

Test-Driven Development

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CSCI 4448/6448 — Lecture 27 — 12/2/08

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Credit where Credit is Due

- Some of the material for this lecture is taken from “Test-Driven Development” by Kent Beck
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- In addition, some material for this lecture is taken from “Agile Software Development: Principles, Patterns, and Practices” by Robert C. Martin
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Goals for this lecture

- Introduce the concept of Test-Driven Development (TDD)
- Present several examples

Test-Driven Development

- The idea is simple
 - No production code is written except to make a failing test pass
- Implication
 - You have to write test cases before you write code

Writing Test Cases First

- This means that when you first write a test case, you may be testing code that does not exist
 - And since that means the test case will not compile, obviously the test case “fails”
 - After you write the skeleton code for the objects referenced in the test case, it will now compile, but also may not pass
 - So, then you write the simplest code that will make the test case pass

Example (I)

- Consider writing a program to score the game of bowling
- You might start with the following test

```
public class TestGame extends TestCase {  
    public void testOneThrow() {  
        Game g = new Game();  
        g.addThrow(5);  
        assertEquals(5, g.getScore());  
    }  
}
```

- When you compile this program, the test “fails” because the Game class does not yet exist. But:
 - You have defined two methods on the class that you want to use
 - You are designing this class from a client’s perspective

Example (II)

- You would now write the Game class

```
public class Game {  
    public void addThrow(int pins) {  
    }  
    public int getScore() {  
        return 0;  
    }  
}
```

- The code now compiles but the test will still fail: `getScore()` returns 0 not 5
 - In Test-Driven Design, Beck recommends taking small, simple steps
 - So, we get the test case to compile before we get it to pass

Example (III)

- Once we confirm that the test still fails, we would then write the simplest code to make the test case pass; that would be

```
public class Game {  
    public void addThrow(int pins) {  
    }  
  
    public int getScore() {  
        return 5;  
    }  
}
```

- The test case now passes!

Example (IV)

- But, this code is not very useful!
- Lets add a new test case to enable progress

```
public class TestGame extends TestCase {
    public void testOneThrow() {
        Game g = new Game();
        g.addThrow(5);
        assertEquals(5, g.getScore());
    }
    public void testTwoThrows() {
        Game g = new Game()
        g.addThrow(5)
        g.addThrow(4)
        assertEquals(9, g.getScore());
    }
}
```

- The first test passes, but the second case fails (since $9 \neq 5$)
 - This code is written using JUnit; it uses reflection to invoke tests automatically

Example (V)

- We have duplication of information between the first test and the Game class
 - In particular, the number 5 appears in both places
 - This duplication occurred because we were writing the simplest code to make the test pass
 - Now, in the presence of the second test case, this duplication does more harm than good
 - So, we must now refactor the code to remove this duplication

Example (VI)

```
public class Game {  
    private int score = 0;  
    public void addThrow(int pins) {  
        score += pins;  
    }  
    public int getScore() {  
        return score;  
    }  
}
```

Both tests now pass. Progress!

Example (VII)

- But now we to make additional progress, we add another test case to the TestGame class

...

```
public void testSimpleSpare() {  
    Game g = new Game()  
    g.addThrow(3); g.addThrow(7); g.addThrow(3);  
    assertEquals(13, g.scoreForFrame(1));  
    assertEquals(16, g.getScore());  
}
```

...

