

4. A Testing Framework

A Testing Framework

Sources

- > JUnit documentation (from www.junit.org)

Roadmap

- > Junit — a testing framework
 - Testing practices
 - Frameworks vs. Libraries
 - Junit 3.x vs. Junit 4.x (annotations)
- > Money and MoneyBag — a testing case study
- > Double Dispatch — how to add different types of objects
- > JExample



Roadmap

- > **Junit — a testing framework**
 - Testing practices
 - Frameworks vs. Libraries
 - Junit 3.x vs. Junit 4.x (annotations)
- > Money and MoneyBag — a testing case study
- > Double Dispatch — how to add different types of objects
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The Problem

“Testing is not closely integrated with development. This prevents you from measuring the progress of development — you can't tell when something starts working or when something stops working.”

— Test Infected

Interactive testing is tedious and seldom exhaustive.

Automated tests are better, but,

- how to introduce tests interactively?
- how to organize suites of tests?

Testing Practices

During Development

- > When you need to add new functionality, *write the tests first*.
 - You will be done when the test runs.
- > When you need to redesign your software to add new features, refactor in small steps, and *run the (regression) tests after each step*.
 - Fix what's broken before proceeding.

During Debugging

- > When someone discovers a defect in your code, *first write a test* that demonstrates the defect.
 - Then debug until the test succeeds.

“Whenever you are tempted to type something into a print statement or a debugger expression, write it as a test instead.”
Martin Fowler

JUnit - A Testing Framework

- > JUnit is a simple framework to write repeatable tests. It is an instance of the xUnit architecture for unit testing frameworks written by Kent Beck and Erich Gamma
- > For documentation of how to use JUnit <http://junit.sourceforge.net/doc/cookbook/cookbook.htm>

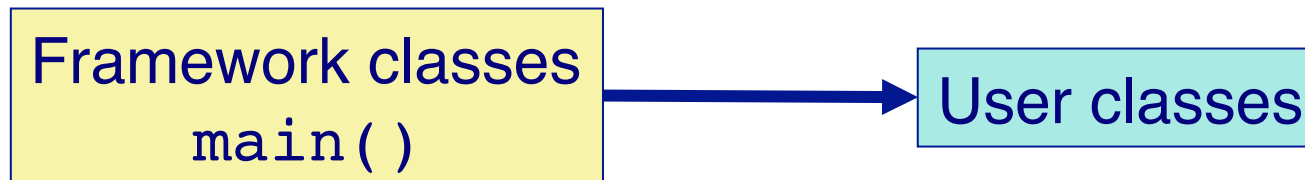


Frameworks vs. Libraries

In traditional application architectures, user code makes use of library functionality in the form of procedures or classes:



A framework reverses the usual relationship between generic and application code. Frameworks provide both generic functionality and application architecture:



*Essentially, a framework says:
"Don't call me — I'll call you."*

JUnit 3.8

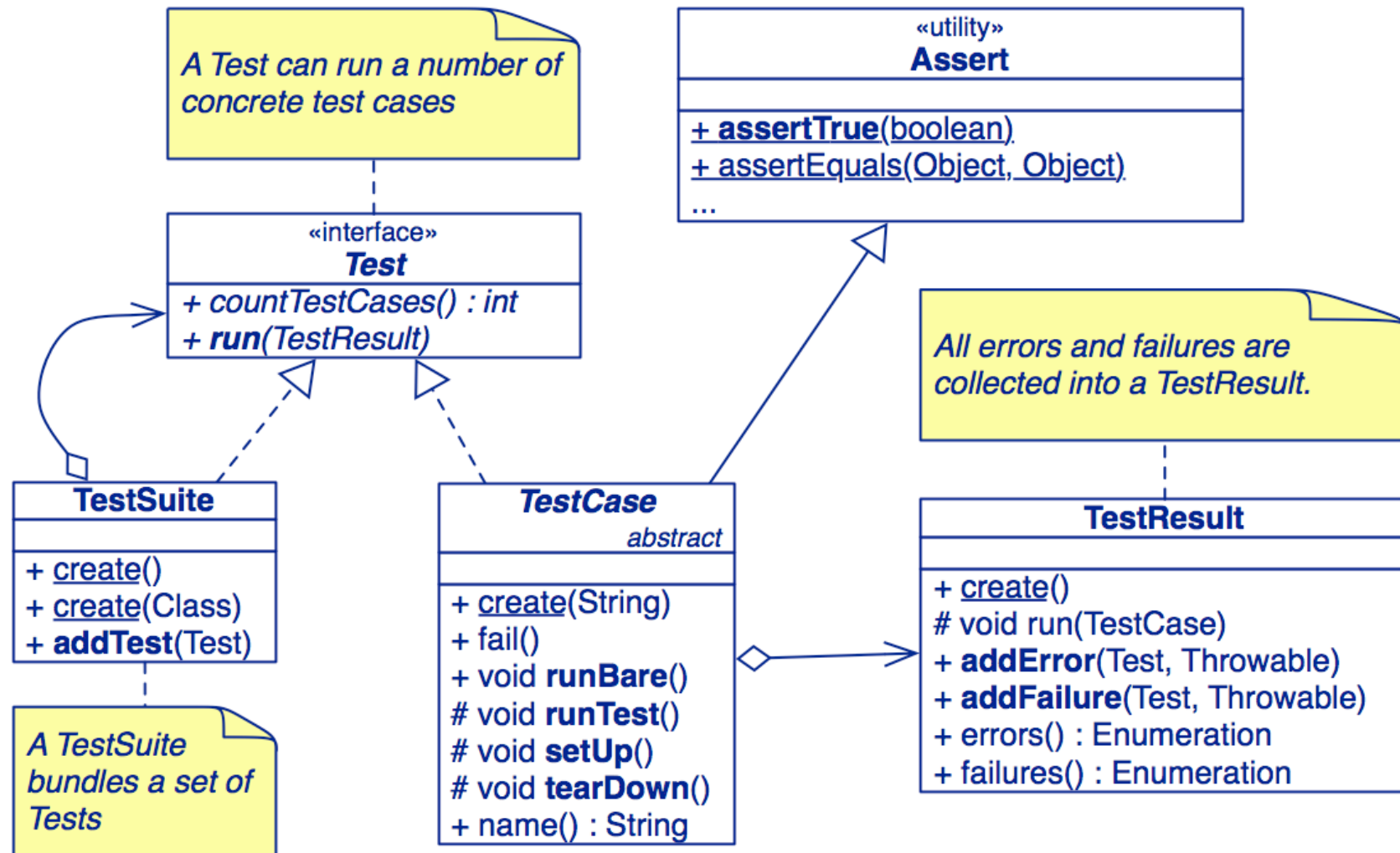
JUnit is a simple “testing framework” that provides:

