SOFT2201/COMP9201: Software Construction and Design 1

Testing

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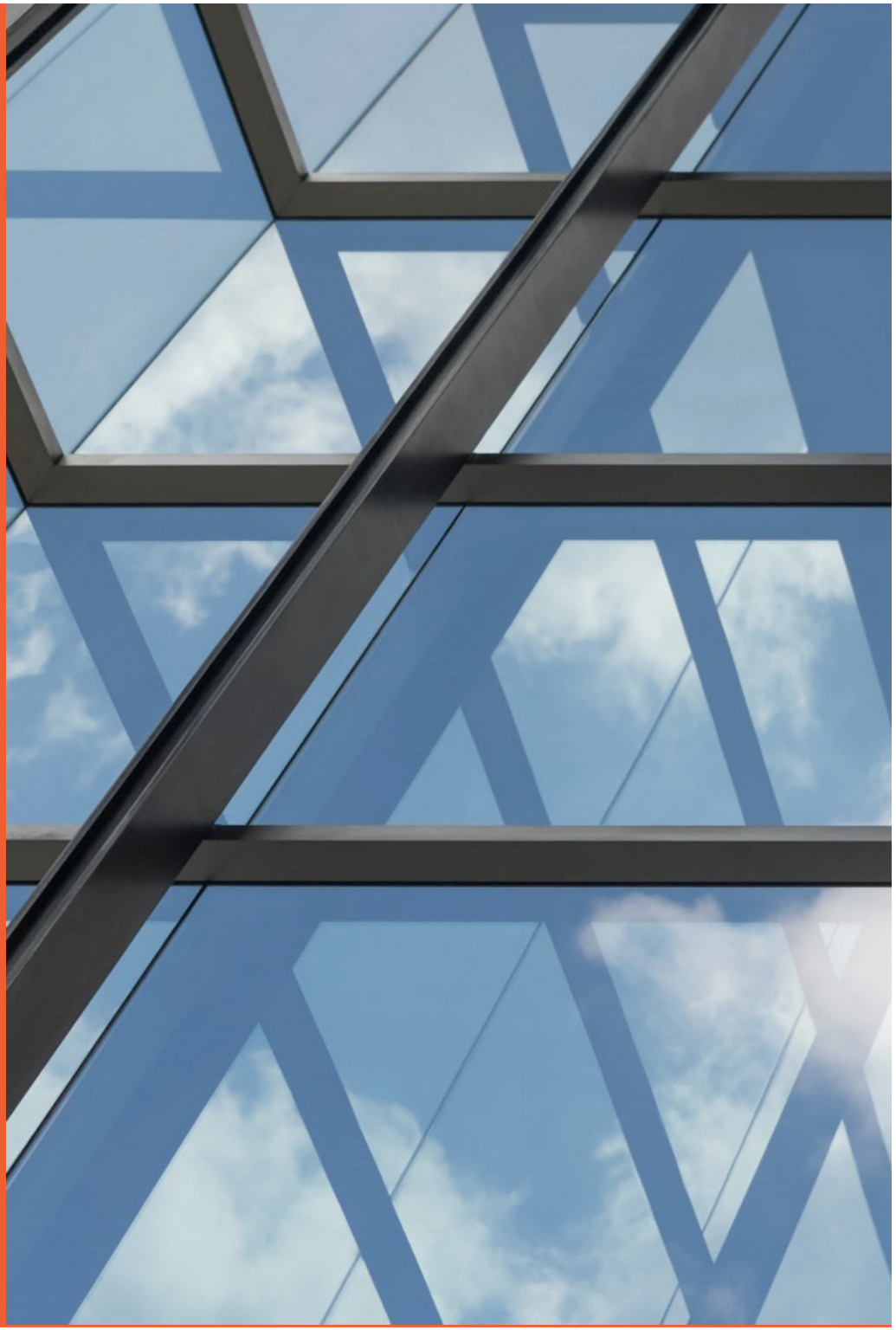

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Agenda

- Software Testing
- Unit Testing

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 Testing?

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Software is Everywhere!

- Societies, businesses and governments depend on SW
  - 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 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?

- Design error, incorrect analysis of changing requirements, inadequate validation and verification, testing and reviews, ineffective development processes and management

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

Why Software Testing?

