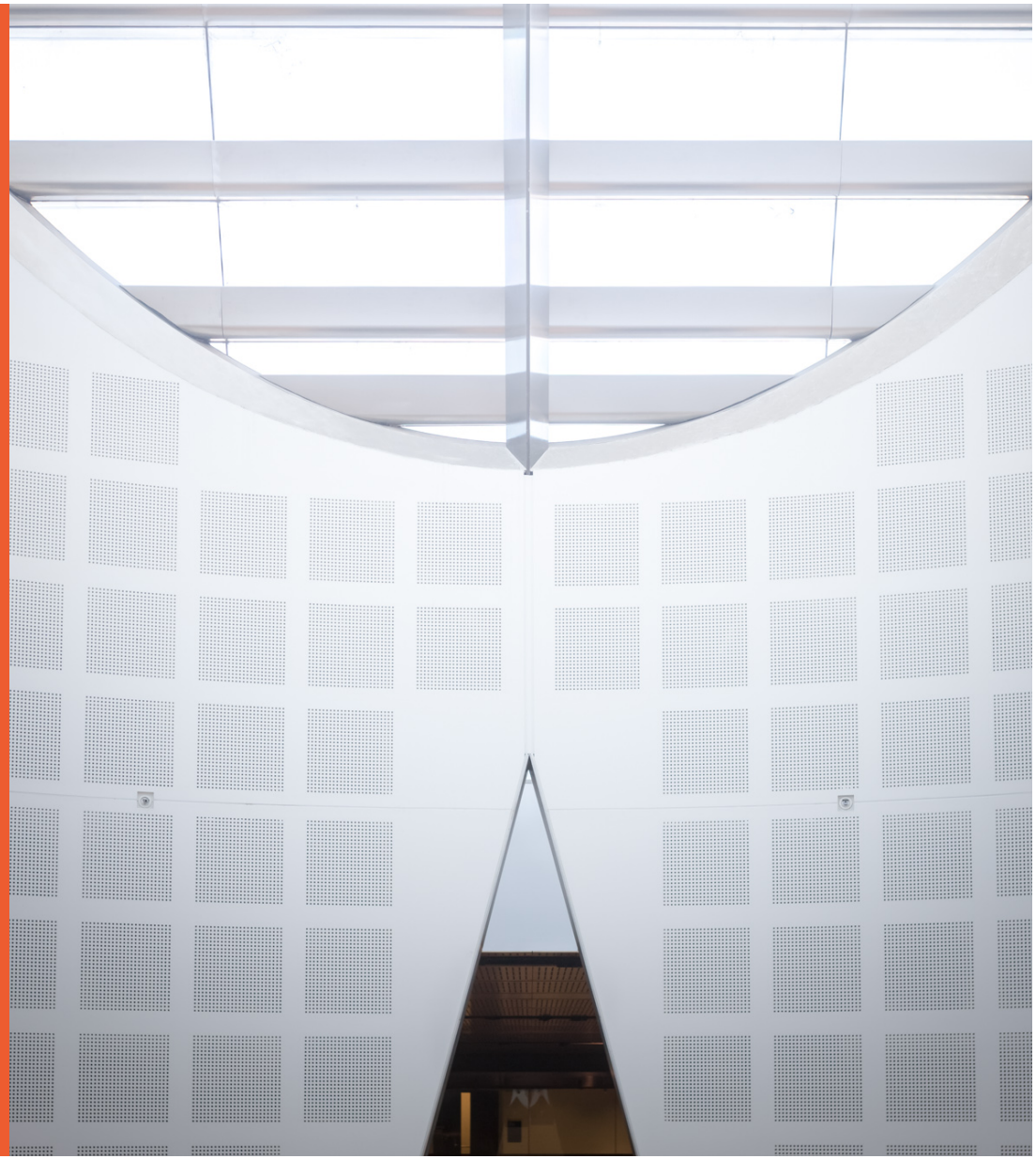
Software Design and Construction 2
SOFT3202 / COMP9202
Software Testing Theory

