Running many tests with Test Suites

```
public class LogRecordTest extends TestCase {
  …
  public static Test suite() {
    TestSuite suite = new TestSuite();
    suite.addTest(new LogRecordTest("equals1") {
       protected void runTest() { testEquals1();}
    });
    suite.addTest( new LogRecordTest(“equals2") {
      protected void runTest() { testEquals2();}
    });
    return suite;
  }
}
```

Test Suites (cont’d)

- If you follow certain constraints (discussed later), you can create test suites more easily:

```
public static Test suite() {
    TestSuite suite = new TestSuite();
    suite.addTest(newLogRecordTest("testEquals1"));
    suite.addTest(newLogRecordTest("testEquals2"));
    return suite; }
```

- Or simply:

```
public static Test suite() {
    return new TestSuite(LogRecordTest.class); }
```

Test Runner

- To execute test suite, pick a class:
  - For graphical display
    - junit.awtui.TestRunner *TestCaseClass* or
    - junit.swingui.TestRunner *TestCaseClass*
  - For textual display
    - junit.textui.TestRunner *TestCaseClass*
- Or run from within your own code:

```
public static void main(String args[]) {
    junit.textui.TestRunner.run(suite());
}
```

Using **Junit** with **DrJava**

- At the top of the file, include:
  - **import junit.framework.TestCase;**
- The main class of the file:
  - must be **public**, extend **TestCase**, and have a constructor of the form:
    - **public** *classname***(String name) { super(name);**
- Tests run automatically
  - must be **public** and *not* **static**, return **void**, take no arguments, and have a name beginning with **test**
  - can use **suite()** as well
- Verify results using
  - **void assertTrue(String, boolean)**, **void assertEquals(String, int, int)**, and **void fail(String)**
- Set up tests using
  - **protected void setUp()**

Example

```
import junit.framework.*;
import java.io.*;

public class LogRecordTest extends TestCase {
  protected String event1, event2;
  LogRecord tmp1, tmp2, tmp3;

  public LogRecordTest(String name) { super (name); }

  protected void setUp() {
    event1 = "event string1"; event2 = "event string2";
    tmp1 = new LogRecord(event1);
    tmp2 = new LogRecord(event2);
    tmp3 = new LogRecord(event2);
  }

  public void testEquals1() { assertTrue(tmp1.equals(tmp1)); }
  public void testEquals2() { assertTrue(!tmp1.equals(tmp2)); }
```

Example, cont’d

```
  public void testEquals3() { assertTrue(!tmp3.equals(tmp2)); }

  public void testPubConstructor1() {
    assertTrue(tmp1.getEvent() == event1);
    assertTrue(tmp1.getTimestamp().compareTo(new java.util.Date()) <= 0);
  }

  public void testCompareTo1() {
    assertTrue (tmp1.compareTo(tmp1) == 0);
    assertTrue (tmp1.compareTo(tmp2) < 0);
    assertTrue (tmp2.compareTo(tmp1) > 0);
    assertTrue (tmp2.compareTo(tmp3) < 0);
    assertTrue (tmp3.compareTo(tmp2) > 0);
    assertTrue (tmp1.compareTo(tmp3) < 0);
    assertTrue (tmp3.compareTo(tmp1) > 0);
  }
```

Example, cont'd

```
public void testFormatFromFormat1() {
  StringWriter s = new StringWriter ();
  tmp1.format(new PrintWriter(s));
  LogRecord tmp4 = tmp1.fromFormat(new BufferedReader (new
    StringReader(s.toString())));
  assertTrue (tmp1.toString().equals(tmp4.toString()));
}
public static Test suite() {
  return new TestSuite(LogRecordTest.class);
}
public static void main(String args[]) {
  junit.textui.TestRunner.run(suite());
}
}
```

How to come up with tests?

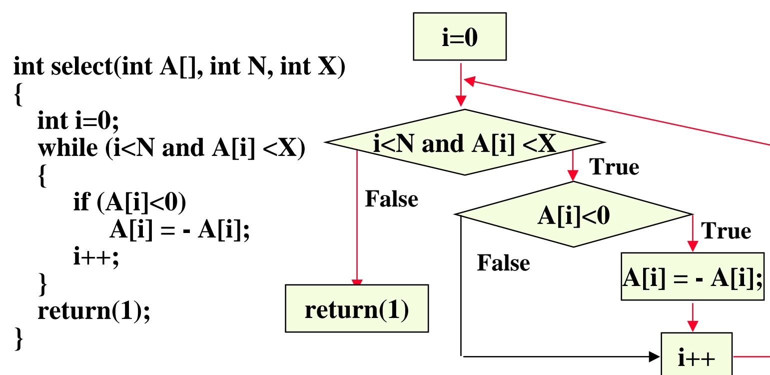
- Strive to write tests that completely "cover" the code we're testing
- Structural coverage testing (i.e. white box):
  - based on control flow of the program
  - it can be a reasonable and objective criterion
  - It can be (partially) automated
- But
  - no assurance of software quality