- > classes for writing *Test Cases and Test Suites*
- > methods for *setting up and cleaning up test data* (“fixtures”)
- > methods for *making assertions*
- > textual and graphical tools for *running tests*

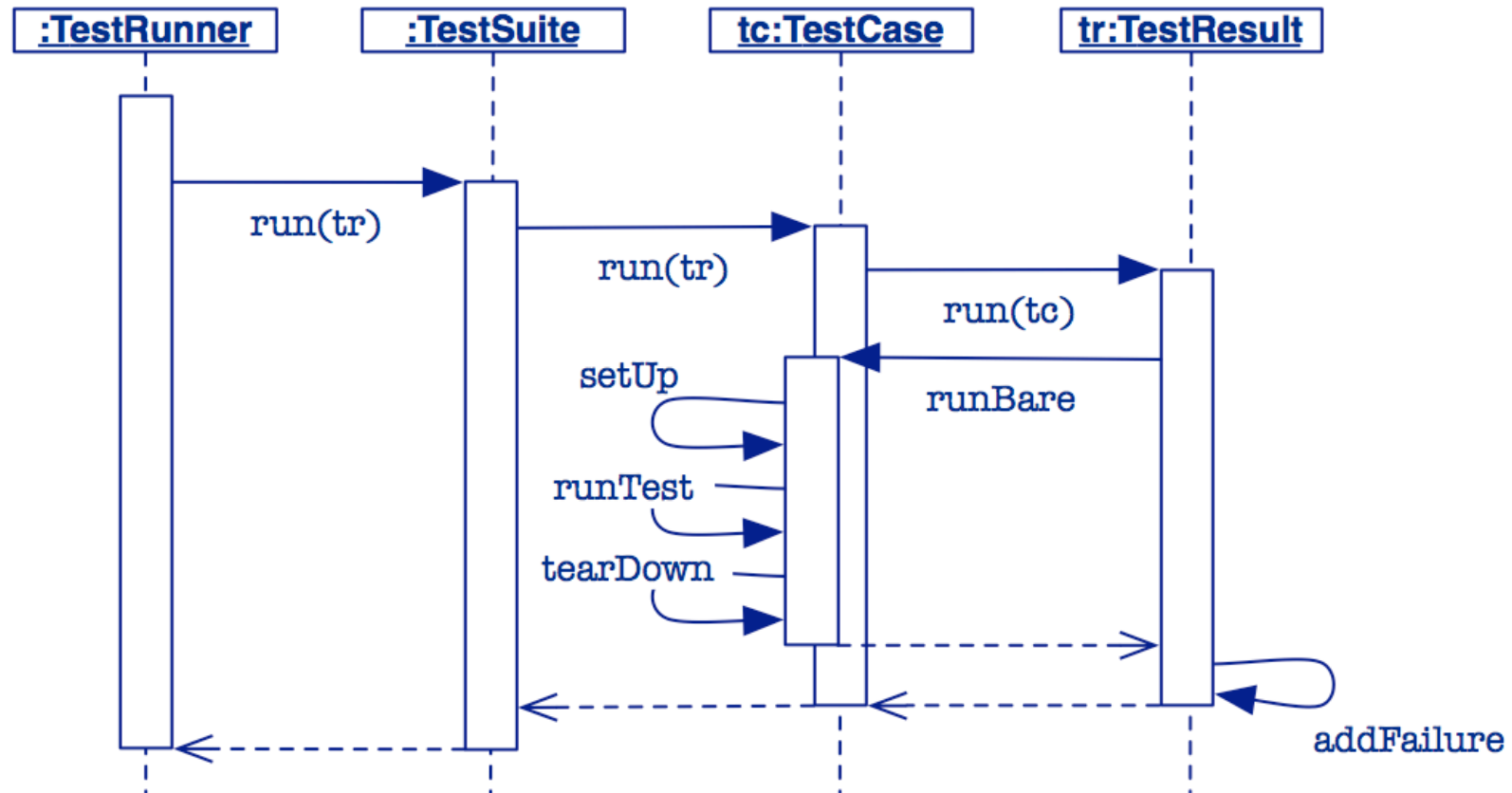
JUnit distinguishes between *failures and errors*:

- > A failure is *a failed assertion*, i.e., an anticipated problem that you test.
- > An error is *a condition you didn't check for*, i.e., a runtime error.

