CS 2110

Software Design Principles II

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Overview

- Last week:
  - Design Concepts & Principles
  - Refactoring

- Today: Test-Driven Development
  - TDD + JUnit by Example

The Example

- A collection class `SmallSet`
  - containing up to N objects (hence "small")
  - typical operations:

`add`	adds item
`contains`	item in the set?
`size`	# items

  - we'll implement `add()`, `size()`

Test Driven Development

- We'll go about in small iterations
  1. add a test
  2. run all tests and watch the new one fail
  3. make a small change
  4. run all tests and see them all succeed
  5. refactor (as needed)

- We'll use JUnit

JUnit

- What do JUnit tests look like?

SmallSet.java

```
package edu.cornell.cs.cs2110;

public class SmallSet {
   ...
}
```

SmallSetTest.java

```
package edu.cornell.cs.cs2110;

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

public class SmallSetTest {
   @Test public void testFoo() {
      SmallSet s = new SmallSet();
      ...
      assertTrue(...);
   }

   @Test public void testBar() {
      ...
   }
}
```

A List of Tests

- We start by thinking about how to test,
  not how to implement
  - size=0 on empty set
  - size=N after adding N distinct elements
  - adding element already in set doesn't change it
  - throw exception if adding too many
  - ...
- Each test verifies a certain "feature"

A First Test

- We pick a feature and test it:

SmallSet
```
class SmallSet {}
```

SmallSetTest
```
class SmallSetTest {
   @Test public void testEmptySetSize() {
      SmallSet s = new SmallSet();
      assertEquals(0, s.size());
   }
}
```

- This doesn't compile: `size()` is undefined
- But that's all right: we've started designing the interface by using it

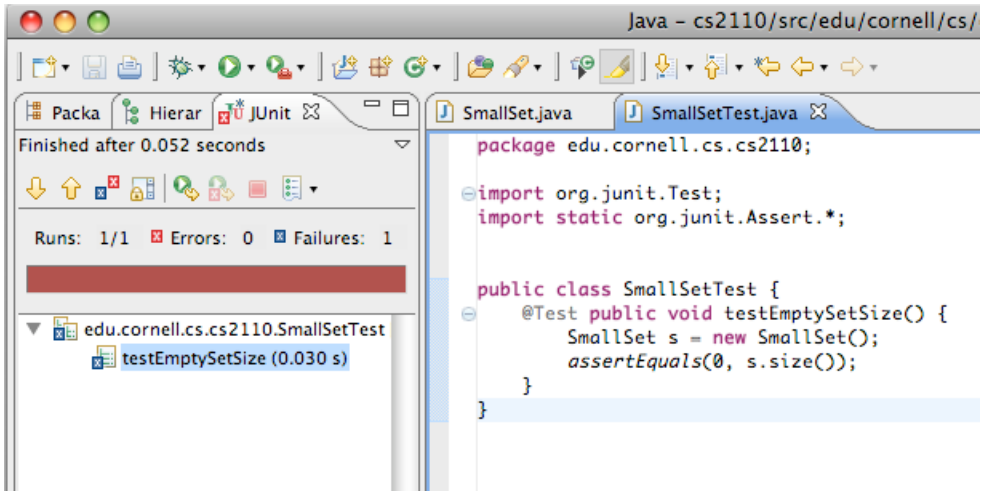
Red Bar

- We need the test to fail, so we define `size()`

SmallSet

```
class SmallSet {
   public int size() {
      return 42;
   }
}
```

- Running the test yields a red bar indicating failure:



- We've tested the test, and it works!

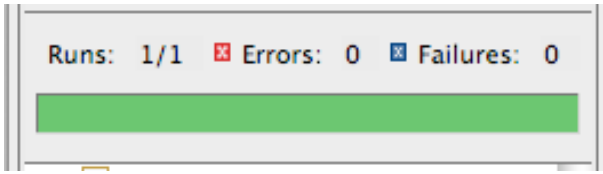
Green Bar

- What's the simplest way to make the test pass?

SmallSet

```
class SmallSet {
   public int size() {
      return 0;
   }
}
```

- "Fake it till you make it"
- Re-running yields the legendary JUnit Green Bar:



- We could now refactor, but we choose to move on with the next feature instead

Adding Items

- To implement adding items, we first test for it:

SmallSetTest

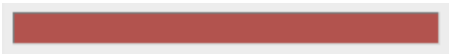
```
class SmallSetTest {
   @Test public void testEmptySetSize() ...

   @Test public void testAddOne() {
      SmallSet s = new SmallSet();
      s.add(new Object());
      assertEquals(1, s.size());
   }
}
```

- `add()` is undefined, so to run the test we define it:

SmallSet

```
public int size() ...

public void add(Object o) {}
```

Adding Items

- The test now fails as expected: 
- It seems obvious we need to count the number of items:

```
SmallSet
private int _size = 0;

public int size() {
   return 0;
   return _size;
}

public void add(Object o) {
   ++_size;
}
```

- And we get a green bar: 

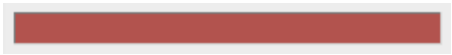
Adding Something Again

- So what if we added an item already in the set?

SmallSetTest

```
class SmallSetTest {
   @Test public void testEmptySetSize() ...

   @Test public void testAddOne() ...

   @Test public void testAddAlreadyInSet() {
      SmallSet s = new SmallSet();
      Object o = new Object();
      s.add(o);
      s.add(o);
      assertEquals(1, s.size());
   }
}
```

- As expected, the test fails...



