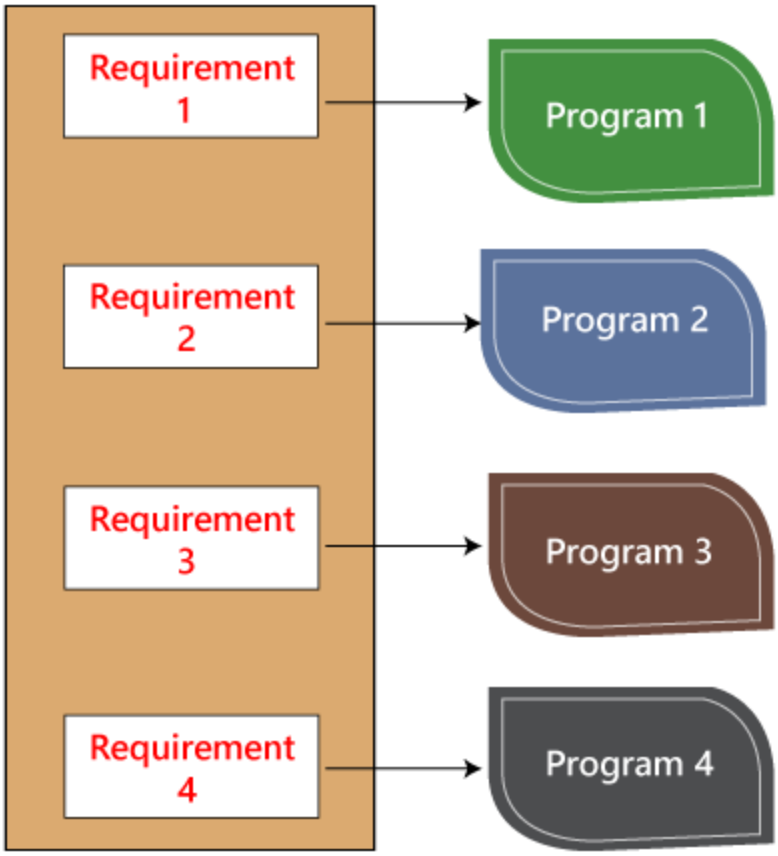
For example: we have one program where the developers have given about 50,000 loops.

1. {
2. while(50,000)
3. ……
4. ……
5. }

We cannot test this program manually for all the 50,000 loops cycle. So we write a small program that helps for all 50,000 cycles, as we can see in the below program, that test P is written in the similar language as the source code program, and this is known as a Unit test. And it is written by the developers only.

1. Test P
2. {
3. ……
4. …… }

As we can see in the below image that, we have various requirements such as 1, 2, 3, 4. And then, the developer writes the programs such as program 1,2,3,4 for the parallel conditions. Here the application contains the 100s line of codes.

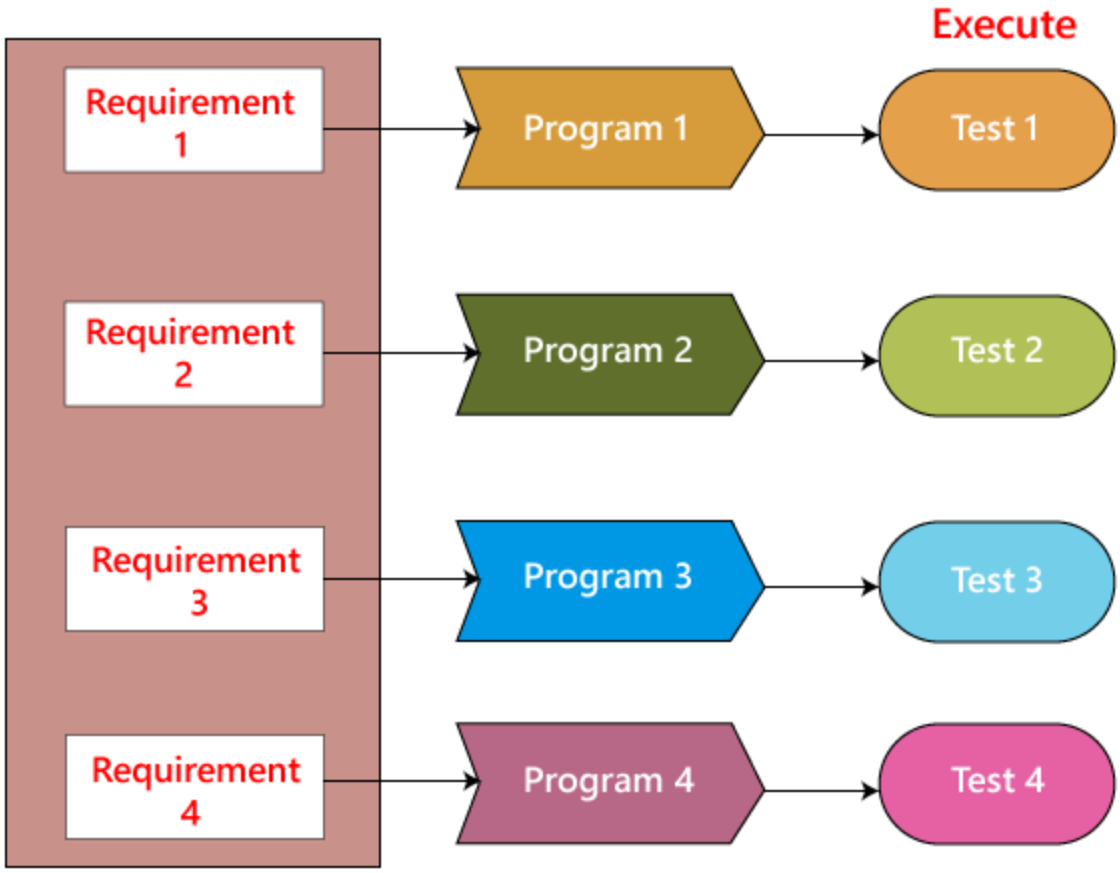


The developer will do the white box testing, and they will test all the five programs line by line of code to find the bug. If they found any bug in any of the programs, they will correct it. And they again have to test the system then this process contains lots of time and effort and slows down the product release time.