The JUnit 3.x Framework



A Testing Scenario



The framework calls the test methods that you define for your test cases.

JUnit 3.x Example Code

```
import junit.framework.*;

public class MoneyTest extends TestCase {
    private Money f12CHF;           // fixtures
    private Money f14CHF;

    protected void setUp() {       // create the test data
        f12CHF = new Money(12, "CHF");
        f14CHF = new Money(14, "CHF");
    }

    void testAdd() {                // create the test data
        Money expected = new Money(26, "CHF");
        assertEquals("amount not equal",
                     expected, f12CHF.add(f14CHF));
    }

    ...
}
```

Annotations in J2SE 5

- > J2SE 5 introduces the **Metadata** feature (data about data)
- > Annotations allow you to add **decorations** to your code (remember javadoc tags: *@author*)
- > Annotations are used for code documentation, compiler processing (*@Deprecated*), code generation, runtime processing
- > (<http://java.sun.com/docs/books/tutorial/java/javaOO/annotations.html>)

JUnit 4.x

JUnit is a simple “testing framework” that provides:

- > Annotations for marking methods as *tests*
- > Annotations for marking methods that *setting up and cleaning up test data* (“fixtures”)
- > methods for *making assertions*
- > textual and graphical tools for *running tests*

JUnit 4.x Example Code

```
import junit.framework.*;
import org.junit.*;
import static org.junit.Assert.*;
public class MoneyTest extends TestCase {
    private Money f12CHF;
    private Money f14CHF;

    @Before public void setUp() {                // create the test data
        f12CHF = new Money(12, "CHF");           // - the fixture
        f14CHF = new Money(14, "CHF");
    }
    @Test public void testadd() {                // create the test data
        Money expected = new Money(26, "CHF");
        assertEquals("amount not equal",
            expected, f12CHF.add(f14CHF));
    }
    ...
}
```

Testing Style

“The style here is to write a few lines of code, then a test that should run, or even better, to write a test that won't run, then write the code that will make it run.”

- > write unit tests that *thoroughly test a single class*
- > write tests *as you develop* (even before you implement)
- > write tests for *every new piece of functionality*

“Developers should spend 25-50% of their time developing tests.”

Roadmap

- > Junit — a testing framework
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 - Frameworks vs. Libraries
 - Junit 3.x vs. Junit 4.x (annotations)
- > **Money and MoneyBag — a testing case study**
- > Double Dispatch — how to add different types of objects
- > JExample



Representing multiple currencies

The problem ...

*“The program we write will solve the problem of **representing arithmetic with multiple currencies**. Arithmetic between single currencies is trivial, you can just add the two amounts. ... Things get more interesting once multiple currencies are involved.”*

MoneyTest

We start by defining a *TestCase* that exercises the interface we would like our Money class to support:

```
import org.junit.*;
import static org.junit.Assert.*;
public class MoneyTest {
    private Money f12CHF;
    private Money f14CHF;

    @Before public void setUp() {    // create the test data
        f12CHF = new Money(12, "CHF");
        f14CHF = new Money(14, "CHF");
    }
    ...
}
```

Some basic tests

We define methods to test what we expect to be true ...

```
@Test public void testEquals() {  
    assertNotNull(f12CHF);  
    assertEquals(f12CHF, f12CHF);  
    assertEquals(f12CHF, new Money(12, "CHF"));  
    assertFalse(f12CHF.equals(f14CHF));  
}  
  
@Test public void testSimpleAdd() {  
    Money expected = new Money(26, "CHF");  
    Money result = f12CHF.add(f14CHF);  
    assertEquals(expected, result);  
}
```

NB: `assertTrue`, etc. are static imported methods of the `Assert` class of the JUnit 4.x Framework and raise an `AssertionError` if they fail.

JUnit 3.x raises a `JUnit AssertionFailedError` (!)

Money

We now implement a Money class that fills our first few requirements:

```
public class Money {  
    ...  
    public Money add(Money m) {  
        return new Money(...);  
    }  
    ...  
}
```

Money
- fAmount : int
- fCurrency : String
+ <u>create</u> (int, String)
+ amount() : int
+ currency() : String
+ add(Money) : Money
+ equals(Object) : boolean
+ toString() : String

