CMSC 433 – Programming Language Technologies and Paradigms Fall 2002

Developing, Testing, Debugging

Some slides adapted from FSE'98 Tutorial by Michal Young and Mauro Pezze'

Tools, Testing, Debugging

- Goal: write reliable, correct software
  - And do it without too much pain!
- The development process
  - Analyze requirements (what am I trying to do?)
  - Write code (how am I doing it?)
  - Test code (does my code work?)
  - Debug code (nope—what's wrong?)
  - then iterate! (has what I've written met the requirements?)

Holistic Development: IDE's

- Interactive Development Environments
  - Typically simplify writing of code (editor + compiler hook)
  - May help with debugging (syntax checking, debugger interface)
  - May help with testing (interface to test tool)
  - May help with search, transformation, etc.
- Many available
  - Eclipse JDT
  - Dr. Java
  - Visual Studio
  - …

Dr. Java

- Editing
  - Syntax coloring
  - Auto-indent
  - Brace matching
- Testing
  - Integrates with Junit testing framework
  - Interaction panel allows interactive method invocations
- Debugging
  - Integrates with Java debugger
  - Interactions panel also useful

Testing

How do I know my program works?

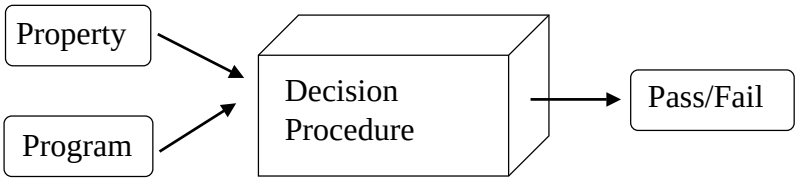
- Identify properties of interest
- Formally prove they are upheld, or
- Test them by running with various inputs

- But which properties? How do I do it? What if my program changes? When am I done? Ahhh!!!

- It gets worse …

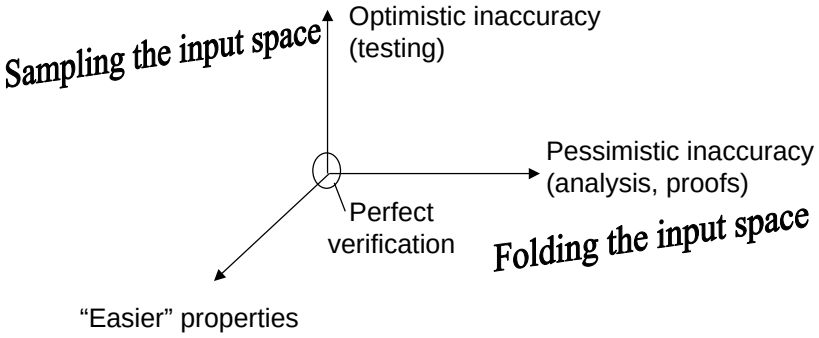
You can't ~~always~~ ever get what you want

- Correctness properties are undecidable
  - the halting problem can be embedded in almost every property of interest



Getting what you need ...

- We must make the problem of verification "easier" by permitting some kind of inaccuracy



Easier Properties - Example: Unmatched Semaphore Operations

```
if ( .... ) {
   ...
   lock(S);
}
...
if ( ... ) {
   ...
   unlock(S);
}
```

Static checking for match is necessarily inaccurate ... ... so Java prescribes a more restrictive, but statically checkable construct.

```
synchronized(S) {
        ...
        ...
}
```

Testing

- Executing the program on a sample of input data
- *Dynamic technique*: programs must be executed
- Optimistic inaccuracy
  - the program runs on a (very small) *subset* of input data
  - the behavior of the program on *every* input is assumed to be consistent with the examined behaviors

Goals of Testing

- Find faults ("Debug" Testing):
  - a test is successful *iff* the program fails[1]
- Provide confidence (Acceptance Testing)
  - of reliability
  - of (probable) correctness
  - of detection (therefore absence) of particular faults

1. *Goodeneogh, Gerhart, "Toward a Theory of Test Data Selection", IEEE Transactions on Software Engineering, Jan. 85*

Testing Activities

- Test case execution is only a part of the process
- Must also consider
  - Test case generation
  - Test result evaluation
- Planning is essential
  - To achieve early and continuous visibility
  - To choose appropriate techniques at each stage
  - To build a testable product
  - To coordinate complementary analysis and testing

The Test Case Generation Problem

- What tests will show that my program works?
  - Must consider “operational scenarios”
  - What is legitimate input?
  - What is the correct action or output?
- How can I make sure that all of the important behaviors of my program have been tested?

