Verifying and Documenting ADTs: Javadoc, Java Assertions and JUnits

Documenting Java Code

- Regular Java comments: /* … */
  - for programmers who must *read or modify* your code
- "One Liners": // …
  - for programmers who must *read or modify* your code
- Javadoc comments: /** … */
  - for those who must ***use*** your code

Comments and Documentation

- Already mentioned distinction between comments and documentation
  - **Comments** embedded in the code
    - for the benefit of you and other programmers
  - **Documentation** separate from the code
    - for the benefit of anyone who wants to use your code
- Both are essential in software of any size
  - traditionally completely separate
  - but Java provides a tool to help bridge this gap…

JavaDoc

- A tool that reads comments and produces documentation from them
  - Comments must be written in a *particular style*
  - Documentation generated is limited to a particular style
    - not complete on its own
    - still need user manuals etc…

General Form of a JavaDoc Comment (1/2)

- **The first line** is indented to line up with the code below the comment, and starts with the begin-comment symbol (/**) followed by a return
- **Subsequent lines** start with an asterisk (*). They are indented an additional space so the asterisks line up. A space separates the asterisk from the descriptive text or tag that follows it
- Insert a **blank comment line** between the description and the list of tags, as shown
- Insert additional blank lines to create **"blocks" of related tags**

```
/**
 * This is the description part of a doc comment.
 *
 * @tag Comment for the tag
 */
```

General Form of a JavaDoc Comment (2/2)

- **The last line** begins with the end-comment symbol (*/) indented so the asterisks line up and followed by a return
  - Note that the end-comment symbol contains *only a single asterisk* (*)
- Break any doc-comment lines exceeding 80 characters in length, if possible
  - If you have more than one paragraph in the doc comment, separate the paragraphs with a <p> paragraph tag
- Comments can contain **HTML tags** (including links)

First Sentence

- Should be a **summary sentence**, containing a concise but complete description of the API item
- The Javadoc tool copies this first sentence to the appropriate member, class/interface or package summary
- This sentence ends at the first period that is followed by a blank, tab, or line terminator, or at the first tag (as defined below). For example, this first sentence ends at "Prof.":

```
/**
 * This is a simulation of Prof. Knuth's MIX computer.
 */
```

- you can work around this by typing an HTML meta-character such as "&" or "<" immediately after the period, such as:

```
/**
 * This is a simulation of Prof.  Knuth's MIX computer.
 */
```

Tagged Paragraphs

- Tags that can be inserted in comments depend on what is commented:
  - **class**
    - general description, cross-references, author, version
  - **field**
    - general description, cross-references
  - **method**
    - general description, cross-references, parameters, return value
- Tagged Paragraphs begin with @followed by keyword
  - End at the next tag or end of the comment

JavaDoc Comment Syntax

- Required syntax:

```
/**
 * general comment
 * @tag1 value for tag1
 * @tag2 value for tag2
 *  …
 * @tagn value for tagn
 */
```

- Anything that doesn't conform to this syntax is ignored!

Main Tags:

author:	@author
version:	@version
cross-reference:	@see
method parameter:	@param
method return value:	@return

@see (Cross-References)

- **Classes**
  - *ClassName* e.g. `@see Amoeba`
- **Fields**
  - *#LocalFieldName* e.g. `@see #number_of_feet`
  - *ClassName#FieldName* e.g. `@see Mammal#number_of_feet`
- **Methods**
  - *#LocalMethodName* e.g. `@see #sayHello`
  - *ClassName#MethodName* e.g. `@see Student#sayHello`
  - *ClassName#MethodName(params)* e.g. `@see Person#sayHello(String)`
- **Other docs**

```
@see <a href="spec.html">Java Spec</a>
```

@author

- May be used for class and interface declarations

```
@author Nikos Armenatzoglou
```

- A documentation comment may contain more than one `@author` tag

```
@author Nikos Armenatzoglou
@author Vassilis Christophides
```

@version

- May be used for class and interface declarations

```
@version 493.0.1beta
```

- A documentation comment may contain at most one @version tag

@param

- May be used in comments for method and constructor declarations

```
@param i The begin index
```

- Parameters should be documented in the order in which they are declared

@return

- Used to provide a short description of the return value

```
@return The object at the top of the stack
```

- May be used in documentation comments for declarations of methods whose result type is not `void`
- Cannot be used in constructors (constructors do not return anything; only create!!!)

