



CS1632, Lecture 12: Writing Testable Code

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Testable Code

- Code for which it is easy to perform tests
 - Whether automated and manual
 - Whether at unit level or system level
- ... and track down errors when tests fail

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
- Move TUFs out of TUCs

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 = _monkeyList.size();
    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 = _monkeyList.size();
    return numMonkeys;
}
```

Give Yourself Something to Test

- Return values are worth their weight in gold!
 - Easy to assert against
- What if method does not have a return value?
 - Try adding a success/fail return value
 - Try throwing exceptions to indicate problems
 - Try modifying value of an accessible attribute
 - Always, something is better than nothing!

// Bad. No state to check for defects.

```
public void addMonkey(Monkey m) {  
    if (m != null) {  
        _monkeyList.add(m);    // _monkeyList is private  
    }  
}
```

Refactor

// Better. Can assert on return value.

```
public boolean addMonkey(Monkey m) {  
    if (m != null) {  
        _monkeyList.add(m);  
        return true;  
    }  
    return false;  
}
```

// Also better. Can catch exception and assert there.

```
public void addMonkey(Monkey m) throws NullMonkeyException {  
    if (m != null) {  
        _monkeyList.add(m);  
    } else {  
        throw NullMonkeyException();  
    }  
}
```

Make It Repeatable

- Dependence on random or external data == Bad
 - Random data makes it impossible to repeat result (as you can imagine)
 - External data also makes repeating results very hard
- What is external data?
 - Value of global variables
 - Value extracted from a global data structure
 - Value returned from a database query
 - Value read from a file
 - Basically any value that you did not pass in as arguments or locally produce

Not Repeatable Code

```
public Result playOverUnder() {  
    // random throw of the dice  
    int dieRoll = (new Die()).roll();  
    if (dieRoll > globalThreshold) {  
        return RESULT_OVER;  
    }  
    else if (dieRoll < globalThreshold) {  
        return RESULT_UNDER;  
    }  
    else {  
        return RESULT_AT;  
    }  
}
```

- Two reasons why the result is not repeatable:
 1. dieRoll will obtain a random value on every call
 2. globalThreshold may be different across calls
- What if tester pre-sets globalThreshold before performing unit test?
 - globalThreshold may be modified internally (e.g. by Die.roll())

Refactor

```
public Result playOverUnder(Die d) {  
    // random throw of the dice  
    int dieRoll = d.roll(); // Can stub roll()  
    if (dieRoll > globalThreshold) {  
        return RESULT_OVER;  
    }  
    else if (dieRoll < globalThreshold) {  
        return RESULT_UNDER;  
    }  
    else {  
        return RESULT_AT;  
    }  
}
```

- Now, a test double can be passed in for `Die` and `roll()` can be stubbed
- This type of refactoring is called *dependency injection*
 - Passing dependencies in as parameters to the tested method

Even Better

```
public Result playOverUnder(int dieRoll) {  
    if (dieRoll > globalThreshold) {  
        return RESULT_OVER;  
    }  
    else if (dieRoll < globalThreshold) {  
        return RESULT_UNDER;  
    }  
    else {  
        return RESULT_AT;  
    }  
}
```

- Now, no need to even create a test double or stub!
- What about `globalThreshold`?
 - Inject that dependency too!

The Best

```
public Result playOverUnder(int dieRoll, int threshold) {  
    if (dieRoll > threshold) {  
        return RESULT_OVER;  
    }  
    else if (dieRoll < threshold) {  
        return RESULT_UNDER;  
    }  
    else {  
        return RESULT_AT;  
    }  
}
```

- Now, this method has become a pure function
 - Pure function: function where result is computed purely from parameters
 - A pure function is by definition always repeatable
- Try to make your functions pure functions whenever possible
 - Segregate hard-to-test code with side-effects into a small corner

DRY - Don't Repeat Yourself

- Don't copy and paste code
- Don't have multiple methods with similar functionality
- Make use of “generic” classes and methods
 - Classes and methods that have parameterized types
 - E.g. Java `List<Type>` is parameterized by `Type` so that user can make a list of integers (`List<Integer>`) or list of strings (`List<String>`) using the same class
 - Language implementations: Java generics, C++ templates, ...

Why DRY?

- Twice as much room for error
- Bloated codebase
- A bug fix or enhancement must be replicated on all copies of the code – another source of error

Bad: Replicated code but with different types

```
private ArrayList<Animal> _animalList;
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();  
}
```

Bad: What if there is no superclass?

