MCA Part-II

Paper-XI: Software Engineering

Topic: Software Testing

PREPARED BY: DR. KIRAN PANDEY

(School of Computer Science)

Email-id: kiranpandey.nou@gmail.com

Introduction

Testing is the process of evaluating a system or its component(s) with the intent to find whether it satisfies the specified requirements or not. Testing is executing a system in order to identify any gaps, errors, or missing requirements in contrary to the actual requirements. Software Testing is evaluation of the software against requirements gathered from users and system specifications. Testing is conducted at phase level in software development life cycle or at module level in program code. Software testing comprises of Validation and Verification.

Validation is : "**Are we building the correct system?", and**

Verification is : "**Are we building the system correctly?".**

To be more specific, software testing means that executing a program or its components in order to assure:

- The correctness of software with respect to requirements or intent;
- The performance of software under various conditions;
- The robustness of software, that is, its ability to handle erroneous inputs and unanticipated conditions;
- The usability of software under various conditions;
- The reliability, availability, survivability or other dependability measures of software; or
- Installability and other facets of a software release.

The purpose of testing is to show that the program has errors. The aim of most testing methods is to systematically and actively locate faults in the program and repair them. Debugging is the next stage of testing. Debugging is the activity of:

- Determining the exact nature and location of the suspected error within the program and
- Fixing the error. Usually, debugging begins with some indication of the existence of an error.

Who does Testing?

It depends on the process and the associated stakeholders of the project(s). In the IT industry, large companies have a team with responsibilities to evaluate the developed software in context of the given requirements. Moreover, developers also conduct testing which is called **Unit Testing**. In most cases, the following professionals are involved in testing a system within their respective capacities:

- Software Tester
- Software Developer
- Project Lead/Manager
- End User

Different companies have different designations for people who test the software on the basis of their experience and knowledge such as Software Tester, Software Quality Assurance Engineer, QA Analyst, etc.

It is not possible to test the software at any time during its cycle. The next two sections state when testing should be started and when to end it during the SDLC.

When to Start Testing?

An early start to testing reduces the cost and time to rework and produce error-free software that is delivered to the client. However in Software Development Life Cycle (SDLC), testing can be started from the Requirements Gathering phase and continued till the deployment of the software. It also depends on the development model that is being used. For example, in the Waterfall model, formal testing is conducted in the testing phase; but in the incremental model, testing is performed at the end of every increment/iteration and the whole application is tested at the end.

Testing is done in different forms at every phase of SDLC:

- During the requirement gathering phase, the analysis and verification of requirements are also considered as testing.
- Reviewing the design in the design phase with the intent to improve the design is also considered as testing.
- Testing performed by a developer on completion of the code is also categorized as testing.

Software Validation and Verification

Validation is process of examining whether or not the software satisfies the user requirements. It is carried out at the end of the SDLC. If the software matches requirements for which it was made, it is validated.

- Validation ensures the product under development is as per the user requirements.
- Validation answers the question – "Are we developing the product which attempts all that user needs from this software ?".
- Validation emphasizes on user requirements.

Software verification is the process of confirming if the software is meeting the business requirements, and is developed adhering to the proper specifications and methodologies.

- Verification ensures the product being developed is according to design specifications.
- Verification answers the question– "Are we developing this product by firmly following all design specifications ?"
- Verifications concentrates on the design and system specifications.

Target of the test are -

- **Errors** - These are actual coding mistakes made by developers. In addition, there is a difference in output of software and desired output, is considered as an error.

- **Fault** - When error exists fault occurs. A fault, also known as a bug, is a result of an error which can cause system to fail.
- **Failure** - failure is said to be the inability of the system to perform the desired **task. Failure occurs when fault exists in the system.**

These two terms are very confusing for most people, who use them interchangeably. The following table highlights the differences between verification and validation.

