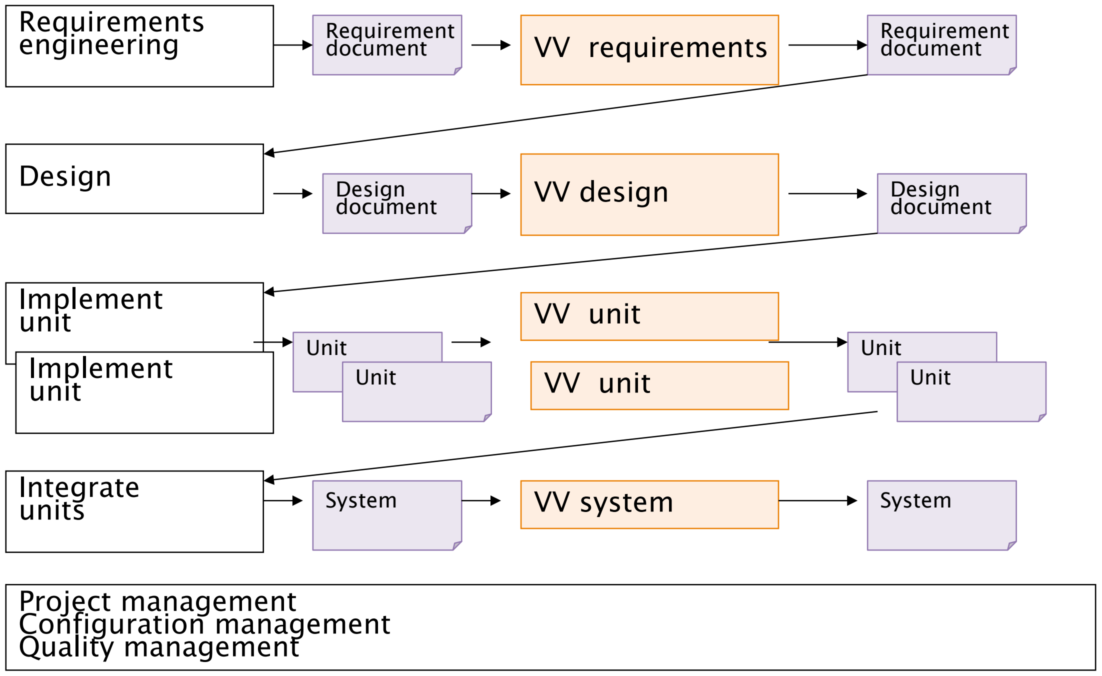
# Verification and Validation

## Object Oriented Programming

http://softeng.polito.it/courses/09CBI

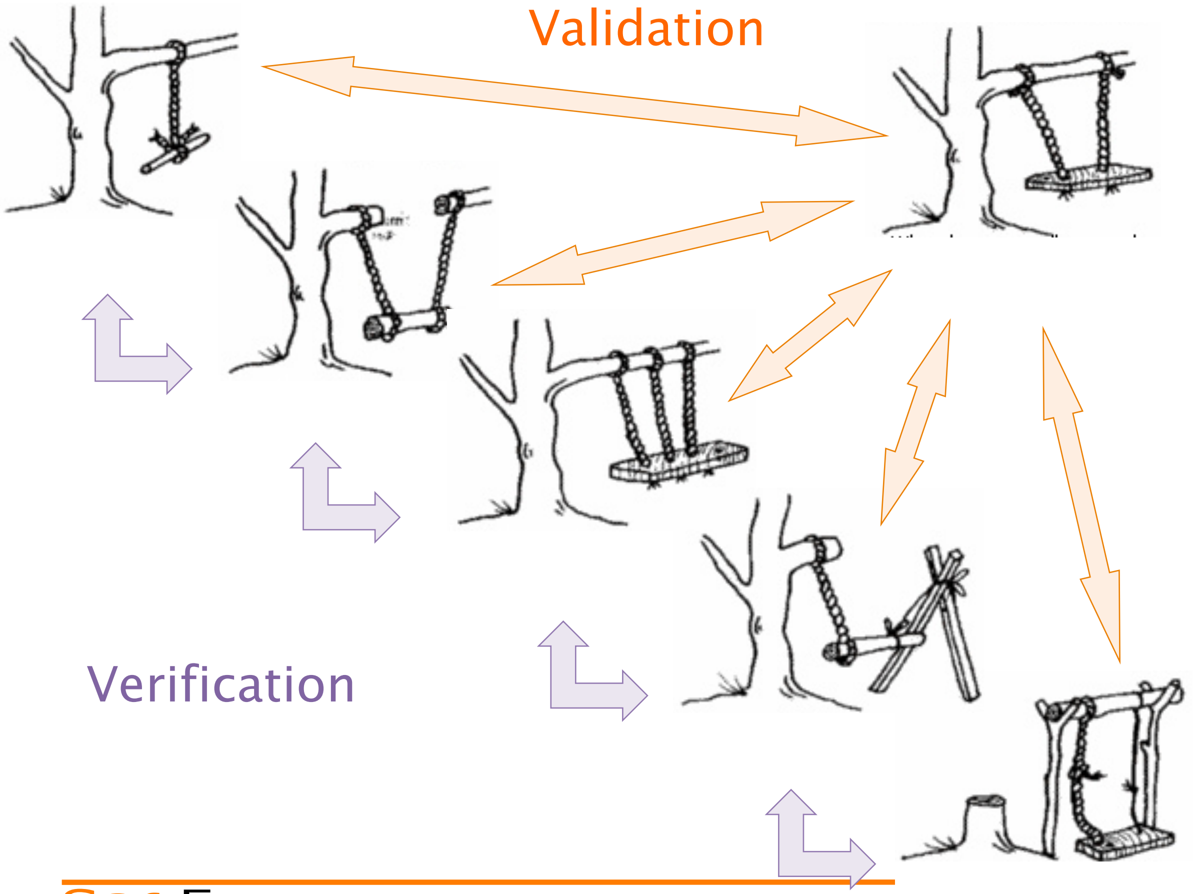
Version 1.1.0 – May 2018

# Development process

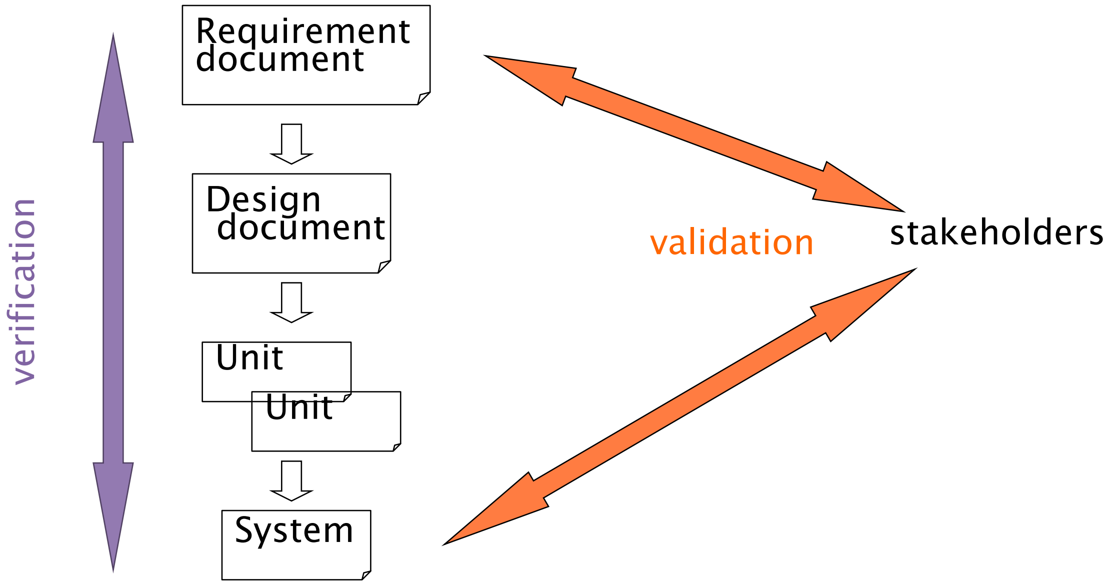


# V&V

- Validation
  - is it the right software system?
  - effectiveness
  - external (vs. user)
  - reliability
- Verification
  - is the software system right?
  - efficiency
  - internal (correctness of transformations)
  - correctness


