

CMSC 132: OBJECT-ORIENTED PROGRAMMING II



Program Testing

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Debugging Is Harder Than Coding!

“Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it”

– Brian W. Kernighan and P. J. Plauger, *The Elements of Programming*

Program Testing

- Empirical testing
 - Test software with selected test cases
 - More scalable than verification
 - Test failures frequently indicate software errors
 - Absence of failures doesn't prove software correct
 - If code isn't exercised by any test, hard to have confidence in it
 - Even if it has been “formally verified”

Kinds of Testing

- Automated testing
 - The software is tested by a completely automatic process
 - e.g., JUnit or submit server testing
 - Can be expensive or difficult to construct, but fairly cheap to repeat
- Manual testing
 - A person uses the software, perhaps guided by a script, and notes bugs
 - Often easier to conduct than writing test cases, but very expensive to repeat

Test Size

- Small
 - Unit test – test individual components
- Medium
 - Integration tests
 - Test subsystems containing several components
 - Can test interactions between components, properties that are only demonstrated in larger systems
- Large
 - System or acceptance tests
 - Test entire system, including non-software components

Types of Testing

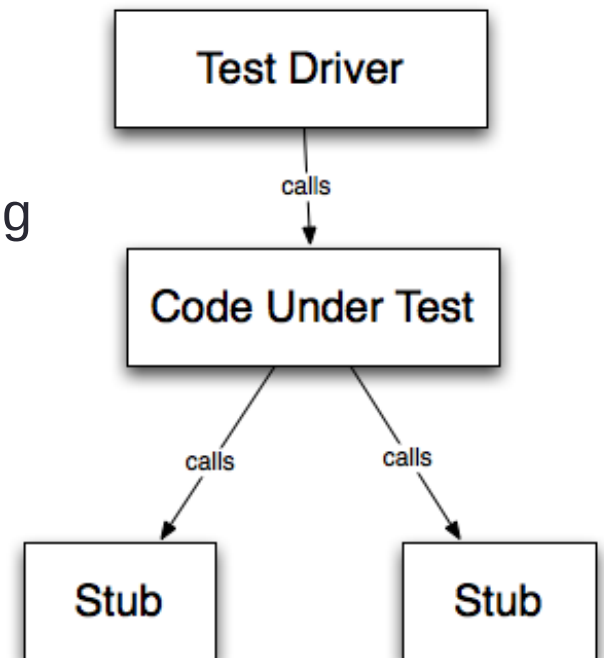
- Clear box testing
 - Allowed to examine code
 - Attempt to improve thoroughness of tests
- Black box testing
 - No knowledge of code
 - Treat program as “black box”
 - Test behavior in response to inputs

Testing – Terminology

- Test case
 - Individual test
- Test suite
 - Collection of test cases
- Test harness
 - Program that executes a series of test cases
- Test framework
 - Software that facilitates writing & running tests
 - Example → JUnit

Testing – Terminology

- Test driver
 - Program to create environment for running tests
 - Declares variables, creates objects, assigns values
 - Invokes tested code, checks results, reports failures
- Stub
 - Skeleton code in place of unfinished method / class
 - Implements minimal functionality to allow test to occur
 - Allows software testing to begin



Mock Objects

- Similar to a stub
- But they record the calls made to them
- If the wrong calls are made to them, the test fails
- Can prerecord the sequence of expected calls
 - Also eliminates need for mock objects to contain any logic
- Or the test driver can query the calls after the test
 - Useful if calls aren't deterministic and need more careful logic to check

When to Use Mock Objects

- If you want to test the calls made to other objects, rather than the return values or output of the methods under test
- Mock objects can also be easier to use than creating functional stubs
- Mock objects can simulate situations that might be hard to test on real code
 - e.g., Does the code recover if the network fails?