- Software development and maintenance costs
  - Financial burden of failure

- Total costs of imperfect software testing for the US in 2002 was AUD86 billion*
  - One third of the cost could be eliminated by 'easily' improved software testing

- Need to develop functional, robust and reliable software
  - Human/social factor
    - Dependence on software in many aspects of their lives
  - Small software errors can lead to disasters

* NIST study 2002

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 behaviour caused by defects (defect testing)
    - e.g. crashes, incorrect results, data corruption
- Part of the software Verification and Validation (V&V) process

Types of testing

- **Unit testing**
  - Verify functionality of software components independent of the whole system
- **Integration testing**
  - Verify interactions between software components
- **System Testing**
  - Verify functionality and behaviour of the entire software system
  - Includes security, performance, reliability, and external interfaces
- **Acceptance testing**
  - Verify desired acceptance criteria are met from the users point of view

Software Verification and Validation

- Software testing is part of software 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 correctly
  - Ensure the software meets the stated functional and non-functional requirements

Black box or White box

- **Black box testing**
  - The internals of the software system is unknown
  - Only inputs to the system are controlled, and outputs from the system are measured
  - Specification-based testing
  - May be the only choice to test libraries without access to internal

- **White box testing**
  - The internals of the software system are known
  - The internal structure is tested directly
  - Unit, integration, system testing

Types of testing

Functional testing

- Unit
- Integration
- System
- Regression
- Interface
- User Acceptance
- Configuration
- Sanity

Non-functional testing

- Performance
- Stress
- Reliability
- Usability
- Load
- Security

Who should design and run tests?

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Test engineer

- **Independent testers**
  - Independent testers do not have the same biases as the developer
  - Different assumptions
  - Domain specific knowledge of testing

- **Developer**
  - Understands the system being developed
  - Domain specific knowledge of the system
  - Cheaper
  - Can finish writing the system faster without tests since they won't make mistakes

Unit Testing

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Unit testing

- The process of verifying functionality of software components independently
  - Unit can mean methods, functions, or object classes
  - Verify that each unit behaves as expected
  - Carried out by developers and software testers
  - First level of testing

Why unit testing

- Maintain and change code at a smaller scale
- Discover defects early and fix it when its cheaper
- Simplify integration testing
- Simplify debugging
- Code reusability

How to do the unit test

- Identify the unit that you want to test
- Design test case
- Prepare test data (input and expected output)
- Run test case using test data
- Compare result to expected output
- Prepare test reports

Designing test cases

- Effective test cases show:
  - The unit does what it is supposed to do
  - Reveal defects, if they exist (does not do what it is not supposed to do)

- Design two types of test case
  - Test normal operation of the unit
  - Test abnormal operation (common problems)

Designing test cases - techniques

- Partition testing (equivalence partitioning)
  - Identify groups of tests that have common characteristics
  - From each group, choose specific tests
  - Use program specifications, documentation, and experience

- Guideline-based testing
  - Use testing guidelines based on previous experience of the kinds of errors made
  - Depends on the existence of previous experience (developer/product)

Equivalence partitioning

- Groups of test input that have common characteristics
  - Positive numbers
  - Negative numbers
  - Boundaries
- Program is expected to behave in a comparable way for all members of a group
  - Control flow should be similar for all members
- Choose test cases from each partition

Test case selection

- Understanding developers thinking
  - Easy to focus on typical values of input
    - Common case, and what was asked for
  - Easy to overlook a typical value of input
    - Users, other developers, new features, all have different expectations
- Choose test cases that are
  - On boundaries of partitions
  - In 'midpoint' of partitions
  - NB: Boundaries may be unclear (-1, 0, 1, 0.5)

Test cases – identifying partitions

- Consider this specification:
  - The program accepts 4 to 8 inputs that are five digit integers greater than 10,000

- Identify the input partitions and possible test inputs

?

Test cases – identifying partitions

- Consider this specification:
  - The program accepts 4 to 8 inputs that are five digit integers greater than 10,000

- Identify the input partitions and possible test inputs

- How many values
  - <4, 4-8, >8
- How many digits
  - < 5, 5, > 5, non-digits
- How big
  - > 10000
  - etc.

Test case selection guidelines

- Knowledge of types of test case effective for finding errors
- If testing sequences, arrays, lists:
  - Single value
  - Different sequences of different sizes
  - Test partition boundaries (first, middle, last)
  - Consider order of values

Test case selection guidelines

- Choose inputs that force the system to generate all expected error messages
- Design inputs that cause buffer overflows
- Repeat input
- Force invalid outputs to be generated
- Force computations results that are too large or too small
- Domain specific knowledge!

Acquiring domain specific knowledge

- Be an expert on the system, or type of system
- **or,**
- Make many mistakes
- Identify mistakes
- Write tests to identify mistakes
- Fix mistakes
- Be an expert on the system, or type of system

- Regression testing!

Regression testing

- If a defect is identified in software it can be fixed
  - How did it get there?
  - How do you stop it happening again?