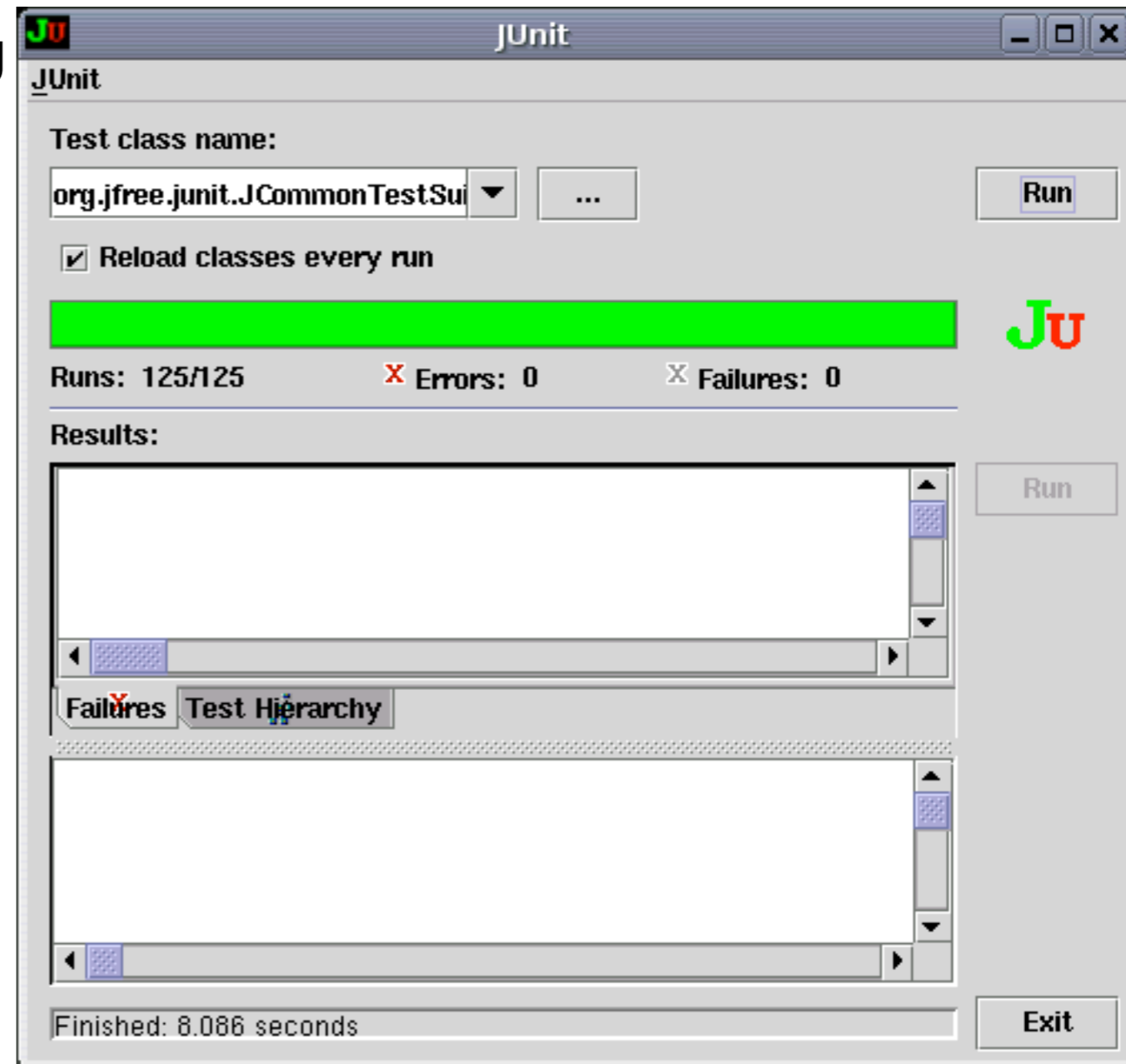
- We're back to the code not compiling due to scoreForFrame()
 - We'll need to add a method body for this method and give it the simplest implementation that will make all three of our tests cases pass

TDD Life Cycle

- The life cycle of test-driven development is
 - Quickly add a test
 - Run all tests and see the new one fail
 - Make a simple change
 - Run all tests and see them all pass
 - Refactor to remove duplication
- This cycle is followed until you have met your goal;
 - note that this cycle simply adds testing to the “add functionality; refactor” loop covered in the last two lectures

TDD Life Cycle, continued

- Kent Beck likes to perform TDD using a testing framework, such as JUnit.
- Within such frameworks
 - failing tests are indicated with a “red bar”
 - passing tests are shown with a “green bar”
- As such, the TDD life cycle is sometimes described as
 - “red bar/green bar/refactor”



JUnit: Red Bar...

