Software Design and Construction 2
SOFT3202 / COMP9202

Introduction
Software Testing

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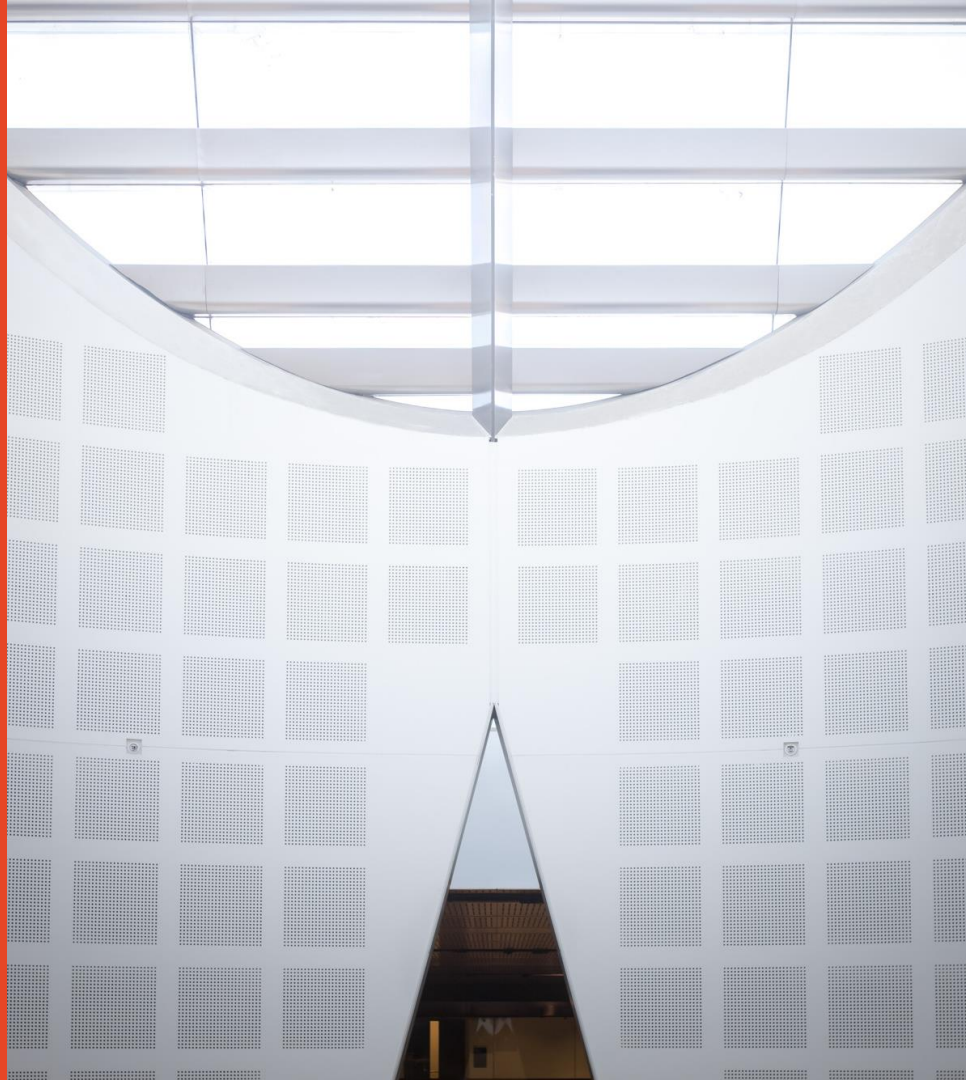