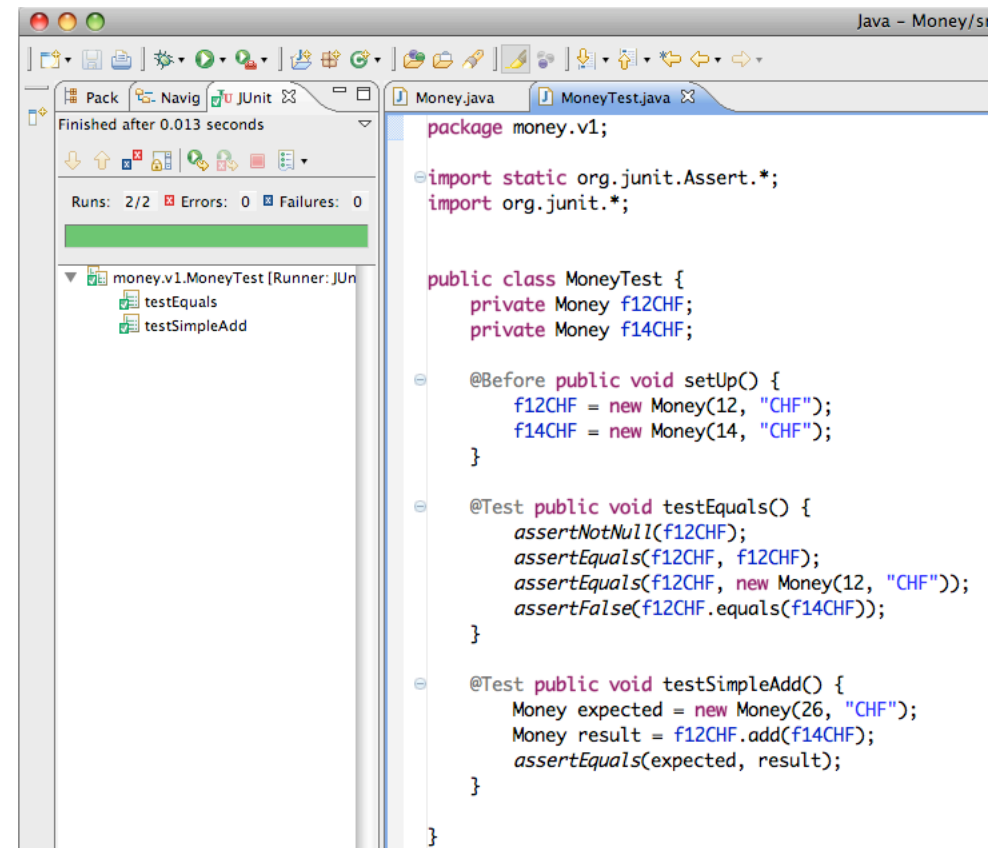
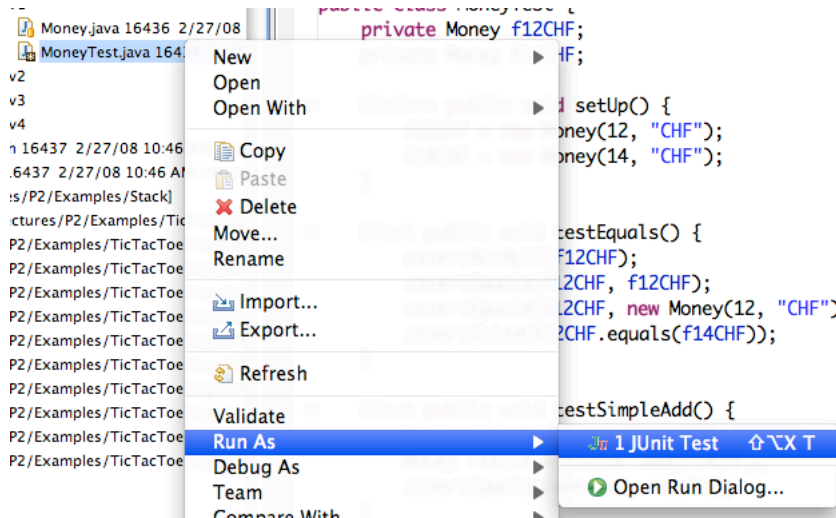
Note how the test case drives the design!

NB: The first version does not consider how to add different currencies!

What should the class invariant be?

Running tests from eclipse

- > Right-click on the class (or package) to run the tests



Testing MoneyBags (I)

To handle multiple currencies, we introduce a MoneyBag class that can hold several instances of Money:

```
import static org.junit.Assert.*;
public class MoneyTest {
    ...
    @Before public void setUp() {
        f12CHF = new Money(12, "CHF");
        f14CHF = new Money(14, "CHF");
        f7USD = new Money( 7, "USD");
        f21USD = new Money(21, "USD");
        fMB1 = new MoneyBag(f12CHF, f7USD);
        fMB2 = new MoneyBag(f14CHF, f21USD);
    }
}
```

Testing MoneyBags (II)

... and define some new (obvious) tests ...

```
@Test public void testBagEquals() {  
    assertNotNull(fMB1);  
    assertEquals(fMB1, fMB1);  
    assertFalse(fMB1.equals(f12CHF));  
    assertFalse(f12CHF.equals(fMB1));  
    assertFalse(fMB1.equals(fMB2));  
}
```