Prof Bernhard Scholz

School of Computer Science

THE UNIVERSITY OF SYDNEY



Agenda

- Theory of Testing
- Design of Tests
- Test Coverage

Software Testing

Revisit – Theory behind

THE UNIVERSITY OF SYDNEY

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 Objectives

"Program testing can be used to show the presence of bugs, but never to show their absence" - **Edsger W. Dijkstra**

- Defect discovery
- Dealing with unknowns
- Incorrect or undesired behaviour, missing requirement, system property
- Verifying different system properties
  - Functional specification correctly implemented
  - Non-functional properties
    - security, performance, reliability, interoperability, and usability

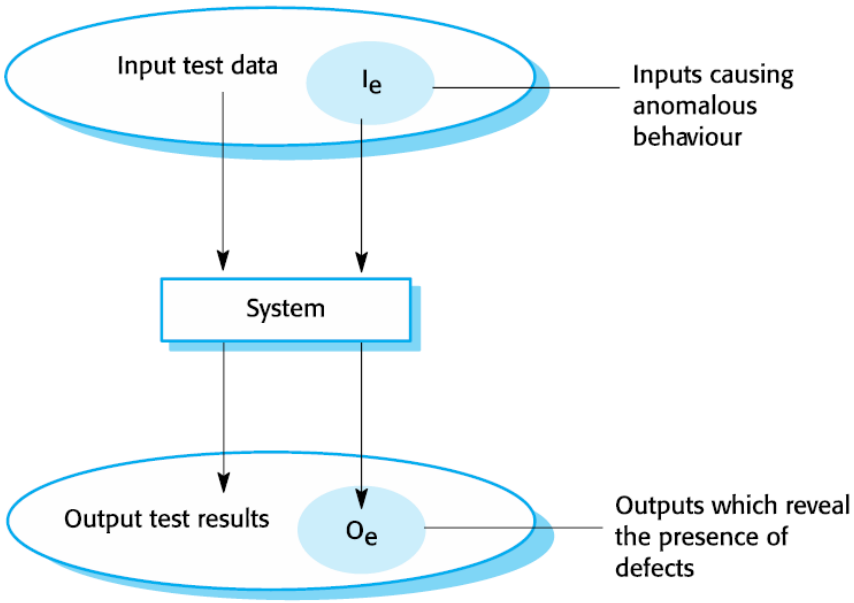
Testing Objectives

- State **precisely** and **quantitatively** for measuring and controlling test processes

- Test completeness is infeasible
  - Impossibility of exhaustive testing due to state space.
  - Risk-driven or risk management strategy to increase our confidence
- How much testing is enough?
  - Select test cases sufficient for a specific purpose (test adequacy criteria)
  - Coverage criteria and graph theories used to analyse test effectiveness

Validation Testing vs. Defect Testing

- Testing modelled as input test data and output test results
- Defect testing: find $\mathbf{I_e}$ that cause anomalous output $\mathbf{O_e}$ (defects/problems)
- Validation testing: find inputs that lead to expected correct outcomes



Who Does Testing?

- Developers test their own code
- Developers in a team test one another's code
- Many methodologies also have specialist role of tester
  - Testers often have different personality type from coders
  - Tester might be more productive finding software anomalies
- Real users, doing real work
  - Especially acceptance tests

Testing takes creativity

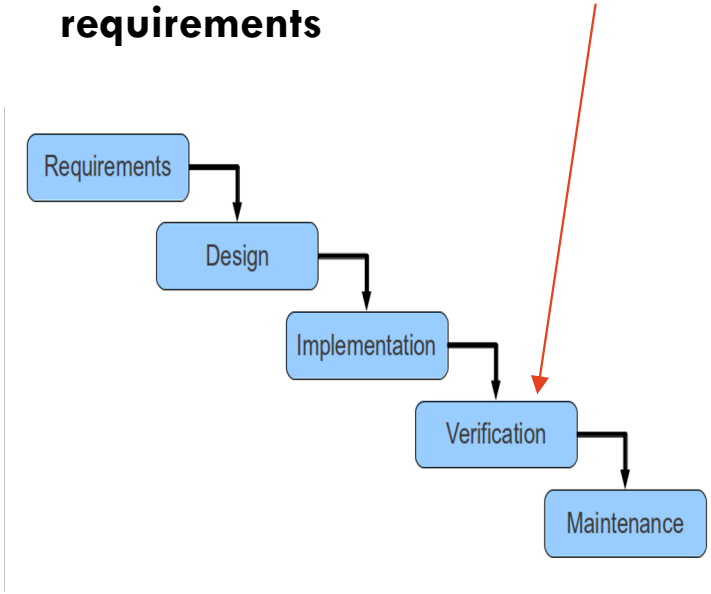
- To develop an effective test, one must have:
  - Detailed understanding of the system / understand the context of the software
  - Application and solution domain knowledge
  - Knowledge of the testing techniques
  - Skill to apply these techniques
  - Understand code

