Lecture 15 — Testing: Intro & JUnit

Jeff Zarnett & Patrick Lam
jzarnett@uwaterloo.ca & p.lam@ece.uwaterloo.ca

Department of Electrical and Computer Engineering
University of Waterloo

November 14, 2015

Software Testing

Testing attempts to verify the functionality of software.

It is somewhat like testing physical systems.

But software can fail in many bizarre ways.

Most problems: design problems, not manufacturing problems.

Software does not corrode; so problems were always there.

Software Testing

Software bugs are a fact of life. Not because programmers are careless; because software's complex.

Human ability to deal with complexity is limited.

We can have problems of design or implementation.

Programs are dynamic: a change can have side effects.

A test that previously passed might now fail.

Software Testing

It will never be possible to test software completely.

We cannot guarantee a bug-free program.

But testing makes our software better.

Software Testing

NIST says that in 2002, software bugs cost the US economy: \$59.5 Billion.

They estimate $1/3$ could be saved with better testing practice.

The earlier a bug is found, the cheaper it is to fix.

Software Testing

When testing, you'll run test suites consisting of test cases.

A *test case* contains:

- what you feed to software; and
- what the software should output in response.

You can organize the collection of test cases you need to write according to a *test plan*.

Knowing the Answer

We have to know what is the correct output, independent of the actual output of the software

Dangerous if we don't know that answer.

Tests are often written after implementation and just use the current output as correct.

Imagine if the function returns $2 + 2 = 5$ and a programmer wrote a test that expects the answer 5!

Testing vs. Correctness

Common view: testing is only for finding defects.

Recent research allows proving correctness with testing.

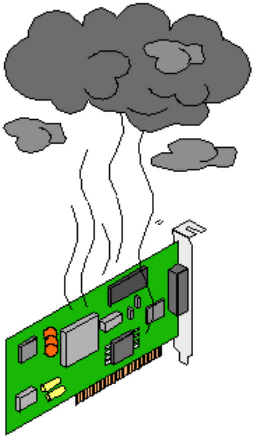
Levels of Testing

Testing is often performed at several different levels:

- Smoke tests
- Unit tests
- Integration tests
- Stress tests
- System tests

Smoke Testing

From Computer Desktop Encyclopedia
© 1998 The Computer Language Co. Inc.



Unit Testing

Units: small parts of a software system (methods, classes, sets of classes).

Two Key Ideas:

1. Test units independently.
2. Specify desired behaviour using tests.

Properties of Unit Tests

- Focus on the unit being tested
- Easy to run
- Easy to write

Some advice on Unit Testing:

- specify and document the requirements of the unit.
- test behaviour, not state; use mock objects to verify behaviour.
- Test-Driven Development: write tests before the code.

About JUnit

Most popular unit testing framework for Java.

Tests depend on the notion of assertions.

Assertions

An assertion is a statement about the world.

In code, logical expression that should always be true.

If not, throw `AssertionError`.

This usually stops the program.

Objective: Unit Tests

Learn how to write simple JUnit tests for Java code.

Use `assertTrue` or `assertEquals` to verify test results.

JUnit Test Organization

JUnit tests belong to test classes.

A test:

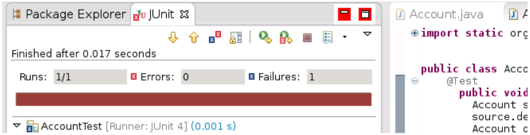
- is labelled `@org.junit.Test`;
- is a method with no parameters;
- makes calls to the class under test;
- verifies that the class is doing the right thing using assertions.

Using JUnit Tests

After writing the tests:

1. press a button in your IDE;
2. it will run the tests automatically for you.

If the tests fail:



Package Explorer | JUnit

Finished after 0.017 seconds

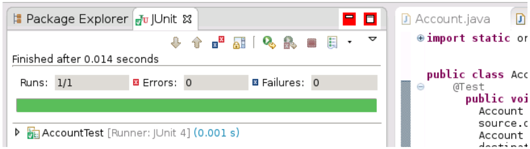
Runs: 1/1 Errors: 0 Failures: 1

AccountTest [Runner: JUnit 4] (0.001 s)

Account.java

```
⊕import static org
 public class Acco
⊖    @Test
       public void
         Account s
         source.de
         Account c
```

If the tests pass:



Package Explorer | JUnit

Finished after 0.014 seconds

Runs: 1/1 Errors: 0 Failures: 0

AccountTest [Runner: JUnit 4] (0.001 s)

Account.java

```
⊕import static or
 public class Acc
⊖    @Test
       public voi
         Account
         source.c
         Account
```

Why Unit Tests?

Biggest benefit of unit tests:

- they can run automatically.