Now, suppose we have another case, where the clients want to modify the requirements, then the developer will do the required changes and test all four program again, which take lots of time and efforts.

These issues can be resolved in the following ways:

In this, we will write test for a similar program where the developer writes these test code in the related language as the source code. Then they execute these test code, which is also known as **unit test programs**. These test programs linked to the main program and implemented as programs.



Therefore, if there is any requirement of modification or bug in the code, then the developer makes the adjustment both in the main program and the test program and then executes the test program.

Condition testing

In this, we will test all logical conditions for both **true** and **false** values; that is, we will verify for both **if** and **else** condition.

For example:

```
if(condition) - true
{
…..
……
```

……

}

else - false

{

…..

……

……

}

The above program will work fine for both the conditions, which means that if the condition is accurate, and then else should be false and conversely.

Testing based on the memory (size) perspective

The size of the code is increasing for the following reasons:

- **The reuse of code is not there**: let us take one example, where we have four programs of the same application, and the first ten lines of the program are similar. We can write these ten lines as a discrete function, and it should be accessible by the above four programs as well. And also, if any bug is there, we can modify the line of code in the function rather than the entire code.
- The **developers use the logic** that might be modified. If one programmer writes code and the file size is up to 250kb, then another programmer could write a similar code using the different logic, and the file size is up to 100kb.
- The **developer declares so many functions and variables** that might never be used in any portion of the code. Therefore, the size of the program will increase.

For example,

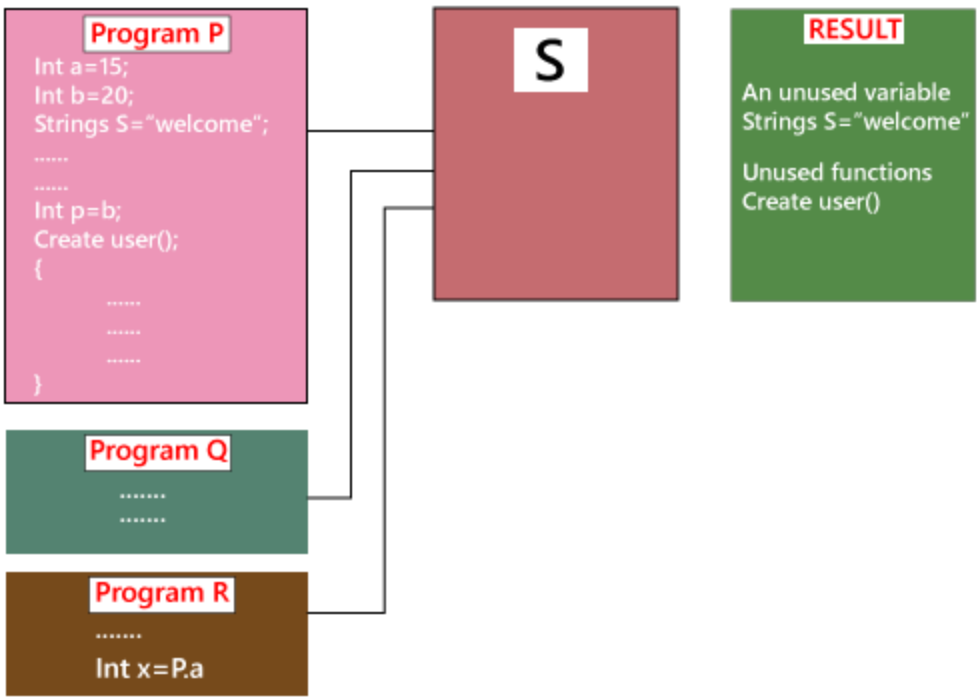
Int a=15;

Int b=20;

```
String S= "Welcome";
….
…..
…..
….
…..
Int p=b;
Create user()
{
……
……
….. 200's line of code
}
```

In the above code, we can see that the **integer a** has never been called anywhere in the program, and also the function **Create user** has never been called anywhere in the code. Therefore, it leads us to memory consumption.

We cannot remember this type of mistake manually by verifying the code because of the large code. So, we have a built-in tool, which helps us to test the needless variables and functions. And, here we have the tool called **Rational purify**.



Suppose we have three programs such as Program P, Q, and R, which provides the input to S. And S goes into the programs and verifies the unused variables and then gives the outcome. After that, the developers will click on several results and call or remove the unnecessary function and the variables.