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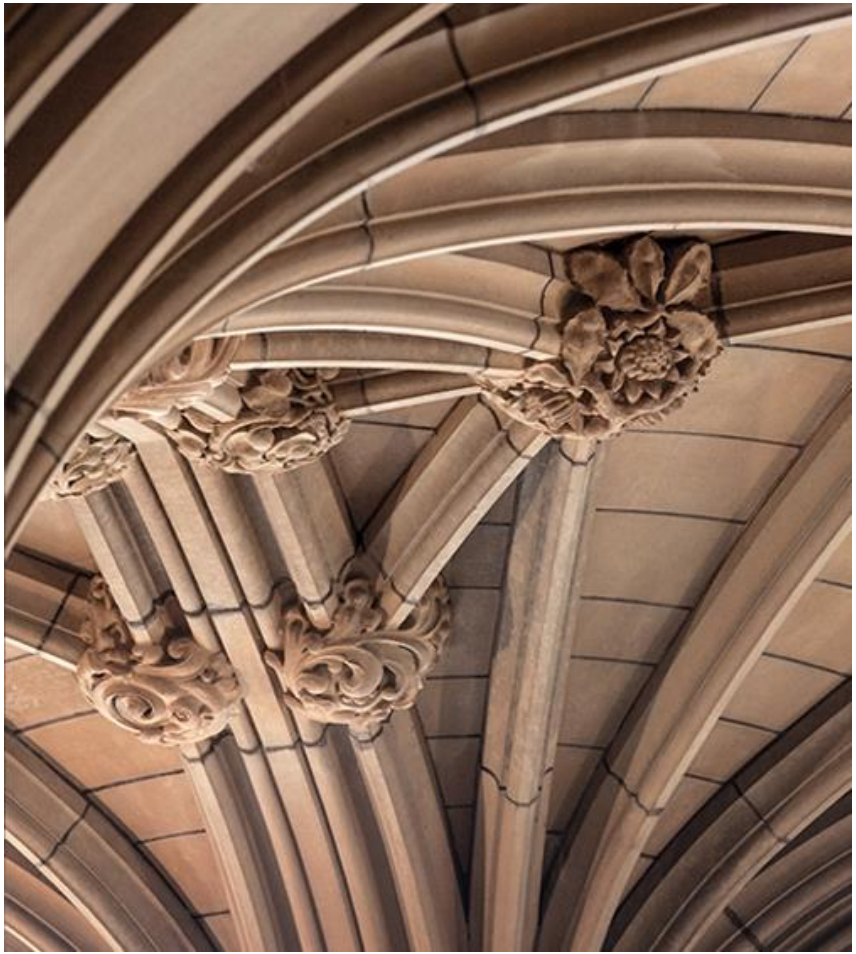
Agenda

- Software Engineering
- Software Testing
- Unit Testing

Testing in Software Engineering



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Software is Everywhere!

- Societies, businesses and governments dependent on SW systems
  - Power, Telecommunication, Education, Government, Transport, Finance, Health
  - Work automation, communication, control of complex systems
- Large software economies in developed countries
  - IT application development expenditure in the US more than $250bn/year[1]
  - Total value added GDP in the US[2]: $1.07 trillion
- Emerging challenges
  - Security, robustness, human user-interface, and new computational platforms

[1] Chaos Report, Standish group Report, 2014
[2] softwareimpact.bsa.org

Software Engineering Body of Knowledge

- Software Requirements
- **Software Design / Modelling**
- **Software Construction**
- **Software Testing**
- Software Maintenance
- Software Configuration Management
- Software Engineering Process
- Software Engineering Tools and Methods
- Software Quality

Software Engineering Body of Knowledge (SWEBOK) https://www.computer.org/web/swebok/

Why Software Engineering?

Need to build high quality software systems under resource constraints

- Social
  - Satisfy user needs (e.g., functional, reliable, trustworthy)
  - Impact on people's lives (e.g., software failure, data protection)
- Economical
  - Reduce cost; open up new opportunities
  - Average cost of IT development ~$2.3m, ~$1.3m and ~$434k for large, medium and small companies respectively[3]
- Time to market
  - Deliver software on-time