Remember that Item?...

- We need to remember which items are in the set...

SmallSet

```
private int _size = 0;
public static final int MAX = 10;
private Object _items[] = new Object[MAX];

...
public void add(Object o) {
   for (int i=0; i < MAX; i++) {
      if (_items[i] == o) {
         return;
      }
   }

   _items[_size] = o;
   ++_size;
}
```

- All tests pass, so we can refactor that loop...

Refactoring

- (...loop) which doesn't "speak to us" as it could...

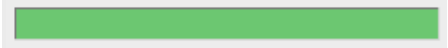
SmallSet (before)

```
public void add(Object o) {
   for (int i=0; i < MAX; i++) {
      if (_items[i] == o) {
         return;
      }
   }

   _items[_size] = o;
   ++_size;
}
```

SmallSet (after)

```
private boolean inSet(Object o) {
   for (int i=0; i < MAX; i++) {
      if (_items[i] == o) {
         return true;
      }
   }
   return false;
}

public void add(Object o) {
   if (!inSet(o)) {
      _items[_size] = o;
      ++_size;
   }
}
```

- All tests still pass, so we didn't break it!



Too Many

- What if we try to add more than `SmallSet` can hold?

```
SmallSetTest
...
@Test public void testAddTooMany() {
   SmallSet s = new SmallSet();
   for (int i=0; i < SmallSet.MAX; i++) {
      s.add(new Object());
   }
   s.add(new Object());
}
```

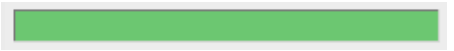
- The test fails with an error: 
  `ArrayIndexOutOfBoundsException`
- "Array..." makes no sense on a Set abstraction...

Size Matters

- We first have `add()` check the size,

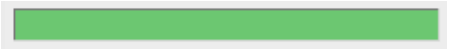
SmallSet

```
public void add(Object o) {
   if (!inSet(o) && _size < MAX) {
      _items[_size] = o;
      ++_size;
   }
}
```

- ... re-run the tests, check for green, 
define our own exception...

SmallSetFullException

```
public class SmallSetFullException extends Error {}
```

- ... re-run the tests, check for green, 
and...

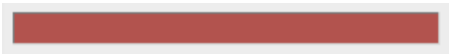
Testing for Exceptions

- ... finally test for our exception:

SmallSetTest

```
@Test public void testAddTooMany() {
   SmallSet s = new SmallSet();
   for (int i=0; i < SmallSet.MAX; i++) {
      s.add(new Object());
   }
   try {
      s.add(new Object());
      fail("SmallSetFullException expected");
   }
   catch (SmallSetFullException e) {}
}
```

- The test fails as expected, so now we fix it...



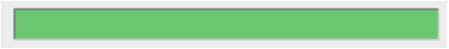
Testing for Exceptions

- ... so now we modify add() to throw:

SmallSet

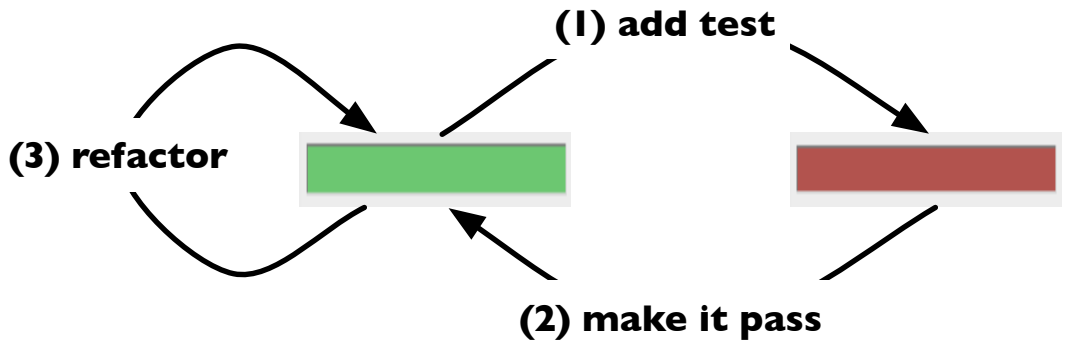
```
public void add(Object o) {
   if (!inSet(o) && _size < MAX) {
      if (_size >= MAX) {
          throw new SmallSetFullException();
      }
      _items[_size] = o;
      ++_size;
   }
}
```

- All tests now pass, so we're done:



Review

- Started with a "to do" list of tests / features
  - could have been expanded
    as we thought of more tests / features
- Added features in small iterations



- "a feature without a test doesn't exist"

Fixing a Bug

- What if after releasing we found a bug?

Reasons for TDD

- By writing the tests first, we
  - test the tests
  - design the interface by using it
  - ensure the code is testable
  - ensure good test coverage
- By looking for the simplest way to make tests pass,
  - the code becomes "as simple as possible, but no simpler"
  - may be simpler than you thought!

Not the Whole Story

- There's a lot more worth knowing about TDD
  - What to test / not to test
    - e.g.: external libraries?
  - How to refactor tests
  - Fixtures
  - Mock Objects
  - Crash Test Dummies
  - ...

* Beck, Kent: *Test-Driven Development: By Example*