ELSEWEDY UNIVERSITY OF TECHNOLOGY
- POLYTECHNIC OF EGYPT -

Software Testing and QA

Lecture 2

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Software is Everywhere

Outline

- Why is testing necessary?
- What is testing?
- Testing Myths
- Software Testing Terminologies
- Test principles
- Fundamental test process
- The psychology of testing
- Limitations of Software Testing

Why is testing necessary?

Why Software Testing is Important?

- China Airlines Airbus A300

Crashed due to a **software bug** on April 26, 1994, killing **264** innocent live

Why Software Testing is Important?

- Canada's Therac-25 radiation therapy machine

Malfunctioned in 1985 due to **software bug** and delivered lethal radiation doses to patients, leaving 3 people dead and critically injuring 3 others.

Why Software Testing is Important?

- $1.2 billion military satellite launch

Failed In April of 1999 because of a software bug. The costliest accident in history

Why Software Testing is Important?

- US Bank Accounts

A **software bug** caused 823 customers to be credited $920 million

Case Study – Ariane 5: Lessons Learned in Software Eng.

- Test! Test! Test!
- Test! Even when the code is reused.
- When reuse, ensure the assumptions are still valid.
- When write reusable code, document the assumptions.
- Write fail-safe code.
- Do not propagate errors.

Why Software Testing is Important?

from

- History is full of such examples. Look for more examples!
- Testing is **important** because software bugs could be **expensive** or even **dangerous**.
- Software bugs can potentially cause **monetary** and **human loss**,

Why Programs fail

Congratulations!

- Your code is complete. It compiles. It runs …
- Your program fails. How can this be?
- There is a defect in the code. When the code is executed, the defect causes bad behavior, which later becomes visible as a failure.
- Before a program can be debugged, we must set it up such that it can be *tested* — that is, executed with the intent to make it fail.
- The first step in debugging is to *reproduce* the problem in question — that is, to create a test case that causes the program to fail in the specified way.
    - The first reason is to bring it under control, such that it can be observed.
    - The second reason is to verify the success of the fix.
- Now you will have the fun of testing and debugging!

Why Do We Test?

From

- Testing is expensive.
  - So are failures!
- What do we gain from that cost?
  - Finding bugs
  - Leading to
    - Fixing bugs
    - Raising the quality of the program or system we are testing

Trade-Offs of Cost and Failures

Total Cost of Quality (CoQ) =

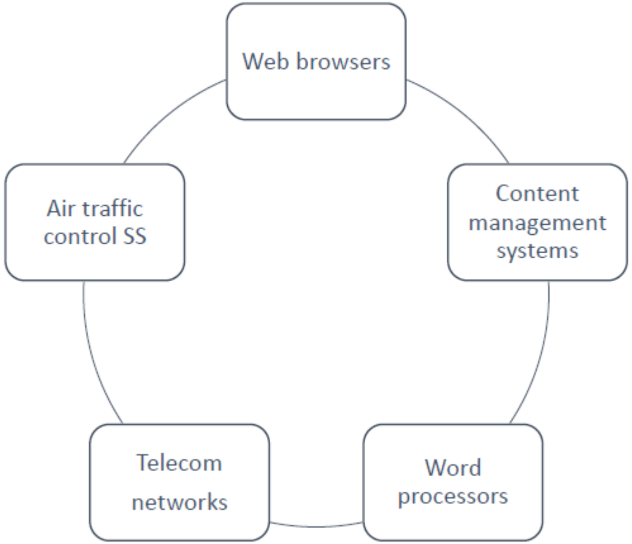
Cost of Conformance (CoC) +

Cost of Non-Conformance (CoNC)

- Cost of Conformance
  - Prevention: quality planning, investment in tools, quality training
  - Appraisal: testing, inspection
- Cost of Non-Conformance
  - Internal failures: rework
  - External failure: liability, loss of properties, loss of lives

