University of Sheffield

COM3529 Software Testing and Analysis

Test Doubles

Professor Phil McMinn

A Testing Problem

To: p.mcminn@sheffield.ac.uk
From: student3529@sheffield.ac.uk
Subject: A Problem with Testing – Please help!!!

Dear Phil

For my dissertation code, I want to test the logic in my class using a unit test, but the class also involves a database connection.

To include the database is kind of complex, and I do not want to test integration aspects at the same time as unit testing the logic.

What should I do?

Yours,
Stu

A Testing Solution

To: student3529@sheffield.ac.uk
From: p.mcminn@sheffield.ac.uk
Subject: Re: A Problem with Testing – Please help!!!

Dear Stu,

Have no fear.

You might want to consider using a **test double**.

We're going to cover this in the next lecture – be sure to be there!

Best,
Phil

Scenario

We have a class called `BankAccount`.

A database is used to store and retrieve bank account information.

How do we unit test the logic of this class without interacting with the actual database?

```
public class BankAccount {

    private final int bankAccountNumber;
    private final BankAccountDatabaseConnection bankAccountDatabaseConnection;

    public BankAccount(BankAccountDatabaseConnection bankAccountDatabaseConnection,
                       int openingBalance, int overdraft) {
        this.bankAccountDatabaseConnection = bankAccountDatabaseConnection;
        this.bankAccountNumber = bankAccountDatabaseConnection.createBankAccount();
        setOverdraft(overdraft);
        bankAccountDatabaseConnection.setBalance(bankAccountNumber, openingBalance);
    }

    public void withdraw(int amount) {
        if (amount <= 0) {
            throw new BankAccountException("Cannot withdraw a zero or negative amount");
        }
        int balance = getBalance();
        int maxWithdrawalAmount = balance + getOverdraft();
        if (amount > maxWithdrawalAmount) {
            throw new BankAccountException(
              "Cannot withdraw more than the current balance plus the overdraft");
        }
        bankAccountDatabaseConnection.setBalance(bankAccountNumber, balance - amount);
    }

    public void deposit(int amount) {
        if (amount <= 0) {
            throw new BankAccountException("Cannot deposit a zero or negative amount");
        }
        bankAccountDatabaseConnection.setBalance(bankAccountNumber, getBalance() + amount);
    }

    public void setOverdraft(int amount) {
        if (amount < 0) {
```

Scenario

We have a class called `BankAccount`.

A database is used to store and retrieve bank account information.

How do we unit test the logic of this class without interacting with the actual database?

```
        int balance = getBalance();
        int maxWithdrawalAmount = balance + getOverdraft();
        if (amount > maxWithdrawalAmount) {
            throw new BankAccountException(
              "Cannot withdraw more than the current balance plus the overdraft");
        }
        bankAccountDatabaseConnection.setBalance(bankAccountNumber, balance - amount);
    }

    public void deposit(int amount) {
        if (amount <= 0) {
            throw new BankAccountException("Cannot deposit a zero or negative amount");
        }
        bankAccountDatabaseConnection.setBalance(bankAccountNumber, getBalance() + amount);
    }

    public void setOverdraft(int amount) {
        if (amount < 0) {
            throw new BankAccountException("Overdraft cannot be negative");
        }
        bankAccountDatabaseConnection.setOverdraft(bankAccountNumber, amount);
    }

    public int getBankAccountNumber() {
        return bankAccountNumber;
    }

    public int getBalance() {
        return bankAccountDatabaseConnection.getBalance(bankAccountNumber);
    }

    public int getOverdraft() {
        return bankAccountDatabaseConnection.getOverdraft(bankAccountNumber);
    }
}
```