- Testing by independent testers
  - Programmers have a different mindset; think out-of-the-box for tests
  - Programmers often concentrate on standard use-cases; not on corner cases.
  - Testers reveal program behavior by using a different set of use-case.

When is Testing happening?

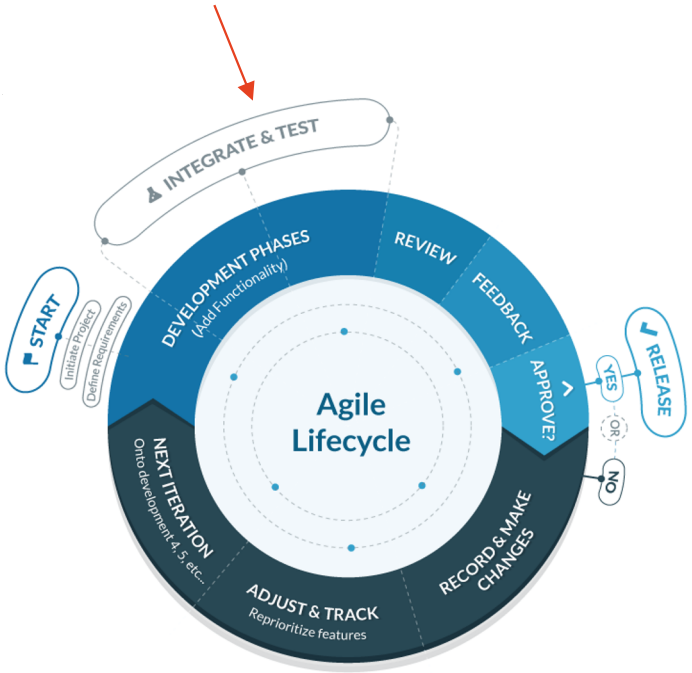
Waterfall Software Development

- **Test whether system works according to requirements**



Agile Software Development

- Testing is at the heart of agile practices
- Daily unit testing



https://www.spritecloud.com/wp-content/uploads/2011/06/waterfall.png
https://blog.capterra.com/wp-content/uploads/2016/01/agile-methodology-720x617.png

Software Testing Classification

Functional Testing

- Unit testing
- Integration testing
- System testing
- Regression testing
- Interface testing
- User Acceptance Testing (UAT) – Alpha and Beta testing
- Configuration, smoke, sanity, end-to-end testing