- When a test fails:
 - You see a red bar
 - Failures/Errors are listed
 - Clicking on a failure displays more detailed information about what went wrong



Example Background: Multi-Currency Money

- Lets design a system that will allow us to perform financial transactions with money that may be in different currencies
 - e.g. if we know that the exchange rate from Swiss Francs to U.S. Dollars is 2 to 1 then we can calculate expressions like
 - $5 \text{ USD} + 10 \text{ CHF} = 10 \text{ USD}$
 - or
 - $5 \text{ USD} + 10 \text{ CHF} = 20 \text{ CHF}$

Starting From Scratch

- Lets start developing such an example
- How do we start?
 - TDD recommends writing a list of things we want to test
 - This list can take any format, just keep it simple
 - Example
 - $\$5 + 10 \text{ CHF} = \10 if rate is 2:1
 - $\$5 * 2 = \10

First Test

- The first test case looks a bit complex, lets start with the second
 - 5 USD * 2 = 10 USD
- First, we write a test case

```
public void testMultiplication() {  
    Dollar five = new Dollar(5);  
    five.times(2);  
    assertEquals(10, five.amount)  
}
```

Discussion on Test Case

```
public void testMultiplication() {  
    Dollar five = new Dollar(5);  
    five.times(2);  
    assertEquals(10, five.amount)  
}
```

- What benefits does this provide?
 - target class plus some of its interface
 - we are designing the interface of the Dollar class by thinking about how we would want to use it
 - We have made a testable assertion about the state of that class after we perform a particular sequence of operations

What's Next?

- We need to update our test list
 - The test case revealed some things about Dollar that we will want to address
 - We are representing the amount as an integer, which will make it difficult to represent values like 1.5 USD; how will we handle rounding of fractional amounts?
 - Dollar.amount is public; violates encapsulation
 - What about side effects?; we first declared our variable as “five” but after we performed the multiplication it now equals “ten”

Update Testing List

- The New List
 - $5 \text{ USD} + 10 \text{ CHF} = 10 \text{ USD}$
 - $\$5 * 2 = \10
 - make “amount” private
 - Dollar side-effects?
 - Money rounding?
- Now, we need to fix the compile errors
 - no class Dollar, no constructor, no method: times(), no field: amount

First version of Dollar Class

```
public class Dollar {  
    public Dollar(int amount) {  
    }  
  
    public void times(int multiplier) {  
    }  
  
    public int amount;  
}
```

- Now our test compiles and fails!

Too Slow?

- Note: we did the simplest thing to make the test compile;
- now, we are going to do the simplest thing to make the test pass
- Is this process too slow?
 - Yes, as you get familiar with the TDD life cycle you will gain confidence and make bigger steps
 - No, taking small simple steps avoids mistakes;
 - beginning programmers try to code too much before invoking the compiler;
 - they then spend the rest of their time debugging!

How do we make the test pass?

- Here's one way

```
public void times(int multiplier) {  
    amount = 5 * 2;  
}
```

- The test now passes, we received a “green bar”!
- Now, we need to “refactor to remove duplication”
 - But where is the duplication?
 - Hint: its between the Dollar class and the test case

Refactoring

- To remove the duplication of the test data and the hard-wired code of the times method, we think the following
- “We are trying to get a 10 at the end of our test case and we’ve been given a 5 in the constructor and a 2 was passed as a parameter to the times method”
 - So, lets connect the dots...

First version of Dollar Class

```
public class Dollar {  
    public Dollar(int amount) {  
        this.amount = amount;  
    }  
    public void times(int multiplier) {  
        amount = amount * multiplier;  
    }  
    public int amount;  
}
```

- Now our test compiles and passes, and we didn't have to cheat!

One loop complete!

- Before writing the next test case, we update our testing list
 - 5 USD + 10 CHF = 10 USD
 - ~~\$5 * 2 = \$10~~
 - make “amount” private
 - Dollar side-effects?
 - Money rounding?

One more example

- Lets address the “Dollar Side-Effects” item and then move on to general lessons
- So, lets write the next test case
 - When we called the times operation our variable “five” was pointing at an object whose amount equaled “ten”; not good
 - the times operation had a side effect which was to change the value of a previously created “value object”
 - Think about it, as much as you might like to, you can’t change a 5 dollar bill into a 500 dollar bill; the 5 dollar bill remains the same throughout multiple financial transactions

Next test case

- The behavior we want is

```
public void testMultiplication() {  
    Dollar five = new Dollar(5);  
    Dollar product = five.times(2);  
    assertEquals(10, product.amount);  
    product = five.times(3);  
    assertEquals(15, product.amount);  
    assertEquals(5, five.amount);  
}
```

Test fails

- The test fails because it won't compile;
- We need to change the signature of the times method; previously it returned void and now it needs to return Dollar

```
public Dollar times(int multiplier) {  
    amount = amount * multiplier;  
    return null;  
}
```

- The test compiles but still fails; as Kent Beck likes to say “Progress!”