[3] Chaos Report, Standish group Report, 2014

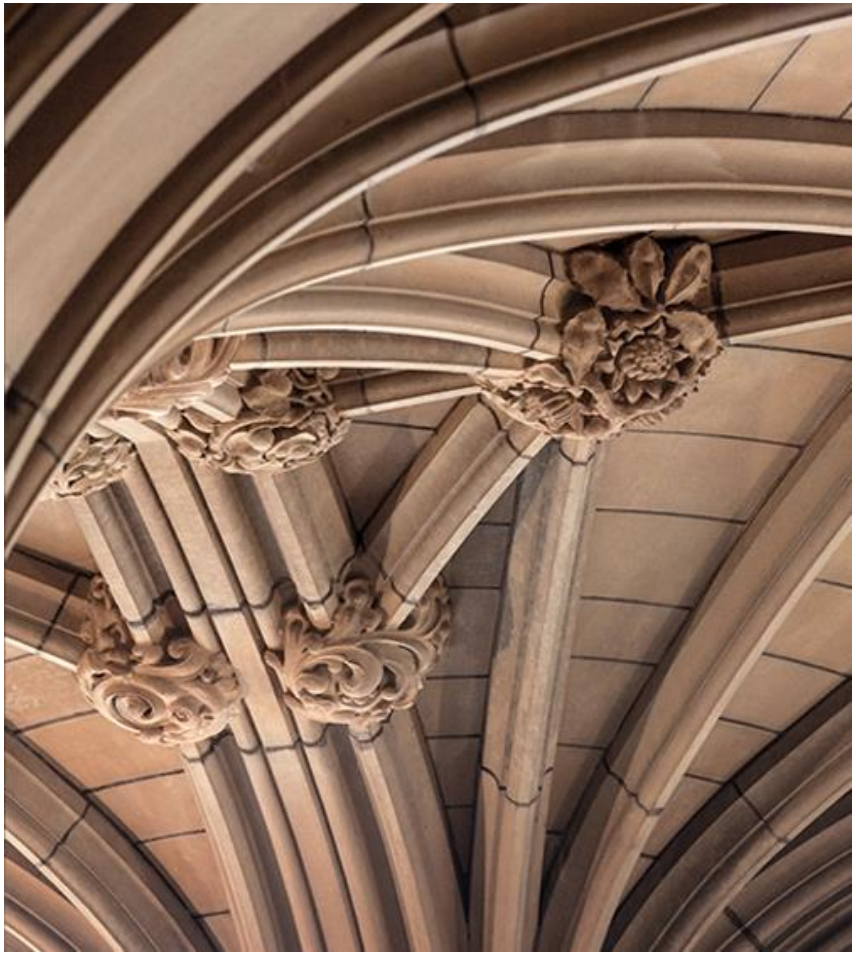
Software Quality Assurance

- Quality (products)
  - "Fitness for use"
- Software quality
  - Satisfying end use's needs; correct behaviour, easy to use, does not crash, etc
  - Easy to the developers to debug and enhance
- Quality Assurance (QA)
  - Processes and standards that lead to manufacturing high quality products
- Software Quality Assurance
  - Ensuring software under development have high quality and creating processes and standards in organization that lead to high quality software
  - Software quality is often determined through Testing

Juran and Gryna 1998

Software Testing

Why software testing?



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Therac-25 Overdose*

- **What happened?**
  - Therac-25 radiation therapy machine
  - Patients exposed to overdose of radiation (100 times more than intended) - 3 lives!!

- **Why Did happen?**
  - Particular nonstandard sequence of keystrokes was entered within 8 seconds
  - Operator override a warning message with error code ("MALFUNCTION" followed by a number from 1 to 64) - not explained in the user manual
  - Software checks safety replacing hardware interlocks in previous Therac versions
  - Absence of independent software code review
  - software and hardware integration has never been tested until assembled in the hospital (*Big Bang Testing*')

*https://en.wikipedia.org/wiki/Therac-25#Problem_description

Software Failure - Ariane 5 Disaster[5]

What happened?

- European large rocket - 10 years development, ~$7 billion
- Unmanaged software exception resulted from a data conversion from 64-bit floating point to a 16-bit signed integer
- Backup processor failed straight after using the same software
- Exploded 37 seconds after lift-off

Why did it happen?

- *Inadequate validation and verification, testing and reviews*, design error, incorrect analysis of changing requirements, ….

[5] http://iansommerville.com/software-engineering-book/files/2014/07/Bashar-Ariane5.pdf

Nissan Recall - Airbag Defect*

- **What happened?**
  - ~ 3.53 million vehicles recall of various models 2013-2017
  - Front passenger airbag may not deploy in an accident
- **Why Did happen?**
  - Software that activates airbags deployment improperly classify occupied passenger seat as empty in case of accident
  - Software defect that could lead to improper airbag function (failure)
  - No warning that the airbag may not function properly
  - Software sensitivity calibration due to combination of factors (high engine vibration and changing seat status)

http://www.reuters.com/article/us-autos-nissan-recall/nissan-to-recall-3-53-million-vehicles-air-bags-may-not-deploy-idUSKCN0XQ2A8
https://www.nytimes.com/2014/03/27/automobiles/nissan-recalls-990000-cars-and-trucks-for-air-bag-malfunction.html

Software Project Failures

Project	Duration	Cost	Failure/Status
Pust Siebel - Swedish Police case management (Swedish Police)	2011 - 2014	$53m (actual)	Permanent failure – scraped due to poor functioning, inefficient in work environments
US Federal Government Health Care Exchange Web application	2013 – ongoing	$93.7m (expected), $1.5bn (actual)	Ongoing problems - too slow, poor performance, people get stuck in the application process (frustrated users)

https://en.wikipedia.org/wiki/List_of_failed_and_overbudget_custom_software_projects

Why Software Testing?