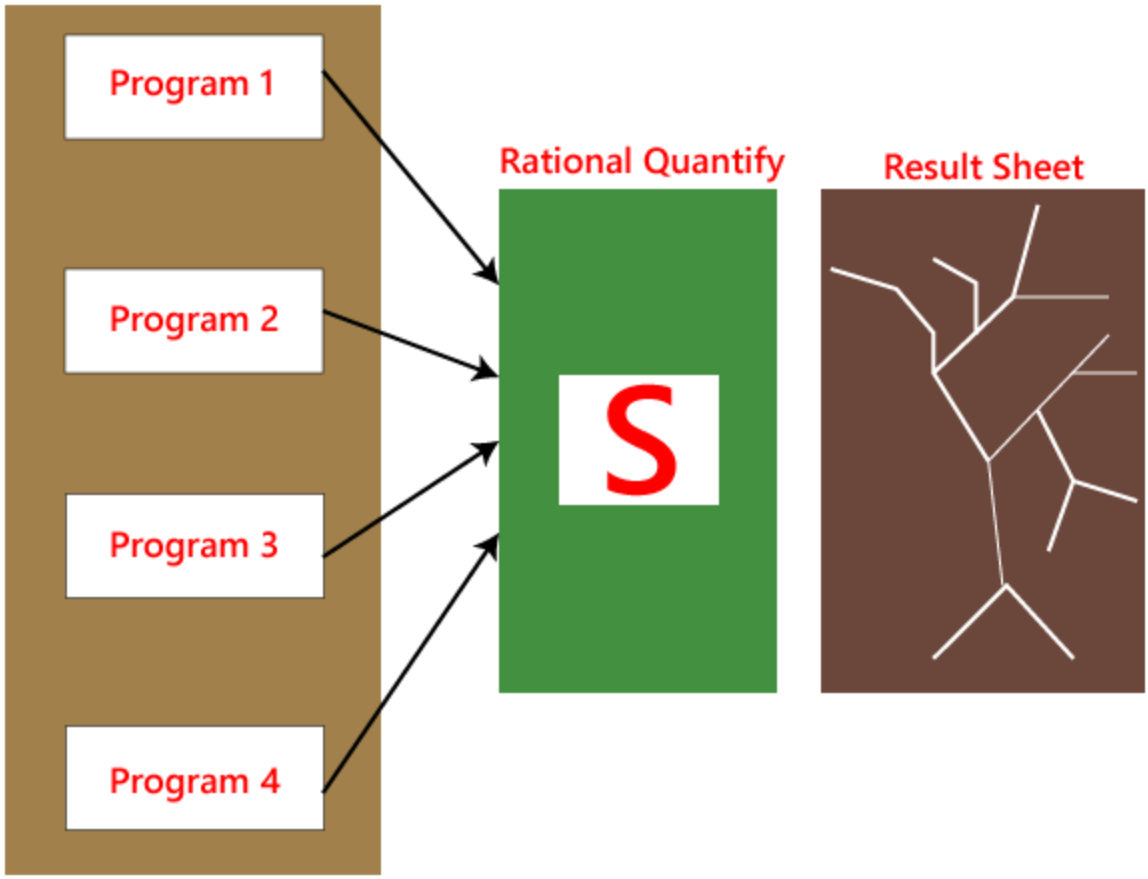
This tool is only used for the C programming language and C++ programming language; for another language, we have other related tools available in the market.

- The developer does not use the available in-built functions; instead they write the full features using their logic. Therefore, it leads us to waste of time and also postpone the product releases.

Test the performance (Speed, response time) of the program

The application could be slow for the following reasons:

- When logic is used.
- For the conditional cases, we will use **or** & **and** adequately.
- Switch case, which means we cannot use **nested if**, instead of using a switch case.



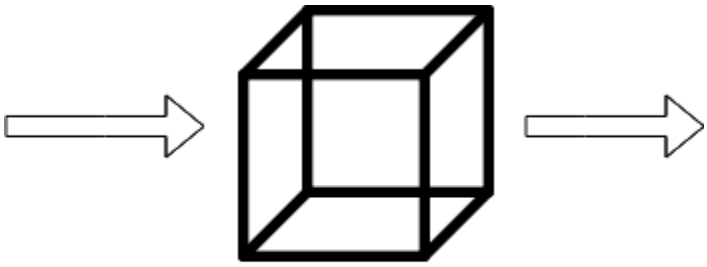
As we know that the developer is performing white box testing, they understand that the code is running slow, or the performance of the program is also getting deliberate. And the developer cannot go manually over the program and verify which line of the code is slowing the program.

To recover with this condition, we have a tool called **Rational Quantify**, which resolves these kinds of issues automatically. Once the entire code is ready, the rational quantify tool will go through the code and execute it. And we can see the outcome in the result sheet in the form of thick and thin lines.

Here, the thick line specifies which section of code is time-consuming. When we double-click on the thick line, the tool will take us to that line or piece of code automatically, which is also displayed in a different color. We can change that code and again and use this tool. When the order of lines is all thin, we know that the presentation of the program has enhanced. And the developers will perform the

white box testing automatically because it saves time rather than performing manually.

Test cases for white box testing are derived from the design phase of the software development lifecycle. Data flow testing, control flow testing, path testing, branch testing, statement and decision coverage all these techniques used by white box testing as a guideline to create an error-free software.



Whitebox Testing

White box testing follows some working steps to make testing manageable and easy to understand what the next task to do. There are some basic steps to perform white box testing.

Generic steps of white box testing

- Design all test scenarios, test cases and prioritize them according to high priority number.
- This step involves the study of code at runtime to examine the resource utilization, not accessed areas of the code, time taken by various methods and operations and so on.
- In this step testing of internal subroutines takes place. Internal subroutines such as nonpublic methods, interfaces are able to handle all types of data appropriately or not.
- This step focuses on testing of control statements like loops and conditional statements to check the efficiency and accuracy for different data inputs.
- In the last step white box testing includes security testing to check all possible security loopholes by looking at how the code handles security.

Reasons for white box testing

- It identifies internal security holes.
- To check the way of input inside the code.
- Check the functionality of conditional loops.
- To test function, object, and statement at an individual level.

Advantages of White box testing

- White box testing optimizes code so hidden errors can be identified.
- Test cases of white box testing can be easily automated.
- This testing is more thorough than other testing approaches as it covers all code paths.
- It can be started in the SDLC phase even without GUI.

Disadvantages of White box testing

- White box testing is too much time consuming when it comes to large-scale programming applications.
- White box testing is much expensive and complex.
- It can lead to production error because it is not detailed by the developers.
- White box testing needs professional programmers who have a detailed knowledge and understanding of programming language and implementation.

Techniques Used in White Box Testing

Data Flow Testing	Data flow testing is a group of testing strategies that examines the control flow of programs in order to explore the sequence of variables according to the sequence of events.
Control Flow Testing	Control flow testing determines the execution order of statements or instructions of the program through a control structure. The control structure of a program is used to develop a test case for the program. In this technique, a particular part of a large program is selected by the tester to set the testing path. Test cases represented by the control graph of the program.
Branch Testing	Branch coverage technique is used to cover all branches of the control flow graph. It covers all the possible outcomes (true and false) of each condition of decision point at least once.
Statement Testing	Statement coverage technique is used to design white box test cases. This technique involves execution of all statements of the source code at least once. It is used to calculate the total number of executed statements in the source code, out of total statements present in the source code.
Decision Testing	This technique reports true and false outcomes of Boolean expressions. Whenever there is a possibility of two or more outcomes from the statements like do while statement, if statement and case statement (Control flow statements), it is considered as decision point because there are two outcomes either true or false.

