

Test Code Patterns

How to design your test code

Testing and Inheritance

- Should you retest inherited methods?
- Can you reuse superclass tests for inherited and overridden methods?
- To what extent should you exercise interaction among methods of all superclasses and of the subclass under test?

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Inheritance

- In the early years people thought that inheritance will reduce the need for testing
 - Claim 1: "If we have a well-tested superclass, we can reuse its code (in subclasses, through inheritance) with confidence and without retesting inherited code"
 - Claim 2: "A good-quality test suite used for a superclass will also be sufficient for a subclass"
- Both claims are wrong.

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Inheritance-related bugs

- Missing Override
 - A subclass omits to provide a specialized version of a superclass method
 - Subclass objects will have to use the superclass version, which might not be appropriate
 - E.g. method `equals` in `Object` tests for reference equality. In a given class, it might be right to override this behaviour

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Inheritance-related bugs

- Direct access to superclass fields from the subclass code
 - Changes to the superclass implementation can create subclass bugs
 - Subclass bugs or side effects can cause failure in superclass methods
 - If a superclass is changed, all subclasses need to be tested
 - If a subclass is changed, superclass features used in the subclass must be retested

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Testing of Inheritance

- Principle: inherited methods should be retested in the context of a subclass
- Example 1: if we change some method **m** in a superclass, we need to retest **m** inside all subclasses that inherit it

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Example 2

```
class A {
  int x; // invariant: x > 100
  void m() { // correctness depends on
            // the invariant } }
```

```
class B extends A {
  void m2() { x = 1; } }
```

- If we add a new method **m2** that has a bug and breaks the invariant, method **m** is incorrect in the context of **B** even though it is correct in **A**
 - Therefore, **m** should be tested in **B**

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Example 3

```
class A {
  void m() { ...; m2(); ... }
  void m2() { ... } }
```

```
class B extends A {
  void m2() { ... } }
```

- If inside **B** we override a method from **A**, this indirectly affects other methods inherited from **A**
 - e.g., method **m** calls **B.m2**, not **A.m2**: so, we cannot be sure that **m** is correct anymore and we need to retest it inside **B**

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Testing of Inheritance (cont)

- Test cases developed for a method **m** defined in class **A** are not necessarily sufficient for retesting **m** in subclasses of **A**
 - e.g., if **m** calls **m2** in **A** and then some subclass overrides **m2** we have a completely new interaction that may not be covered well by the old test cases for **m**
- Still it is essential to run all superclass tests on a subclass
 - Goal: check behavioral conformance of the subclass w.r.t. the superclass (LSP)

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Inheritance-related bugs

- Square Peg in a Round Hole
 - Design Problem
 - A subclass is incorrectly located in a hierarchy
 - Liskov Substitution Principle: Functions that use references to base classes must be able to use objects of derived classes without knowing it.

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An example

- Consider class Rectangle below

```
class Rectangle{
  public void setWidth(double w) {itsWidth=w;}
  public void setHeight(double h) {itsHeight=w;}
  public double getHeight() {return itsHeight;}
  public double getWidth() {return itsWidth;}

  private double itsWidth;
  private double itsHeight;
};
```

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An example

- Assume that the system containing Rectangle needs to deal with squares as well
- Since a square is a rectangle, it seems to make sense to have a new class Square that extends Rectangle
- That very “reasonable” design can cause some significant problems

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Problems with this design

- Do not need both `getHeight` and `getWidth`
- `setWidth` and `setHeight` can bring a Square object to a corrupt state (when height is not equal to width)

One solution

```
class Square{
    setWidth(double w){
        super.setWidth(w);
        super.setHeight(w);
    }
    // Similar for setHeight
}
```

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Not really a solution

- Consider this client code

```
Rectangle r;
...
r.setWidth(5);
r.setHeight(4);
assert(r.getWidth() * r.getHeight() == 20);
```

- The problem is definitely not with the client code

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What went wrong?

- The Liskov substitution principle was violated
 - If you are expecting a rectangle, you can not accept a square
- The overridden versions of `setWidth` and `setHeight` broke the postconditions of their superclass versions
- Isn't a square a rectangle? Yes, but not when it pertains to its behaviour

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Effect of Inheritance on Testing?