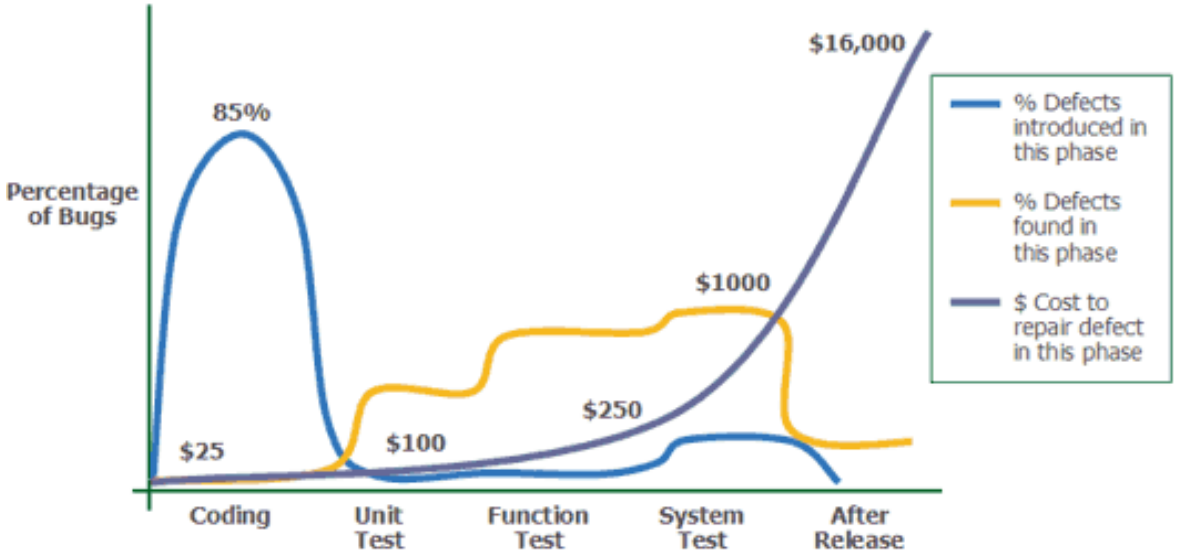
- Software development and maintenance costs
  - Big financial burden

- Total costs of inadequate software testing on the US economy is $59.5bn
  - NIST study 2002*
  - One-third of the cost could be eliminated by *improved software testing*

- Need to develop functional, robust and reliable software systems
  - Human/social factor - society dependency on software in every aspect of their lives
    - Critical software systems - medical devices, flight control, traffic control
  - Meet user needs and solve their problems
  - Small software errors could lead to disasters

* https://www.nist.gov/sites/default/files/documents/director/planning/report02-3.pdf

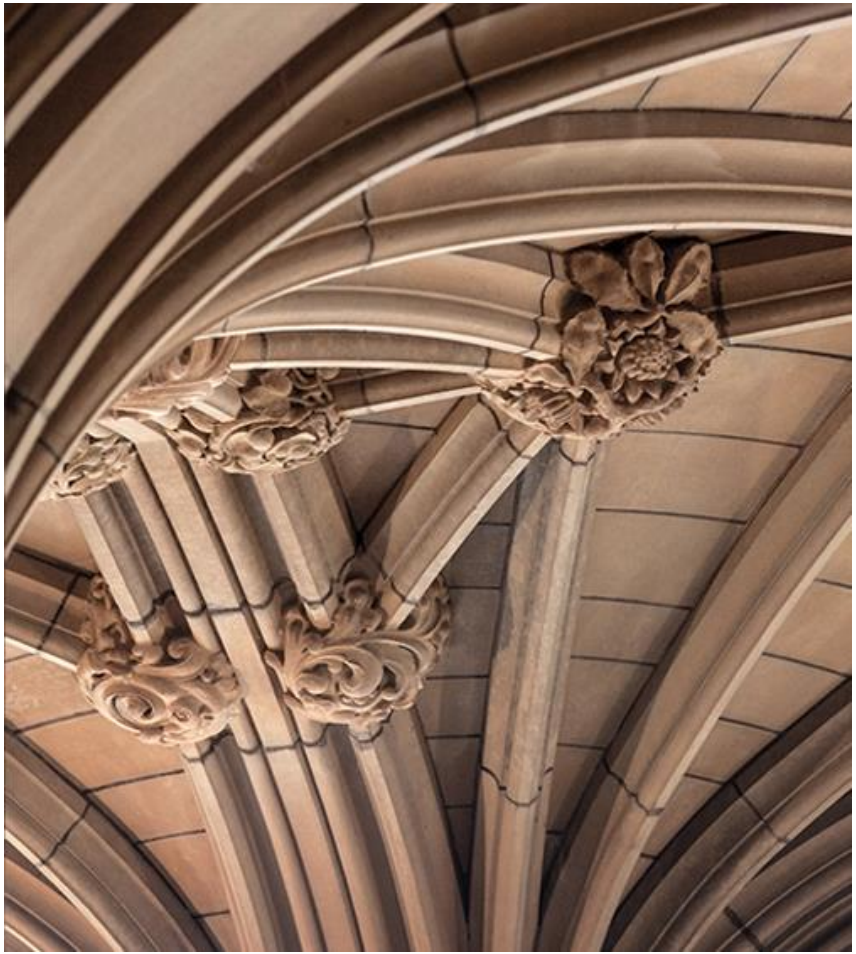
Software Testing - Costs



Capers Jones, Applied software measurement (2nd ed.): assuring productivity and quality, (1997), McGraw-Hill

Software Testing

What is software testing?