S.N.	**Verification**	**Validation**
1	Verification addresses the concern: "Are you building it right?"	Validation addresses the concern: "Are you building the right thing?"
2	Ensures that the software system meets all the functionality.	Ensures that the functionalities meet the intended behavior.
3	Verification takes place first and includes the checking for documentation, code, etc.	Validation occurs after verification and mainly involves the checking of the overall product.
4	Done by developers.	Done by testers.
5	It has static activities, as it includes collecting reviews, walkthroughs, and inspections to verify a software.	It has dynamic activities, as it includes executing the software against the requirements.
6	It is an objective process and no subjective decision should be needed to verify a software.	It is a subjective process and involves subjective decisions on how well a software works.

Audit and Inspection

Audit : It is a systematic process to determine how the actual testing process is conducted within an organization or a team. Generally, it is an independent examination of processes involved during the testing of a software. As per IEEE, it is a review of documented processes that organizations implement and follow. Types of audit include Legal Compliance Audit, Internal Audit, and System Audit.

Inspection : It is a formal technique that involves formal or informal technical reviews of any artifact by identifying any error or gap. As per IEEE94, inspection is a formal evaluation technique in which software requirements, designs, or codes are examined in detail by a person or a group other than the author to detect faults, violations of development standards, and other problems.

Formal inspection meetings may include the following processes: Planning, Overview Preparation, Inspection Meeting, Rework, and Follow-up.

Types of Testing

This section describes the different types of testing that may be used to test a software during SDLC.

Manual Testing

Manual testing includes testing a software manually, i.e., without using any automated tool or any script. In this type, the tester takes over the role of an end-user and tests the software to identify any unexpected behavior or bug. There are different stages for manual testing such as unit testing, integration testing, system testing, and user acceptance testing.

Testers use test plans, test cases, or test scenarios to test a software to ensure the completeness of testing. Manual testing also includes exploratory testing, as testers explore the software to identify errors in it.

Automation Testing

Automation testing, which is also known as Test Automation, is when the tester writes scripts and uses another software to test the product. This process involves automation of a manual process. Automation Testing is used to re-run the test scenarios that were performed manually, quickly, and repeatedly.

Apart from regression testing, automation testing is also used to test the application from load, performance, and stress point of view. It increases the test coverage, improves accuracy, and saves time and money in comparison to manual testing.

Software Testing Strategies

The different testing strategies are Black Box Testing and White Box Testing.

Black-Box Testing

The technique of testing without having any knowledge of the interior workings of the application is called black-box testing. The tester is oblivious to the system architecture and does not have access to the source code. Typically, while performing a black-box test, a tester will interact with the system's user interface by providing inputs and examining outputs without knowing how and where the inputs are worked upon.

It is carried out to test functionality of the program. It is also called 'Behavioral' testing. The tester in this case, has a set of input values and respective desired results. On providing input, if the output matches with the desired results, the program is tested 'ok', and problematic otherwise.

Figure 1: Black Box Testing

In this testing method, the design and structure of the code are not known to the tester, and testing engineers and end users conduct this test on the software.

Black-box testing techniques:

- **Equivalence class** - The input is divided into similar classes. If one element of a class passes the test, it is assumed that all the class is passed. The aim of equivalence partitioning is to divide the input domain of the program or module into classes (sets) of test cases that have a similar effect on the program. The classes are called Equivalence classes.

Equivalence Classes

An Equivalence *Class* is a set of inputs that the program treats identically when the program is tested. In other words, a test input taken from an equivalence class is representative of all of the test inputs taken from that class. Equivalence classes are determined from the specification of a program or module. Each equivalence class is used to represent certain conditions (or predicates) on the input domain. For equivalence partitioning it is usual to also consider valid and invalid inputs. The terms input condition, valid and invalid inputs, are not used consistently. But, the following definition spells out how we will use them in this subject. An input condition on the input domain is a predicate over the values of the input domain. A *Valid* input to a program or module is an element of the input domain that is expected to return a non-error value. An *Invalid* input is an input that is expected to return an error value. Equivalence partitioning is then a systematic method for identifying interesting input conditions to be tested. An input condition can be applied to a set of values of a specific input variable, or a set of input variables as well.

