IS2545, Lecture 10: TDD and Testable Code

BILL LABOON

THE DARK AGES

Bill Laboon

Nowadays…

- We know how important tests are to prevent issues like that
- Code quality is everyone's responsibility, including developers'
- Developers write tests (usually unit tests)

But…

- What to test?
- How deep to go into testing?
- How many edge cases?
- How to prioritize testing and development?
- What order should I write tests?
- How do I structure code to be testable?

There is no one right answer

- Many studies done
- Different domains, different developers, different languages, etc…
- “No silver bullet”

Test-Driven Development

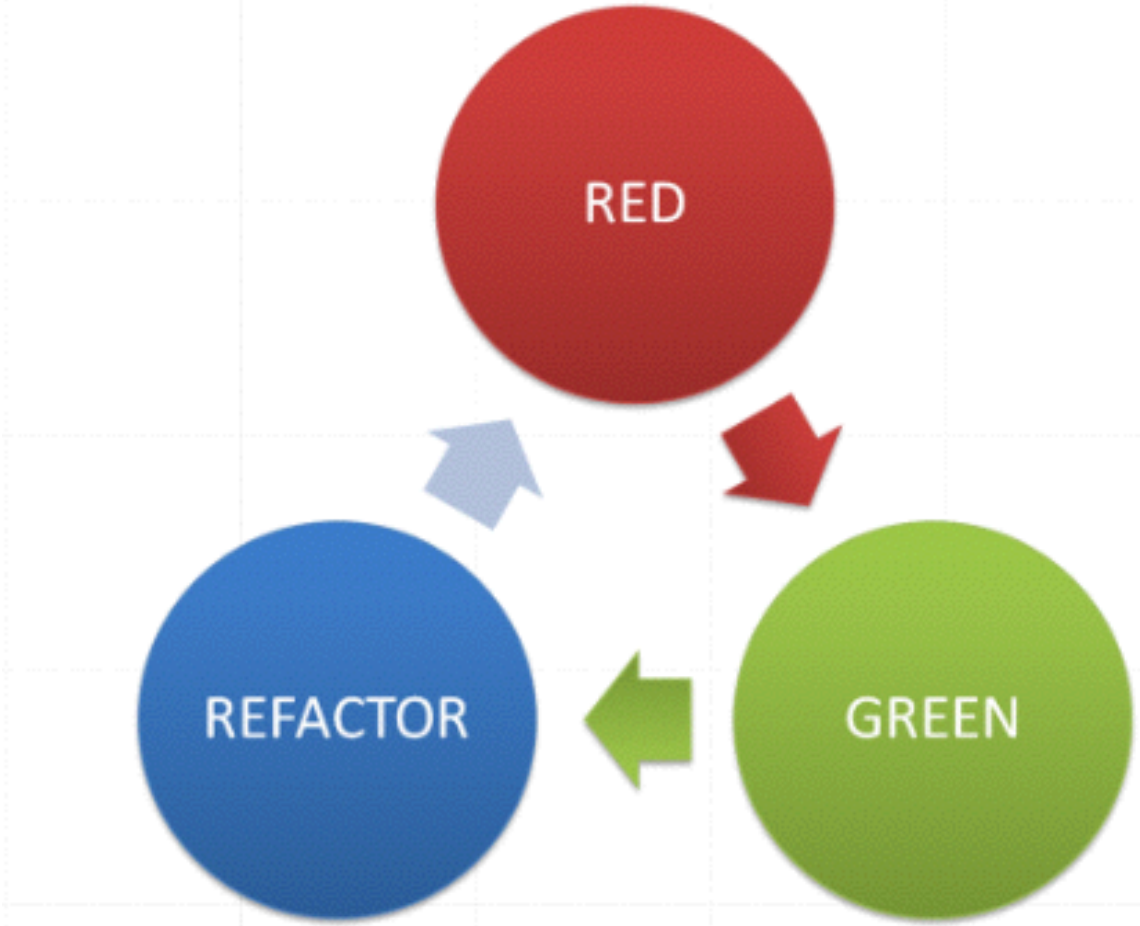
- A strategy for developing highly tested, quality software
- Not the be-all and end-all of strategies
- Google “TDD is dead” for a great argument against it
- Welcome to the still-forming world of software development!