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Software Testing

- Software process to
  - Demonstrate that software meets its requirements (*validation testing*)
  - Find incorrect or undesired behavior caused by defects/bugs (defect testing)
    - E.g., System crashes, incorrect computations, unnecessary interactions and data corruptions
- Part of software verification and validation (V&V) process

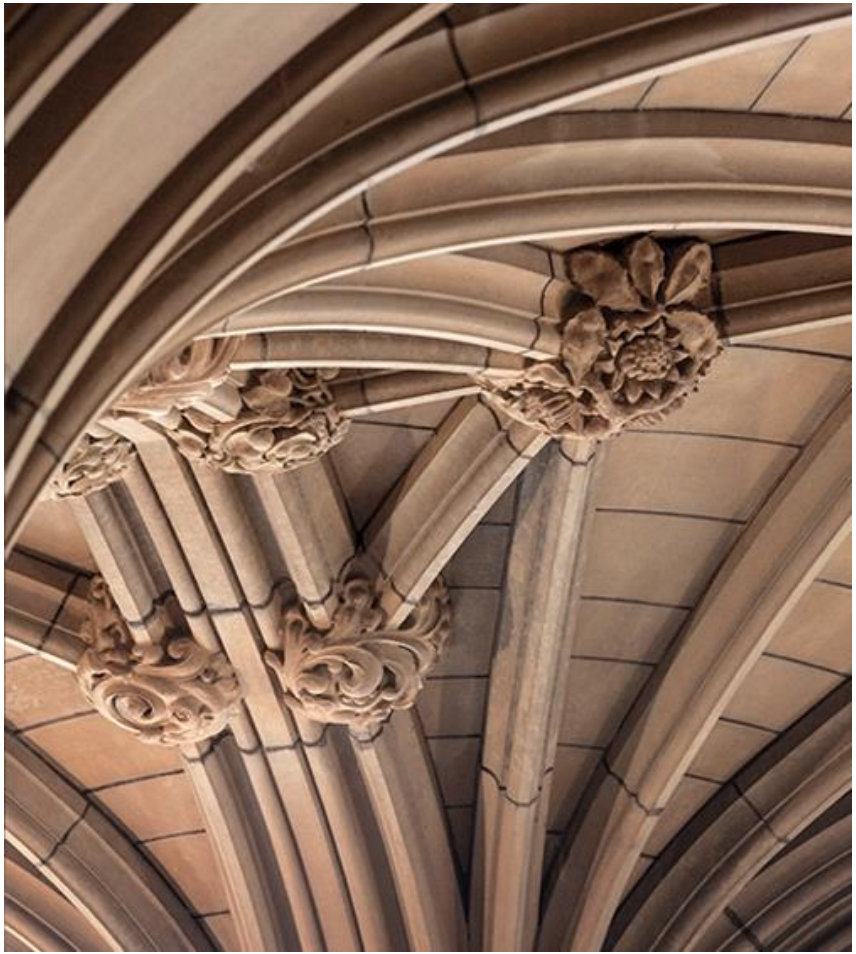
Testing (Levels)

Testing level	Description
Unit / Functional Testing	The process of verifying functionality of software components (functional units, subprograms) independently from the whole system
Integration Testing	The process of verifying interactions/communications among software components. Incremental integration testing vs. “Big Bang” testing
System Testing	The process of verifying the functionality and behaviour of the entire software system including security, performance, reliability, and external interfaces to other applications
Acceptance Testing	The process of verifying desired acceptance criteria are met in the system (functional and non-functional) from the user point of view

Software Verification and Validation

- Software testing is part of software Verification and Validation (V&V)
- The goal of V&V is to establish confidence that the software is "*fit for purpose*"
- Software Validation
  - Are we building the right product?
  - Ensures that the software meets customer expectations
- Software Verification
  - Are we building the product right?
  - Ensures that the software meets its stated functional and non-functional requirements

Unit Testing



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Unit Testing

- The process of verifying functionality of software components independently
  - Unit → methods, functions or object classes
  - Verify that each functional unit behaves as expected (defect testing)
  - Carried out by developers / SW testers
  - First level of testing