The Problematic Object

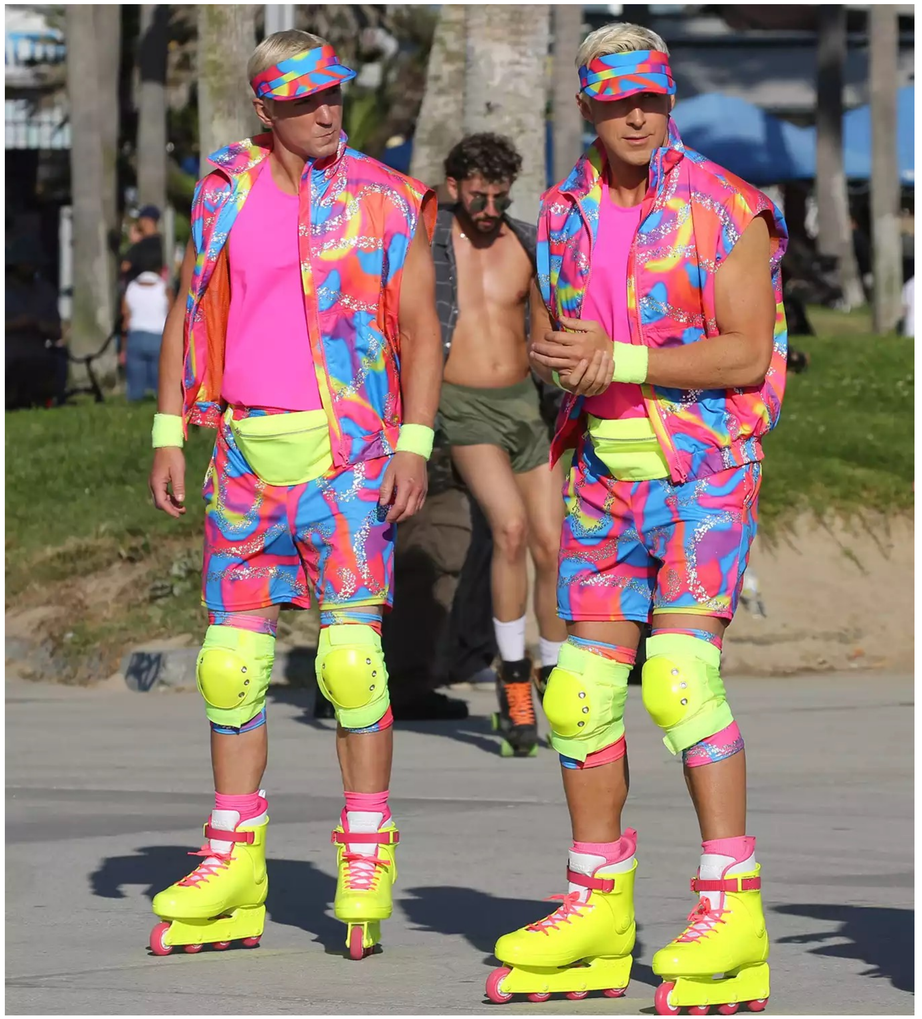
We want to test the logic in `BankAccount` without having to worry about the underlying database that it uses … implemented by this class – which sends SQL queries to the database and returns values contained in it.

```
public class BankAccountDatabaseConnection {

    public int createBankAccount() {
        // make database calls
    }

    public int getBalance(int bankAccountNo) {
        // make database calls
    }

    public void setBalance(int bankAccountNo, int amount) {
        // make database calls
    }

    public int getOverdraft(int bankAccountNo) {
        // make database calls
    }

    public void setOverdraft(int bankAccountNo, int amount) {
        // make database calls
    }
}
```

Test Doubles

Test Doubles are classes that "stand in" for some original class, allowing tests to avoid some of the complexity needed if that original class had been used instead.

Test doubles are a bit like stunt doubles – instead of using the real actor, we use another that looks like it but makes all the tough stuff look easy!



Ryan Gosling and his stunt double on the set of the "Barbie" movie.

Types of Test Double

1. Dummies
2. Stubs
3. Fakes
4. Mocks
5. Spies

Dummies

Dummies are objects that stand in place of the real object.

However the test never makes use of the dummy, its purpose is just to satisfy the compiler.

In this and the following slides, we assume `BankAccountDatabaseConnection` is a Java interface that we can implement in different ways for testing. But the methods of a real class could easily be overridden to achieve the same effect.

```
public class DummyBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    @Override
    public int createBankAccount() {
        return 0;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
    }

    @Override
    public int getOverdraft(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setOverdraft(int bankAccountNo, int amount) {
    }
}
```

Dummy

Dummies

Method under test

```
public void withdraw(int amount) {
    if (amount <= 0) {
        throw new BankAccountException("Cannot withdraw a zero or negative amount");
    }
    int balance = getBalance();
    int maxWithdrawalAmount = balance + getOverdraft();
    if (amount > maxWithdrawalAmount) {
        throw new BankAccountException(
          "Cannot withdraw more than the current balance plus the overdraft");
    }
    bankAccountDatabaseConnection.setBalance(bankAccountNumber, balance - amount);
}
```

The database itself does not matter for the purposes of this test. So we just need a dummy to get the test to compile.