So What is TDD?

A software development methodology that comprises:

1. Writing tests BEFORE writing code
2. Writing ONLY code that is tested
3. Writing ONLY tests that test the code
4. A very short turnaround cycle
5. Refactoring early and often

The Red-Green-Refactor Loop



The Red-Green-Refactor Loop

- Red – Write a test for new functionality
  - This should immediately fail!
- Green
  - Write only enough code to make the test pass
- Refactor
  - Review code and make it better

Detailed Run-Through of RGR Loop

1. Write a test for new functionality
2. Run test suite - only the new test should fail
3. Write only enough code to make test pass
4. Run test suite
5. If any tests fail, go to step 3
6. Refactor code
7. Run test suite
8. If any tests fail, go to step 6
9. If any more functionality, go to step 1; otherwise done

TDD = A Kind of Test-First Development

- Basic idea is to think about expected behavior FIRST, before code
- You don't want to "corrupt" your mind with implementation details
- Figure out what the program should do (requirements!)

- Side note: there are other kinds of test-first development, such as ATDD (Acceptance Test Driven Development) and BDD (Behavior Driven Development)

Step 1 – Write a test

- This test should be a small unit of functionality, say one input value and output value for a method.
- For pure TDD, you should not write multiple tests or tests which are very complex.

Step 2 – Run Test Suite

- Run all the tests - only the one you've just added should fail.
- If it doesn't fail, you've already written the code for it! This might be a redundant test.
- If other tests fail, something weird happened. Completed tests should always be passing at this point.

Step 3 – Write the Code

- Write just enough code to have the test pass.
- Avoid the temptation to over-engineer your solution or add more functionality than the test covers!

Step 4 – Re-run the Test Suite

- All the tests should pass this time, assuming you actually added the functionality.
- Otherwise:
  - If only your new test fails:
    - You have not written your code (or possibly test) correctly.
  - If other tests fail:
    - You have created a regression failure; that is, you've broken other functionality on the system!
  - Note that these are not mutually exclusive!

Step 5 – Check Test Results

- If any tests fail, fix them – either tests or code!
- Never move on before having an ENTIRELY GREEN (i.e. passing) test suite!

Step 6 - Refactor

- Your first attempt at writing code will probably not be perfect
  - Poor algorithm choice?
  - Bad variable names?
  - Poor performance?
  - Badly documented?
  - Magic numbers?
  - Not easily comprehensible?
  - General bad design?

Step 6 - Refactor

- Remember – you already have a working version before you refactor
  - We know it works because it provides the correct expected behavior according to the unit test suite
- When it comes to code, being right is more important than being good-looking

Step 7 – Re-run Test Suite Again

- Make sure that your refactoring did not cause any problems
- It should have the same functionality (according to the unit test suite), just better code
- That is, all unit tests should still pass

Step 8 – Check test results

- If any tests fail, something broke.
- Go and fix it before moving on!
- We are always aiming to have all-green tests

Step 9 - Done

Congratulations! You now have working code and can prove it with a test.

If there is more functionality to add, go back to step 1 and write a new test.

If not, SHIP IT.

YAGNI

- "You Ain't Gonna Need It“
- Don't add functionality you don't need right now. Chances are you won't need it and you're just going to waste time writing code for it.
- Code to the test!

KISS

- “Keep It Simple, Smarty-pants”
- Don't try to write overly complex, clever, over-engineered code. Make it easy to understand and modify.
- “Premature optimization is the root of all evil” –Donald Knuth
- Prefer:

```
i++;
```

over

```
i += (NUM_A / (c.getNum() - d.getNum));
```

Fake It ‘til You Make It

- Obviously applies to mocks/stubs
- But you can apply to smaller levels of functionality

Test:

```
assertEquals(sqrt(4), 2);
```

Code:

```
public void sqrt(int n) {
    return 2;
}
```

Avoid Slow-Running Tests

- Note that each iteration requires at least three test suite runs. If your tests take a long time to run, TDD is impractical.