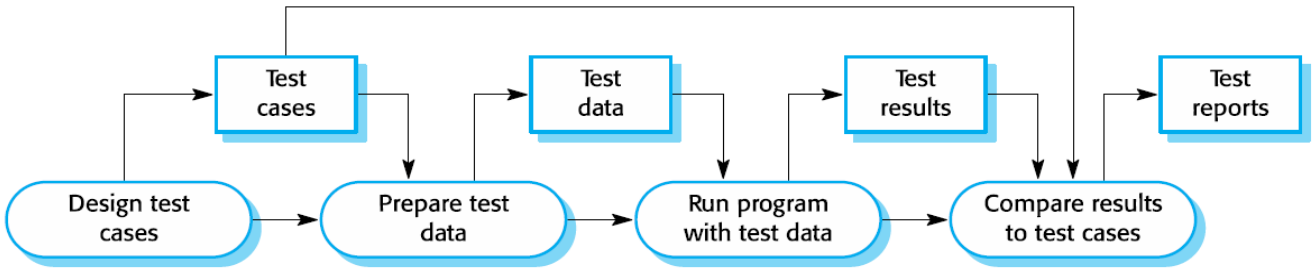
Why Unit Testing?

- Change and maintain code at smaller scale
- Discover defects early and fix it at cheaper costs
- Ease debugging
- Code reusability
- Reduce integration testing

Unit Testing – How?

1. Design test cases
2. Prepare test data
3. Run test cases using test data
4. Compare results to test cases
5. Prepare test reports

Software Testing Process



Ian Sommerville. 2016. *Software Engineering* (10th ed.). Addison-Wesley, USA.

Designing Test Cases

- Effective test cases show:
  - The unit under test does what it spoused to do
  - Reveal defects in the unit, if there is any

- Design two types of test cases
  - Test normal operation of the unit
  - Test abnormality (common problems/defects)

Choosing Test Cases – Techniques

- Partition testing (equivalence partitioning)
  - Identify groups of inputs that have common characteristics
  - From within each of these groups, choose tests
  - Use program specifications, documentation and/or experience

- Guideline-based testing
  - Use testing guidelines based on previous experience of the kinds of errors often made

Equivalence Partitioning

- Different groups with common characteristics
  - E.g., positive numbers, negative numbers
- Program behave in a comparable way for all members of a group
- Choose test cases from each of the partitions

Test Case Selection

- Understanding developers thinking
  - Developers tend to think of typical values of input
  - Developers sometimes overlook atypical values of input

- Choose test cases that are:
  - On the boundaries of the partitions
  - Close to the midpoint of the partition

Test Cases – Identifying Partitions

- Consider the following brief program specification:
  - A program accepts 4 to 8 inputs which are five-digits integers greater than 10,000

- Exercise:
  - Identify the input partitions and possible test input values

Choose Test Cases – Testing Guidelines

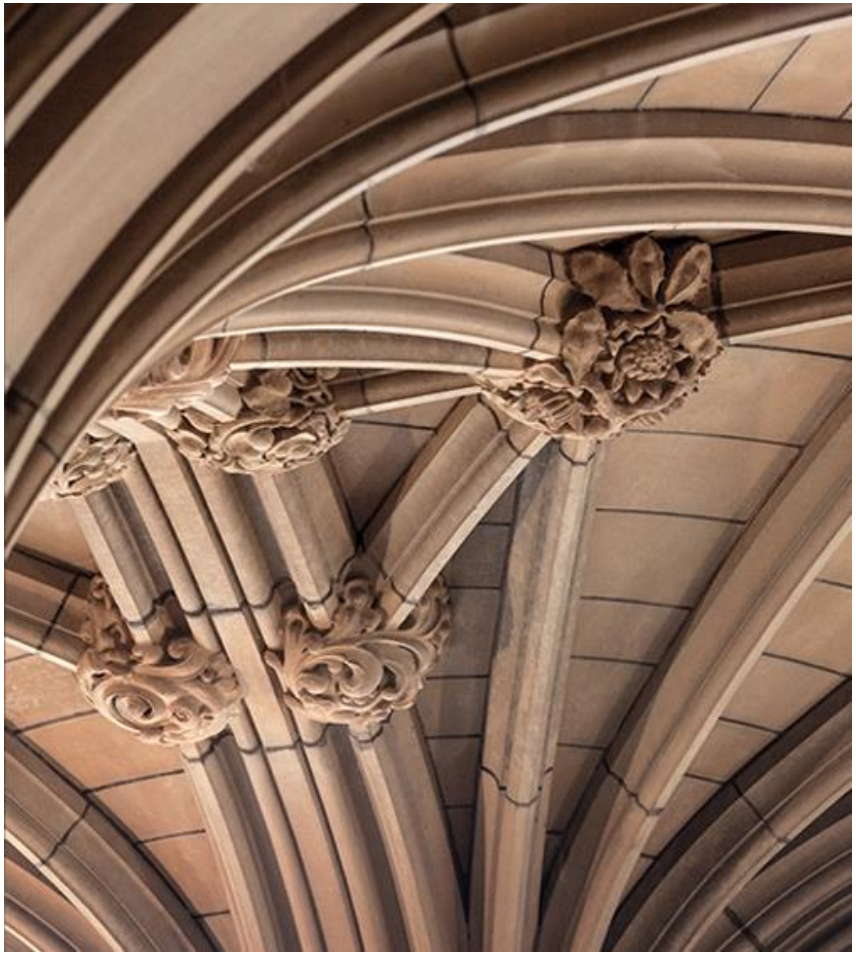
- Knowledge of type of test cases effective for finding errors
- Example of test cases for testing sequences, arrays or lists:
  - Test single value
  - Test different sequences of different sizes in different tests
  - Test partition boundaries (first, middle and last elements)