Black-Box Testing:

Black box testing is a type of software testing in which the functionality of the software is not known. The testing is done without the internal knowledge of the products.

In this method, tester selects a function and gives input value to examine its functionality, and checks whether the function is giving expected output or not. If the function produces correct output, then it is passed in testing, otherwise failed. The test team reports the result to the development team and then tests the next function. After completing testing of all functions if there are severe problems, then it is given back to the development team for correction.

Generic steps of black box testing

- The black box test is based on the specification of requirements, so it is examined in the beginning.
- In the second step, the tester creates a positive test scenario and an adverse test scenario by selecting valid and invalid input values to check that the software is processing them correctly or incorrectly.
- In the third step, the tester develops various test cases such as decision table, all pairs test, equivalent division, error estimation, cause-effect graph, etc.
- The fourth phase includes the execution of all test cases.
- In the fifth step, the tester compares the expected output against the actual output.
- In the sixth and final step, if there is any flaw in the software, then it is cured and tested again.

Techniques Used in Black Box Testing:

1. Decision Table

Decision Table Technique is a systematic approach where various input combinations and their respective system behaviors are captured in a tabular form. It is appropriate for the functions that have a logical relationship between two and more than two inputs.

Ex:

Most of us use an email account, and when you want to use an email account, for this you need to enter the email and its associated password.

If both email and password are correctly matched, the user will be directed to the email account's homepage; otherwise, it will come back to the login page with an error message specified with "Incorrect Email" or "Incorrect Password."

Decision Table for login function is as follows.

Email(Condition1)	T	T	F	F
Password(Condition2)	T	F	T	F
Expected Result(Action)	Emails Account Homepage	Incorrect Password	Incorrect Email	Incorrect Email and Password

While using the decision table technique, a tester determines the expected output, if the function produces expected output, then it is passed in testing, and if not then it is failed. Failed software is sent back to the development team to fix the defect.

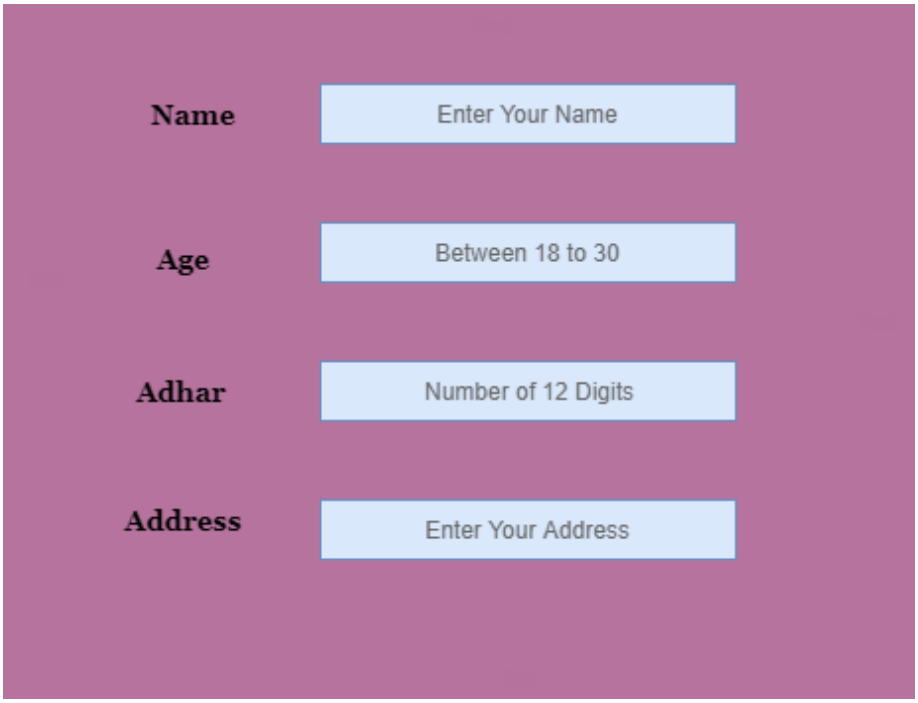
2. Boundary Value Technique

Boundary Value Technique is used to test boundary values; boundary values are those that contain the upper and lower limit of a variable. It tests, while entering boundary value whether the software is producing correct output or not.

Ex:

Boundary values are those that contain the upper and lower limit of a variable. Assume that, age is a variable of any function, and its minimum value is 18 and the maximum value is 30, both 18 and 30 will be considered as boundary values.

There is 18 and 30 are the boundary values that's why tester pays more attention to these values, but this doesn't mean that the middle values like 19, 20, 21, 27, 29 are ignored. Test cases are developed for each and every value of the range.



Testing of boundary values is done by making valid and invalid partitions. Invalid partitions are tested because testing of output in adverse condition is also essential.

Ex:

Invalid test cases	Valid test cases	Invalid test cases
11, 13, 14, 15, 16, 17	18, 19, 24, 27, 28, 30	31, 32, 36, 37, 38, 39

The software system will be passed in the test if it accepts a valid number and gives the desired output, if it is not, then it is unsuccessful. In another scenario, the

software system should not accept invalid numbers, and if the entered number is invalid, then it should display error massage.

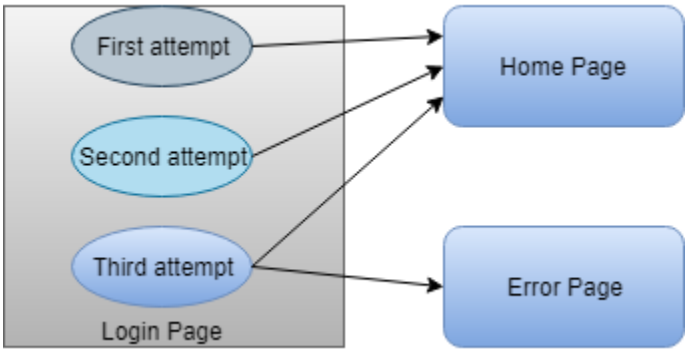
3. State Transition Technique

State Transition Technique is used to capture the behavior of the software application when different input values are given to the same function. This applies to those types of applications that provide the specific number of attempts to access the application.