MoneyBags

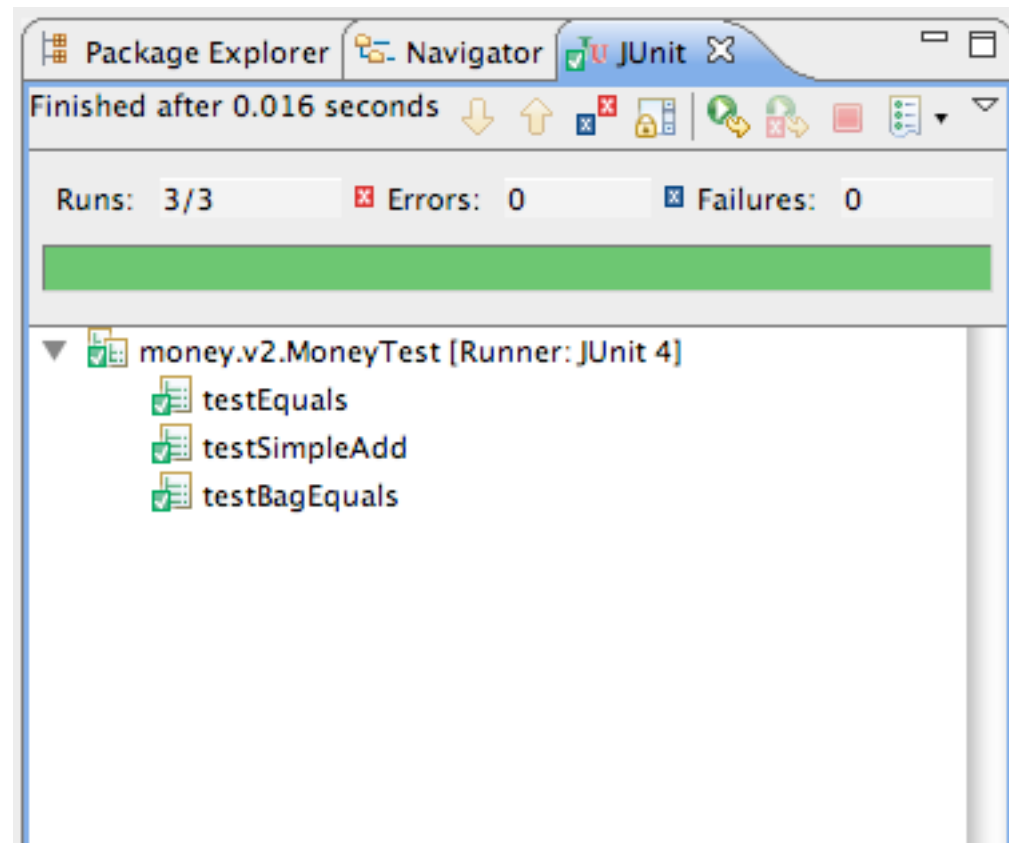
We can use a HashTable to keep track of multiple Monies:

```
class MoneyBag {
    private Hashtable monies = new Hashtable(5);
    MoneyBag(Money m1, Money m2) { ... }
    MoneyBag(Money bag[]) {
        for (Money money : bag) {
            appendMoney(money);
        }
    }
    private void appendMoney(Money aMoney) {
        Money m = (Money) monies.get(aMoney.currency());
        if (m != null) { m = m.add(aMoney); }
        else { m = aMoney; }
        monies.put(aMoney.currency(), m);
    }
}
```

MoneyBag
- fMonies : Hashtable
+ <u>create</u> (Money, Money)
+ <u>create</u> (Money [])
- appendMoney(Money)
+ toString() : String

Testing MoneyBags (III)

and we run the tests.



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Adding MoneyBags

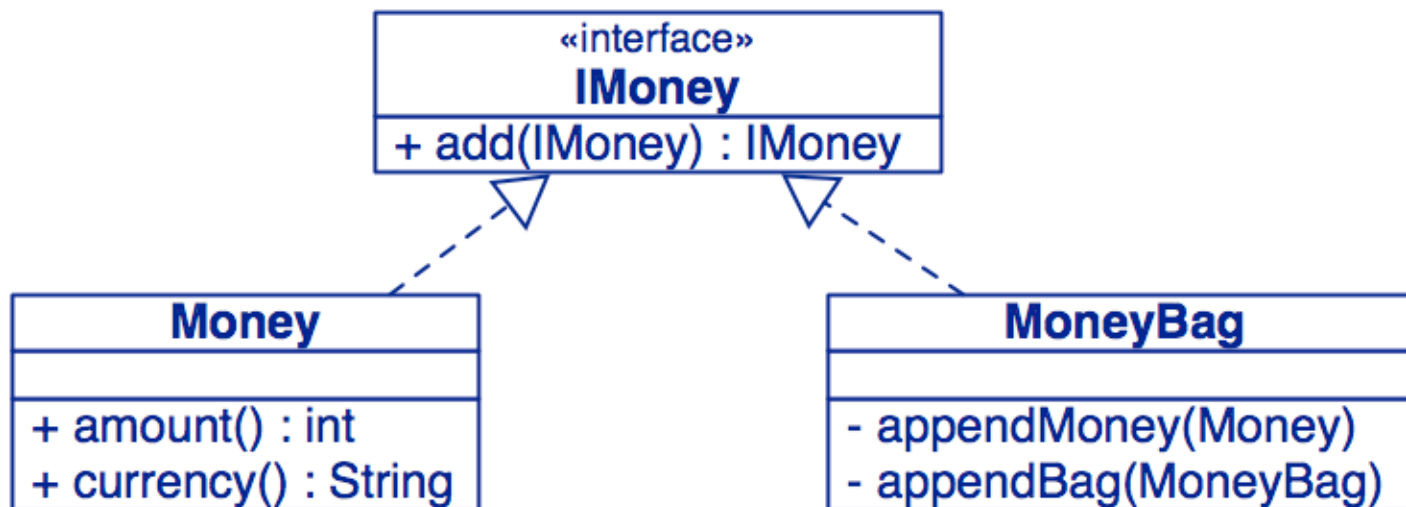
We would like to freely add together arbitrary Monies and MoneyBags, and be sure that *equals behave as equals*:

```
@Test public void mixedSimpleAdd() {  
    // [12 CHF] + [7 USD] == {[12 CHF][7 USD]}  
    Money bag[] = { f12CHF, f7USD };  
    MoneyBag expected = new MoneyBag(bag);  
    assertEquals(expected, f12CHF.add(f7USD));  
}
```