@exception (or @throws)

- May be used in documentation comments for method and constructor declarations

```
@throws IndexOutOfBoundsException The matrix is
  too large
```

- The name of the class followed by a short description of when it is thrown

@deprecated

- Adds a comment indicating that this API should no longer be used (even though it may continue to work).

```
@deprecated deprecated-text
```

- Javadoc moves the deprecated-text ahead of the description, placing it in *italics* and preceding it with a bold warning: **"Deprecated".**

- The first sentence of *deprecated-text* should at least tell the user when the API was deprecated and what to use as a replacement.

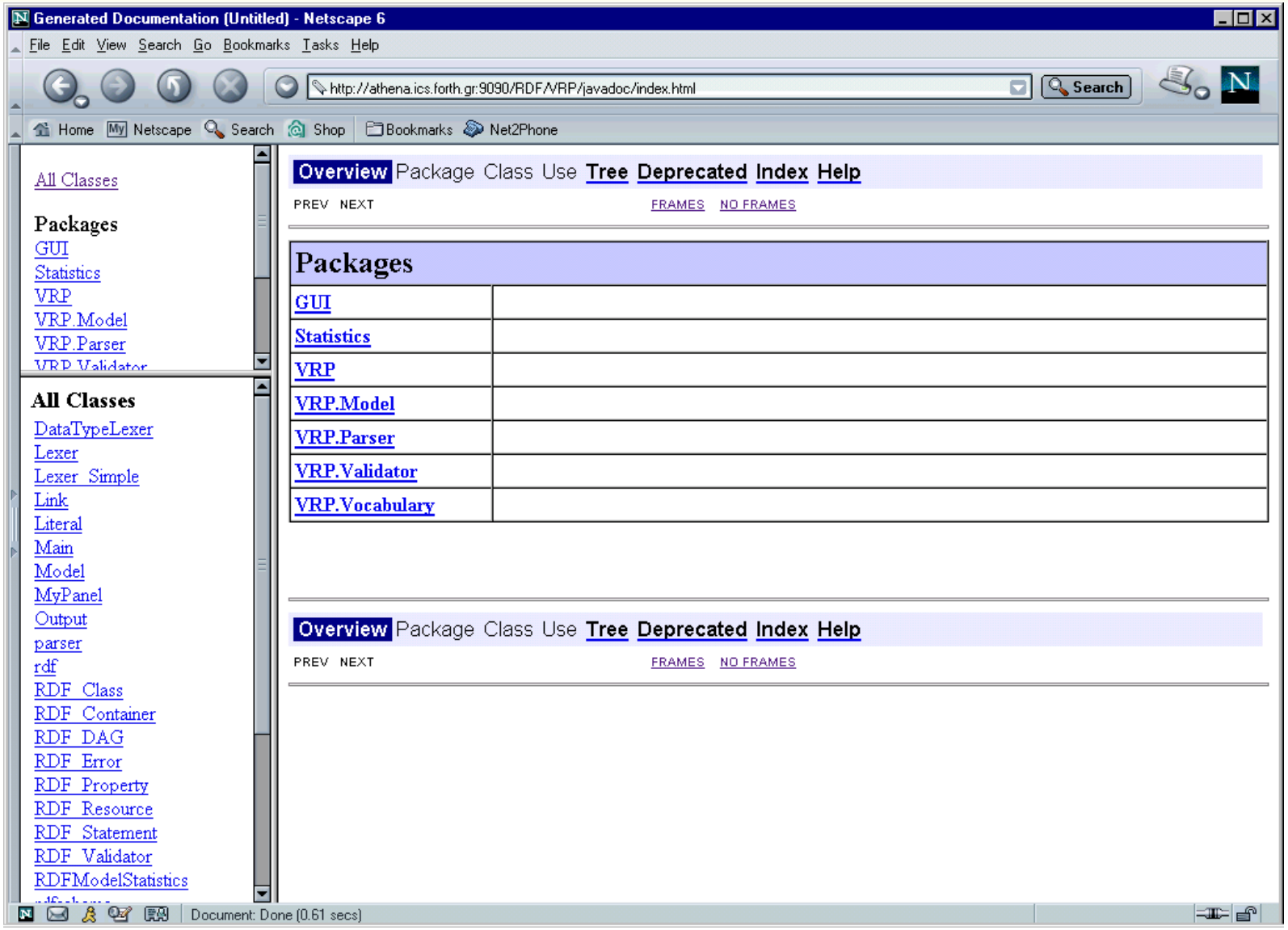
JavaDoc Example (1/3)

```
/**
 * The root of the Class hierarchy. Every Class in the
 * system has Object as its ultimate parent. Every
 * variable and method defined here is available in every
 * object.
 *
 * @see  Class
 * @version  1.37, 6 Nov 2007
 */

public class Object {
     …
}
```