Ex:

The ATMs, when we withdraw money from it, it displays account details at last. Now we again do another transaction, then it again displays account details, but the details displayed after the second transaction are different from the first transaction, but both details are displayed by using the same function of the ATM. So the same function was used here but each time the output was different, this is called state transition. In the case of testing of a software application, this method tests whether the function is following state transition specifications on entering different inputs.

Ex:



The above example shows the application which provides a maximum three number of attempts, and after exceeding three attempts, it will be directed to an error page.

State transition table

STATE	LOGIN	VALIDATION	REDIRECTED
S1	First Attempt	Invalid	S2
S2	Second Attempt	Invalid	S3
S3	Third Attempt	Invalid	S5
S4	Home Page		
S5	Error Page		

Let's see state transition table if third attempt is valid:

STATE	LOGIN	VALIDATION	REDIRECTED
S1	First Attempt	Invalid	S2
S2	Second Attempt	Invalid	S3
S3	Third Attempt	Valid	S4
S4	Home Page		
S5	Error Page		

4. **All-pair Testing Technique**

All-pair testing Technique is used to test all the possible discrete combinations of values. This combinational method is used for testing the application that uses checkbox input, radio button input, list box, text box, etc.

Ex:

Suppose, you have a function of a software application for testing, in which there are 10 fields to input the data, so the total number of discrete combinations is 10 ^ 10 (100 billion), but testing of all combinations is complicated because it will take a lot of time.

So, let's understand the testing process with an example:

Assume that there is a function with a list box that contains 10 elements, text box that can accept 1 to 100 characters, radio button, checkbox and OK button.

The input values are given below that can be accepted by the fields of the given function.

1. Check Box - Checked or Unchecked
2. List Box - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9,
3. Radio Button - On or Off
4. Text Box - Number of alphabets between 1 to 100.
5. OK - Does not accept any value, only redirects to the next page.

Calculation of all the possible combinations:

Check Box = 2

List Box = 10

Radio Button = 2

Text Box = 100

Total number of test cases = 2*10*2*100 = 4000

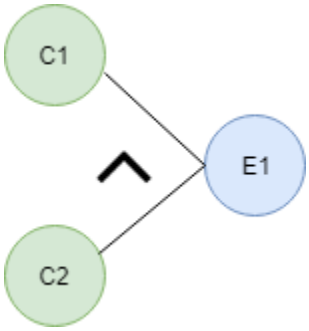
5. **Cause-Effect Technique**

Cause-Effect Technique underlines the relationship between a given result and all the factors affecting the result. It is based on a collection of requirements.

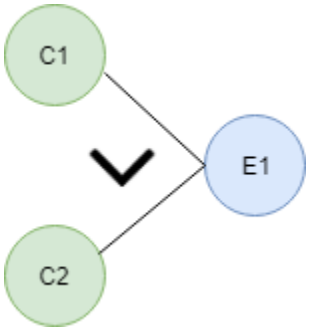
Cause-Effect graph technique is based on a collection of requirements and used to determine minimum possible test cases which can cover a maximum test area of the software.

The main advantage of cause-effect graph testing is, it reduces the time of test execution and cost.

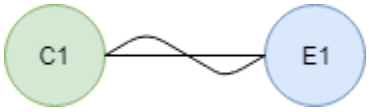
AND - E1 is an effect and C1 and C2 are the causes. If both C1 and C2 are true, then effect E1 will be true.



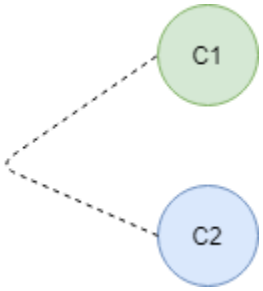
OR - If any cause from C1 and C2 is true, then effect E1 will be true.



NOT - If cause C1 is false, then effect E1 will be true.



Mutually Exclusive - When only one cause is true.



Ex:

The character in column 1 should be either A or B and in the column 2 should be a digit. If both columns contain appropriate values then update is made. If the input of column 1 is incorrect, i.e. neither A nor B, then message X will be displayed. If the input in column 2 is incorrect, i.e. input is not a digit, then message Y will be displayed.

- A file must be updated, if the character in the first column is either "A" or "B" and in the second column it should be a digit.
- If the value in the first column is incorrect (the character is neither A nor B) then massage X will be displayed.
- If the value in the second column is incorrect (the character is not a digit) then massage Y will be displayed.

Column 1	***Column 2***
Correct value - A or B	*Correct value- Any digit*
Incorrect value - Any character except A or B	*Incorrect value- Any character except digit*

Now, we are going to make a Cause-Effect graph for the above situation:

Causes are:

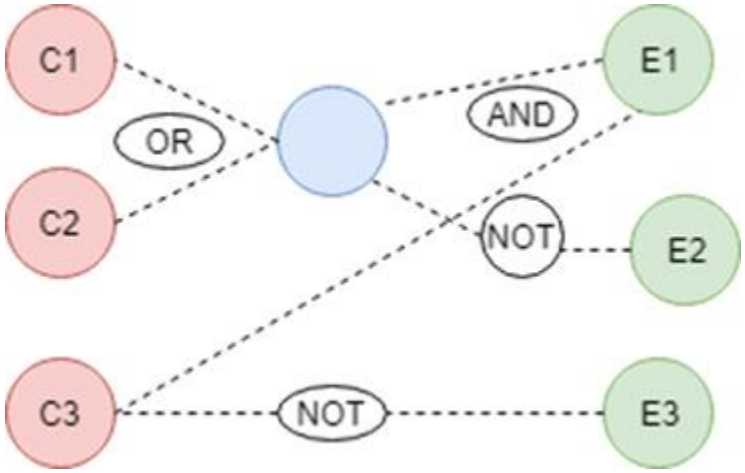
- C1 - Character in column 1 is A
- C2 - Character in column 1 is B

- C3 - Character in column 2 is digit!

Effects:

- E1 - Update made (C1 OR C2) AND C3
- E2 - Displays Massage X (NOT C1 AND NOT C2)
- E3 - Displays Massage Y (NOT C3)

Where AND, OR, NOT are the logical gates.