Validation
Verification

# V & V

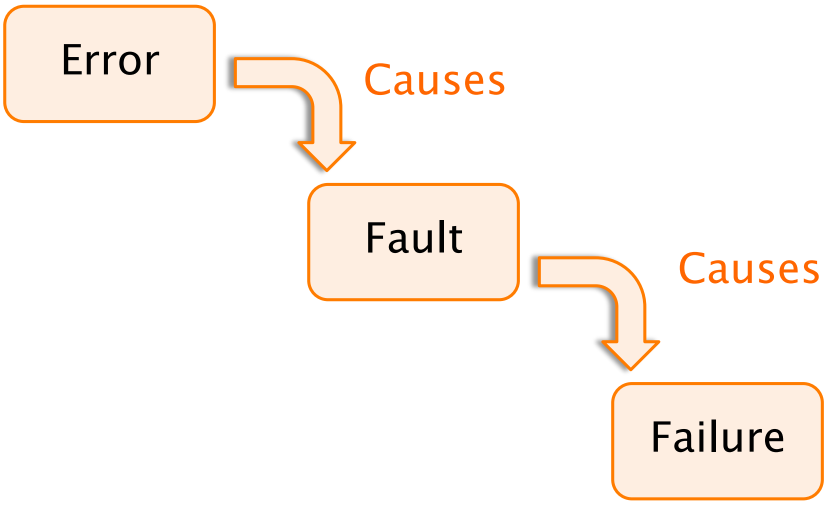

Requirement document
Design document
Unit
Unit
System
verification
validation
stakeholders

# TERMINOLOGY

# Failure, fault, defect

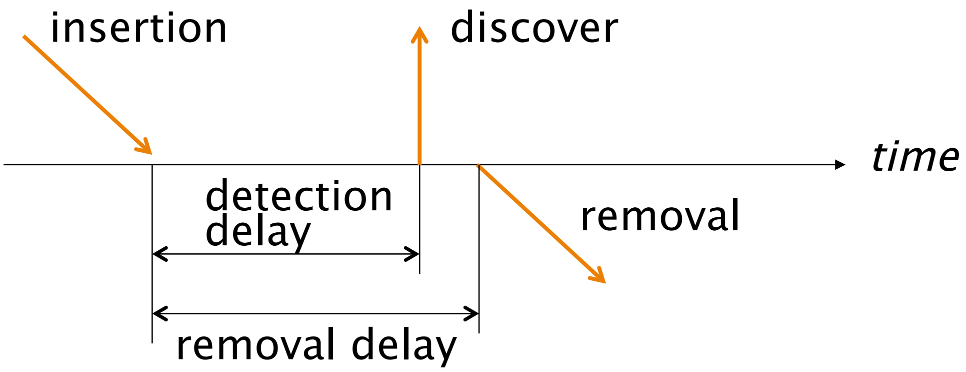
- Error
  - A mistake e.g. committed by a programmer
- Fault (Bug)
  - The feature of software that causes a failure
  - May be due to:
    - An error in software
    - Incomplete/incorrect requirements
- Failure
  - An execution event where the software behaves in an unexpected way
- Defect
  - Typically a fault (sometimes a failure)