Structural Coverage Testing

- Adequacy criteria
  - If significant parts of program structure are not tested, testing is surely inadequate
- Control flow coverage criteria
  - Statement (node, basic block) coverage
  - Branch (edge) coverage
  - Condition coverage
- Attempted compromise between the impossible and the inadequate

Statement Coverage

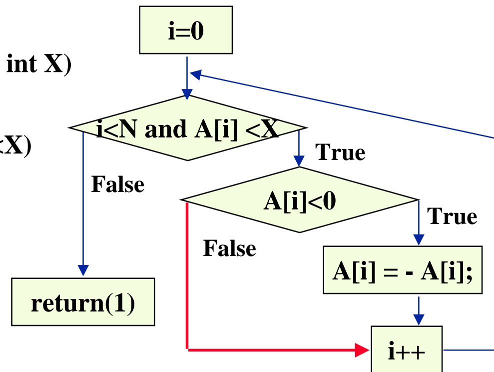
```
int select(int A[], int N, int X)
{
   int i=0;
   while (i<N and A[i] <X)
   {
      if (A[i]<0)
         A[i] = - A[i];
      i++;
   }
   return(1);
}
```



One test datum (N=1, A[0]=-7, X=9) is enough to guarantee statement coverage of function select
Faults in handling positive values of A[i] would not be revealed

Branch Coverage

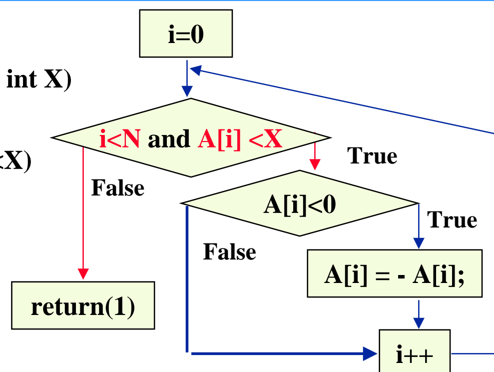
```
int select(int A[], int N, int X)
{
   int i=0;
   while (i<N and A[i] <X)
   {
      if (A[i]<0)
         A[i] = - A[i];
      i++;
   }
   return(1);
}
```



We must add a test datum (N=1, A[0]=7, X=9) to cover branch False of the if statement. Faults in handling positive values of A[i] would be revealed. Faults in exiting the loop with condition A[i] <X would not be revealed

Condition Coverage

```
int select(int A[], int N, int X)
{
   int i=0;
   while (i<N and A[i] <X)
   {
      if (A[i]<0)
         A[i] = - A[i];
      i++;
   }
   return(1);
}
```



Both conditions (i<N), (A[i]<X) must be false and true for different tests. In this case, we must add tests that cause the while loop to exit for a value greater than X. Faults that arise after several iterations of the loop would not be revealed.

Debugging

Debugging

- My program doesn’t work: why?
- Some part of the program has a “bug;” narrow down the possible locations of the bug
  - Figure out which parts of the program work
  - Test the rest
  - Iterate
- How to figure out which parts work?
  - Testing!

Starting to Debug

- What are the symptoms of the misbehavior?
  - Input/output
  - Stack trace (from thrown exception)
- At what point did the program fail?
- Reason backwards: what could have led to this failure?
- What invariants should have been preserved?
- Test the invariants, narrow down the problem

Checking that Invariants Hold

- Print statements
  - Print out expected invariants
- Automatic debugger
  - Allows you to step through the program interactively
  - Verify expected invariants
  - Use as part of testing

Dr. Java Interactions Pane

- Can evaluate Java expressions interactively
  - Can bind variables, execute expressions/statements
- Benefits
  - Make sure that methods work as expected
  - Test invariants by constructing expressions not in program text
  - Combines with interactive debugger

Dr. Java's Automatic Debugger

- Set execution breakpoints
- Step through execution
  - **into**, **over**, and **out** of method calls
- Examine the stack
- Examine variable contents
- Set watchpoints
  - Notified when variable contents change

Using the Debugger

- Start Dr. Java with the debug libraries:
  - java -classpath /usr/local/drjava/drjava-20020814.jar:/usr/local/j2sdk1.4.0/lib/tools.jar edu.rice.cs.drjava.DrJava
- Creates debugging menu
  - Select debug mode to on
    - Turns on debug panel with state information
- Set break point(s) in Java source
- Run the program

Tips

- Make the bug reproducible
  - If it's not reproducible, what does that imply?
- Boil it down to the smallest program that reproduces the bug
  - Reveals the core problem
- Explain the problem to someone else (i.e. the instructor or TA)
  - Explaining may reveal the flaw in your logic
- Keep notes: don't make the same mistake twice

Avoiding Errors

- Test as you go
  - Using Junit
  - Using the on-line debugger
- Do not ignore possible error states
  - Deal with exceptions appropriately
- Codify your invariants
  - Include assertions in the code when entering/exiting functions, iterating on loops

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