That implies that Money and MoneyBag should implement a common interface ...

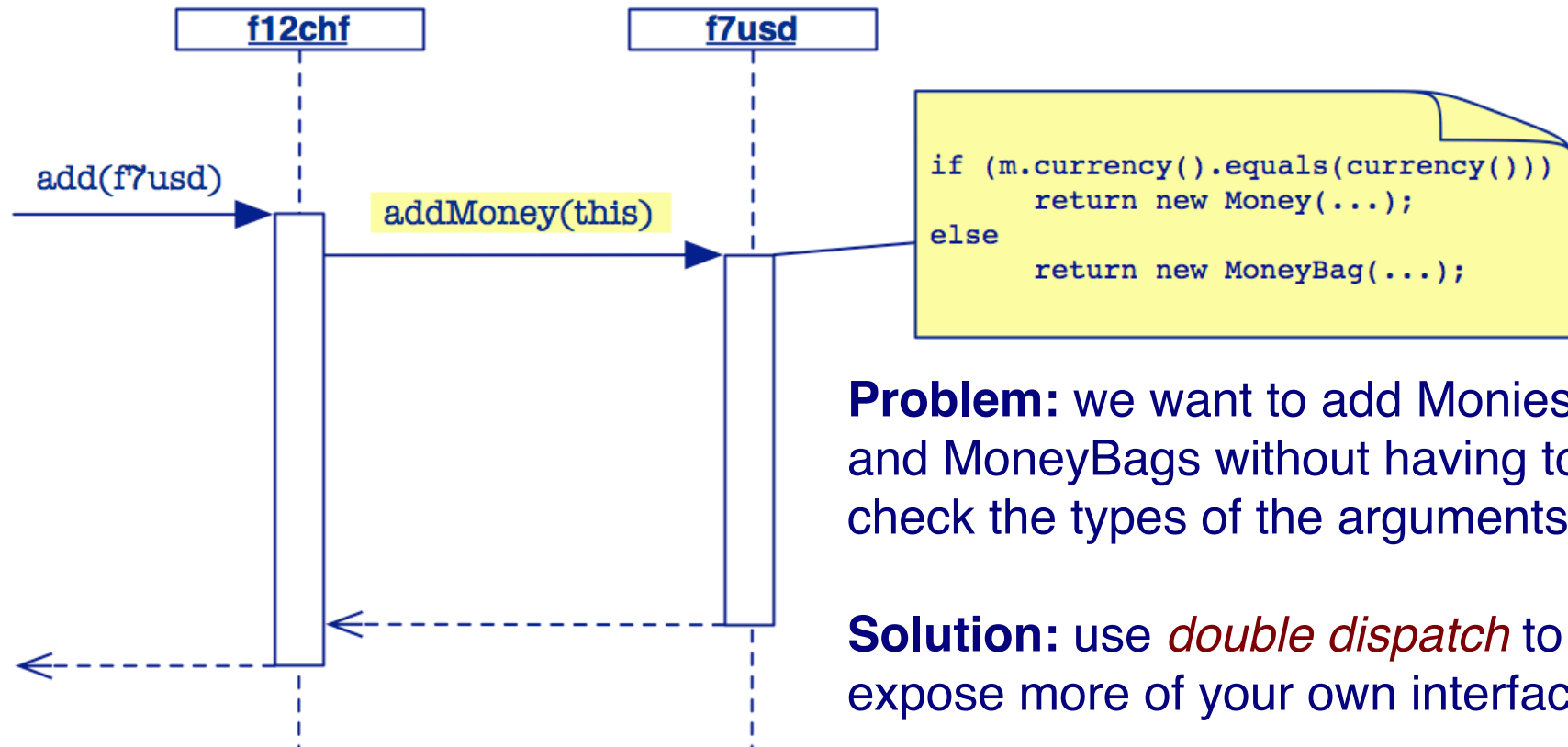
The IMoney interface (I)

Monies know how to be added to other Monies



Do we need anything else in the IMoney interface?

Double Dispatch (I)



Problem: we want to add Monies and MoneyBags without having to check the types of the arguments.

Solution: use *double dispatch* to expose more of your own interface.