Test Passes

- To make the test pass, we need to return a new Dollar object whose amount equals the result of the multiplication

```
public Dollar times(int multiplier) {  
    return new Dollar(amount * multiplier);  
}
```

- Test Passes;
- Cross “Dollar Side Effects?” off the testing list; second loop complete!
- There was no need to refactor in this situation

Discussion of the Example

- There is still a long way to go
 - only scratched the surface
- But
 - we saw the life cycle performed twice
 - we saw the advantage of writing tests first
 - we saw the advantage of keeping things simple
 - we saw the advantage of keeping a testing list to keep track of our progress
- Plus, as we write new code, we will know if we are breaking things because our old test cases will fail if we do;
 - if the old tests stay green, we can proceed with confidence

Principles of TDD

- Testing List
 - keep a record of where you want to go;
 - Beck keeps two lists, one for his current coding session and one for “later”; You won’t necessarily finish everything in one go!
- Test First
 - Write tests before code, because you probably won’t do it after
 - Writing test cases gets you thinking about the design of your implementation;
 - does this code structure make sense?
 - what should the signature of this method be?

Principles of TDD, continued

- Assert First
 - How do you write a test case?
 - By writing its assertions first!
 - Suppose you are writing a client/server system and you want to test an interaction between the server and the client
 - Suppose that for each transaction
 - some string has to have been read from the server, and
 - the socket used to talk to the server should be closed after the transaction
 - Lets write the test case

Assert First

```
public void testCompleteTransaction {  
    ...  
    assertTrue(reader.isClosed());  
    assertEquals("abc", reply.contents());  
}
```

- Now write the code that will make these asserts possible

Assert First, continued

```
public void testCompleteTransaction {
    Server writer = Server(defaultPort(), "abc")
    Socket reader = Socket("localhost", defaultPort());
    Buffer reply = reader.contents();
    assertTrue(reader.isClosed());
    assertEquals("abc", reply.contents());
}
```

- Now you have a test case that can drive development
 - if you don't like the interface above for server and socket, then write a different test case
 - or refactor the test case, after you get the above test to pass

Principles of TDD, continued

- Evident Data

- How do you represent the intent of your test data
- Even in test cases, we'd like to avoid magic numbers; consider this rewrite of our second "times" test case

```
public void testMultiplication() {  
    Dollar five = new Dollar(5);  
    Dollar product = five.times(2);  
    assertEquals(5 * 2, product.amount);  
    product = five.times(3);  
    assertEquals(5 * 3, product.amount);  
}
```

- Replace the "magic numbers" with expressions

Summary

- Test-Driven Design is a “mini” software development life cycle that helps to organize coding sessions and make them more productive
 - Write a failing test case
 - Make the simplest change to make it pass
 - Refactor to remove duplication
 - Repeat!

Reflections

- Test-Driven Design builds on the practices of Agile Design Methods
 - If you decide to adopt it, not only do you “write code only to make failing tests pass” but you also get
 - an easy way to integrate refactoring into your daily coding practices
 - an easy way to introduce “integration testing/building your system every day” into your work environment
 - because you need to run all your tests to make sure that your new code didn’t break anything; this has the side effect of making refactoring safe
 - courage to try new things, such as unfamiliar design pattern, because now you have a safety net

Ken's Corner: Testing Frameworks

- JUnit Tutorial: <<http://clarkware.com/articles/JUnitPrimer.html>>
- PyUnit: <<http://wiki.python.org/moin/PyUnit>>
- Unit testing in Objective-C and Xcode:
 - <<http://developer.apple.com/mac/articles/tools/unittestingwithxcode3.html>>
- Unit testing with C#: <<http://www.csunit.org/tutorials/tutorial7/>>
- Unit testing for Ruby:
 - <<http://www.ruby-doc.org/stdlib/libdoc/test/unit/rdoc/classes/Test/Unit.html>>
 -

Coming Up Next

- Lecture 28: Additional UML Models; Grasp Intro
- Lecture 29: Grasp
- Lecture 30: Concurrency in OO Systems

- NOTE: This schedule is tentative and may change!

- NEED VOLUNTEER: We will administer FCQs for this class at the end of lecture on Thursday