```
// No superclass for List<Monkey>, List<Giraffe>, List<Rabbit>

public void addOne(List<Monkey> l, Monkey m) {
    if (m != null) {
        l.add(m);
    }
}

public void addOne(List<Giraffe> l, Giraffe g) {
    if (g != null) {
        l.add(g);
    }
}

public void addOne(List<Rabbit> l, Rabbit b) {
    if (b != null) {
        l.add(b);
    }
}
```

Refactor

```
// Use a generic method.  
// addOne() accepts an argument of type List<T>.  
// T can be any type.
```

```
public <T> void addOne(List<T> l, T e) {  
    if (e != null) {  
        l.add(e);  
    }  
}
```


Bad: Two copies of very similar code (but slightly different)

```
public int addUpArray(int[] x) {
    int toReturn = 0;
    for (int j=0; j<x.length; j++) {
        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;
}
```

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

```
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

- When in Rome, do as the Romans do
- Automated testing frameworks are geared towards the dominant programming paradigm for that language
- Java is an Object Oriented Programming (OOP) language
 - Program in an OOP way!
 - It will allow you to use test doubles, stubs, mocks, ...

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 OOP Language, Write OOP Code

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

Don't make life hard for the tester

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

No TUFs Inside TUCs

That is, no

Test-Unfriendly Features

inside

Test-Unfriendly Constructs

Examples of Test-Unfriendly Features

- Printing to console
- Reading/writing from a database
- Reading/writing to a filesystem
- Accessing a different program or system
- Accessing the network
- ☛ Code that you typically *want* to fake using stubs

Examples of Test-Unfriendly Constructs

- Private methods
- Final methods
- Final classes
- Class constructors / destructors
- Static methods
- ☛ Code that is *hard* to fake using stubs

No TUFs Inside TUCs

- In other words ...
- Do not put code that you want to fake inside that is hard to fake

Dealing with Legacy Code



Image from <https://goiabada.blog>

Dealing With Legacy Code

- In most classes, you had it easy
 - You either wrote greenfield code (that is, code from scratch)
 - Or modified code that your professor wrote to make it easy on you (even though it may not always look like that).
- The real world is seldom so tidy
 - Code is often written hurriedly under pressure, with no consideration for testing, let alone any testing code
 - Often there is little to no documentation and you aren't even sure how the legacy code even works
- Where do you start?

Start by Writing Pinning Tests

- *Pinning Test*: A test done to pin down existing behavior
 - Note: existing behavior may be different from expected behavior
 - Want to pin down all behavior, bugs and all, before modifying
 - Even obscure corner case behaviors may sometimes be used
 - ☛ Must make sure these don't get accidentally modified
- Pinning tests are typically done using unit testing
 - Where do I look for places where I can unit test?
 - Look for seams!

Look for Seams in your Legacy Code

- *Seams*: Places where *behavior* can be modified without modifying *code*

- Example with no seam:

```
void executeSql(String sql) {  
    DatabaseConnection db = new DatabaseConnection();  
    db.executeSql(sql);  
}
```

- ☛ Hard to unit test since we need a working DB connection

- Example with seam:

```
void executeSql(String sql, DatabaseConnection db) {  
    db.executeSql(sql);  
}
```

- ☛ Easy to unit test by passing a test double DB connection

Look for Seams in your Legacy Code

- Does this really have no seam?

```
void executeSql(String sql) {  
    DatabaseConnection db = new DatabaseConnection();  
    db.executeSql(sql);  
}
```

- Maybe it does, if you look closely enough!

Look for Seams in your Legacy Code

- Suppose you have this legacy class

```
class LegacyClass
{
    void executeSql(String sql) {
        DatabaseConnection db = new DatabaseConnection();
        db.executeSql(sql);
    }
}
```

- Now create a new class JustForTestingClass

```
class JustForTestingClass : public LegacyClass
{
    void executeSql(String sql) {
        DatabaseConnection db =
Mockito.mock(DatabaseConnection.class);
        // Stub db to specify whatever behavior you want
        db.executeSql(sql);
    }
}
```

- Use JustForTestingClass for testing purposes

Dealing With Legacy Code

- After pinning down behavior, you can slowly start refactoring the code
- Leave the codebase better than when you found it.
- Don't sink into the Swamp of Sadness.