# Error–Fault–Failure

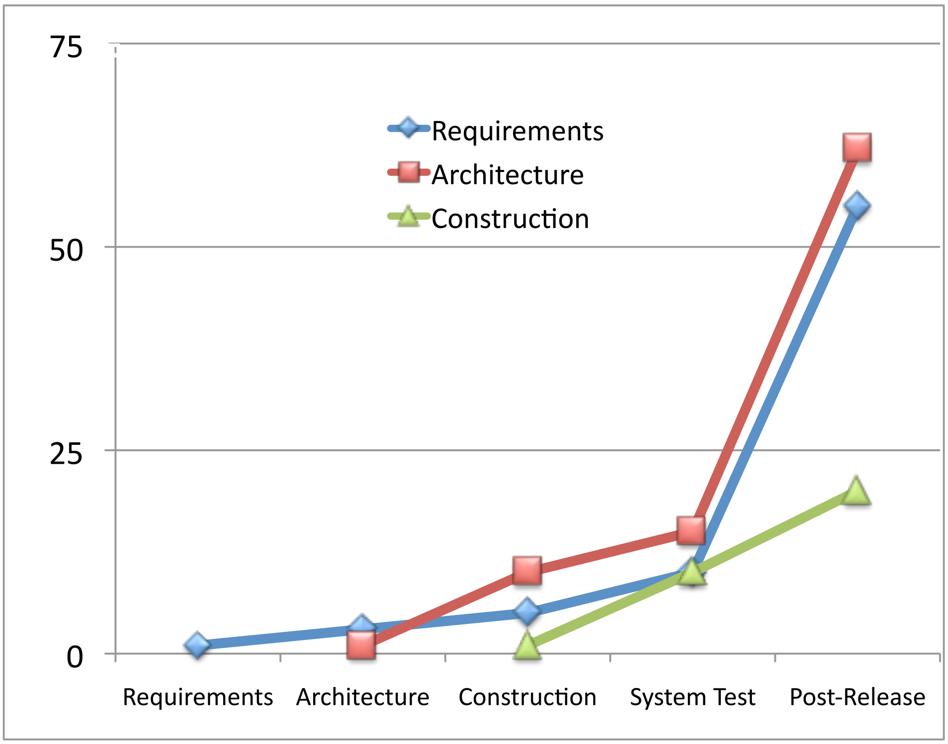


# Insertion / removal

- Defect is characterized by
  - Insertion activity (phase)
  - Discovery
  - Removal activity (phase)



# Cost of detection delay



# Basic goals of VV

- Minimize number of defects inserted
  - Cannot be zero due to inherent complexity of software
- Maximize number of defects discovered and removed
  - Cannot prove 100% is achieved
- Minimize detection delay

# V&V approaches

- Static
  - inspections
  - source code analysis
- Dynamic
  - testing

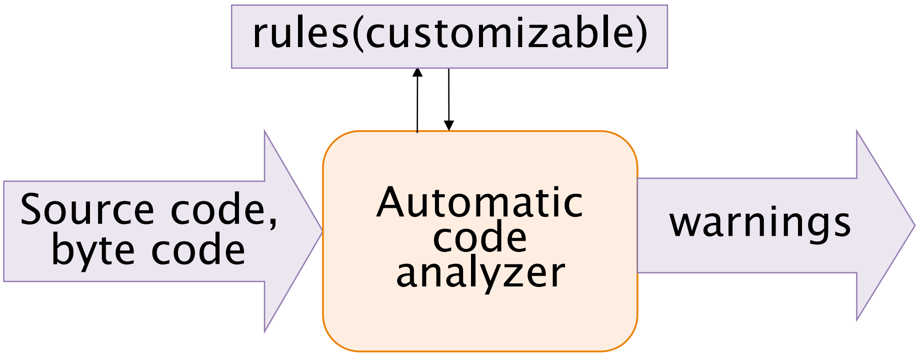
# STATIC ANALYSIS

# Static analysis techniques

- Compilation static analysis
- Control flow analysis
- Data flow analysis
- Symbolic execution
- Inspections

# Automatic code analysis

- It is performed
  - without actually executing programs (at compile time)
  - On source code, or byte code



rules(customizable)

Source code, byte code

Automatic code analyzer

warnings

# Code smells

- A code smell is a surface indication that usually corresponds to a deeper problem in the system
- Smells are certain structures in the code that indicate violation of fundamental design principles and negatively impact design quality

Fowler et al., Refactoring, Improving quality of existing code. Addison-Wesley

# Technical Debt

- Technical debt reflects the extra development work that arises when code that is easy to implement in the short run is used instead of applying the best overall solution

# Technical Debt

- "Shipping first time code is like going into debt. A little debt speeds development so long as it is paid back promptly with a rewrite... The danger occurs when the debt is not repaid. Every minute spent on not-quite-right code counts as interest on that debt."