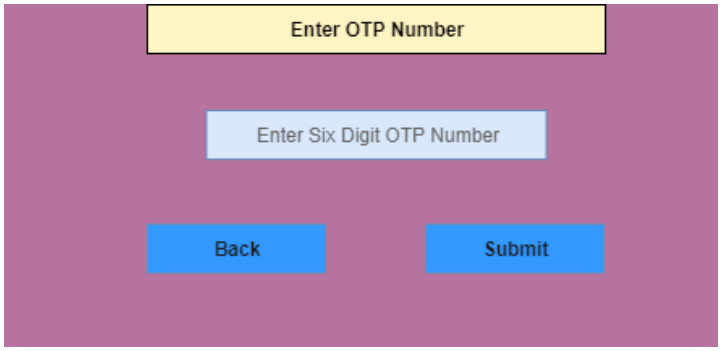


So, it is the cause-effect graph for the given situation. A tester needs to convert causes and effects into logical statements and then design cause-effect graph. If function gives output (effect) according to the input (cause) so, it is considered as defect free, and if not doing so, then it is sent to the development team for the correction.

6. Equivalence Partitioning Technique

Equivalence partitioning is a technique of software testing in which input data divided into partitions of valid and invalid values, and it is mandatory that all partitions must exhibit the same behavior.
Ex:
An OTP number which contains only six digits, less or more than six digits will not be accepted, and the application will redirect the user to the error page.

OTP Number = 6 digits



INVALID 1 Test case	INVALID 2 Test case	VALID 3 Test case	VALID
DIGITS >=7	DIGITS<=5	DIGITS = 6	DIGITS = 6
93847262	9845	456234	451483

Advantages and disadvantages of Equivalence Partitioning technique

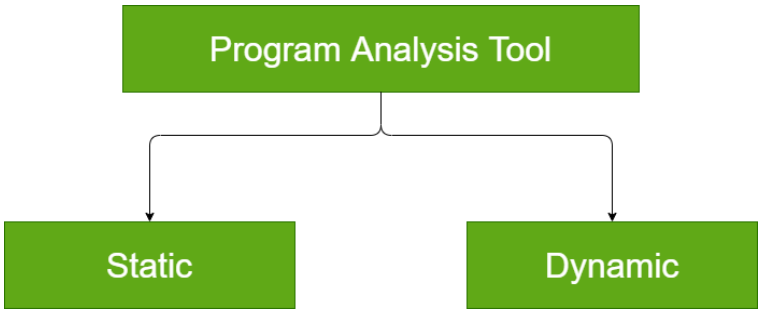
Advantages	**disadvantages**
It is process-oriented	All necessary inputs may not cover.
We can achieve the Minimum test coverage	This technique will not consider the condition for boundary value analysis.
It helps to decrease the general test execution time and also reduce the set of test data.	The test engineer might assume that the output for all data set is right, which leads to the problem during the testing process.

Programming Analysis Tool:

Program Analysis Tool is an automated tool whose input is the source code or the executable code of a program and the output is the observation of characteristics of the program. It gives various characteristics of the program such as its size, complexity, adequacy of commenting, adherence to programming standards and many other characteristics.

Classification of Program Analysis Tools:

Program Analysis Tools are classified into two categories:



- **Static Program Analysis Tools:**
  Static Program Analysis Tool is such a program analysis tool that evaluates and computes various characteristics of a software product without executing it. Normally, static program analysis tools analyze some structural representation of a program to reach a certain analytical conclusion. Basically some structural properties are analyzed using static program analysis tools.

The structural properties that are usually analyzed are:

1. Whether the coding standards have been fulfilled or not.
2. Some programming errors such as uninitialized variables.
3. Mismatch between actual and formal parameters.
4. Variables that are declared but never used.

Code walkthroughs and code inspections are considered as static analysis methods but static program analysis tool is used to designate automated analysis tools. Hence, a compiler can be considered as a static program analysis tool.

- **Dynamic Program Analysis Tools:**

Dynamic Program Analysis Tool is such type of program analysis tool that require the program to be executed and its actual behavior to be observed. A dynamic program analyzer basically implements the code. It adds additional statements in the source code to collect the traces of program execution. When the code is executed, it allows us to observe the behavior of the software for different test cases. Once the software is tested and its behavior is observed, the dynamic program analysis tool performs a post execution analysis and produces reports which describe the structural coverage that has been achieved by the complete testing process for the program.

For example, the post execution dynamic analysis report may provide data on extent statement, branch and path coverage achieved.

The results of dynamic program analysis tools are in the form of a histogram or a pie chart. It describes the structural coverage obtained for different modules of the program. The output of a dynamic program analysis tool can be stored and printed easily and provides evidence that complete testing has been done. The result of dynamic analysis is the extent of testing performed as white box testing. If the testing result is not satisfactory then more test cases are designed and added to the test scenario. Also dynamic analysis helps in elimination of redundant test cases.

Integration Testing:

Integration testing is the process of testing the interface between two software units or modules. It focuses on determining the correctness of the interface. The purpose of integration testing is to expose faults in the interaction between integrated units. Once all the modules have been unit tested, integration testing is performed.

Integration testing is a software testing technique that focuses on verifying the interactions and data exchange between different components or modules of a

software application. The goal of integration testing is to identify any problems or bugs that arise when different components are combined and interact with each other. Integration testing is typically performed after unit testing and before system testing. It helps to identify and resolve integration issues early in the development cycle, reducing the risk of more severe and costly problems later on.

Integration testing can be done by picking module by module. This can be done so that there should be a proper sequence to be followed. And also if you don't want to miss out on any integration scenarios then you have to follow the proper sequence. Exposing the defects is the major focus of the integration testing and the time of interaction between the integrated units.
Integration test approaches – There are four types of integration testing approaches. Those approaches are the following:

1. Big-Bang Integration Testing – It is the simplest integration testing approach, where all the modules are combined and the functionality is verified after the completion of individual module testing. In simple words, all the modules of the system are simply put together and tested. This approach is practicable only for very small systems. If an error is found during the integration testing, it is very difficult to localize the error as the error may potentially belong to any of the modules being integrated. So, debugging errors reported during big bang integration testing is very expensive to fix.