Non-Functional Testing

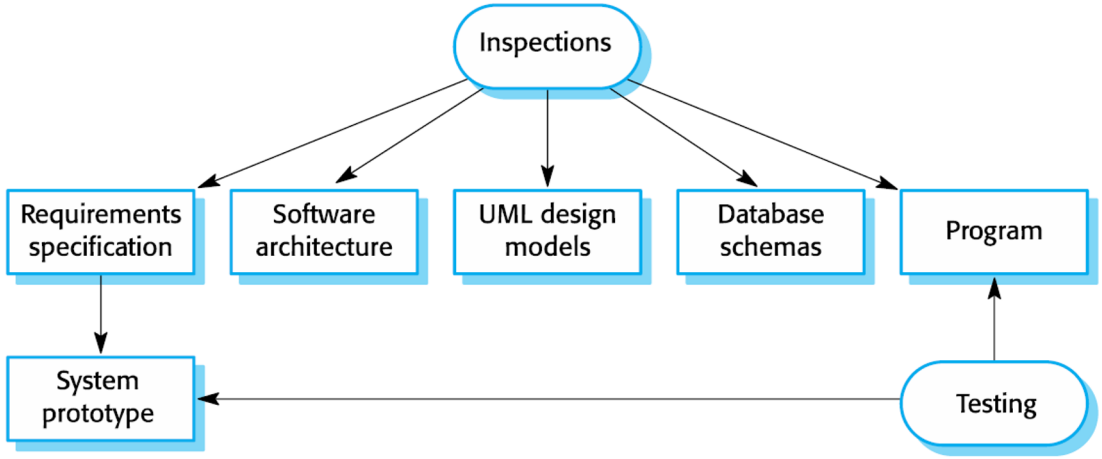
- Performance testing
- Load testing
- Security testing
- Stress testing
- Reliability testing
- Usability testing

Software Testing Process

- Design, execute and manage **test plans** and **activities**
  - Select and prepare suitable test cases (selection criteria)
  - Selection of suitable test techniques
  - Test plans execution and analysis (study and observe test output)
  - Root cause analysis and problem-solving
  - Trade-off analysis (schedule, resources, test coverage or adequacy)
- Test effectiveness and efficiency
  - Available resources, schedule, knowledge and skills of involved people
  - Software design and development practices ("Software testability")
    - Defensive programming: writing programs in such a way it facilitates validation and debugging using assertions

Static Testing

- Static Verification/testing
  - Static system analysis to discover problems
  - May be applied to requirements, design/models, configuration and test data
- Reviews
  - Walk through
  - Code inspection



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

Software Validation and Verification

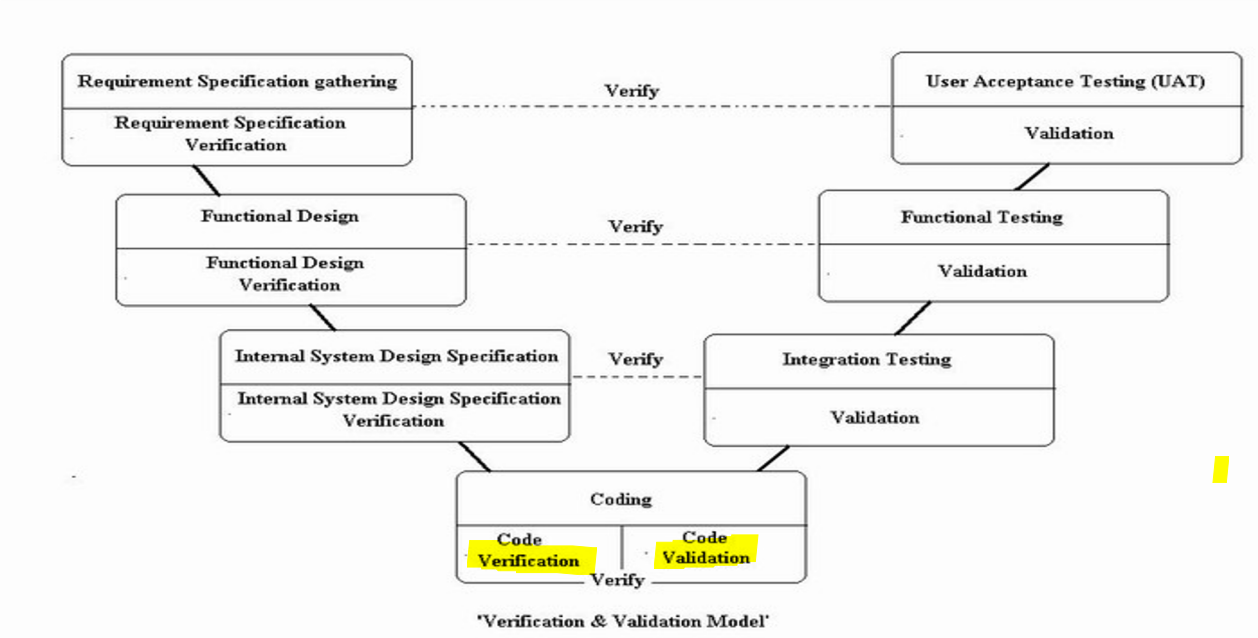
THE UNIVERSITY OF SYDNEY

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 correct product?
  - Process of checking whether the specification captures the customer's needs
  - *Did I build what I said I would?*
- Software Verification
  - Are we correctly building the product?
  - Process of checking that the software meets the specification
  - *Did I build what I need?*