A Method for Choosing Equivalence Classes

The aim is to minimize the number of test cases required to cover all of the identified equivalence classes. The following are two distinct steps in achieving this goal:

Step 1: Identify the equivalence classes

If an input condition specifies a range of values, then identify one valid equivalence class and two invalid equivalence classes.

For example, if an input condition specifies a range of values from 1 to 99, then, three equivalence classes can be identified:

- One valid equivalence class: $1 < X < 99$
- Two invalid equivalence classes $X < 1$ and $X > 99$

Step 2: Choose test cases

The next step is to generate test cases using the equivalence classes identified in the previous step. The guideline is to choose test cases on the boundaries of partitions and test cases close to the midpoint of the partition. In general, the idea is to select at least one element from each equivalence class.

Boundary values - The input is divided into higher and lower end values. If these values pass the test, it is assumed that all values in between may pass too. The basic concept used in Boundary-value-analysis is that if the specific test cases are

designed to check the boundaries of the input domain then the probability of detecting

an error will increase. If we want to test a program written as a function F with two

input variables x and y., then these input variables are defined with some boundaries

like a1 ≤ x ≤ a2 and b1 ≤ y ≤ b2. It means that inputs x and y are bounded by two

intervals [a1, a2] and [b1, b2].

Test Case Selection Guidelines for Boundary Value Analysis

The following set of guidelines is for the selection of test cases according to the

principles of boundary value analysis. The guidelines do not constitute a firm set of

rules for every case. You will need to develop some judgement in applying these

guidelines.

1. If an *input* condition specifies a range of values, then construct valid test cases

   for the ends of the range, and invalid input test cases for input points just

   beyond the ends of the range.

2. If an *input* condition specifies a number of values, construct test cases for the

   minimum and maximum values; and one beneath and beyond these values.

3. If an *output* condition specifies a range of values, then construct valid test cases

   for the ends of the output range, and invalid input test cases for situations just

   beyond the ends of the output range.

4. If an *output* condition specifies a number of values, construct test cases for the

   minimum and maximum values; and one beneath and beyond these values.

5. If the input or output of a program is an ordered set (e.g., a sequential file, linear list, table), focus attention on the first and last elements of the set.

Example 1: Boundary Value Analysis for the Triangle Program

Consider a simple program to classify a triangle. Its input consists of three positive integers (say x, y, z) and the data types for input parameters ensures that these will be integers greater than zero and less than or equal to 100. The three values are interpreted as representing the lengths of the sides of a triangle. The program then prints a message to the standard output that states whether the triangle, if it can be formed, is scalene, isosceles, equilateral, or right-angled.

Solution: Following possible boundary conditions are formed:

Given sides $(A; B; C)$ for a scalene triangle, the sum of any two sides is greater than the third and so, we have boundary conditions $A + B > C$, $B + C > A$ and $A + C > B$.

Given sides $(A; B; C)$ for an isosceles triangle two sides must be equal and so we have boundary conditions $A = B$, $B = C$ or $A = C$. Continuing in the same way for an equilateral triangle the sides must all be of equal length and we have only one boundary where $A = B = C$.

For right-angled triangles, we must have $A^2 + B^2 = C^2$.

On the basis of the above boundary conditions, test cases are designed as follows (*Table 4.1*):

Table 6.1: Test cases for Example-1

Test case	**x**	**y**	**z**	**Expected Output**
1	100	100	100	Equilateral triangle
2	50	3	50	Isosceles triangle

3	40	50	40	Equilatera/triangle
4	3	4	5	Right-angled triangles
5	10	10	10	Equilatera/triangle
6	2	2	5	Isosceles triangle
7	100	50	100	Scalene triangle
8	1	2	3	Non-triangles
9	2	3	4	Scalene triangle
10	1	3	1	Isosceles triangle

- **Cause-effect graphing** - In both previous methods, only one input value at a time is tested. Cause (input) – Effect (output) is a testing technique where combinations of input values are tested in a systematic way.
- **Pair-wise Testing** - The behavior of software depends on multiple parameters. In pairwise testing, the multiple parameters are tested pair-wise for their different values.
- **State-based testing** - The system changes state on provision of input. These systems are tested based on their states and input.