Big-Bang integration testing is a software testing approach in which all components or modules of a software application are combined and tested at once. This approach is typically used when the software components have a low degree of interdependence or when there are constraints in the development environment that prevent testing individual components. The goal of big-bang integration testing is to verify the overall functionality of the system and to identify any integration problems that arise when the components are combined. While big-bang integration testing can be useful in some situations, it can also be a high-risk approach, as the complexity of the system and the number of interactions between components can make it difficult to identify and diagnose problems.

Advantages:

1. It is convenient for small systems.

2. Simple and straightforward approach.
3. Can be completed quickly.
4. Does not require a lot of planning or coordination.
5. May be suitable for small systems or projects with a low degree of interdependence between components.

Disadvantages:

1. There will be quite a lot of delay because you would have to wait for all the modules to be integrated.
2. High-risk critical modules are not isolated and tested on priority since all modules are tested at once.
3. Not Good for long projects.
4. High risk of integration problems that are difficult to identify and diagnose.
5. This can result in long and complex debugging and troubleshooting efforts.
6. This can lead to system downtime and increased development costs.
7. May not provide enough visibility into the interactions and data exchange between components.
8. This can result in a lack of confidence in the system's stability and reliability.
9. This can lead to decreased efficiency and productivity.
10. This may result in a lack of confidence in the development team.
11. This can lead to system failure and decreased user satisfaction.

2. Bottom-Up Integration Testing – In bottom-up testing, each module at lower levels are tested with higher modules until all modules are tested. The primary purpose of this integration testing is that each subsystem tests the interfaces among various modules making up the subsystem. This integration testing uses test drivers to drive and pass appropriate data to the lower-level modules.

Advantages:

- In bottom-up testing, no stubs are required.
- A principal advantage of this integration testing is that several disjoint subsystems can be tested simultaneously.
- It is easy to create the test conditions.
- Best for applications that uses bottom up design approach.
- It is Easy to observe the test results.

Disadvantages:

- Driver modules must be produced.
- In this testing, the complexity that occurs when the system is made up of a large number of small subsystems.
- As Far modules have been created, there is no working model can be represented.

3. Top-Down Integration Testing – Top-down integration testing technique is used in order to simulate the behaviour of the lower-level modules that are not yet integrated. In this integration testing, testing takes place from top to bottom. First, high-level modules are tested and then low-level modules and finally integrating the low-level modules to a high level to ensure the system is working as intended.

Advantages:

- Separately debugged module.
- Few or no drivers needed.
- It is more stable and accurate at the aggregate level.
- Easier isolation of interface errors.
- In this, design defects can be found in the early stages.

Disadvantages:

- Needs many Stubs.
- Modules at lower level are tested inadequately.
- It is difficult to observe the test output.
- It is difficult to stub design.

4. Mixed Integration Testing – A mixed integration testing is also called sandwiched integration testing. A mixed integration testing follows a combination of top down and bottom-up testing approaches. In top-down approach, testing can start only after the top-level modules have been coded and unit tested. In bottom-up approach, testing can start only after the bottom level modules are ready. This sandwich or mixed approach overcomes this shortcoming of the top-down and bottom-up approaches. It is also called the hybrid integration testing. also, stubs and drivers are used in mixed integration testing.

Advantages:

- Mixed approach is useful for very large projects having several sub projects.
- This Sandwich approach overcomes this shortcoming of the top-down and bottom-up approaches.
- Parallel test can be performed in top and bottom layer tests.

Disadvantages:

- For mixed integration testing, it requires very high cost because one part has a Top-down approach while another part has a bottom-up approach.
- This integration testing cannot be used for smaller systems with huge interdependence between different modules.

Applications:

1. **Identify the components:** Identify the individual components of your application that need to be integrated. This could include the frontend, backend, database, and any third-party services.

2. **Create a test plan:** Develop a test plan that outlines the scenarios and test cases that need to be executed to validate the integration points between the different components. This could include testing data flow, communication protocols, and error handling.
3. **Set up test environment:** Set up a test environment that mirrors the production environment as closely as possible. This will help ensure that the results of your integration tests are accurate and reliable.
4. **Execute the tests:** Execute the tests outlined in your test plan, starting with the most critical and complex scenarios. Be sure to log any defects or issues that you encounter during testing.
5. **Analyze the results:** Analyze the results of your integration tests to identify any defects or issues that need to be addressed. This may involve working with developers to fix bugs or make changes to the application architecture.
6. **Repeat testing:** Once defects have been fixed, repeat the integration testing process to ensure that the changes have been successful and that the application still works as expected.

Testing Object oriented programs:

Software typically undergoes many levels of testing, from unit testing to system or acceptance testing. Typically, in-unit testing, small "units", or modules of the software, are tested separately with focus on testing the code of that module. In higher, order testing (e.g, acceptance testing), the entire system (or a subsystem) is tested with the focus on testing the functionality or external behavior of the system.

As information systems are becoming more complex, the object-oriented paradigm is gaining popularity because of its benefits in analysis, design, and coding. Conventional testing methods cannot be applied for testing classes because of problems involved in testing classes, abstract classes, inheritance, dynamic binding, message, passing, polymorphism, concurrency, etc. Testing classes is a fundamentally different problem than testing functions. A function (or a procedure) has a clearly defined input-output behavior, while a class

does not have an input-output behavior specification. We can test a method of a class using approaches for testing functions, but we cannot test the class using these
approaches.

According to Davis the dependencies occurring in conventional systems are:

- Data dependencies between variables
- Calling dependencies between modules
- Functional dependencies between a module and the variable it computes
- Definitional dependencies between a variable and its types.

But in Object-Oriented systems there are following additional dependencies:

- Class to class dependencies
- Class to method dependencies
- Class to message dependencies
- Class to variable dependencies
- Method to variable dependencies
- Method to message dependencies
- Method to method dependencies

Issues in Testing Classes:
Additional testing techniques are, therefore, required to test these dependencies. Another issue of interest is that it is not possible to test the class dynamically, only its instances i.e, objects can be tested. Similarly, the concept of inheritance opens various issues e.g., if changes are made to a parent class or superclass, in a larger system of a class it will be difficult to test subclasses individually and isolate the error to one class.