Principles, Not Laws

- Nobody will throw you in jail if you write two tests during an iteration
- Sometimes tests are hard to make fast
- Etc.
- But they're code smells if you are using TDD.

Benefits of TDD

- Automatically create tests!
  - Research shows that more tests are correlated with fewer defects
- Makes writing tests easy because it's done often
  - Anything you do often, you learn how to do better
- Tests are relevant
  - They are testing the exact functionality you are implementing
- Developer is focused on end result, not code
  - Code is a way to get the functionality the user wants

Benefits of TDD

- Ensures that you take small steps
  - You know where defects lie; help localize errors
  - Research shows more senior engineers take smaller steps
- Code is extensible
  - You are already constantly extending the codebase
- Large test suite automatically created for you!
  - Helps avoid regression errors
  - High code coverage
- Confidence in the codebase

Drawbacks of TDD

- Focus on unit tests may mean other aspects of testing get short shrift
  - Remember that unit tests focus on small units of code, not integration
- Extra up-front time
  - May be saved in large projects due to fewer defects / test coverage
- May not appropriate for prototyping
  - You may not always know expected behavior
- Hard to do large architectural changes
  - Some things just aren't possible to do in small steps

Drawbacks of TDD

- Complex or mission/life-critical systems will require a more robust testing strategy
- Tests become part of the overhead of the project
  - Especially if they are brittle/fragile, or poorly written!
- Could fall into trap of overtesting
  - More time-consuming test suite runs, which hurts productivity
- Can be difficult to implement TDD on existing projects developed in a different paradigm
  - TDD assumes easy-to-write, fast-to-execute tests

Fizzbuzzin' With TDD

Print out the numbers from 1 to 100, each on a separate line. If a number is evenly divisible by 3, print "Fizz" instead. If a number is evenly divisible by 5, print "Buzz" instead. If a number is evenly divisible by 3 and 5, print "FizzBuzz" instead. Otherwise, just print the number.

1

2

Fizz

4

Buzz

Fizz

...

Start Out Nice and Easy

```
@Test
public void testNumber() {
   assertEquals(_fb.value(1), "1");
  }
// Code
public String value(int n) {
   return "1";
}
```

Let's Add Another Test

```
@Test
public void testNumber2() {
   assertEquals(_fb.value(2), "2");
 }
// Code
public String value(int n) {
  return "1";
}
```


WELCOME
TO
FAIL
POPULATION: YOU

Let's Make A Little Change

```
public String value(int n) {
  if (n == 1) {
    return "1";
  } else {
    return "2";
  }
}
```

But could be better!

Let's Refactor – now much nicer, and tests still pass!

```
public String value(int n) {
   return String.valueOf(n);
}
```

Add Another Test – it fails

```
@Test
public void testNumber3() {
   assertEquals(_fb.value(3), "Fizz");
}
```

We Need to Add Fizzy Code!

```
private boolean fizzy(int n) {
   return (n % 3 == 0);
}

public String value(int n) {
   if (fizzy(n)) {
    return "Fizz";
   } else {
    return String.valueOf(n);
   }
}
```


YESSS!!!
quickmeme.com

Let's Add A Test For Buzziness - It should fail.

```
@Test
public void testNumber5() {
  assertEquals(_fb.value(5), "Buzz");
}
```

Add and Integrate buzzy(n) Method

```
private boolean buzzy(int n) {
    return (n % 5 == 0);
}
public String value(int n) {
    if (fizzy(n)) {
      return "Fizz";
    } else if (buzzy(n)) {
      return "Buzz";
    } else {
      return String.valueOf(n);
    }
}
```

The Final Equivalence Class

```
 @Test
public void testNumber15() {
  assertEquals(_fb.value(15), "FizzBuzz");
}
```

Modify The value() Method

```
public String value(int n) {
   if (fizzy(n) && buzzy(n)) {
    return "FizzBuzz";
   } else if  (fizzy(n)) {
    return "Fizz";
   } else if (buzzy(n)) {
    return "Buzz";
   } else {
    return String.valueOf(n);
   }
}
```

Result?