The following table lists the advantages and disadvantages of black-box testing.

Advantages	Disadvantages
• Well suited and efficient for large code segments. • Code access is not required. • Clearly separates user's perspective from the developer's perspective through visibly defined roles. • Large numbers of moderately skilled testers can test the application with no knowledge of implementation, programming language, or operating	• Limited coverage, since only a selected number of test scenarios is actually performed. • Inefficient testing, due to the fact that the tester only has limited knowledge about an application. • Blind coverage, since the tester cannot target specific

systems.	code segments or error-prone areas. - The test cases are difficult to design.

White-Box Testing

White-box testing is the detailed investigation of internal logic and structure of the code. White-box testing is also called **glass testing** or **open-box testing**. In order to perform **white-box** testing on an application, a tester needs to know the internal workings of the code.

The tester needs to have a look inside the source code and find out which unit/chunk of the code is behaving inappropriately.

It is conducted to test program and its implementation, in order to improve code efficiency or structure. It is also known as 'Structural' testing.

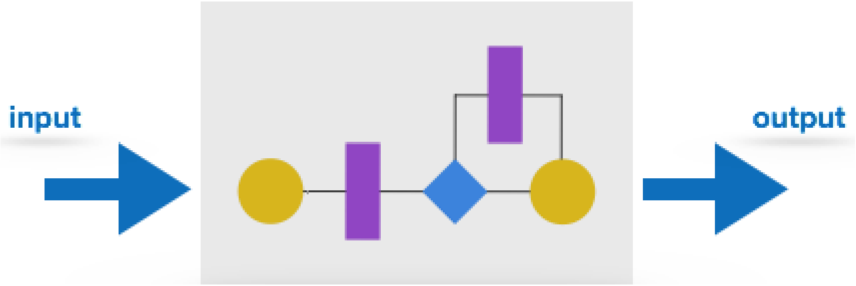


Figure 2: White Box Testing

In this testing method, the design and structure of the code are known to the tester. Programmers of the code conduct this test on the code.

The below are some White-box testing techniques:

In this approach, complete knowledge about the internal structure of the source code is required. For *White-box testing strategies,* the methods are:

- Coverage Based Testing
- Cyclomatic Complexity
- Mutation Testing

Coverage based testing

The aim of coverage based testing methods is to *'cover'* the program with test cases that satisfy some fixed coverage criteria. Put another way, we choose test cases to exercise as much of the program as possible according to some criteria.

Coverage Based Testing Criteria

Coverage based testing works by choosing test cases according to well-defined 'coverage' criteria. The more common coverage criteria are the following.

- **Statement Coverage or Node Coverage:** Every statement of the program should be exercised at least once.
- **Branch Coverage or Decision Coverage:** Every possible alternative in a branch or decision of the program should be exercised at least once. For *if* statements, this means that the branch must be made to take on the values *true* or *false*.
- **Decision/Condition Coverage**: Each condition in a branch is made to evaluate to both true and false and each branch is made to evaluate to both true and false.
- **Multiple condition coverage**: All possible combinations of condition outcomes within each branch should be exercised at least once.
- **Path coverage**: Every execution path of the program should be exercised at least once.

In this section, we will use the control flow graph to choose white box test cases according to the criteria above. To motivate the selection of test cases, consider the simple program given in Program 6.1.

Example:

```
void main(void)
{
int x1, x2, x3;
scanf("%d %d %d", &x1, &x2, &x3); if ((x1 > 1)
&& (x2 == 0))
x3 = x3 / x1;
if ((x1 == 2) || (x3 > 1)) x3 = x3 + 1;
while (x1 >= 2) x1 = x1 - 2;
printf("%d %d %d", x1, x2, x3);
```

}

Program 6.1: A simple program for white box testing

The first step in the analysis is to generate the flow chart, which is given in Figure .1. Now what is needed for statement coverage? If all of the branches are true, at least once, we will have executed every statement in the flow chart. Put another way to execute every statement at least once, we must execute the path ABCDEFGF. Now, looking at the conditions inside each of the three *branches,* we derive a set of constraints on the values of x1, x2 and x3 such that all the three branches are extended. A test case of the form (x1; x2; x3) = (2; 0; 3) will execute all of the statements in the program.