V-Model

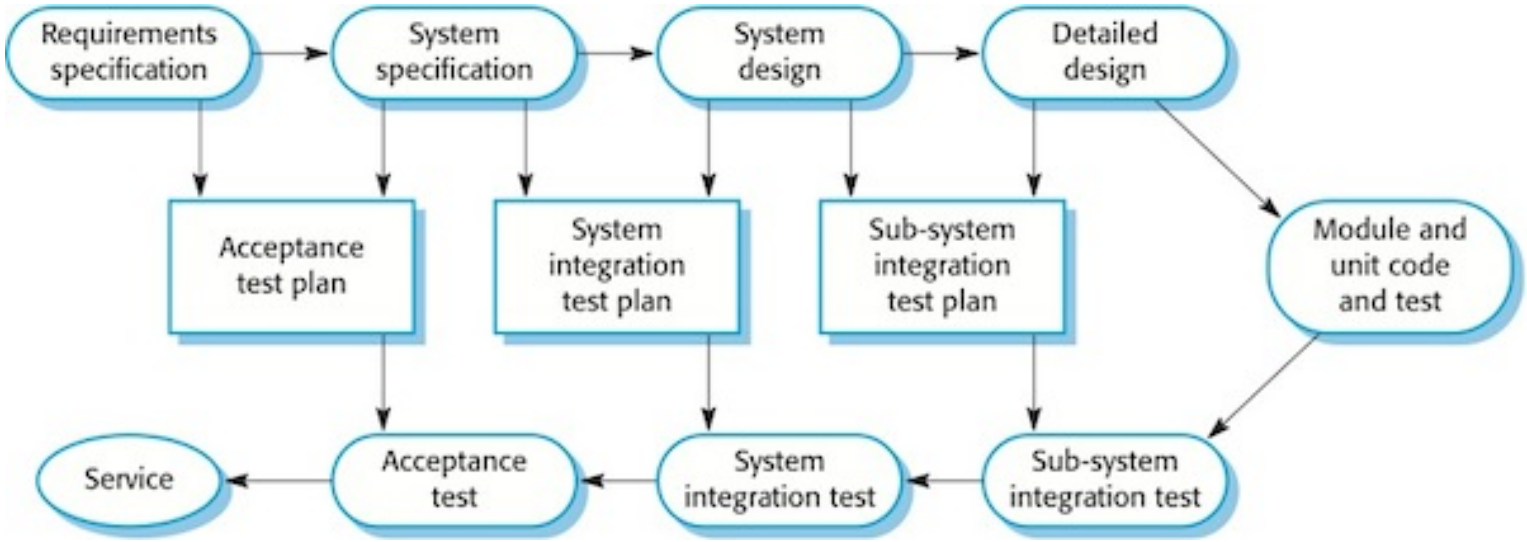
- Link each phase of the SDLC with its associated testing phase
- Each verification stage relates to a validation stage



https://www.buzzle.com/editorials/4-5-2005-68117.asp

V-Model

- Link each phase of the SDLC with its associated testing phase
- Each verification stage relates to a validation stage



Test Cases Can Disambiguate the Requirements

- A requirement expressed in English may not capture all the details
- But we can write test cases for the various situations
  - the expected output is a way to make precise what the stakeholder wants
  - E.g., write a test case with empty input, and say what output is expected