Software systems context

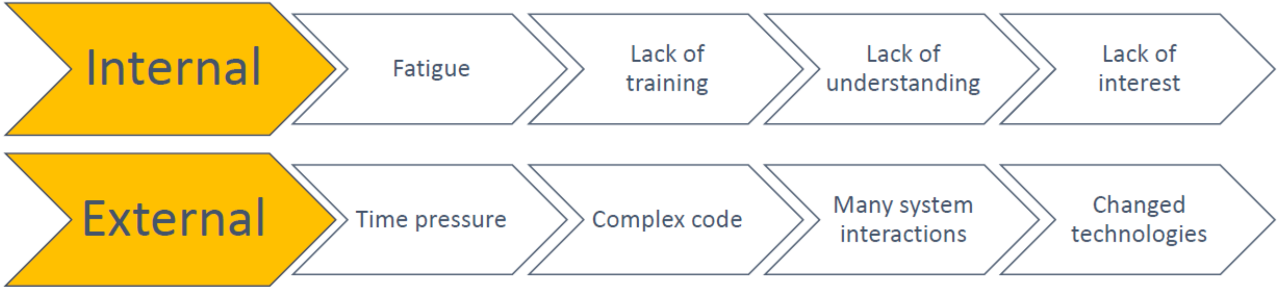
- Software systems are an important part of life:



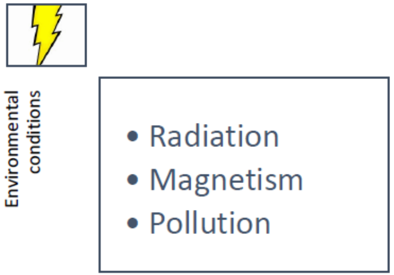
- Most people had experience with software not working as expected.
- If the SW system doesn't wok correctly, it can lead to problems like:
  - Loss of money
  - Loss of business reputation
  - Injury or death

Causes of software defects

- Human Error



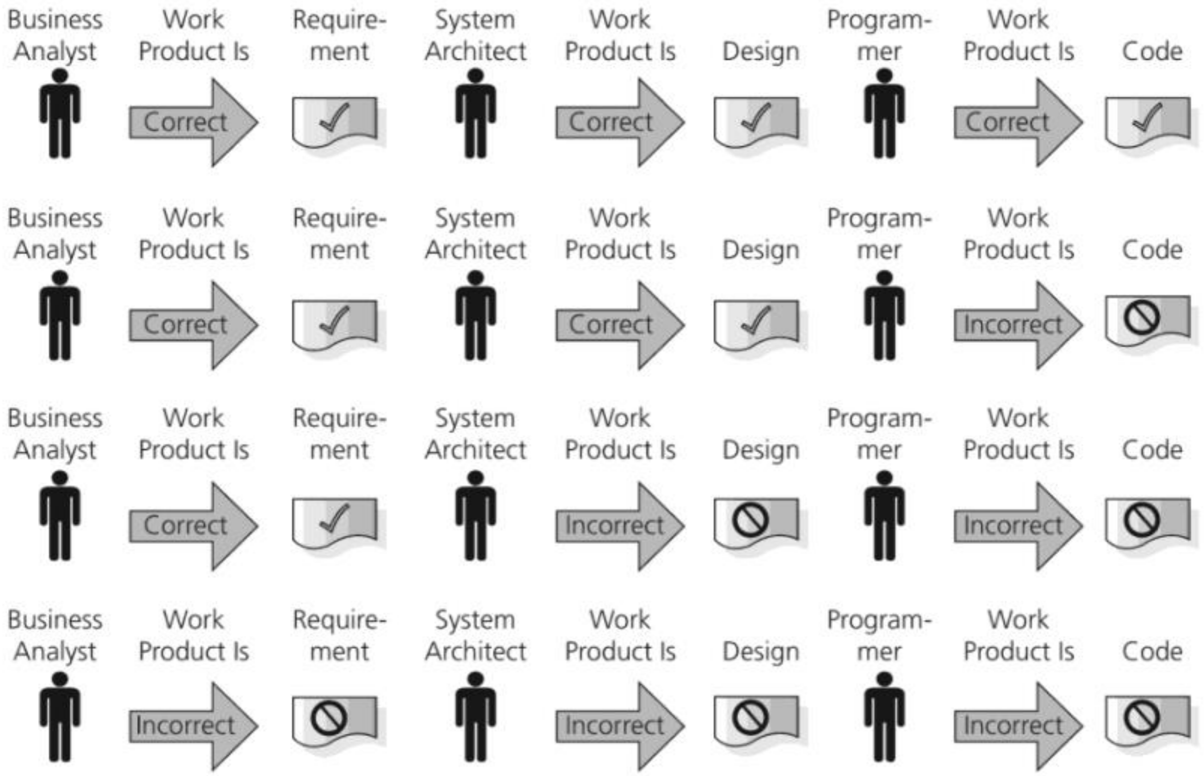
- Non-controllable events (i.e. environmental conditions)