Note that we need not make every branch evaluate to true and false, nor have we make every condition evaluate to true and false, nor we traverse every path in the program.

To make the first branch true, we have test input (2; 0; 3) that will make all of the branches true. We need a test input that will now make each one false. Again looking at all of the conditions, the test input (1; 1; 1) will make all of the branches false.

For any of the criteria involving condition coverage, we need to look at each of the five conditions in the program: C1 = (x1>1), C2 = (x2 == 0), C3 = (x1 == 2), C4 = (x3>1) and C5 = (x1 >= 2). The test input (1; 0; 3) will make C 1 false, C2 true, C3 false, C4 true and C5 false.

Cyclomatic Complexity Control Flow Graph

A control flow graph describes the sequence in which different instructions of a program get executed. It also describes how the flow of control passes through the program. In order to draw the control flow graph of a program, we need to first number all the statements of a program. The different numbered statements serve as nodes of the control flow graph. An edge from one node to another node exists if the execution of the statement representing the first node can result in the transfer of control to the other node. Following structured programming constructs are represented as CFG:

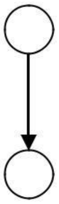


Figure 3 : sequence

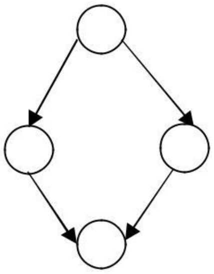
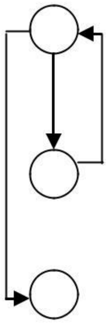


Figure 4 : if –else



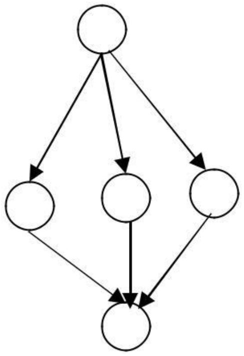


Figure 5 : while-loop **Figure 6: case**

Cyclomatic Complexity: This technique is used to find the number of independent paths through a program. If CFG of a program is given, the Cyclomatic complexity V(G) can be computed as: V(G) = E – N + 2, where N is the number of nodes of the CFG and E is the number of edges in the CFG. For the example 4, the Cyclomatic Complexity = 6 – 5 + 2 = 3.

The following are the properties of Cyclomatic complexity:

- V(G) is the maximum number of independent paths in graph G
- Inserting and deleting functional statements to G does not affect V(G)
- G has only one path if and only if V(G) = 1.

Mutation Testing

Mutation Testing is a powerful method for finding errors in software programs. In this technique, multiple copies of programs are made, and each copy is altered; this altered copy is called a mutant. Mutants are executed with test data to determine whether the test data are capable of detecting the change between the original program and the mutated program. The mutant that is detected by a test case is termed “killed” and the goal of the mutation procedure is to find a set of test cases that are able to kill groups of mutant programs. Mutants are produced by applying mutant operators. An operator is essentially a grammatical rule that changes a single expression to another expression. It is essential that all mutants must be killed by the test cases or shown to be equivalent to the original expression. If we run a mutated program, there are two possibilities:

1. The results of the program were affected by the code change and the test suite detects it. We assumed that the test suite is perfect, which means that it must detect the change. If this happens, the mutant is called a killed mutant.

2. The results of the program are not changed and the test suite does not detect the mutation. The mutant is called an equivalent mutant.

If we take the ratio of killed mutants to all the mutants that were created, we get a number that is smaller than 1. This number gives an indication of the sensitivity of program to the changes in code. In real life, we may not have a perfect program and we may not have a perfect test suite. Hence, we can have one more scenario:

3. The results of the program are different, but the test suite does not detect it because it does not have the right test case.

The following table lists the advantages and disadvantages of white-box testing.