Choosing Test Cases

THE UNIVERSITY OF SYDNEY

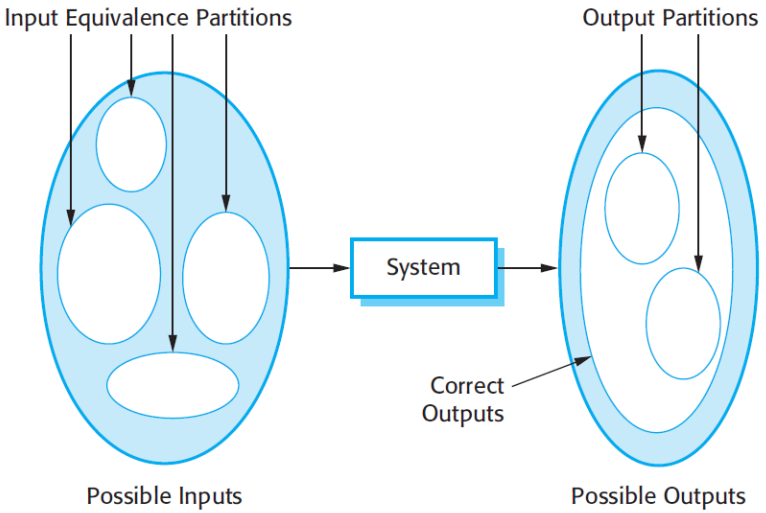
Choosing Test Cases – Techniques

- Partition testing (equivalence partitioning)
  - Identify groups of inputs that have common characteristics
  - From within each of these groups, choose tests

- 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
- Boundary cases
  - Select elements from the edges of the equivalence class
  - Developers tend to select normal/typical cases



Choosing Test Cases – Exercise

- For the following class method, apply equivalence partitioning to define appropriate test cases.

```
1 class MyGregorianCalendar {
2     ....
3         public static int getNumDaysInMonth(int month, int year){
4         ....
5     }
6 }
```

Test Case Selection

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

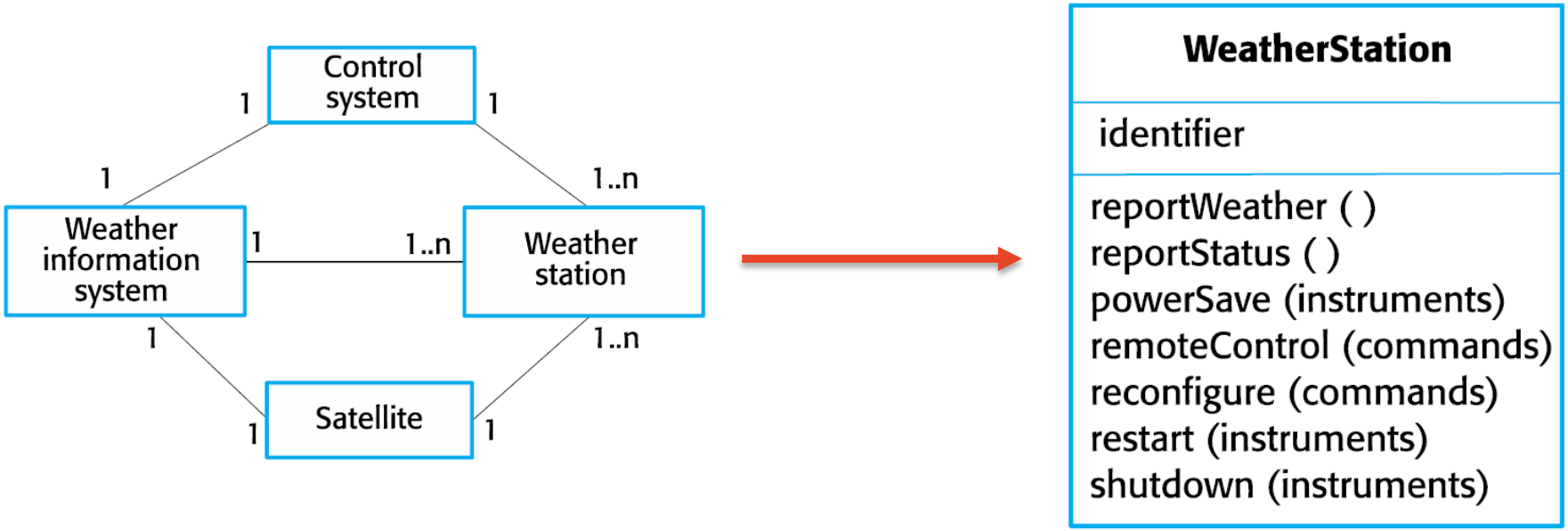
- Choose test cases that are:
  - On the boundaries of the partitions
  - Close to the midpoint of the partition