  [W.Cunningham]

# Tools

- Static Analysis
  - SonarQube
  - Cast

# TESTING

## Definition

The process of

operating a system or component

under specified conditions

observing and recording the results

to detect the differences between actual and expected behavior (i.e. failures)

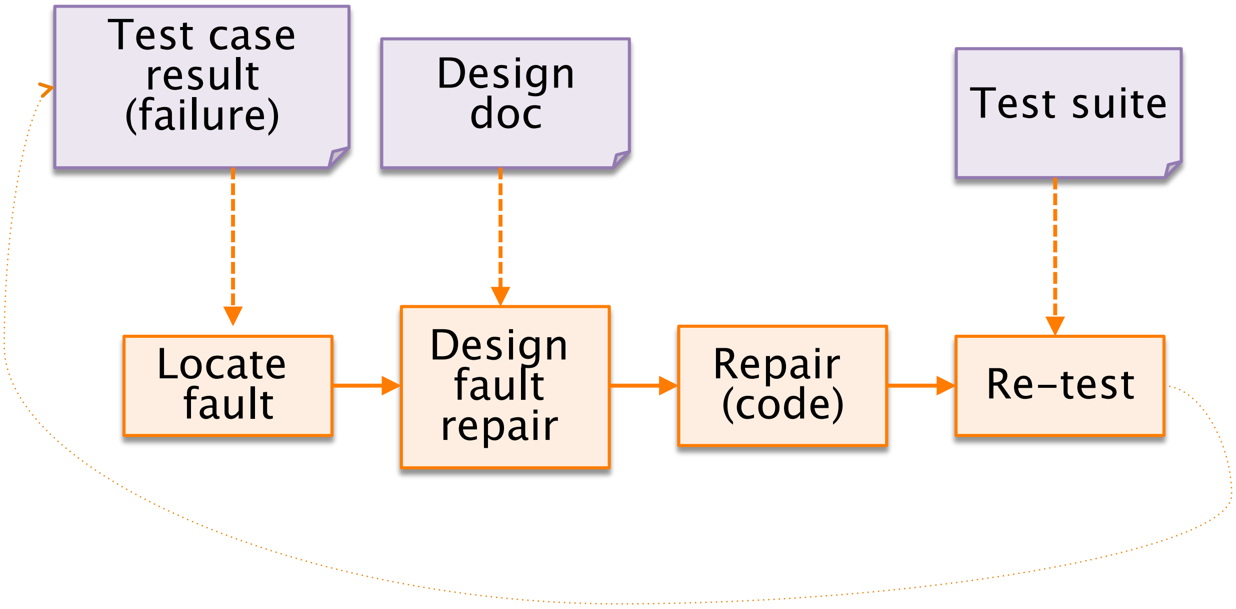
# Purpose of test

- The purpose of testing process is to find defects in software products
  - A test process is successful if it is able to detect failures

# Testing vs. debugging

- Defect testing and debugging are different activities
  - Often performed by different roles in different times
- Testing tries to detect failures
- Debugging searches for the location of the relative faults and removes them

# Debugging



# Test case

- A given stimulus applied to executable (system or unit), consists in
  - name
  - input (or sequence of –)
  - expected output
- With defined constraints/context
  - E.g. version and type of OS, DBMS, GUI ..
- Test suite = set of related test cases

# Good test case

- Reasonable chance of catching failure
- Does interesting things
- Doesn’t do unnecessary things
- Neither too simple nor too complex
- Non redundant w.r.t. other tests
- Makes failures obvious
- Mutually Exclusive
- Collectively Exhaustive