Advantages	Disadvantages
• As the tester has knowledge of the source code, it becomes very easy to find out which type of data can help in testing the application effectively. • It helps in optimizing the code. • Extra lines of code can be removed which can bring in hidden defects. • Due to the tester's knowledge about the code, maximum coverage is attained during test scenario writing.	• Due to the fact that a skilled tester is needed to perform white-box testing, the costs are increased. • Sometimes it is impossible to look into every nook and corner to find out hidden errors that may create problems, as many paths will go untested. • It is difficult to maintain white-box testing, as it requires specialized tools like code analyzers and debugging tools.

Grey-Box Testing

Grey-box testing is a technique to test the application with having a limited knowledge of the internal workings of an application. In software testing, the phrase the more you know, the better carries a lot of weight while testing an application.

Mastering the domain of a system always gives the tester an edge over someone with limited domain knowledge. Unlike black-box testing, where the tester only tests the application's user interface; in grey-box testing, the tester has access to design documents and the database. Having this knowledge, a tester can prepare better test data and test scenarios while making a test plan.

Advantages	Disadvantages
• Offers combined benefits of black-box and white-box testing wherever possible. • Grey box testers don't rely on the source code; instead they rely on interface definition and functional specifications. • Based on the limited information available, a grey-box tester can design excellent test scenarios especially around communication protocols and data type handling. • The test is done from the point of view of the user and not the designer.	• Since the access to source code is not available, the ability to go over the code and test coverage is limited. • The tests can be redundant if the software designer has already run a test case. • Testing every possible input stream is unrealistic because it would take an unreasonable amount of time; therefore, many program paths will go untested.

A Comparison of Testing Methods

The following table lists the points that differentiate black-box testing, grey-box testing, and white-box testing.

Black-Box Testing	Grey-Box Testing	White-Box Testing
The internal workings of an application need not be known.	The tester has limited knowledge of the internal workings of the application.	Tester has full knowledge of the internal workings of the application.

Also known as closed-box testing, data-driven testing, or functional testing.	Also known as translucent testing, as the tester has limited knowledge of the insides of the application.	Also known as clear-box testing, structural testing, or code-based testing.
Performed by end-users and also by testers and developers.	Performed by end-users and also by testers and developers.	Normally done by testers and developers.
Testing is based on external expectations - Internal behavior of the application is unknown.	Testing is done on the basis of high-level database diagrams and data flow diagrams.	Internal workings are fully known and the tester can design test data accordingly.
It is exhaustive and the least time-consuming.	Partly time-consuming and exhaustive.	The most exhaustive and time-consuming type of testing.
Not suited for algorithm testing.	Not suited for algorithm testing.	Suited for algorithm testing.
This can only be done by trial-and-error method.	Data domains and internal boundaries can be tested, if known.	Data domains and internal boundaries can be better tested.

Software Testing - Levels

Mainly, Software goes through three levels of testing:

- Unit testing
- Integration testing
- System testing.

Levels of testing include different methodologies that can be used while conducting software testing. The main levels of software testing are:

- Functional Testing
- Non-functional Testing

(i)Functional Testing

This is a type of black-box testing that is based on the specifications of the software that is to be tested. The application is tested by providing input and then the results are examined that need to conform to the functionality it was intended for. Functional testing of a software is conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements.

There are five steps that are involved while testing an application for functionality.

Steps	Description
I	The determination of the functionality that the intended application is meant to perform.
II	The creation of test data based on the specifications of the application.
III	The output based on the test data and the specifications of the application.
IV	The writing of test scenarios and the execution of test cases.
V	The comparison of actual and expected results based on the executed test cases.

An effective testing practice will see the above steps applied to the testing policies of every organization and hence it will make sure that the organization maintains the strictest of standards when it comes to software quality.

Unit Testing

This type of testing is performed by developers before the setup is handed over to the testing team to formally execute the test cases. Unit testing is performed by the respective developers on the individual units of source code assigned areas. The developers use test data that is different from the test data of the quality assurance team.

The goal of unit testing is to isolate each part of the program and show that individual parts are correct in terms of requirements and functionality.

Limitations of Unit Testing

Testing cannot catch each and every bug in an application. It is impossible to evaluate every execution path in every software application. The same is the case with unit testing.