Unit Testing

Part 2

THE UNIVERSITY OF SYDNEY

Unit Testing – Case Study



Unit Testing – Techniques

- Partitioning
- Boundary
- Path
- State testing
- Black and white testing

JUnit

Part 2

THE UNIVERSITY OF SYDNEY

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 – Test Execution Order

Exercise:

Examine the test code and identify the execution order of the included test methods.

```java
import org.junit.Test;
import org.junit.runners.MethodSorters;

public class TestMethodOrder {

    @Test
    public void testA() {
        System.out.println("first");
    }
    @Test
    public void testB() {
        System.out.println("second");
    }
    @Test
    public void testC() {
        System.out.println("third");
    }
}
```

Junit – Test Execution Order

- Junit assumes that all test methods can be executed in an arbitrary order
- Good test code should not depend on other tests and should be well defined
  - lead into problems / poor test practices
- By default, Junit 4.11uses a deterministic order *(MethodSorters.DEFAULT)*
- @FixMethodOrder to change test execution order (not recommended practice)
  - *@FixMethod Order(MethodSorters.JVM)*
  - *@FixMethod Order(MethodSorters.NAME ASCENDING)*

https://junit.org/junit4/
https://junit.org/junit4/javadoc/4.12/org/junit/FixMethodOrder.html

Junit – Parameterized Test

- A class that contains a test method and that test method is executed with different parameters provided
- Marked with *@RunWith(Parameterized.class)* annotation
- The test class must contain a static method annotated with @Parameters
  - This method generates and returns a collection of arrays. Each item in this collection is used a s a parameter for the test method

Junit – Parameterized Test Example

```java
package testing;
import org.junit.Test;
import org.junit.runner.RunWith;
import org.junit.runners.Parameterized;
import org.junit.runners.Parameterized.Parameters;
import java.util.Arrays;
import java.util.Collection;
import static org.junit.Assert.assertEquals;
import static org.junit.runners.Parameterized.*;

@RunWith(Parameterized.class)
public class ParameterizedTestFields {

    // fields used together with @Parameter must be public
    @Parameter(0)
    public int m1;
    @Parameter(1)
    public int m2;
    @Parameter(2)
    public int result;

    // creates the test data
    @Parameters
    public static Collection<Object[]> data() {
        Object[][] data = new Object[][] { { 1 , 2, 2 }, { 5, 3, 15 }, { 121, 4, 484 } };
        return Arrays.asList(data);
    }

    @Test
    public void testMultiplyException() {
        MyClass tester = new MyClass();
        assertEquals("Result", result, tester.multiply(m1, m2));
    }


    // class to be tested
    class MyClass {
        public int multiply(int i, int j) {
            return i *j;
        }
    }

}
```

Junit – Verifying Exceptions

- Verifying that code behaves as expected in exceptional situations (exceptions) is important
- The *@Test* annotation has an optional parameter "expected" that takes as values subclasses of *Throwable*

```
1
2 new ArrayList<Object>().get(0);
3
```

Verify that ArrayList throws IndexOutOfBoundException

```
1
2 @Test(expected = IndexOutOfBoundsException.class)
3 public void empty() {
4       new ArrayList<Object>().get(0);
5 }
```

Junit – Verify Tests Timeout Behaviour (1)

- To automatically fail tests that 'runaway' or take too long:

- Timeout parameter on @Test
  - Cause test method to fail if the test runs longer than the specified timeout
  - Test method runs in separate thread
  - *Optionally specify timeout in milliseconds in @Test*

```
1 @Test(timeout=1000)
2 public void testWithTimeout() {
3     ...
4 }
```