- We now have a working, tested implementation of FizzBuzz
- We have automated test coverage for all equivalence classes
- We had a path forward at all points

TDD makes you feel…

Testable Code

Code for which it is easy to write and perform tests, automated and manual, at various levels of abstraction, and track down errors when tests fail.

Good Code Is Not The Same As Testable Code

- Good code is testable code
- But not all testable code is good code
- So let’s learn to write good code and make it testable

Key Ideas for Testable Code

- Segment code - make it modular
- Give yourself something to test
- Make it repeatable
- DRY (Don’t repeat yourself)
- Use the dominant paradigm of the language

Segment Code

- Methods should be SMALL and SPECIFIC
- Do one thing and do it well

```
// Bad
public int getNumMonkeysAndSetDatabase(Database d) {
   if (d != null) {
      _database = d;
   } else {
      _database = DEFAULT_DATABASE;
   }
   setDefaultDatabase(_database);
   int numMonkeys = getNormalizedMonkeys();
   if (numMonkeys < 0) {
      numMonkeys = 0;
   }
   return numMonkeys;
}
```

Refactor

```
// Better
public void setDatabase(Database d) {
   if (d != null) {
      _database = d;
   } else {
      _database = DEFAULT_DATABASE;
   }
   setDefaultDatabase(_database);
}

public int getNumMonkeys() {
   int numMonkeys = getNormalizedMonkeys();
   if (numMonkeys < 0) {
      numMonkeys = 0;
   }
   return numMonkeys;
}
```

Give Yourself Something to Test

- Return values are worth their weight in gold!
  - Easy to assert against
  - Guaranteed to exist (in Java)

- Exceptions, modified accessible attributes, etc… something is better than nothing!

```
public void addMonkey(Monkey m) {
    if (m != null) {
        addMonkeyToMonkeyList(m);
    }
}
```

Refactor

```
// Better
public int addMonkey(Monkey m) throws NullMonkeyException {
   int toReturn = -1;
   if (m != null) {
      toReturn = addMonkeyToMonkeyList(m);
   } else {
      throw NullMonkeyException();
   }
   return toReturn;
}
```

Make It Repeatable

- Randomness or Dependence on External Data should be minimized

- Try to segregate PURE FUNCTIONS from SIDE-EFFECT-FUL CODE
  Pure functions = output depends ONLY on input, do nothing else
  Side effects = write to database, read a global variable, write to file system, etc.

Well, This Is Bad

```
public CrapsStatus rollDiceFirst() {
   // random throws of the dice
   int dieRoll1 = (new Die()).roll();
   int dieRoll2 = (new Die()).roll();
   int total = dieRoll1 + dieRoll2;
   switch (total) {
      case 2: case 3: case 12:
        return CRAPS_LOSE;
      case 7: case 11:
         return CRAPS_WIN;
      case 4: case 5: case 6: case 8: case 9: case 10:
         _firstRoll = total;
         return CRAPS_PLAY;
      default:
         return CRAPS_ERROR;
      }
   }
}
```

Refactor

```
// Better
public CrapsStatus rollDiceFirst(Die d1, Die d2) {
   // random throws of the dice
   int dieRoll1 = d1.roll(); // Can stub roll!
   int dieRoll2 = d2.roll();
   int total = dieRoll1 + dieRoll2;
   switch (total) {
      case 2: case 3: case 12:
        return CRAPS_LOSE;
      case 7: case 11:
         return CRAPS_WIN;
      case 4: case 5: case 6: case 8: case 9: case 10:
         _firstRoll = total;
         return CRAPS_PLAY;
      default:
         return CRAPS_ERROR;
      }
   }
}
```