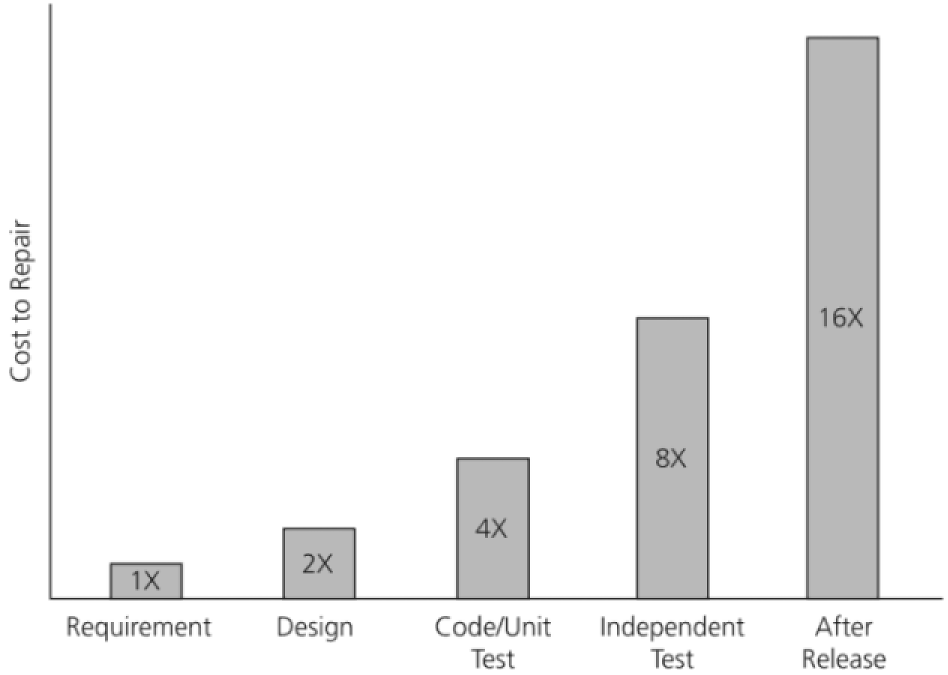
Causes of software defects

- Both causes of errors produce defects(= faults, bugs) in the code.
- Defects, if executed, may result in failures of the SW system (the system will fail to do what it should).
- Failures can affect seriously the users of the SW system, i.e.:
  - Break pedal not working
  - Miscalculations in financial SW systems

Four typical scenarios



Cost to repair



Role of testing

- Testing has an important role in all stages of a SW product’s life cycle:
    - Planning
    - Development
    - Maintenance
    - Operations

Role of testing

- To reduce the risk of problems occurring during operation
- To check if the SW system meets:
  - legal requirements
  - Industry specific standards
- To learn more about the SW system

Testing …

to

Measures the quality the SW in terms of defects found

- Functional aspects
- Non functional aspects (Reliability, Usability, Portability)

Creates confidence in the quality of the SW

- If it's properly tested and a minimum of defects are found

Teaches us lessons to apply in future projects

- By understanding the root causes of defects, processes can be improved. This can prevent defects from reoccurring.

What is testing?

It is a systematic process of discovering and correcting defects before releasing software to the user.

What is Software Testing?

- It is a systematic process used to identify the **correctness, completeness,** and **quality** of developed software. It includes a set of activities conducted with the intent of finding errors in a software so it can be corrected before the product is released to the end users
- **In simple words:** Software testing is an activity that ensures the software system is defect free.
- It can be either done **manually** or using **automated tools.**

Definition of testing

- The **process of testing** all SW life-cycle activities:
  - *both static and dynamic,*
- concerned with:
  - *planning, preparation and evaluation*
- of :
  - software products and related work products
- to:
  - determine that they satisfy specified requirements
  - demonstrate that they are fit for purpose
  - detect defects.