General Testing Guidelines – Examples

- Choose inputs that force the system to generate all error messages;
- Design inputs that cause input buffers to overflow
- Repeat the same input or series of inputs numerous times
- Force invalid outputs to be generated
- Force computation results to be too large or too small

J. A. Wittaker (2009) Exploratory Software Testing, Adison-Wesley

Unit Testing



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Unit Testing – Terminology

- Code under test
- Unit test
  - a piece of code written by a developer that executes a specific functionality in the code under test and asserts a certain behavior or state
  - Small unit of code e.g., a method or class
  - External dependencies are removed (mocks can be used)
  - Not suitable for complex user interface or component interaction
- Test Fixture
  - The context for testing
    - Usually shared set of testing data
    - Methods for setup those data
    - E.g., a fixed string (test fixture), which is used as input for a method

Unit Testing Frameworks for Java

- Junit
- TestNG
- Jtest (commercial)
- Many others …

https://en.wikipedia.org/wiki/List_of_unit_testing_frameworks#Java

Unit Testing Frameworks – Junit

- An open source framework for writing and running tests for Java
  - Test cases and fixtures, test suites, test runner
- One of the unit testing frameworks collectively known as xUnit
- Uses annotations to identify methods that specify a test
- Can be integrated with Eclipse, and build automation tools (e.g., Ant, Maven, Gradle)

https://github.com/junit-team/junit4

Junit – Constructs

- **Junit test (Test class)**
  - A method contained in a class which is only used for testing (called *Test class*)
- **Test suite**
  - Contains several test classes which will be executed all in the specified order
- **Test Annotations**
  - To define/denote test methods (e.g., @Test, @Before)
  - Such methods execute the code under test
- **Assertion methods (assert)**
  - To check an expected result versus actual results
  - Variety of methods
  - Provide meaningful messages in assert statements

Junit – Annotations

JUnit 4*	Description
import org.junit.*	Import statement for using the following annotations
@Test	Identifies a method as a test method
@Before	Executed before each test. To prepare the test environment (e.g., read input data, initialize the class)
@After	Executed after each test. To cleanup the test environment (e.g., delete temporary data, restore defaults) and save memory
@BeforeClass	Executed once, before the start of all tests. To perform time intensive activities, e.g., to connect to a database. Need to be defined as static to work with Junit
@AfterClass	Executed once, after all tests have been finished. To perform clean-up activities, e.g., to disconnect from a database. Need to be defined as static to work with Junit

*See Junit 5 annotations and compare them https://junit.org/junit5/docs/current/user-guide/#writing-tests-annotations

Junit – Assert Class

- Assert class provides *static* methods to test for certain conditions

- Assertion method compares the actual value returned by a test to the expected value
  - Specify the expected and actual results and the error message
  - Throw an *AssertionException* if the comparison fails

Junit – Methods to Assert Test Results

Method	Description
fail([message])	Let the method fail. E.g., to check that a certain part of the code not reached or to have a failing test before the test code implemented
assertTrue([message,] boolean condition) assertFalse([message,] boolean condition)	Checks that the Boolean condition is true Checks that the Boolean condition is false
assertEquals([message,] expected, actual)	Tests that two values are the same. Note: for arrays the reference is checked not the content of the arrays.
assertEquals([message,] expected, actual, tolerance)	Test that float or double values match. The tolerance is the number of decimals which must be the same
assertNull([message,] object) assertNotNull([message,] object)	Checks that the object is null Checks that the object is not null

*Also check assertions in Junit 5 – https://junit.org/junit5/docs/current/user-guide/#writing-tests-assertions

Junit Test – Example

```
1
2 //Class to be tested
3 public class MyClass{
4     public int multiply (int m, int n){
5         return m * n;
6     }
7
8 }
9
```