Regression testing

- Regression: a defect that has been fixed before, happens again
  - Human error
  - Version control problems
  - Specific case is fixed, but the general case remains
  - Convergent evolution

Regression testing

- As defects in software are fixed, tests are written that demonstrate that the software is fixed (at least in regard to that particular defect)

  - Tests can be re-run with each change in the software system

    - Regression testing

    - Frequently automated

When to test

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When to test

- Continuously

- When the software system changes
  - Code changes
  - Design changes
  - Infrastructure changes
  - At regular intervals in case the above missed a change

How to test

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How to test

- Write testable code

```
public static void main(String[] args) {
    // All the code
    // All
}
```

How to test

- Write testable code

```
public static void main(String[] args) {
    Application app = new Application();
}

Public class Application {
    Application() {
        // All the code
    }
}
```

How to test

- Write testable code

```
public static void main(String[] args) {
    Application app = new Application();
    app.doEverything();
}

public class Application {
    Application() {
        // Construct the application
    }
    public void doEverything() {
      // All the code
    }
}
```

How to test

- Write testable code

```
public class Application {
    Application() {
        // Construct the application
    }
    public void doEverything() {
      // Most of the code
      doSomeOfTheThings();
    }
    public void doSomeOfTheThings() {
        // Some of the code
    }
}
```

How to test

- Write testable code

```
public class Application {
    Application() {
        // Construct the application
    }
    public void doEverything() {
      // Some code
      Thing = doSomeOfTheThings(thing);
      // More code
    }
    public BigThing doSomeOfTheThings(LittleThing littleThing) {
        // Some of the code that deals with LittleThings
    }
}
```

How to test

- Write testable code

```
public class Application {
    // ...
    public void doEverything(LittleThingFactory littleThingFactory) {
      LittleThing firstThing= littleThingFactory.makeThing();
      LitteThing secondThing = doStuff(firstThing);
      doStuff(secondThing);
      doStuffWithTwoThings(firstThing, secondThing);
      doSomeOfTheThings(thing);
      // ...
    }
    protected BigThing doSomeOfTheThings(LittleThing littleThing) {
        // Some of the code that deals with LittleThings
    }
    // ...
}
```

Unit Testing in Java

Unit testing terminology

- **Unit test**
  - A piece of code written by a developer that executes a specific functionality in the code under test and asserts a certain behaviour or state as correct
  - Small unit of code (method/class)
  - External dependencies are removed
    - (Mocking)
- **Test fixture**
  - Testing context
    - Shared test data
    - Methods for setting up test data

Unit testing frameworks for Java

- JUnit
- TestNG
- Jtest
- Many others
- Custom, developer-written, tests

JUnit

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;

import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        assertEquals(2, calculator.add(1, 1));
    }
}
```

JUnit

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import static org.junit.Assert.assertEquals;
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JUnit

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;

import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        int expected = 2;
        int actual = calculator.add(1, 1);
        assertEquals(expected, actual);
    }
}
```

JUnit

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;

import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
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    }
}
```

JUnit

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;

import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        int expected = 2;
        int actual = calculator.add(1, 1);
        assertEquals(expected, actual);
    }
}
```

JUnit constructs

- **JUnit test**
  - A method only used for testing
- **Test suite**
  - A set of test classes to be executed together
- **Test annotations**
  - Define test methods (e.g., @Test, @Before)
  - JUnit uses the annotations to build the tests
- **Assertion methods**
  - Check expected result is the actual result
  - e.g., assertEquals, assertTrue, assertSame

JUnit annotations

- **@Test**
  - Identifies a test method
- **@Before**
  - Execute before each test
- **@After**
  - Execute after each test
- **@BeforeClass**
  - Execute once, before all tests in this class
- **@AfterClass**
  - Execute once, after all tests in this class

JUnit assertions

- assertEquals(expected, actual)

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;
import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        int expected = 2;
        int actual = calculator.add(1, 1);
        assertEquals(expected, actual);
    }
}
```

JUnit assertions

- assertEquals(message, expected, actual)

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;
import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        int expected = 2;
        int actual = calculator.add(1, 1);
        assertEquals("Expected value != actual", expected, actual);
    }
}
```

JUnit assertions

- assertTrue

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;
import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        assertTrue(2 == calculator.add(1, 1));
    }
}
```

JUnit assertions

- assertTrue

```
import static org.junit.Assert.assertEquals;
import org.junit.Test;
import mypackage.Calculator;

class CalculatorTest {
    @Test
    void addition() {
        Calculator calculator = new Calculator();
        assertTrue("Can't do 1 + 1 :(", 2 == calculator.add(1, 1));
    }
}
```

JUnit assertions

```
import ...

class CalculatorTest {
    Calculator calculator
    @Before
    void setup() {
        calculator = new Calculator();
    }
    @Test
    void additionBothPositive() {
        assertEquals(2, calculator.add(1, 1));
        assertEquals(5, calculator.add(4, 1));
         assertEquals(5, calculator.add(2, 3));
    }
    ...
```

Tasks for Week 11

- Submit weekly exercise on canvas before 23.59pm Saturday
- Continue assignment 3 and ask questions on Ed platform.
  - All assignments are individual assignments
  - Please note that: work must be done individually without consulting someone else's solutions in accordance with the University's "Academic Dishonesty and Plagiarism" policies

What are we going to learn next week?

- Creational Design Pattern
  - Singleton
- Structural Design pattern
  - Decorator and Façade