- Does not reduce the volume of test cases
- Rather, number of interactions to be verified goes up at each level of the hierarchy

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Polymorphic Server Test

- Consider all test cases that exercise polymorphic methods
- According to LSP, these should apply at every level of the inheritance hierarchy
- Expand each test case into a set of test cases, one for each polymorphic variation

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An example

```
class TestAccount {
    Account a;
    @Before
    public void setUp(){
        a = new Account();
    }
    @Test
    public final void testDeposit(){
        a.deposit(100);
        assertTrue(a.getBalance() == 100);
    }
}
```

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An example

```
class TestSavingsAccount
    extends TestAccount{
    SavingsAccount sa;
    @Before
    public void setUp(){
        a = new SavingsAccount();
        sa = new SavingsAccount();
    }
    @Test
    public void testInterest(){
        sa.deposit(100);
        sa.applyInterest();
        assertTrue(sa.getBalance()==101);
    }
}
```

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Testing abstract classes

- Abstract classes cannot be instantiated
- However, they define an interface and behaviour (contracts) that implementing classes will have to adhere to
- We would like to test abstract classes for functional compliance
 - Functional Compliance is a module's compliance with some documented or published functional specification

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Functional vs. syntactic compliance

- The compiler can easily test that a class is syntactically compliant to an interface
 - All methods in the interface have to be implemented with the correct signature
- Tougher to test functional compliance
 - A class implementing the interface `java.util.List` may be implementing `get(int index)` or `isEmpty()` incorrectly
- Think LSP...

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Abstract Test Pattern

- This pattern provides the following
 - A way to build a test suite that can be reused across descendants
 - A test suite that can be reused for future as-yet-unidentified descendants
 - Especially useful for writers of APIs.

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An example

- Consider a statistics application that uses the Strategy design pattern

```
public interface StatPak
{
    public void reset();
    public void addValue(double x);
    public double getN();
    public double getMean();
    public double getStdDev();
}
```

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Abstract Test Rule 1

- Write an abstract test class for every interface and abstract class
- An abstract test should have test cases that cannot be overridden
- It should also have an abstract Factory Method for creating instances of the class to be tested.

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Example abstract test class

```
public abstract TestStatPak {
    private StatPak statPak;
    @Before
    public final setUp() throws Exception {
        statPak = createStatPak();
        assertNotNull(statPak);
    }
    // Factory Method. Every test class of a
    // concrete subclass K must override this
    // to return an instance of K
    public abstract StatPak createStatPak();
    //Continued in next slide...
```

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Example abstract test class

```
@Test
public final void testMean() {
    statPak.addValue(2.0);
    statPak.addValue(3.0);
    statPak.addValue(4.0);
    statPak.addValue(2.0);
    statPak.addValue(4.0);
    assertEquals("Mean value of test data
should be 3.0", 3.0,statPak.getMean());
}
@Test
public final void testStdDev() { ... }
```

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Abstract Test Rule 2

- Write a concrete test class for every implementation of the interface (or abstract class)
- The concrete test class should extend the abstract test class and implement the factory method

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Example concrete test class

```
public class TestSuperSlowStatPak
    extends TestStatPak {

    public StatPak createStatPak()
    {
        return new SuperSlowStatPak();
    }
}
```

Only a few lines of code and all the test cases for the interface have been reused

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Guideline

- Tests defining the functionality of the interface belong in the abstract test class
- Tests specific to an implementation belong in a concrete test class
 - We can add more test cases to `TestSuperSlowStatPak` that are specific to its implementation

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Crash Test Dummy

- Most software systems contain a large amount of error handling code
- Sometimes, it is quite hard to create the situation that will cause the error
 - Example: Error creating a file because the file system is full
- Solution: Fake it!

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```

import java.io.File;
import java.io.IOException;

class FullFile extends File {

    public FullFile(String path) {
        super(path);
    }

    public boolean createNewFile()
        throws IOException {
        throw new IOException();
    }
}

```

```

public void testFileSystemFull() {
    File f = new FullFile("foo");
    try {
        saveAs(f);
        fail();
    }
    catch (IOException e)
    {}
}

```

```

public void testFileSystemFull() {
    File f = new FullFile("foo") {
        public boolean createNewFile()
            throws IOException {
            throw new IOException();
        }
    };
    try {
        saveAs(f);
        fail();
    }
    catch (IOException e)
    {}
}

```

Log String

- Often one needs to test that the sequence in which methods are called is correct
- Solution: Have each method append to a log string when it is called
 - Then, assert that the log string is the correct one
 - Requires changes to the implementation

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Accessing private fields

- Object-oriented design guidelines often designate that certain fields should be private / protected
- This can be a problem for testing since a tester may need to assert certain conditions about private fields
- Making these fields public defeats the purpose

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A solution

- Using reflection, one can actually call private methods and access private attributes!
- An example

```

class A {
    private String sayHello(String name) {
        return "Hello, " + name;
    }
}

```

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```
import java.lang.reflect.Method;

public void testPrivateMethod {
    A test = new A();
    Method[] methods =
        test.getClass().getDeclaredMethods();
    for (int i = 0; i < methods.length; ++i) {
        if (methods[i].getName().equals("sayHello")) {
            Object params[] = {"Ross"};
            methods[i].setAccessible(true);
            Object ret = methods[i].invoke(test, params);
            System.out.println(ret);
        }
    }
}
```