Granularity of Tests

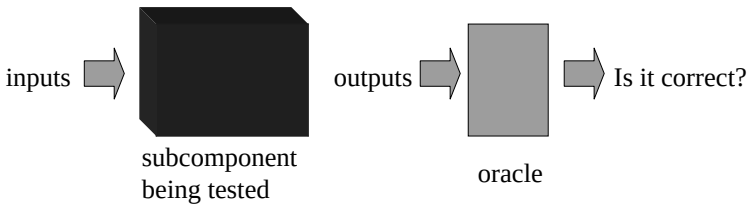
- Whole program
  - Test case inputs to whole program, and outputs examined
- Piece-meal
  - Individual components of a program are tested
    - Methods
    - Classes/packages
    - Processes of a distributed system

Styles of Tests

- Functional (black box)
  - based on specifications (“external behavior”)
- Structural (white box)
  - based on code
- Fault based
  - based on classes of faults

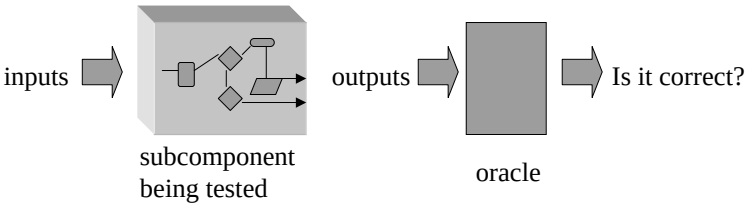
Black Box Testing

- Pick a subcomponent of the program
  - Internals of component not considered
- Give it inputs
- Compare against correct outputs



White Box Testing

- Pick a subcomponent of the program
- Give it inputs
  - Inputs determined based on component code
- Compare against correct outputs



White vs. Black box

- Black box
  - depends on spec
  - scales up
    - different techniques at different granularity levels
  - it cannot reveal code coverage problems
    - same specification implemented with different modules
- White box
  - depends on control or data flow coverage
  - does not scale up
    - mostly applicable at unit and integration testing level
  - cannot reveal missing path errors
    - part of the specification that is not implemented

The Testing Environment

- Want to create a scaffold for executing tests
  - Code infrastructure that allows tests to be run easily and the results checked for correctness
- Many benefits
  - Can automate testing process
  - Useful for regression testing
- But, can take some time to implement

Testing Environment Components

- A *user* to generate input for tested component
- An *oracle* for verifying the results are correct

- These two may be combined into a single system

Unit Testing with **Junit**

- Testing environment for writing black-box tests
  - Write special **TestCase** classes to test other classes
  - Several ways to use/set up test cases
- Can be downloaded from
  - http://www.junit.org
- Simple version included in Dr. Java
  - Implements only a subset of Junit functionality

Junit Philosophy

- Iterative, incremental process
  - Write small black-box test cases (as needed)
  - Test-as-you-go
    - i.e., after changes, when new method added, when bug identified
- **Junit** test cases must be completely automated
  - No human judgment
  - Easy to run many of them at the same time
- Goal: lots of bang for the buck
  - Even simple tests can find many bugs quickly

Junit Components

- Test cases (class **TestCase**)
  - Individual tests
  - Can reuse test case setup (optional)
- Test suites (class **TestSuite**)
  - Test case container
- Test runner (various classes)
  - Executes test suites and presents results

Each test has three 3 parts

- Code that creates test objects
  - Create a subclass of junit.framework.TestCase
- Code that executes the test
  - Override the method runTest() (which executes the test)
- Code that verifies the result
  - e.g., use junit.framework.assertTrue() to check results (throws exception is test fails)

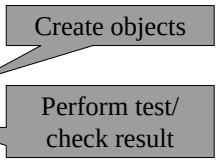
TestCase Example with LogRecord

```
public class LogRecordTest extends TestCase {
  protected String event1 = “test”;

public void testEquals1() {
    LogRecord tmp1 = new LogRecord(event1+”1”);
    LogRecord tmp2 = new LogRecord(event1+”2”);
    assertTrue(tmp1.equals(tmp1)); // should pass
    assertTrue(tmp1.equals(tmp2)); // should fail
  }

public void runTest () { testEquals1(); }

public static void main (String [] args) {
      TestResult result = (new LogRecordTest("testLogRecord")).run();
      if (!result.wasSuccessful()) { System.out.println(“Doh!”); }
} }
```



Setup/Teardown

- Creating objects for each test too simple
  - Setup overhead grows as number of tests grows
  - Instead, group setup (and teardown) code in one place and reuse
- junit.framework.TestCase.run() executes test case:
  - public void **run**() { setUp(); runTest(); tearDown(); }
  - Put setup code in setUp() method
  - Put cleanup code in tearDown() method

TestCase Example, again

```
public class LogRecordTest extends TestCase {
  protected String event1;
  LogRecord tmp1, tmp2;

  public void setUp() {
    event1 = “test”;
    tmp1 = new LogRecord(event1+”1”);
    tmp2 = new LogRecord(event1+”2”);
  }

  public void testEquals1() {
    assertTrue(tmp1.equals(tmp1)); // should pass
    assertTrue(tmp1.equals(tmp2)); // should fail
  }
  // other cases here will reuse tmp1, tmp2, event1, etc. …
}
```

Create objects at outset

Perform test/ check result