# Test case log

- Test case reference

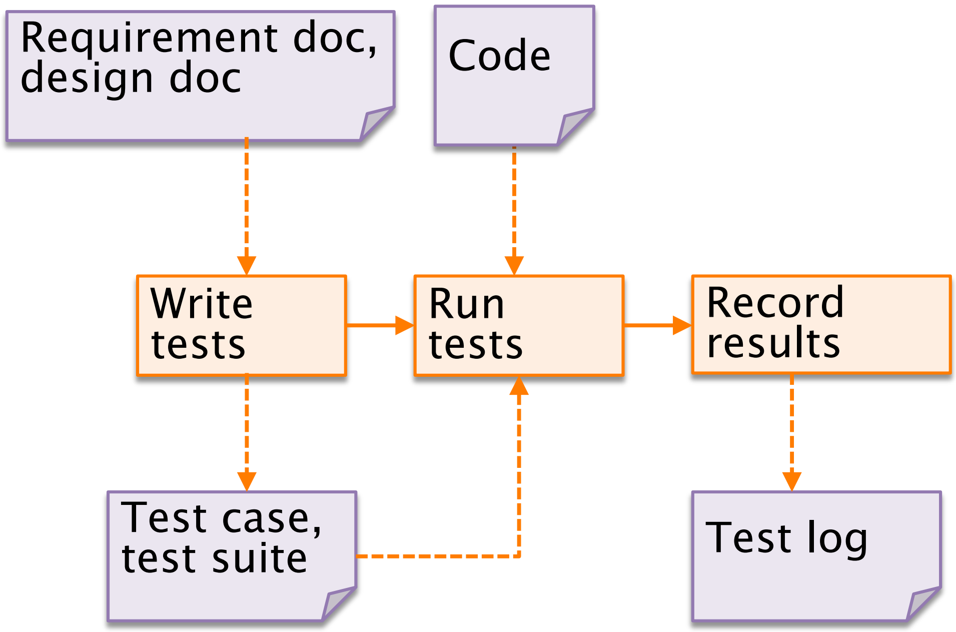
+

- Time and date of application
- Actual output
- Result (pass / no pass)

# Test cases examples

- Function **`add(int x, int y)`**
- Test case:
  - T1: (1,1; 2)
  - T2: (3,5; 8)
- Test suite
  - TS1: {T1, T2}
- Test log
  - T1, 16-3-2018 9:31, result 2, success
  - T2, 16-3-2018 9:32, result 9, fail

# Test activities



Requirement doc, design doc

Code

Write tests

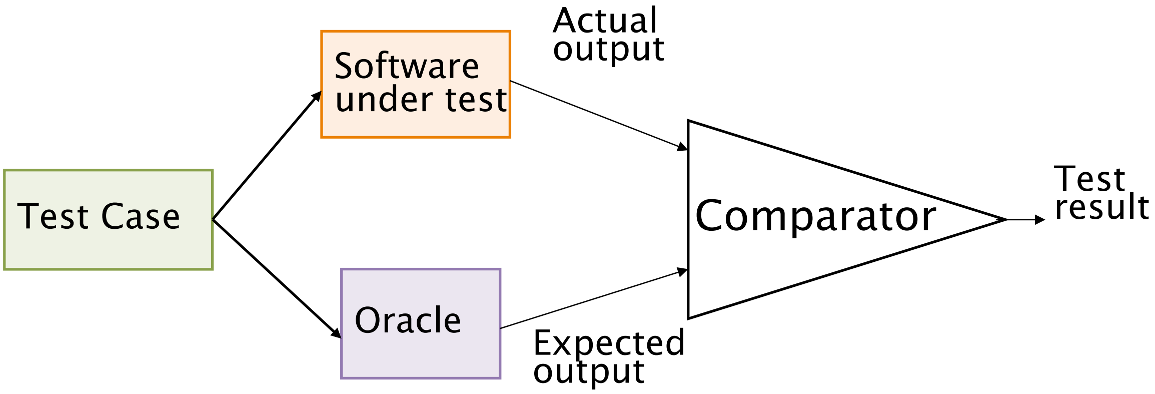
Run tests

Record results

Test case, test suite

Test log

# Oracle



# Oracle

- The ideal condition would be to have an automatic oracle and an automatic comparator
  - The former is very difficult to have
  - The latter is available only in some cases
- A human oracle is subject to errors
- The oracle is based on the program specifications (which can be wrong)

# Oracle

- Necessary condition to perform testing:
  - Know the expected behavior of a program for a given test case (oracle)
- Human oracle
  - Based on req. specification or judgment
- Automatic oracle
  - Generated from (formal) req. specification
  - Same software developed by other parties
  - Previous version of the program (regression)

# Software peculiarities

- No ageing
  - If function sum(2,3) works, it works forever
    - Supporting microprocessor will eventually fail for age, not the software
- Not linear, not continuous
  - If sum(2,3) works, may be sum(2,4) does not