There is a limit to the number of scenarios and test data that a developer can use to verify a source code. After having exhausted all the options, there is no choice but to stop unit testing and merge the code segment with other units.

Integration Testing

Integration testing is defined as the testing of combined parts of an application to determine if they function correctly. Integration testing can be done in two ways: Bottom-up integration testing and Top-down integration testing.

S.N.	Integration Testing Method
1	Bottom-up integration This testing begins with unit testing, followed by tests of progressively higher-level combinations of units called modules or builds.
2	Top-down integration In this testing, the highest-level modules are tested first and progressively, lower-level modules are tested thereafter.

In a comprehensive software development environment, bottom-up testing is usually done first, followed by top-down testing. The process concludes with multiple tests of the complete application, preferably in scenarios designed to mimic actual situations.

System Testing

The software is compiled as product and then it is tested as a whole. This can be accomplished using one or more of the following tests:

- **Functionality testing** - Tests all functionalities of the software against the requirement.
- **Performance testing** - This test proves how efficient the software is. It tests the effectiveness and average time taken by the software to do desired task. Performance testing is done by means of load testing and stress testing where the software is put under high user and data load under various environment conditions.
- **Security & Portability** - These tests are done when the software is meant to work on various platforms and accessed by number of persons.

System testing tests the system as a whole. Once all the components are integrated, the application as a whole is tested rigorously to see that it meets the specified Quality Standards. This type of testing is performed by a specialized testing team.

System testing is important because of the following reasons:

- System testing is the first step in the Software Development Life Cycle, where the application is tested as a whole.
- The application is tested thoroughly to verify that it meets the functional and technical specifications.
- The application is tested in an environment that is very close to the production environment where the application will be deployed.
- System testing enables us to test, verify, and validate both the business requirements as well as the application architecture.

Regression Testing

Whenever a change in a software application is made, it is quite possible that other areas within the application have been affected by this change. Regression testing is performed to verify that a fixed bug hasn't resulted in another functionality or business rule violation. The intent of regression testing is to ensure that a change, such as a bug fix should not result in another fault being uncovered in the application.

Regression testing is important because of the following reasons:

- Minimize the gaps in testing when an application with changes made has to be tested.
- Testing the new changes to verify that the changes made did not affect any other area of the application.
- Mitigates risks when regression testing is performed on the application.
- Test coverage is increased without compromising timelines.
- Increase speed to market the product.

Acceptance Testing

When the software is ready to hand over to the customer it has to go through last phase of testing where it is tested for user-interaction and response. This is important because even if the software matches all user requirements and if user does not like the way it appears or works, it may be rejected. It is conducted by the Quality Assurance Team who will gauge whether the application meets the intended specifications and satisfies the client’s requirement. The Quality Assurance team will have a set of pre-written scenarios and test cases that will be used to test the application.

More ideas will be shared about the application and more tests can be performed on it to gauge its accuracy and the reasons why the project was initiated. Acceptance tests are not only intended to point out simple spelling mistakes, cosmetic errors, or interface gaps, but also to point out any bugs in the application that will result in system crashes or major errors in the application.

By performing acceptance tests on an application, the testing team will deduce how the application will perform in production. There are also legal and contractual requirements for acceptance of the system. Acceptance testing can be broadly divided into the following categories:

Alpha testing - The team of developer themselves perform alpha testing by using the system as if it is being used in work environment. They try to find out how user would react to some action in software and how the system should respond to inputs. This test is the first stage of testing. Unit testing, integration testing and system testing when combined together is known as alpha testing. During this phase, the following aspects will be tested in the application:

- Spelling Mistakes
- Broken Links
- Cloudy Directions
- The Application will be tested on machines with the lowest specification to test loading times and any latency problems.