MyClass' multiply(int, int) method

```
1  import static org.junit.Assert.assertEquals;
2
3  import org.junit.Test;
4
5  public class MyClassTests {
6
7      @Test
8      public void multiplicationOfZeroIntegersShouldReturnZero() {
9          MyClass tester = new MyClass(); // MyClass is tested
10
11         // assert statements
12         assertEquals(0, tester.multiply(10, 0), "10 x 0 must be 0");
13         assertEquals(0, tester.multiply(0, 10), "0 x 10 must be 0");
14         assertEquals(0, tester.multiply(0, 0), "0 x 0 must be 0");
15     }
16 }
```

MyClassTests class for testing the method multiply(int, int)

Junit – Executing Tests

- Tests can be executed from the command line
  - *runClass()* of the *org.junit.runner.JUnitCore* class allows developers to run one or several test classes
  - Information about tests can be retrieved using the *org.junit.runner.**Result*** object

- Test automation
  - Build tools such as Maven or Gradle along with a Continuous Integration Server (e.g., Jekins) can be configured to run tests automatically on a regular basis
  - Essential for regular daily tests (agile development)

Junit – Executing Tests

- To run tests from the command line

```
1  import org.junit.runner.JUnitCore;
2  import org.junit.runner.Result;
3  import org.junit.runner.notification.Failure;
4
5  public class MyTestRunner {
6    public static void main(String[] args) {
7      Result result = JUnitCore.runClasses(MyClassTest.class);
8      for (Failure failure : result.getFailures()) {
9        System.out.println(failure.toString());
10     }
11   }
12 }
```

Junit – Test Suites

- **Test suite** contains several test classes which will be executed all in the specified order

```
1  import org.junit.runner.RunWith;
2  import org.junit.runners.Suite;
3  import org.junit.runners.Suite.SuiteClasses;
4
5  @RunWith(Suite.class)
6  @SuiteClasses({
7          MyClassTest.class,
8          MySecondClassTest.class })
9
10 public class AllTests {
11
12 }
```

Junit – Static Import

- Static import is a feature that allows fields and methods in a class as public static to be used without specifying the class in which the field s defined

```
// without static imports you have to write the following statement
Assert.assertEquals("10 x 5 must be 50", 50, tester.multiply(10, 5));


// alternatively define assertEquals as static import
import static org.junit.Assert.assertEquals;

// more code

// use assertEquals directly because of the static import
assertEquals("10 x 5 must be 50", 50, tester.multiply(10, 5));
```

Junit – Eclipse Support

- Create Junit tests via wizards or write them manually
- Eclipse IDE also supports executing tests interactively
  - Run-as Junit Test will starts JUnit and execute all test methods in the selected class
- Extracting the failed tests and stack traces
- Create test suites

Automated Test Frameworks

- Key sign of good practice is that tests are kept as an asset of the process
  - and can be run automatically, and frequently

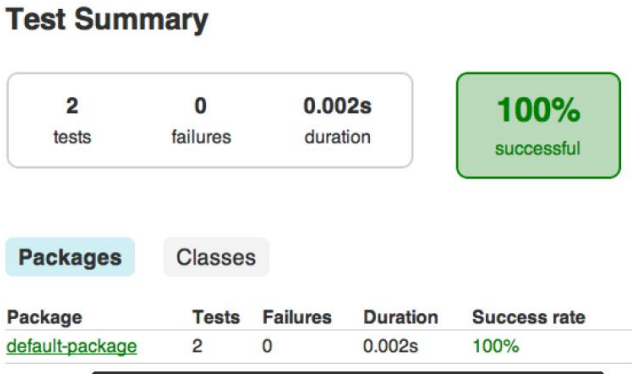
- Also, reports should be easy to understand
  - Big Green or Red Signal

- A framework is some software that allows test cases to be described in standard form and run automatically

Tests Automation – Junit with Gradle

- To use Junit in your Gradle build, add a testCompile dependency to your build file
- Gradle adds the test task to the build graph and needs only appropriate Junit JAR to be added to the classpath to fully activate the test execution

```
1 ...
2 apply plugin: 'java'
3
4 repositories {
5     mavenCentral()
6 }
7 dependencies {
8     testCompile 'junit:junit:4.8.2'
9 }
```



Junit with Gradle – Parallel Tests

```
1  ...
2  apply plugin: 'java'
3
4  repositories {
5      mavenCentral()
6  }
7  dependencies {
8      testCompile 'junit:junit:4.8.2'
9  }
10 test {
11     maxParallelForks = 5
12     forkEvery = 50
13 }
```

maximum simultaneous JVMs spawned

causes a test-running JVM to close and be replaced by a brand new one after the specified number of tests have run under an instance

Next week ….

Theory of Testing, Design of Test Cases and more unit testing

Tutorial - Unit Testing

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- Junit 4, Project Documentation, https://junit.org/junit4/

- Vogella GmbH, JUnt Testing with Junit – Tutorial (Version 4.3,21.06.2016) http://www.vogella.com/tutorials/JUnit/article.html