# Exhaustive test

- function: Y = A + B
- A and B integers, 32 bit

- Total number of test cases: $2^{32} * 2^{32} = 2^{64} \approx 10^{20}$
- 1 ns/test ⇒ ~ 3171 years

# Exhaustive test

- Exhaustive test is impossible
- Goal of test is finding defects, not demonstrating that systems is defect free
- Final objective of test (and VV in general) is assuring a *good enough* level of quality, confidence in sw

# Dijkstra thesis

- *Testing can only reveal the presence of errors, never their absence*

E. W. Dijkstra. Notes on Structured Programming.
In *Structured Programming,* O.-J. Dahl, E. W. Dijkstra, and C. A. R. Hoare, Eds. Academic, New York, 1972, pp. 1-81.

# Test classification

- Per phase/granularity level
  - Unit, integration, system
  - Regression
- Per approach
  - Black box (functional)
  - White box (structural)
  - Reliability assessment/prediction
  - Risk based (safety security)

# Test per granularity level/phase

- Unit tests
  - Individual modules
- Integration tests
  - Modules when working together
- System tests
  - The system as a whole (usable system)
- Acceptance tests
  - The system by customer

# Unit test

- Black box (functional)
  - Random
  - Equivalence classes partitioning
  - Boundary conditions
- White Box (structural)
  - Coverage of structural elements
    - Statement
    - Decision, condition (simple, multiple)
    - Path
    - Loop

# Integration test

- Add one unit at a time, test the partial aggregate
  - Defects found, most likely, come by last unit/interaction added

# Stub, driver

- Driver
  - Unit (function or class) developed to pilot another unit
- Stub
  - Unit developed to substitute another unit (fake unit)

- Also called mockups

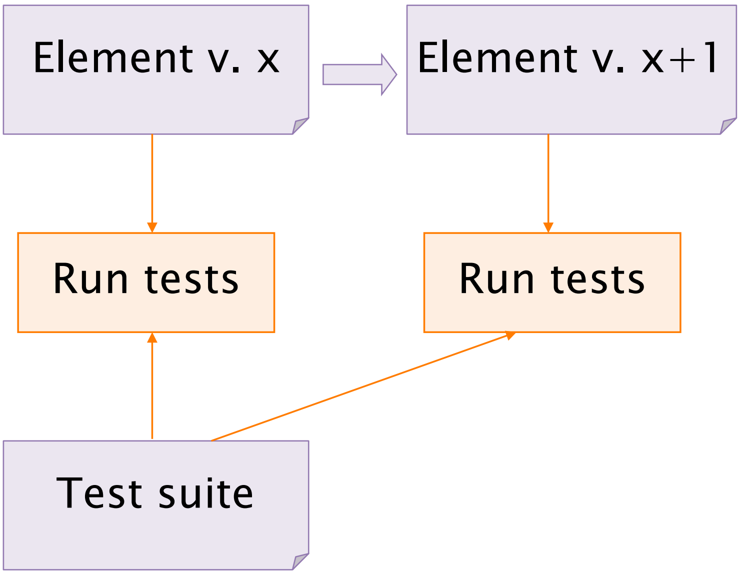
# System test

- Is applied to the software system as a whole
  - Aims at verifying the correspondence of the system to the requirements
- Test of functional requirements
  - Coverage of uses cases/scenarios as listed in requirement document
  - Consider usage profile (the most common, typical ways of using the system)
- Test in conditions as far as possible close to working conditions

# Regression testing

- Regression testing
  - Tests previously defined are repeated after a change
  - To assure that the change has not introduced defects
    - Time0
      - Element (unit, system ) in v0, test set t0 is defined and applied, all tests pass
    - Time1
      - Element is changed to v1
      - Test set t0 is re-applied, do all tests still pass?

# Regression testing



# References and Further Readings

- IEEE Std 829-2008: **IEEE Standard for Software and System Test Documentation**
- Fowler et al., Refactoring, Improving quality of existing code. Addison-Wesley
- E. W. Dijkstra. Notes on Structured Programming. In Structured Programming, O.-J. Dahl, E. W. Dijkstra, and C. A. R. Hoare, Eds. Academic, New York, 1972, pp. 1-81.