Test-Driven Development

CSCI 5828: Foundations of Software Engineering
Lecture 22 — 11/03/2016

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

- Note: use of the word “production”
  - which refers to code that is going to be deployed to and used by real users
- It does not say: “No code is written except…”

Test-Driven Design in a Nutshell

- 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 ≠ 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, 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());
}
```

  …

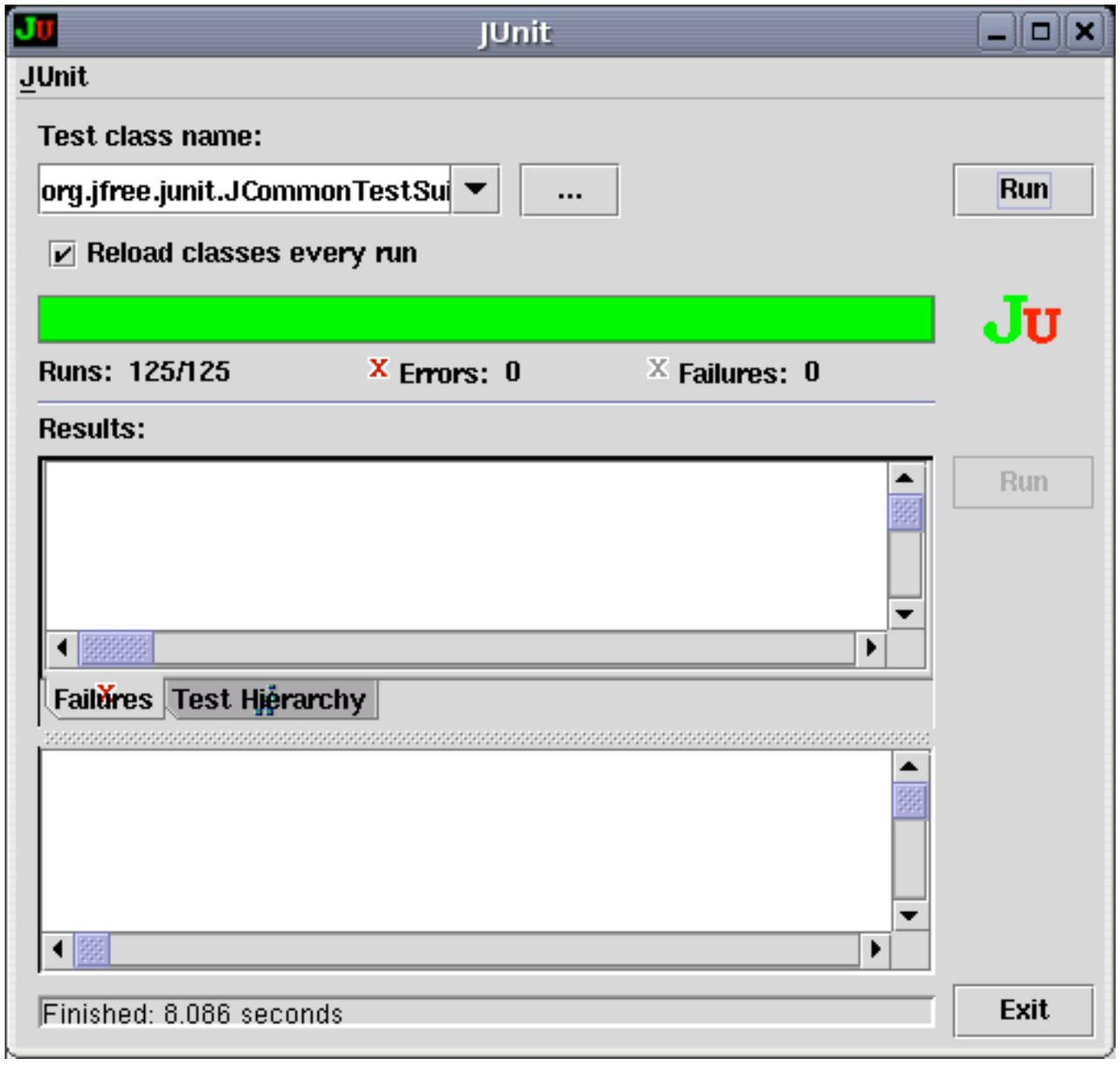
- We’re back to the code not compiling due to scoreForFrame()
  - We’ll need to add a method body for this method and give it the simplest implementation that will make all three of our tests cases pass

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

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 USD + 10 CHF = 10 USD
  - or
    - 5 USD + 10 CHF = 20 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 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 factional 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 USD + 10 CHF = 10 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;
  - novice 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?

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 another example
- 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

But how does it integrate with life cycles?

- With traditional software life cycles, TDD can be “test-driven development”
  - You’ll do requirements, use cases, class diagrams, etc. ➟ top down
  - Then TDD, coding from scratch to test your design ➟ bottom up
- With agile life cycles, TDD can be “test-driven design”
  - You create a new user story and use TDD to “discover” the classes that will help you implement that feature ➟ bottom up