Definition of testing

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- Depending on the objectives of the test process, testing can be focused on
  - Confirming that the SW system meets the requirements
  - Causing as many failures as possible
  - Checking that no defects have been introduced during changes
  - Assessing the quality of the SW (with no intention of finding
  - Finding defects
    - reduces the probability of undiscovered defects
  - Creating confidence in the level of quality
  - Providing information for decision-making
  - Preventing defects

Definition of testing

- Finding defects
  - reduces the probability of undiscovered defects
- Creating confidence in the level of quality
- Providing information for decision-making
- Preventing defects

A Self Assessment Test

Test the Following Program

- The program reads in 3 integer values that represent the lengths of the sides of a triangle.
- The program prints a message that states whether the triangle is
    - Equilateral (all 3 sides are equal)
    - Isosceles (exactly 2 of the 3 sides are equal)
    - Scalene (all 3 sides are of a different length)

Write a set of test cases that you feel would adequately test this program.

Test Case	Sample Test Data		Expected Results
Enter no values	nil		Error. 3 integers must be given.
Enter 1 value	12		Error. 3 integers must be given.
Enter 2 values	12, 13		Error. 3 integers must be given.
Happy path - Equilateral	5, 5, 5		Equilateral
Happy path - Isosceles	3, 3, 4		Isosceles
Happy path - Scalene	2, 3, 4		Scalene
Use incorrect format	2.000, 3.000, 4.000		Error. 3 integers must be given.
Use non-integers	2.5, 7.5, 8.7		Error. 3 integers must be given.
Use spaces			Error. 3 integers must be given.
Use other characters	a, %, Z	&, $, =	Error. 3 integers must be given.
Equilateral Stuff *... all 3 entered values are equal*			
Valid equilateral	12, 12, 12		Equilateral
At least one is 0 (boundary case)	0, 0, 0		Error. All values must be > 0.
At least one is max (boundary case)	25, 25, 25 *		Equilateral
At least one is < 0	-1, -1, -1		Error. All values must be > 0.
At least one is > max	27, 27, 27		Error. All values must be <= max
Isosceles Stuff *... 2 entered values are equal*			
Valid isosceles	2, 2, 1	2, 2, 3	Isosceles
Invalid isosceles	2, 2, 5	2, 2, 4	Error. Not a triangle.
At least one is 0	3, 3, 0	0, 0, 5	Error. All values must be > 0.
At least one is max, and valid triangle	25, 25, 24	24, 24, 25	Isosceles
At least one is max, and invalid triangle	10, 10, 25		Error. Not a triangle.
At least one is < 0	20, 20, -1	-1, -1, -20	Error. All values must be > 0.
At least one is > max	27, 27, 20	16, 16, 28	Error. All values must be <= max
Scalene Stuff *... none of the 3 entered values are equal*			
Valid scalene	2, 3, 4		Scalene
Invalid scalene	2, 3, 25	2, 3, 5	Error. Not a triangle.
At least one is 0	0, 7, 9		Error. All values must be > 0.
At least one is max, and valid triangle	15, 20, 25		Scalene
At least one is max, and invalid triangle	10, 15, 25	2, 3, 25	Error. Not a triangle.
At least one is < 0	-2, -1, 5		Error. All values must be > 0.
At least one is > max	15, 20, 29		Error. All values must be <= max

* For the max value, I just arbitrarily set it to 25 just to better illustrate the cases involving the max value.

How Will You Do It?

Write a set of test cases that you feel would adequately test this program.

- How many cases are needed?
- How do you plan to test the program?
    - Run it once and manually enter the values?
    - Run it many times with different inputs?
    - Run it with a file containing a set of lines with test values?

How will you do it?

- "Smoke test.", aka "Hello World!"
- Check handling of inputs
  - Illegal inputs – text instead of integers
  - Impossible inputs – floating vs. integer
  - Outrageous values – infinities, max and min values
  - Not in domain – negative numbers,
    values outside specifications
  - Input errors – wrong input, e.g. mis-spellings
- Stress test
  - multiple inputs without restart
  - run program for long periods of time

Software Testing Terminologies

Test Cases Terminology

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- Test Case Verdicts
  - Pass
    - The test case execution was completed
    - The function being tested performed as expected
  - Fail
    - The test case execution was completed
    - The function being tested did not perform as expected
  - Error
    - The test case execution was not completed, due to an unexpected event, exceptions, or improper set up of the test case, etc.