EasyMock Example

```
warehouseControl = MockControl.createControl(Warehouse.class);  
warehouseMock = (Warehouse) warehouseControl.getMock();  
Order order = new Order(TALISKER, 50);
```

// setup – record expected calls and return values

```
warehouseMock.hasInventory(TALISKER, 50);  
warehouseControl.setReturnValue(true);  
warehouseMock.remove(TALISKER, 50);  
warehouseControl.replay(); // put mock into replay mode
```

// exercise – execute code under test

```
order.fill(warehouseMock);
```

// verify

```
warehouseControl.verify();  
assertTrue(order.isFilled());
```

Unit Test

- Test individual units extensively
 - Classes
 - Methods
- Central part of Extreme Programming (XP)
 - Extensive unit testing during development
 - Pair programming
 - Design unit tests along with specification
- Approach
 - Test each method of class
 - Test every possible **flow path** through method

Flow Path

- Unique execution sequence through program
- Example

S1

```
while (B1) {  
    if (B2)  
        S2  
    else  
        S3  
}
```



Flows

S1

S1, S2

S1, S3

S1, S2, S2

S1, S2, S3

S1, S3, S2

S1, S3, S3

...

Test Coverage

- Not possible to test all flow paths
 - Many paths by combining conditionals, switches
 - Infinite number of paths for loops
 - New paths caused by exceptions
- Test coverage
 - Whether code is executed by **some** test case
 - Alternative to flow path
 - Ensure high % (if not all) of lines of code tested
 - Does not capture all possible flow paths
 - Even if all lines of code tested by some test case

Test Coverage, Continued

- Branch coverage is stronger than statement coverage
 - Generally achievable
- Can be tricky to cover all exceptions and error cases
- Control flow coverage doesn't tell you about **data coverage**
 - Did you try it with negative integers, or with non-ASCII characters?
- Coverage won't tell you about functionality you forgot to implement or test

When to Test

- If code has never been tested, you have no idea if it ever worked
- But it is also important to perform regression testing
 - Check to see if some functionality that used to work stops working
 - The faster a regression is identified, the cheaper it is to fix, at any scale
 - Within a minute is better than within an hour
 - Within a day is better than within a week

Why Regression Test?

- Running regression tests give developer much more freedom to change existing code
 - “I need to rewrite this component to support new functionality – I wonder if anything might be depending on the details of how it works now?”
- This freedom is key to agile development, and important even in more structured development methodologies

Selecting Regression Tests

- Big, well tested systems will have too many tests to run all of them every time you compile
- Prioritize tests by size
 - Ones that take only a few seconds
 - Ones that need to run over the weekend
- And by proximity to code changed
 - After changing some code, you only need to rerun the tests that executed the code that was changed
- Research work on prioritizing tests

Developing Quality Test Cases

- Useful to have someone else write test cases
 - One person might make the same incorrect assumption in both their code and in their tests
- Tips on developing test cases
 - Develop test data during analysis & design phases
 - Use cases → Test cases
 - Pay close attention to problem specification
 - Check boundary conditions
 - 1st and last iterations of loop
 - 1st and last values added to data structure
 - Improve code coverage

Miscellaneous

- **Bug Tracking**

- Dilbert Comic → <http://dilbert.com/strips/comic/1995-11-13/>
- Computer Bug
<http://www.history.navy.mil/photos/images/h96000/h96566kc.htm>
- Tools for managing, tracking, performing statistics on bugs and vulnerabilities essential, particularly on large projects
 - Bugzilla → <http://www.bugzilla.org/>
 - Jira → <http://www.atlassian.com/software/jira/overview>

- **Javadoc**

- Great tool to generate documentation

- **Submit Server**

- Uses clover for code coverage
- Runs findbugs on all java programs
 - <http://findbugs.sourceforge.net/>

CS History Moment: Donald Knuth

- Renowned computer scientist and Professor Emeritus at Stanford
- Author of the seminal multi-volume work “*The Art of Computer Programming*”
 - A comprehensive series of books (several volumes) that cover many kinds of programming algorithms and their analysis
- Creator of the TeX computer typesetting system
- Info and picture from Wikipedia
 - http://en.wikipedia.org/wiki/Donald_Knuth