Even Better

```
// Better
public CrapsStatus getCrapsStatus(int dieRoll1, int dieRoll2) {
   // Actual die rolls take place elsewhere
   // No need to double/stub!
   // Method is smaller and more focused
   int total = dieRoll1 + dieRoll2;
   switch (total) {
      case 2: case 3: case 12:
        return CRAPS_LOSE;
      case 7: case 11:
         return CRAPS_WIN;
      case 4: case 5: case 6: case 8: case 9: case 10:
         _firstRoll = total;
         return CRAPS_PLAY;
      default:
         return CRAPS_ERROR;
      }
   }
}
```

DRY - Don’t Repeat Yourself

- Don’t copy and paste code from one section of your program to another
- Don’t have multiple methods with the same or similar functionality
- Try to have “generic” methods (not language-specific, but in Java, try to use Generics)

Bad

```
public int addMonkey(Monkey m) {
    if (m != null) {
        _animalList.add(m);
    }
    return _animalList.count();
}
public int addGiraffe(Giraffe g) {
    if (g != null) {
        _animalList.add(g);
    }
    return _animalList.count();
}
public int addRabbit(Rabbit r) {
    if (r != null) {
        _animalList.add(r);
    }
    return _animalList.count();
}
```

Refactor

```
// Animal is superclass for Giraffe,
// Monkey, and Rabbit

public int addAnimal(Animal a) {
    if (a != null) {
        _animalList.add(a);
    }
    return _animalList.count();
}
```

Ensure That You Don’t Have Multiple Methods Doing The Same Thing

```
public int addUpArray(int[] x) {
   int toReturn = 0;
   for (int j=0; j<x.length; x++) {
      toReturn += x[j];
   }
   return toReturn;
}
// elsewhere in codebase..
public int arrayTotal(int[] a) {
   int toReturn = 0;
   int c = 0;
   while (++c < a.length) {
      toReturn = toReturn + a[c];
   }
   return toReturn;
}
```

Why?

- Twice as much room for error
- Bloated codebase
- Perhaps slightly different behavior (look closely at previous code!)
- Harder to find errors
- Which one to use?

Replicated Code Could Be Internal To Methods!

```
// In one method…
String name = db.where("user_id = " +
    id_num).get_names[0];

// Elsewhere, in another method…
String name =
    db.find(id).get_names().first();
```

You Can DRY This Up, Too

```
public static String getName(Database db, int
id) {
    // Add in guard code, try..catch, etc.
    // Can all be here in one place
    return db.find(id).get_names().first();
}

// In one method…
String name = getName(db, id);

// Elsewhere, in another method…
String name = getName(db, id);
```

Use the dominant paradigm of the language

- Java is object-oriented - program in an object-oriented way
- Will help you with making stubs, doubles, mocks, segregating code, etc.

Procedural Style

```
public static int rollDie(Random r) {
   return r.nextInt(6) + 1;
}

public static void main(String[] args) {
   Random rng = new Random(args[0]);
   int dieRoll1 = rollDie(rng);
   int dieRoll2 = rollDie(rng);
   boolean keepPlaying = true;
   while (keepPlaying) {
      ...
```

In An Object-Oriented Language, Write Object-Oriented Code

```
public class Die {
    Random _rng = null;
    public Die() {
        _rng = new Random();
    }
    public Die(int seed) {
        _rng = new Random(seed);
    }
    public int roll() {
        return r.nextInt(6) + 1;
    } r.nextInt(6) + 1;

}
```

Languages Are Designed The Way They Are For a Reason

YOU CAN PROGRAM JAVA IN A FUNCTIONAL WAY

or a procedural way

or a logical way

or a constraint-based way

BUT IT MIGHT BE AS WEIRD, DIFFICULT-TO-USE AND DIFFICULT-TO-UNDERSTAND AS THE FONTS ON THIS SLIDE