Testing: Concepts

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Test Case

Test Scaffolding

Test fixture

Test oracle

Test suite

Test adequacy

Test driver

Testing: Concepts

- Test case (or, simply test)
  - An execution of the software with a given test input, including:
    - Input values
    - Sometimes include execution steps
    - Expected outputs

```
int actual_output=sum(1,2)
assertTrue(actual_output==3);
```

Example JUnit test case for testing "sum(int a, intb)"

Testing: Concepts

- Test oracle
  - The expected outputs of software for given input
  - A part of test cases
  - Hardest problem in auto-testing: test oracle generation

```
int actual_output=sum(1,2)
assertTrue(actual_output==3);
```

Example JUnit test case for testing “sum(int a, intb)”

Testing: Concepts

- Test Scaffolding

Additional code used to run a specific module of the program during testing.

  - To do Unit tests, we have to provide replacements for parts of the program that we will omit from the test.
  - Additional code needed to execute a unit or subsystems in isolation
  - Not useful in production code
    - Needs to be removed

Testing: Concepts

- Test fixture: a fixed state of the software under test used as a baseline for running tests; also known as the test context, e.g.,

  Static data or environment setup before test execution.

  - Loading a database with a specific, known set of data
  - Preparation of input data and set-up/creation of fake or mock objects

Testing: Concepts

- Test suite
  - A collection of test cases
  - Usually these test cases share similar pre-requisites and configuration
  - Usually can be run together in sequence
  - Different test suites for different purposes
  - Certain platforms, Certain feature, performance, …
- Test Script
  - A script to run a sequence of test cases or a test suite automatically

Testing: Concepts

- Test driver

  A framework or program for running tests and verifying results.

  - A software framework that can load a collection of test cases or a test suite
  - It can also handle the configuration and comparison between expected outputs and actual outputs

Testing: Concepts

- Test adequacy A measure of the adequacy of a set of tests.
  - We can't always use all test inputs, so which do we use and when do we stop?
  - We need a strategy to determine when we have done enough
  - Adequacy criterion: A rule that lets us judge the sufficiency of a set of test data for a piece of software

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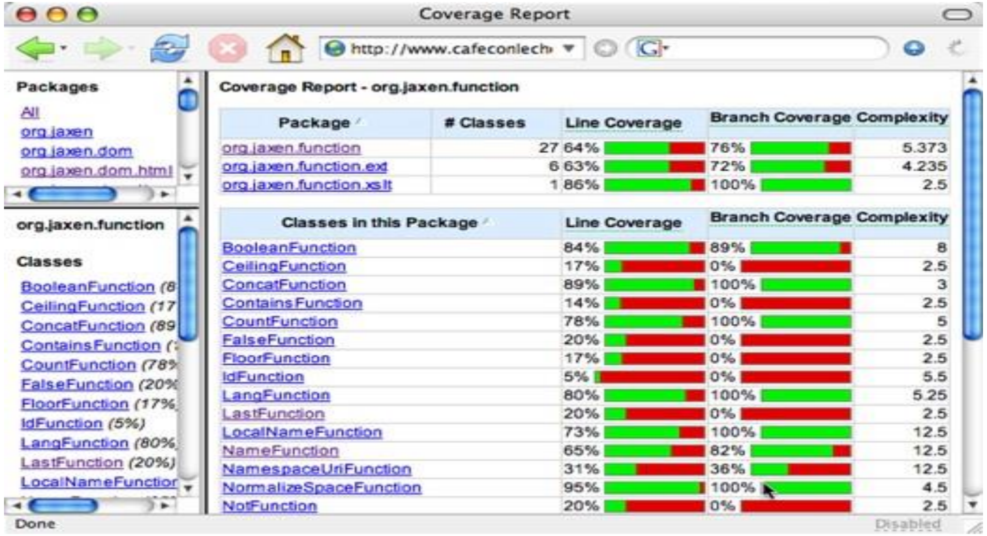
Testing: Concepts

- Test adequacy example: test coverage
  - A measurement to evaluate the percentage of tested code
    - Statement coverage
    - Branch coverage, …



Package	# Classes	Line Coverage	Branch Coverage	Complexity
org.jaxen.function	27	64%	76%	5.373
org.jaxen.function.ext	6	63%	72%	4.235
org.jaxen.function.xslt	1	86%	100%	2.5

Classes in this Package	Line Coverage	Branch Coverage	Complexity
BooleanFunction	84%	89%	8
CeilingFunction	17%	0%	2.5
ConcatFunction	89%	100%	3
ContainsFunction	14%	0%	2.5
CountFunction	78%	100%	5
FalseFunction	20%	0%	2.5
FloorFunction	17%	0%	2.5
IdFunction	5%	0%	5.5
LangFunction	80%	100%	5.25
LastFunction	20%	0%	2.5
LocalNameFunction	73%	100%	12.5
NameFunction	65%	82%	12.5
NamespaceUriFunction	31%	36%	12.5
NormalizeSpaceFunction	95%	100%	4.5
NotFunction	20%	0%	2.5