Test using dummy

```
@Test
public void shouldNotAllowNegativeAmountsToBeWithdrawn() {
    DummyBankAccountDatabaseConnection dummy = new DummyBankAccountDatabaseConnection();

    // Given a bank account
    BankAccount bankAccount = new BankAccount(dummy, 0, 0);

    // When a negative amount is withdrawn, Then an exception is thrown
    assertThrows(BankAccountException.class, () -> {
        bankAccount.withdraw(-1000);
    });
}
```

Stubs

Stubs are objects that override certain methods of the original so that some other class/method can be tested.

```
public BankAccount(BankAccountDatabaseConnection bankAccountDatabaseConnection,
                   int openingBalance, int overdraft) {
    this.bankAccountDatabaseConnection = bankAccountDatabaseConnection;
    this.bankAccountNumber = bankAccountDatabaseConnection.createBankAccount();
    setOverdraft(overdraft);
    bankAccountDatabaseConnection.setBalance(bankAccountNumber, openingBalance);
}
```

BankAccount – **original constructor**

```
public class StubbedBankAccountDatabaseConnection
        implements BankAccountDatabaseConnection {

    @Override
    public int createBankAccount() {
        return 1000;
    }

    // ...
```

Stubbed method of BankAccountDatabaseConnection

```
@Test
public void shouldAssignABankAccountWhenOpeningAnAccount() {
    StubbedBankAccountDatabaseConnection stub = new StubbedBankAccountDatabaseConnection();

    // Given a bank account
    BankAccount bankAccount = new BankAccount(stub, 0, 0);

    // Then it should have a bank account number
    assertThat(bankAccount.getBankAccountNumber(), equalTo(1000));
}
```

Test using stub

1

2

3

Fakes

Fakes provide pseudo-implementations of the real object.

Here – an “in-memory” implementation of the database functionality.

Note the downside of fakes – essentially we’re implementing more functionality that itself needs testing.

```
public class FakeBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    private final int bankAccountNumber;
    private int balance;
    private int overdraft;

    public FakeBankAccountDatabaseConnection(int bankAccountNumber) {
        this.bankAccountNumber = bankAccountNumber;
    }

    @Override
    public int createBankAccount() {
        return bankAccountNumber;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return balance;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
        this.balance = amount;
    }

    // ...
```

Fake

Fakes

Method under test

```
public void withdraw(int amount) {
    if (amount <= 0) {
        throw new BankAccountException("Cannot withdraw a zero or negative amount");
    }
    int balance = getBalance();
    int maxWithdrawalAmount = balance + getOverdraft();
    if (amount > maxWithdrawalAmount) {
        throw new BankAccountException(
          "Cannot withdraw more than the current balance plus the overdraft");
    }
    bankAccountDatabaseConnection.setBalance(bankAccountNumber, balance - amount);
}
```

Test using fake

```
@Test
public void shouldCalculateBalanceCorrectlyFollowingAWithdrawal() {
    FakeBankAccountDatabaseConnection fake = new FakeBankAccountDatabaseConnection(0);

    // Given a bank account with a balance of £500 and an overdraft of £0
    BankAccount bankAccount = new BankAccount(fake, 500, 0);

    // When £100 is withdrawn
    bankAccount.withdraw(100);

    // Then the balance should be £400
    assertThat(bankAccount.getBalance(), equalTo(400));
}
```

Mocks

Mocks extend the idea of a stub – they allow you to control the values returned by a method but also can also **confirm methods were called with the correct values as arguments**.

Method under test

```
public void deposit(int amount) {
    if (amount <= 0) {
        throw new BankAccountException("Cannot deposit a zero or negative amount");
    }
    bankAccountDatabaseConnection.setBalance(bankAccountNumber, getBalance() + amount);
}
```

Unless we use a fake (and write more tests for the fake), there is no way to ascertain that the value going into the database to set the bank account's balance is the correct one.