In object-oriented programs, control flow is characterized by message passing among objects, and the control flow switches from one object to another by inter-object communication. Consequently, there is no control flow within a class like

functions. This lack of sequential control flow within a class requires different approaches for testing. Furthermore, in a function, arguments passed to the function with global data determine the path of execution within the procedure. But, in an object, the state associated with the object also influences the path of execution, and methods of a class can communicate among themselves through this state because this state is persistent across invocations of methods. Hence, for testing objects, the state of an object has to play an important role.

Techniques of object-oriented testing are as follows:

1. **Fault Based Testing:**
   This type of checking permits for coming up with test cases supported the consumer specification or the code or both. It tries to identify possible faults (areas of design or code that may lead to errors.). For all of these faults, a test case is developed to "flush" the errors out. These tests also force each time of code to be executed.

This method of testing does not find all types of errors. However, incorrect specification and interface errors can be missed. These types of errors can be uncovered by function testing in the traditional testing model. In the object-oriented model, interaction errors can be uncovered by scenario-based testing. This form of Object oriented-testing can only test against the client's specifications, so interface errors are still missed.

2. **Class Testing Based on Method Testing:**
   This approach is the simplest approach to test classes. Each method of the class performs a well defined cohesive function and can, therefore, be related to unit testing of the traditional testing techniques. Therefore all the methods of a class can be involved at least once to test the class.

3. **Random Testing:**
   It is supported by developing a random test sequence that tries the minimum variety of operations typical to the behavior of the categories

4. **Partition Testing:**
   This methodology categorizes the inputs and outputs of a category so as to

check them severely. This minimizes the number of cases that have to be designed.

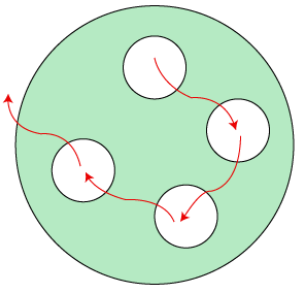
5. **Scenario-based Testing:**
   It primarily involves capturing the user actions then stimulating them to similar actions throughout the test.
   These tests tend to search out interaction form of error.

System Testing:

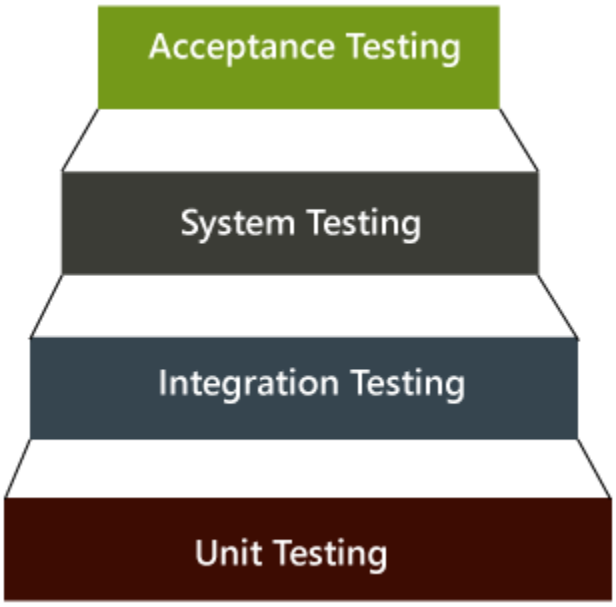
System Testing includes testing of a fully integrated software system. Generally, a computer system is made with the integration of software (any software is only a single element of a computer system). The software is developed in units and then interfaced with other software and hardware to create a complete computer system. In other words, a computer system consists of a group of software to perform the various tasks, but only software cannot perform the task; for that software must be interfaced with compatible hardware. System testing is a series of different type of tests with the purpose to exercise and examine the full working of an integrated software computer system against requirements.

To check the end-to-end flow of an application or the software as a user is known as **System testing**. In this, we navigate (go through) all the necessary modules of an application and check if the end features or the end business works fine, and test the product as a whole system.

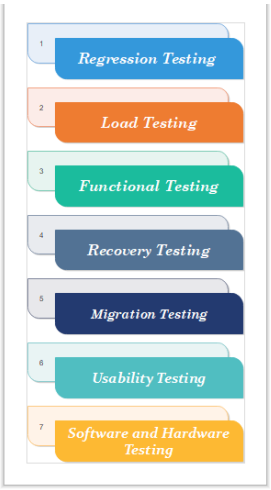
It is **end-to-end testing** where the testing environment is similar to the production environment.



There are four levels of software testing: unit testing, integration testing, system testing and acceptance testing, all are used for the testing purpose. Unit Testing used to test single software; Integration Testing used to test a group of units of software, System Testing used to test a whole system and Acceptance Testing used to test the acceptability of business requirements. Here we are discussing system testing which is the third level of testing levels.



Types of System Testing.



Regression Testing

Regression testing is performed under system testing to confirm and identify that if there's any defect in the system due to modification in any other part of the system. It makes sure, any changes done during the development process have not introduced a new defect and also gives assurance; old defects will not exist on the addition of new software over the time.

Load Testing

Load testing is performed under system testing to clarify whether the system can work under real-time loads or not.

Functional Testing

Functional testing of a system is performed to find if there's any missing function in the system. Tester makes a list of vital functions that should be in the system and can be added during functional testing and should improve quality of the system.

Recovery Testing

Recovery testing of a system is performed under system testing to confirm reliability, trustworthiness, accountability of the system and all are lying on recouping skills of the system. It should be able to recover from all the possible system crashes successfully.

In this testing, we will test the application to check how well it recovers from the crashes or disasters.

Migration Testing

Migration testing is performed to ensure that if the system needs to be modified in new infrastructure so it should be modified without any issue.

Usability Testing

The purpose of this testing to make sure that the system is well familiar with the user and it meets its objective for what it supposed to do.