Cobertura tool

Granularity of Testing

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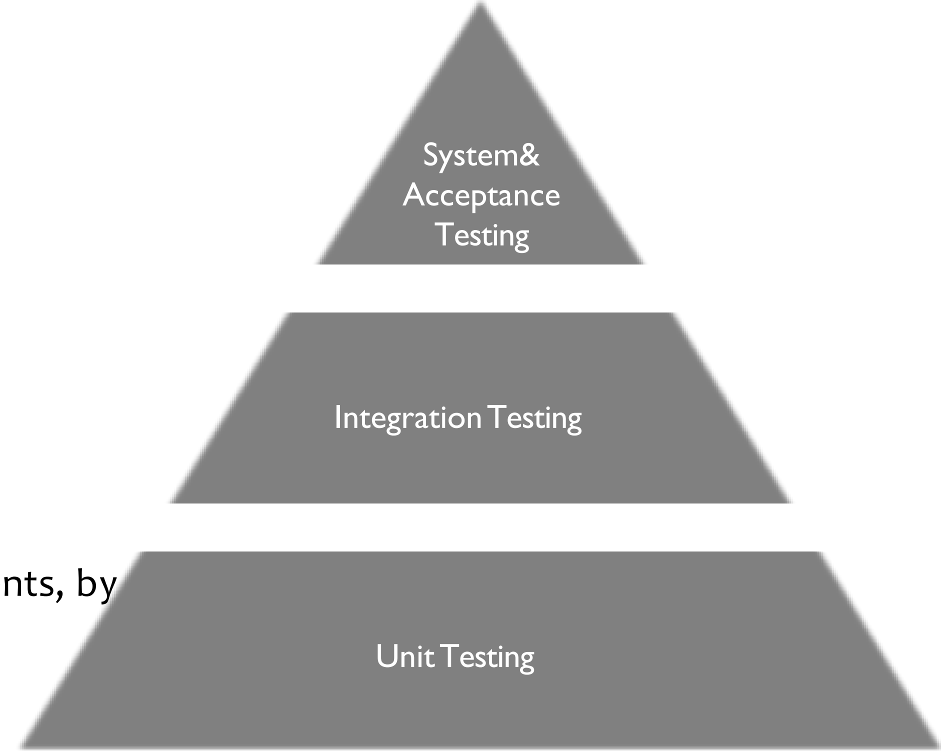
- Unit Testing
  - Test of each single module
- Integration Testing
  - Test the interaction between modules
- System Testing
  - Test the system as a whole, by developers
- Acceptance Testing
  - Validate the system against user requirements, by customers, without formal test cases



Testing Purpose

- The purpose of testing
  - to find defects.
  - to discover every conceivable weakness in a software product.

1. Software testing ≠ Debugging.
2. Software testing ≠ Quality assurance

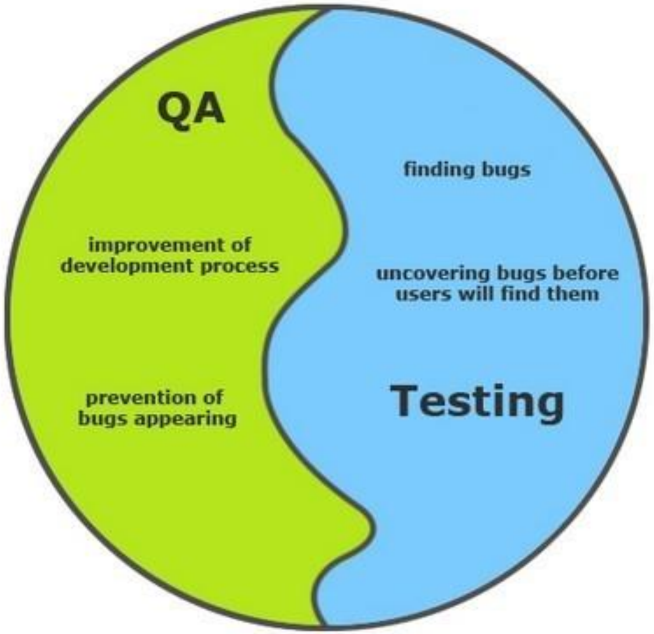
Software Testing vs. Quality Assurance (QA) from

- Software testing is a planned process that is used to identify the correctness, completeness, security and quality of software.
- Quality Assurance (QA) is planned and systematic way to evaluate quality of process used to produce a quality product.
- The goal of a QA is to provide assurance that a product is meeting customer's quality expectations.

