

CMSC 132: OBJECT-ORIENTED PROGRAMMING II



Program Testing

Department of Computer Science
University of Maryland, College Park

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

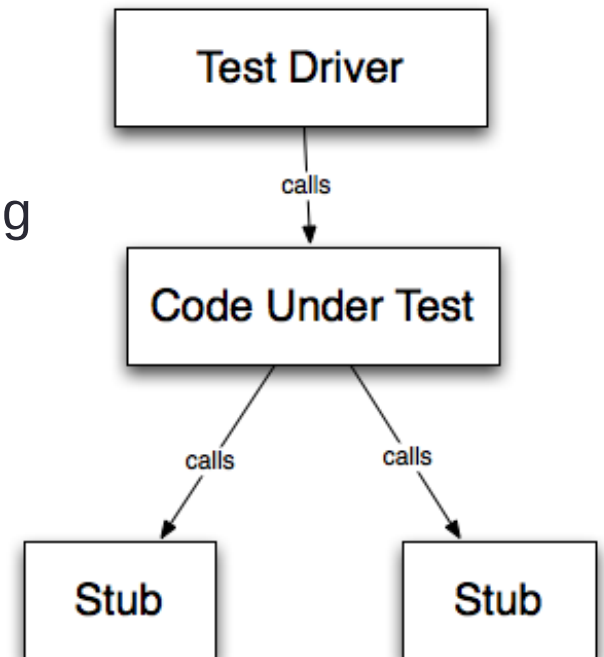
- Clear box testing
 - Allowed to examine code
 - Attempt to improve thoroughness of tests
- Black box testing
 - No knowledge of code
 - Treat program as “black box”
 - Test behavior in response to inputs

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

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