Mocks

Mock

```
public class MockedBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    public boolean verify = false;

    @Override
    public int createBankAccount() {
        return 1000;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return 100;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
        verify = (bankAccountNo == 1000 && amount == 200);
    }

    // ...
```

Test using mock

```
@Test
public void shouldDepositAmount() {
    MockedBankAccountDatabaseConnection mock
        = new MockedBankAccountDatabaseConnection();

    // Given a Bank account with an opening balance of £100 and no overdraft
    BankAccount bankAccount = new BankAccount(mock, 100, 0);

    // When £100 is deposited
    bankAccount.deposit(100);

    // Then a call should be made to set the balance of the account to £200
    // (as signalled by a flag - mock.verify - being set to true)
    assertThat(mock.verify, equalTo(true));
}
```

Explicitly verify the database is instructed to set the balance amount to £200 for the account no. 1000.

Spies

Spies are like mocks but without stubbed methods (methods that return predetermined values).

That is, they just do the **method call logging and checking** part.

They're useful for checking the interface between a unit and an external component. (Sometimes they're even used as part of integration tests.)

For example, they could be used to spy on methods and check that the correct SQL has been generated.

Or, that the contents of an email are as expected, before a service is invoked to send it.

Take Care With Doubles

Note how many of the examples involved a lot of implementation detail about the classes being doubled. In particular:

- **Fakes** need their own tests(!), since they involve more implementation
- **Mocks** record details about individual method calls, making them liable to brittleness.

As such, use doubles with care, and only when necessary.

Keeping things as real as possible is often the best way, and avoiding doubles altogether. (More on this to come.)

Mockito

Writing a new test doubles each time you want to test something can get quite painful, quite quickly.

Mockito is a useful framework for generating mocks for use with JUnit.

Since mocks are stubs and spies, and stubs are more specialised versions of dummies, Mockito can generate all types of double except fakes.

Mock example with Mockito

```java
@Test
public void shouldDepositAmount() {
    MockedBankAccountDatabaseConnection mock
        = new MockedBankAccountDatabaseConnection();

    // Given a Bank account with an opening balance of £100 and no overdraft
    BankAccount bankAccount = new BankAccount(mock, 100, 0);

    // When £100 is deposited
    bankAccount.deposit(100);

    // Then a call should be made to set the balance of the account to £200
    // (as signalled by a flag - mock.verify - being set to true)
    assertThat(mock.verify, equalTo(true));
}
```

Test using manually written mock

```java
public class MockedBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    public boolean verify = false;

    @Override
    public int createBankAccount() {
        return 1000;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return 100;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
        verify = (bankAccountNo == 1000 && amount == 200);
    }

    // ...
```

Manually- written mock class

Mock example with Mockito

```
@Test
public void shouldDepositAmount() {
    // Setup the mock, including to return a bank account number of 1000
    BankAccountDatabaseConnection mock = mock();
    when(mock.createBankAccount()).thenReturn(1000);

    // Given a Bank account with an opening balance of £100 and no overdraft
    BankAccount bankAccount = new BankAccount(mock, 100, 0);

    // Set the database mock to return a balance of £100 for this account number
    // as would have been instructed to have been set in the database via
    // the constructor
    when(mock.getBalance(1000)).thenReturn(100);

    // When £100 is deposited
    bankAccount.deposit(100);

    // Then a call should be made to set the balance of the account to £200
    verify(mock).setBalance(1000, 200);
}
```

Generate the mock object. We never (and don't need) to see any actual code – since it doesn't exist anyway

Generate "stubbed" methods for our mock

Verify that certain calls were made to the mock. Was `setBalance` called on it with a bank account no. of `1000`, with a balance of `200`?

Test using virtual mock

Fake Turned Into a Mock

```java
@Test
public void shouldCalculateBalanceCorrectlyFollowingAWithdrawal() {
    FakeBankAccountDatabaseConnection fake = new FakeBankAccountDatabaseConnection(0);

    // Given a bank account with a balance of £500 and an overdraft of £0
    BankAccount bankAccount = new BankAccount(fake, 500, 0);

    // When £100 is withdrawn
    bankAccount.withdraw(100);

    // Then the balance should be £400
    assertThat(bankAccount.getBalance(), equalTo(400));
}
```

Test using manually written fake

```java
public class FakeBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    private final int bankAccountNumber;
    private int balance;
    private int overdraft;

    public FakeBankAccountDatabaseConnection(int bankAccountNumber) {
        this.bankAccountNumber = bankAccountNumber;
    }

    @Override
    public int createBankAccount() {
        return bankAccountNumber;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return balance;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
        this.balance = amount;
    }

    // ...
```

Manually- written fake class.