Software Testing vs. Quality Assurance (QA)

- Testing is necessary, but not sufficient for quality assurance
  - Testing contributes to improve quality by identifying problems.
- Quality assurance sets the standards for the team/organization to build better software.

Software Testing vs. Quality Assurance (QA) to



The seven test principles

The test principles

- **P1: Testing shows presence of defects**
  - Testing can show that defects are present, but cannot prove there are no defects.
  - Testing reduces the probability of undiscovered defects remaining in the software; but even if no defects are found, this is not a proof of correctness .
- **P2: Exhaustive testing is impossible**
  - Testing everything is not feasible. We use risks and priorities to focus test effort.
- **P3: Early testing**
  - Testing should start as soon as possible in the development life-cycle and should be focused on defined objectives.
- **P4: Defect clustering**
  - A small number of modules contain most of the defects discovered during pre-release testing.
- **P5: Pesticide paradox**
  - If the same set of tests will be repeated over and over, it will no longer find new bugs.
- **P6: Testing is context dependent**
  - I.e., safety-critical SW is tested differently from an e-commerce site.
- **P7: Absence-of-errors fallacy**
  - Finding and fixing defects does not help if the SW system is un-usable or does not meet user's expectations.

P1: Testing shows the presence of defects, not their absence

- Testing can show that defects are present, but cannot prove that there are no defects.

- Testing reduces the probability of undiscovered defects remaining in the software. However, even if no defects are found, this is not a proof of correctness.

P2: Exhaustive testing is impossible

- Testing everything(all combinations of input and preconditions) is not feasible except for specific cases.

- We use risks and priorities to focus the testing.

P3: Early testing saves time and money

- Testing activities should start as early as possible in the software or system development life cycle and should be focused on defined objectives.

P4: Defect clustering defects cluster together

- A small number of modules contains most of the defects discovered during pre release testing.

P5: Pesticide paradox

- If the same tests are repeated over and over again, the same set of test cases will no longer find any new bugs.

- To overcome this 'pesticide paradox', the test cases need to be regularly reviewed and revised, and new and different tests need to be written to investigate different parts of the software.

P6: Testing is context dependent

- Testing is done differently in different contexts.
- For example, testing of safety-critical software is different from e-commerce site testing.

P7: Absence of error fallacy

- Finding and fixing defects does not help if the software system does not fulfill users' needs and expectations .

Fundamental Test Processes

Test Cases and Test Suites

- ***Test case***
  - A test case consists of inputs, steps/actions, and expected results, i.e., pass-fail criterion
- ***Test suite***
  - A group of test cases (usually organized around some principles, e.g. smoke test suite)

Test Plan and Testing Process

- ***Test plan***
  - A document that specifies how a system will be tested, including criteria for success, i.e., the exit criteria.
- ***Testing process***
  - The testing process involves developing test plans, designing test cases, running the test cases, and evaluating the results

Fundamental test processes

- Test planning
- Test monitoring and control
- Test analysis
- Test design
- Test implementation
- Test execution
- Test completion

Test planning , monitoring and control

- **Who, what , why, when and where**

- A plan encompasses: what, how, when, by whom?
    - Scope, objectives and risk analyses
    - Test levels and types that will be applied
    - Documentation that will be produced
    - Assign resources for the different test activities
    - Schedule test implementation, execution, evaluation
- Control and adjust the planning to reflect new information, new challenges of the project.

Analysis and design

- Review test basis:
    - Requirements
    - Product architecture
    - Product design
    - Interfaces
    - Risk analysis report
- Analysis: general test objectives are transformed into:
    - Test conditions
- Design:
    - Test cases
    - Test environments
    - Test data
    - Create traceability

Implementation and execution

- *Implement:*
  - Group tests into scripts
  - Prioritize the scripts
  - Prepare test oracles
  - Write automated test scenarios
- *Execute:*
  - Run the tests and compare results with oracles
  - Report incidents
  - Repeat test activities for each corrected discrepancy
  - Log the outcome of the test execution

Test completion

- *Evaluate*:
  - Assess test execution against the defined objectives
  - Check if:
    - More tests are needed
    - Exit criteria should be changed
- *Report:*
  - Write or extract a test summary report for the stakeholders.
- *Test closure activities*
  - The activities that make the test assets available for later use.