You’ll never run tests that are annoying to run.

Account Example

```
public class Account
{
  private float balance;
  public void deposit (float amount) { balance += amount; }

  public void withdraw (float amount) { balance -= amount; }

  public void transferFunds(Account destination, float amount) {
  }

  public float getBalance() { return balance; }
}
```

JUnit Test for Account

Let’s write a unit test for this class:

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

public class AccountTest {
  @Test
  public void transferFunds() {
    Account source = new Account();
    source.deposit(200.00f);
    Account destination = new Account();
    destination.deposit(150.00f);

    source.transferFunds(destination, 100.00f);
    assertEquals(``destination balance``, 250.00f,
                 destination.getBalance(), 0.01);
    assertEquals(``source balance``, 100.00f,
                 source.getBalance(), 0.01);
  }
}
```

Test Results

If we run this test, we'd get a red bar; `transferFunds` doesn't do anything. Adding this code:

```
public void transferFunds(Account destination, float amount) {
    destination.deposit(amount);
    withdraw(amount);
}
```

makes the bar green, since the test now passes.

JUnit Test Fixtures

Tests often share objects.

Repeatedly allocating these objects is terrible.

Solution: test fixtures.

```
public class AccountTest {
  private Account account1;

  // runs before any tests
  @Before public void setUp() {
    account1 = new Account();
    account1.deposit(200.00f);
  }
}
```

Use `@After` to free resources afterwards.

Caveat: Don't rely on object state between tests: JUnit may shuffle order.

Expected Exceptions

How do you test error-checking code?

Expected Exceptions

How do you test error-checking code?

It should throw exceptions!

Make the test case expect an exception.

From the JUnit cookbook:

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

JUnit 4 versus JUnit 3

So far, we saw the (better) JUnit 4 syntax.

Android uses JUnit 3 syntax. Key differences:

- test classes must extend `TestCase`;
- test names must start with `test`;
- fixture setup method must be called `setUp()`;
- fixture teardown method must be called `tearDown()`;
- testing exceptions is harder.

Useful Concept (not just for Testing)

Imagine a JUnit test for a piece of code that is used for data retrieval.

You have a set of student IDs and student names.

You might have two `Array` objects, defined like this:

```
private ArrayList<String> studentIDs = {''20000000'', ''20000001'', ''20000002''};
private ArrayList<String> studentNames = {''John Doe'', ''Jane Doe'', ''Max Mustermann''};
```

Useful Concept (not just for Testing)

Check: index in the array of Student IDs is the same as the array of Student Names and that the two arrays line up.

Call the function `getName(studentIDs[i])`.

Check with an assertion statement that the name returned matches `studentNames[i]`.

Can we have a relation between the student IDs and names without `i`?

“Key” Idea

A Key-Value Pair.

Key on the left; value on the right.

```
(''20000000'', ''John Doe'')
(''20000001'', ''Jane Doe'')
(''20000002'', ''Max Mustermann'')
```

HashMap

The Java data structure to represent this is a `HashMap`.

A `HashMap` holds a set of keys and values.

Keys must be unique. A key corresponds to exactly 1 value.

HashMap vs. List

A list definition has a type: `ArrayList<String>`.

A `HashMap` has two types:
  the type for the Key and the type for the Value.

Example: `HashMap<String, Money>`.

The types of the key and value can be anything, e.g., `Student` and `Address`.

HashMap vs. List

An `List` of type `T` is effectively a `HashMap<int, T>`.

Give in an integer (0) and get a value (object of type `T`).

The methods used have different names and signatures.
But they are functionally the same.

Their internal representations may be different.

How to Use a HashMap

To retrieve some data from the `HashMap`:

`get()` method with the key of the item you want:
`get(”20000000”)` returns `”John Doe”`.

How to Use a HashMap

To add something to the `HashMap`, use the `put()` method, with the key and the value.

`put(“20000003”, “Mel Mustermann”)` $\rightarrow$ new entry in the map.

Already a value for the key? replaces the value:

`put(”20000000”, ”Michael Doe”)` $\rightarrow$ `”Michael Doe”` replaces `”John Doe”` in the map.

How to Use a HashMap

To remove something from the map, use the `remove()` method with the key of the item to remove:

`remove("20000001")` $\rightarrow$ remove the entry `("20000001", "Jane Doe")` from the map.

How to Use a HashMap

To get a list of all the keys: `keySet()`.

(There are other methods: `clear()`, `containsKey()`, `containsValue()`, `isEmpty()`, `size()`…)

Testing with the HashMap

Test our `getName(String studentID)` function using a `HashMap` called hm.

```
for (String key : hm.keySet()) {
    assertEquals(‘‘Student Name’’,
                          hm.get(key), getName(key));
}
```