Double Dispatch (II)

How do we implement add() without breaking encapsulation?

```
class Money implements IMoney { ...
    public IMoney add(IMoney m) {
        return m.addMoney(this);           // add me as a Money
    } ...
}
class MoneyBag implements IMoney { ...
    public IMoney add(IMoney m) {
        return m.addMoneyBag(this);       // add as a MoneyBag
    } ...
}
```

“The idea behind double dispatch is to use an additional call to discover the kind of argument we are dealing with...”

Double Dispatch (III)

The rest is then straightforward ...

```
class Money implements IMoney { ...
    public IMoney addMoney(Money m) {
        if (m.currency().equals(currency())) {
            return new Money(amount()+m.amount(),currency());
        }
        return new MoneyBag(this, m);
    }
    public IMoney addMoneyBag(MoneyBag s) {
        return s.addMoney(this);
    } ...
}
```

and MoneyBag takes care of the rest.

Double Dispatch (IV)

> **Pros:**

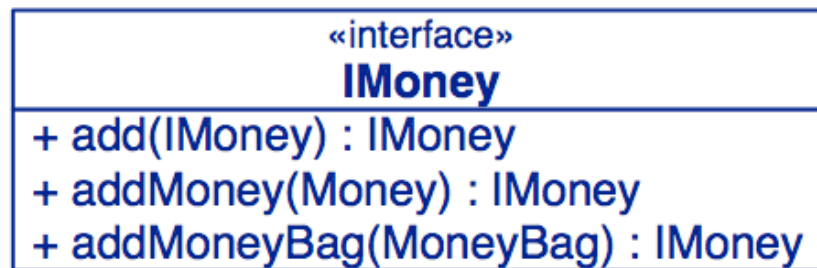
- No violation of encapsulation (no downcasting)
- Smaller methods; easier to debug
- Easy to add a new type

> **Cons:**

- No centralized control
- May lead to an explosion of helper methods

The IMoney interface (II)

So, the common interface has to be:

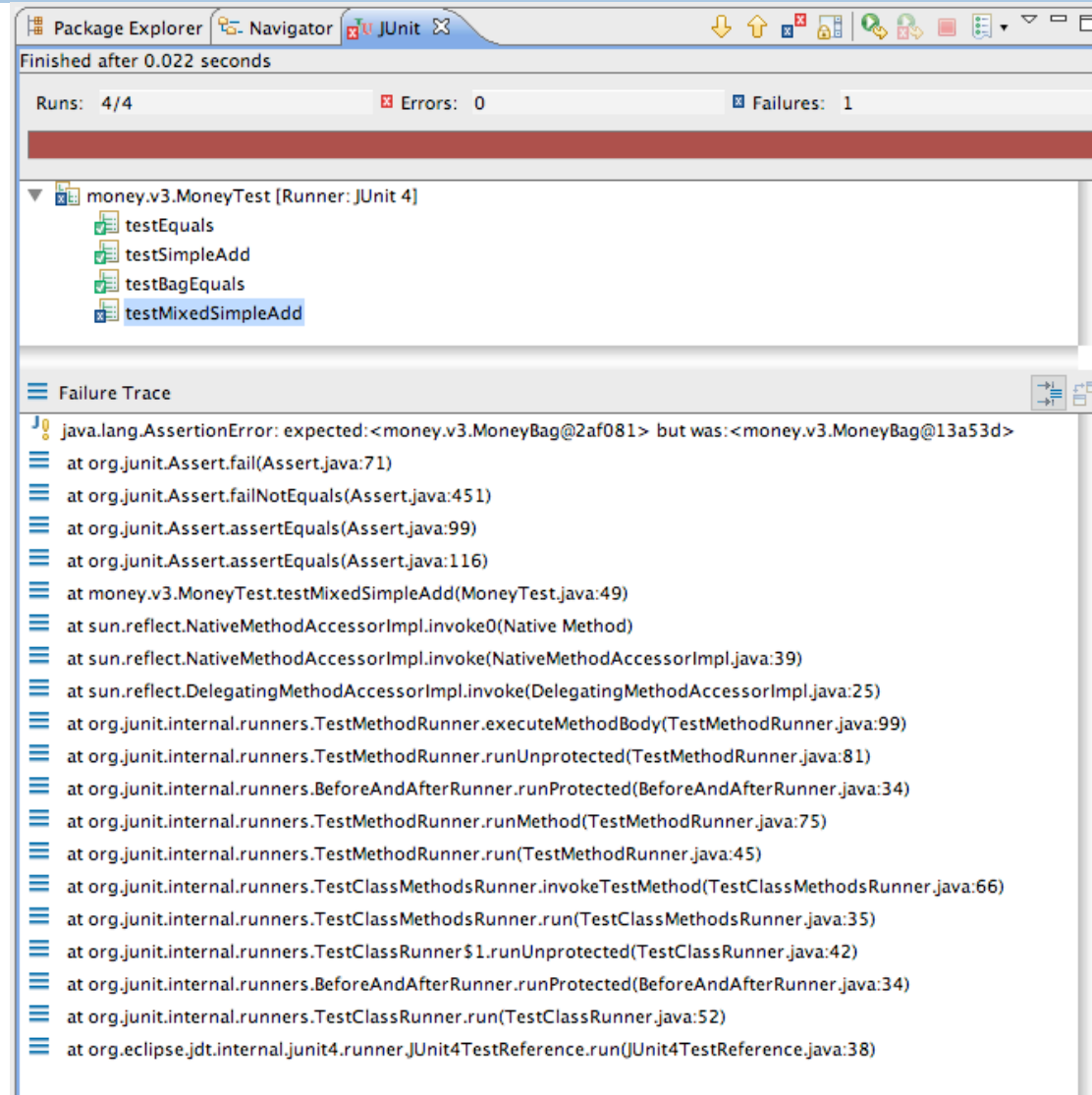


```
public interface IMoney {  
    public IMoney add(IMoney aMoney);  
    IMoney addMoney(Money aMoney);  
    IMoney addMoneyBag(MoneyBag aMoneyBag);  
}
```

NB: addMoney() and addMoneyBag() are only needed within the Money package.