The psychology of testing

A good tester needs:

- Curiosity
- Professional pessimism
- Attention to details
- Good communication skills
- Experience at error guessing

- To communicate defects and failures in a constructive way:
    - fact-focused reports and review of findings

Independence in testing

- A certain degree of independence is often more effective at finding defects and failures.
  - However, the developer can very efficiently find bugs in their own code.
- The level of independence in the testing depends on
  - the objective of testing.

Independence test levels

- Independence levels:
  - Tests designed by the same person who wrote the code
  - Tests designed by another person from the same team, but same organization
  - Tests designed by a person from a separate testing team, but in the same organization
  - Tests designed by a person from an outside organization / company (outsourcing the testing)

Tips and tricks

- Be clear and objective
- Confirm that:
  - You have understood the requirements
  - The person that has to fix the bug has understood the problem

Limitations of Software Testing

Testing vs. Verification

- Both, testing and verification attempts to exhibit **new** failures
- Debugging is a systematic process that finds and eliminates the defect that led to an observed failure
- Programs without **known** failures may still contain defects:
  - If they have not been verified
  - If they have been verified, but the failure is not covered by the specification

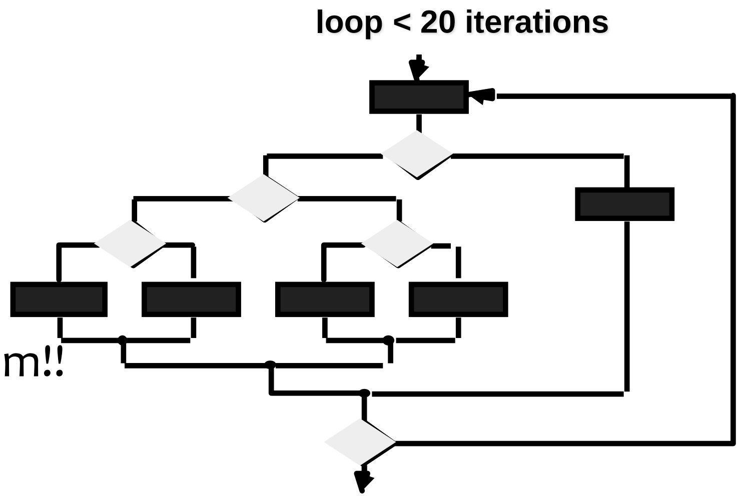
Fundamental Principles Myth

- **Myth:** "Principles are just for reference. I will not use them in practice ."

- **Fact:**
  - This is so very untrue. Test Principles will help you create an effective Test Strategy and draft error catching test cases.
  - Experienced testers have internalized these principles to a level that they apply them without even thinking.
  - Hence the myth that the principles are not used in practice is simply not true.

Exhaustive Testing

- Can we exhaustively test a program?
- Let's consider this simple program
- There are 10^{14} possible paths!
  - If we execute one test per millisecond,
  - it would take 3,170 years to test this program!!
- Exhaustive testing is impossible!



Absence of Defects

"Program testing can be used to show the presence of bugs, but never their absence."

(*Dijkstra*, 1969)

Testing reduces the probability of undiscovered defects remaining in the software but, even if no defects are found, it is not a proof of absence of defects.

How much testing is enough?

It depends on:

Level of risk:

- Technical risks
- Business risks

Project constraints:

- Time
- Budget

- It's impossible to test everything!
- Testing should provide sufficient information for the stakeholders to make informed decisions about:
  - Release of the software
  - Next development steps, etc.

When to Stop Testing?

- One of the most difficult problems in testing is not knowing when to stop.

- You can use metrics to make a guess. Keep track of the defect rate. When it goes towards zero you can use it as an indicator. Or, …
- Even if you do find the last bug, you'll never know it.

How Much Testing is Enough?

- Take into account
  - the level of risk, including technical, safety, and business risks, and
  - project constraints such as time and budget.
- Testing should provide feedback to stakeholders to make informed decisions
  - about the release of the software,
  - for the next development step, or
  - handover to customers.
- Later, we will discuss some techniques for making this decision.