Beta testing - After the software is tested internally, it is handed over to the users to use it under their production environment only for testing purpose. This is not as yet the delivered product. Developers expect that users at this stage will bring minute problems, which were skipped to attend. This test is performed after alpha testing has been successfully performed. In beta testing, a sample of the intended audience tests the application. Beta testing is also known as **pre-release testing**. Beta test versions of software are ideally distributed to a wide audience on the Web, partly to give the program a "real-world" test and partly to provide a preview of the next release. In this phase, the audience will be testing the following:

- Users will install, run the application and send their feedback to the project team.
- Typographical errors, confusing application flow, and even crashes.
- Getting the feedback, the project team can fix the problems before releasing the software to the actual users.

- The more issues you fix that solve real user problems, the higher the quality of your application will be.
- Having a higher-quality application when you release it to the general public will increase customer satisfaction.

(ii) Non-Functional Testing

This section is based upon testing an application from its non-functional attributes. Non-functional testing involves testing a software from the requirements which are nonfunctional in nature but important such as performance, security, user interface, etc.

Some of the important and commonly used non-functional testing types are discussed below.

Performance Testing

It is mostly used to identify any bottlenecks or performance issues rather than finding bugs in a software. There are different causes that contribute in lowering the performance of a software:

- Network delay
- Client-side processing
- Database transaction processing
- Load balancing between servers
- Data rendering

Performance testing is considered as one of the important and mandatory testing type in terms of the following aspects:

- Speed (i.e. Response Time, data rendering and accessing)
- Capacity
- Stability
- Scalability

Performance testing can be either qualitative or quantitative and can be divided into different sub-types such as **Load testing** and **Stress testing**.

Load Testing

It is a process of testing the behavior of a software by applying maximum load in terms of software accessing and manipulating large input data. It can be done at both normal and peak load conditions. This type of testing identifies the maximum capacity of software and its behavior at peak time.

Most of the time, load testing is performed with the help of automated tools such as Load Runner, AppLoader, IBM Rational Performance Tester, Apache JMeter, Silk Performer, Visual Studio Load Test, etc.

Stress Testing

Stress testing includes testing the behavior of a software under abnormal conditions. For example, it may include taking away some resources or applying a load beyond the actual load limit.

The aim of stress testing is to test the software by applying the load to the system and taking over the resources used by the software to identify the breaking point. This testing can be performed by testing different scenarios such as:

- Shutdown or restart of network ports randomly
- Turning the database on or off
- Running different processes that consume resources such as CPU, memory, server, etc.

Usability Testing

Usability testing is a black-box technique and is used to identify any error(s) and improvements in the software by observing the users through their usage and operation.

Usability is the quality requirement that can be measured as the outcome of interactions with a computer system. This requirement can be fulfilled and the end-user will be satisfied if the intended goals are achieved effectively with the use of proper resources.

A user-friendly system should fulfill the following five goals, i.e., easy to Learn, easy to remember, efficient to use, satisfactory to use, and easy to understand.

In addition to the different definitions of usability, there are some standards and quality models and methods that define usability in the form of attributes and sub-attributes such as ISO-9126, ISO-9241-11, ISO-13407, and IEEE std.610.12, etc.

Security Testing

Security testing involves testing a software in order to identify any flaws and gaps from security and vulnerability point of view. Listed below are the main aspects that security testing should ensure:

- Confidentiality
- Integrity
- Authentication
- Availability
- Authorization
- Non-repudiation
- Software is secure against known and unknown vulnerabilities
- Software data is secure
- Software is according to all security regulations
- Input checking and validation
- SQL insertion attacks
- Injection flaws
- Session management issues
- Cross-site scripting attacks
- Buffer overflows vulnerabilities
- Directory traversal attacks

Portability Testing

Portability testing includes testing a software with the aim to ensure its reusability and that it can be moved from another software as well. Following are the strategies that can be used for portability testing:

- Transferring an installed software from one computer to another.
- Building executable (.exe) to run the software on different platforms.

Portability testing can be considered as one of the sub-parts of system testing, as this testing type includes overall testing of a software with respect to its usage over different environments. Computer hardware, operating systems, and browsers are the major focus of portability testing. Some of the pre-conditions for portability testing are as follows:

- Software should be designed and coded, keeping in mind the portability requirements.
- Unit testing has been performed on the associated components.
- Integration testing has been performed.
- Test environment has been established.