A Failed test

This time we are not so lucky ...



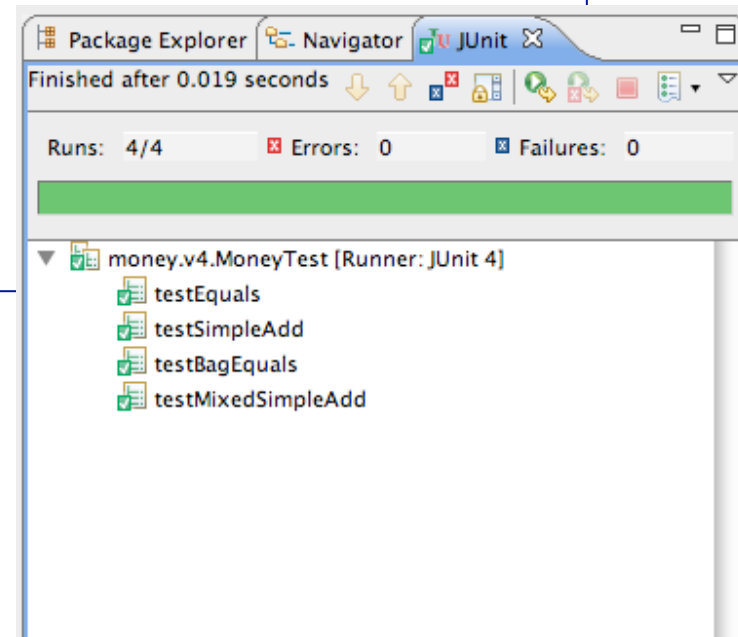
The fix ...

It seems we forgot to implement MoneyBag.equals()!

We fix it:

```
class MoneyBag implements IMoney { ...
    public boolean equals(Object anObject) {
        if (anObject instanceof MoneyBag) {
            ...
        } else {
            return false;
        }
    }
}
```

... test it, and continue developing.



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JExample

- > JExample introduces *producer-consumer relationships* between tests
 - Tests may *depend on* other tests that *produce examples* for them

<http://scg.unibe.ch/Research/JExample/>

Stack example — imports

```
import java.util.Stack;
import java.util.EmptyStackException;
import static org.junit.Assert.*;
import org.junit.Test;
import org.junit.runner.RunWith;

import ch.unibe.jexample.JExample;
import ch.unibe.jexample.Given;

@RunWith(JExample.class)
public class StackTest {
    ...
}
```

Stack example — dependencies

```
public class StackTest {  
  
    @Test  
    public Stack<String> empty() {  
        Stack<String> stack = new Stack<String>();  
        assertTrue(stack.empty());  
        return stack;  
    }  
  
    @Test(expected=EmptyStackException.class)  
    @Given("#empty")  
    public void emptyPopFails(Stack<String> stack) {  
        stack.pop();  
    }  
    ...  
}
```

*Tests may return
example objects*

*Consumer tests declare
dependencies and arguments*

Stack example — chained dependencies

```
public class StackTest {  
    ...  
    @Test  
    @Given("#empty")  
    public Stack<String> pushOnEmpty(Stack<String> stack) {  
        stack.push("foo");  
        assertFalse(stack.empty());  
        assertTrue(stack.size() == 1);  
        return stack;  
    }  
    @Test  
    @Given("#pushOnEmpty")  
    public Stack<String> pushPop(Stack<String> stack) {  
        stack.pop();  
        assertTrue(stack.empty());  
        return stack;  
    }  
    ...  
}
```









*Dependencies
may be chained*

Stack example — multiple dependencies





```
public class StackTest {  
    ...  
    @Test  
    @Given("#pushPop; #empty")  
    public void equality(Stack<String> used,  
                        Stack<String> fresh) {  
        assertEquals(used, fresh);  
    }  
}
```

*A test may depend
on multiple tests*

What you should know!

-  *How does a **framework** differ from a library?*
-  *What is a **unit test**?*
-  *What is an **annotation**?*
-  *How does **JUnit 3.x** differ from **JUnit 4.x**?*
-  *What is a test “**fixture**”?*
-  *What should you test in a **TestCase**?*
-  *How can testing **drive** design?*
-  *What is “**double dispatch**”? What does the name mean?*

Can you answer these questions?

-  *How does implementing `toString()` help in debugging?*
-  *How does the `MoneyTest` suite know which test methods to run?*
-  *How does the `TestRunner` invoke the right `suite()` method?*
-  *Why doesn't the Java compiler complain that `MoneyBag.equals()` is used without being declared?*

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