It’s just for testing, but we’re going to need to test it as well!

Fake Turned Into a Mock

```
@Test
public void shouldCalculateBalanceCorrectlyFollowingAWithdrawal() {
    // Setup the mock, including to return a bank account number of 1000
    BankAccountDatabaseConnection mock = mock();
    when(mock.createBankAccount()).thenReturn(1000);

    // Given a bank account with a balance of £500 and an overdraft of £0
    BankAccount bankAccount = new BankAccount(mock, 500, 0);

    // Set the database mock to return a balance of £500 for this account number
    // as would have been instructed to have been set in the database via
    // the constructor
    when(mock.getBalance(1000)).thenReturn(500);

    // When £100 is withdrawn
    bankAccount.withdraw(100);

    // Then the balance should be £400
    verify(mock).setBalance(1000, 400);
}
```

We can just use a mock instead.

This code is similar to the last example of a mock.

Dummy Example with Mockito

```java
@Test
public void shouldNotAllowNegativeAmountsToBeWithdrawn() {
    DummyBankAccountDatabaseConnection dummy = new DummyBankAccountDatabaseConnection();

    // Given a bank account
    BankAccount bankAccount = new BankAccount(dummy, 0, 0);

    // When a negative amount is withdrawn, Then an exception is thrown
    assertThrows(BankAccountException.class, () -> {
        bankAccount.withdraw(-1000);
    });
}
```

Test using manually written dummy

Manually-written dummy class

```java
public class DummyBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    @Override
    public int createBankAccount() {
        return 0;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {
    }

    @Override
    public int getOverdraft(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setOverdraft(int bankAccountNo, int amount) {
    }
}
```

Dummy Example with Mockito

```
@Test
public void shouldNotAllowNegativeAmountsToBeWithdrawn() {
    // Setup the mock
    BankAccountDatabaseConnection mock = mock();

    // Given a bank account
    BankAccount bankAccount = new BankAccount(mock, 0, 0);

    // When a negative amount is withdrawn, Then an exception is thrown
    assertThrows(BankAccountException.class, () -> {
        bankAccount.withdraw(-1000);
    });
}
```

Generate the mock object. Since we don't go and stub or verify any methods it's effectively a dummy

Test using virtual mock (which is a dummy in this case)

Stub Example with Mockito

```java
@Test
public void shouldAssignABankAccountWhenOpeningAnAccount() {
    StubbedBankAccountDatabaseConnection stub = new StubbedBankAccountDatabaseConnection();

    // Given a bank account
    BankAccount bankAccount = new BankAccount(stub, 0, 0);

    // Then it should have a bank account number
    assertThat(bankAccount.getBankAccountNumber(), equalTo(1000));
}
```

Test using manually written stub

Manually- written stub class

```java
public class StubbedBankAccountDatabaseConnection
             implements BankAccountDatabaseConnection {

    @Override
    public int createBankAccount() {
        return 1000;
    }

    @Override
    public int getBalance(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setBalance(int bankAccountNo, int amount) {

    }

    @Override
    public int getOverdraft(int bankAccountNo) {
        return 0;
    }

    @Override
    public void setOverdraft(int bankAccountNo, int amount) {

    }
}
```

Stub Example with Mockito

```
@Test
public void shouldAssignABankAccountWhenOpeningAnAccount() {
    // Setup the mock, including to return a bank account number of 1000
    BankAccountDatabaseConnection mock = mock();
    when(mock.createBankAccount()).thenReturn(1000);

    // Given a bank account
    BankAccount bankAccount = new BankAccount(mock, 0, 0);

    // Then it should have a bank account number
    assertThat(bankAccount.getBankAccountNumber(), equalTo(1000));
}
```

Generate the mock object and “stub” a method. Since we don’t go and verify any methods it’s effectively a stub.

Mockito – Summary

Mockito can save a lot of work in manually writing doubles.

Mockito can do more than we have covered here, see
https://site.mockito.org/

… but the temptation is to reach for it without considering alternatives.

Doubles can lead to brittle tests.

Always consider whether an integration test is more appropriate.