Junit – Rules

- A way to add or redefine the behaviour of each test method in a test class
  - E.g., specify the exception message you expect during the execution of test code
- Annotate fields with the *@Rule*
- Junit already implements some useful base rules

Junit – Rules

Rule	Description
TemporaryFolder	Creates files and folders that are deleted when the test finishes
ErrorCollector	Continue execution of test after occurrence of first problem
ExpectedException	Allows in-test specification of expected exception types and messages
Timeout	Applies the same timeout to all test methods in a class
ExternalResources	Base class for rules that setup en external resource before a test (a file, socket, database connection)
RuleChain	Allows ordering of TestRules

See full list and code examples of Junit rules https://github.com/junit-team/junit4/wiki/Rules

Junit – Timeout Rule

- Timeout Rule

```java
import org.junit.Rule;
import org.junit.Test;
import org.junit.rules.Timeout;

public class HasGlobalTimeout {
    public static String log;
    private final CountDownLatch latch = new CountDownLatch(1);

    @Rule
    // 10 seconds max per method tested
    public Timeout globalTimeout = Timeout.seconds(10);

    @Test
    public void testSleepForTooLong() throws Exception {
        log += "ran1";
        TimeUnit.SECONDS.sleep(100); // sleep for 100 seconds
    }

    @Test
    public void testBlockForever() throws Exception {
        log += "ran2";
        latch.await(); // will block
    }
}
```

Junit – ErrorCollector Rule Example

- Allows execution of a test to continue after the first problem is found

```
1  public static class UsesErrorCollectorTwice {
2    @Rule
3    public final ErrorCollector collector = new ErrorCollector();
4
5    @Test
6    public void example() {
7      collector.addError(new Throwable("first thing went wrong"));
8      collector.addError(new Throwable("second thing went wrong"));
9    }
10 }
```

Junit – ExpectedException Rule

- How to test a message value in the exception or the state of a domain object after the exception has been thrown?
- *ExpectedException* rule allows specifying expected exception along with the expected exception message

```
1  @Rule
2  public ExpectedException thrown = ExpectedException.none();
3
4  @Test
5  public void shouldTestExceptionMessage() throws IndexOutOfBoundsException {
6      List<Object> list = new ArrayList<Object>();
7
8      thrown.expect(IndexOutOfBoundsException.class);
9      thrown.expectMessage("Index: 0, Size: 0");
10     list.get(0); // execution will never get past this line
11 }
```

Junit – Examples of other Rules

- Check Junit documentation for more examples on rules implementation
- Make sure you use them in for the right situation – the goal is to write good tests (not test smell)

Testable Code

THE UNIVERSITY OF SYDNEY

Writing Testable Code

- Testable code: code that can be easily tested and maintained

- What makes code hard to test (untestable)?
  - Anti-pattern
  - Design/code smells
  - Bad coding practices
  - Others?

http://www.codeops.tech/blog/linkedin/what-causes-design-smells/

..

Testable Code

- Adhere to known design principles
  - **SOLID**: Single responsibility, Open-closed, Liskov Substitution, Interface Segregation, Dependency Inversion
  - **GRASP** (General Responsibility Assignment Software Patterns) principles: Creator, Information Expert, High Cohesion, Low Coupling, Controller (see revision slides at the end)
- Adhere to API design principles
  - KISS, YAGNI, DRY, Occam's Razor
  - Information hiding, encapsulation, documentation, naming convention, parameters selection

- For more details See revision slides on Canvas

Testable Code – Industry/Expert Guide

- Google's guide for 'Writing Testable Code'
  - Guide for Google's Software Engineers

- Understanding different types of flaws, fixing it, concrete code examples before and after
  - Constructor does real work
  - Digging into collaborators
  - Brittle global state & Singletons
  - Class does too much

http://misko.hevery.com/attachments/Guide-Writing%20Testable%20Code.pdf
http://misko.hevery.com/code-reviewers-guide/

Theory of Testing, Design of Test Cases and….

Next Lecture/Tutorial

THE UNIVERSITY OF SYDNEY