JavaDoc Example (2/3)

```
/**
 * Compares two Objects for equality.
 * Returns a boolean that indicates whether this Object
 * is equivalent to the specified Object. This method is
 * used when an Object is stored in a hashtable.
 *
 * @param  obj  The Object to compare with
 * @return True if these Objects are equal;
 *           false otherwise
 * @see    java.util.Hashtable
 */

public boolean equals (Object obj) {
      return (this == obj);
}
```

JavaDoc Example (3/3)



Running Javadoc

- Synopsis:

  javadoc [options] [packagenames] [sourcefiles] [@files]

- Example:
  - Directory where the .html output of the javadoc will be stored: api/
  - Directories with source code: `src/` and `src/folder/`

```
javadoc -d api/ src/*.java src/folder/*.java
```

- For further information type "*javadoc*" at your command line…

Style Guidelines

- Be brief
  - don't repeat things that are obvious from names and types
- Avoid repeating subject
  - e.g. Gets the name. *Not* This method gets the name
  - e.g. The age. *Not* This field contains the age
- Use 3rd person for methods
  - e.g. Gets the label. *Not* Get the label

Adding Preconditions and Postconditions in Javadoc

- In JDK 1.4, we can add preconditions and postconditions as simple Javadoc comments.

```
/**
 * Creates a substring of this string.
 *
 * Precondition: 0 ≤ i < j ≤ length().
 * Postcondition: Returns the substring of this string
 * consisting of the characters whose indexes are i,…,j-1
 * @param i The begin index
 * @param j The end index
 * @return The substring of this string consisting of the
 * characters whose indexes are i, …, j-1
 */
public String substring (int i, int j);
```

Assertions

Verifying your code with assertions

- An *assertion* is a statement that enables you to test your assumptions about your program
- SDK 1.4 introduces a new keyword assert, which allows the insertion of assertions in a Java program.
- Each assertion contains a boolean expression that you believe will be true when the assertion is executed
  - If it is not true, the system will throw an error `AssertionError` (subclass of `java.lang.Error`)
- Assertions can be *activated during the test phase* of the development and *deactivated in the production*

Syntax

- `assert` *`assertion`*`;`

  where *assertion* is a boolean expression

- `assert` *`assertion`* `:` *`expression`*`;`
  - *assertion*: a boolean expression
  - *expression*: is an expression that has a value (It cannot be an invocation of a method that is declared void)
    - passes the value of *expression* to the appropriate `AssertionError` constructor, which uses the string representation of the value as the error's detail message.

Why use assertions?

- By verifying that the boolean expression is indeed true, the assertion confirms your assumptions about the behavior of your program, increasing your confidence that the program is free of errors

- Experience has shown that writing assertions while programming is one of the quickest and most effective ways to detect and correct bugs

Where to use assertions

- **Internal Invariants**
  - assert that an internal invariant has actual *the value that it's expected to have*
- **Control-Flow Invariants**
  - place an assertion at any location you assume *will not be reached*
- **Preconditions, Postconditions**, and **Class Invariants**
  - it can help support an informal *design-by-contract* style of programming

Internal Invariants (1/2)

- Programmers are used to write comments to indicate their assumptions concerning a program's behavior, ex.

```
if (i % 3 == 0) {
        ...
} else if (i % 3 == 1) {
        ...
} else {
 // We know (i % 3 == 2)
        ...
}
```

```
if (i % 3 == 0) {
        ...
} else if (i % 3 == 1) {
        ...
} else {
        assert i % 3 == 2 : i;
        ...
}
```

Use an assertion whenever you would have written a comment that asserts an invariant

Internal Invariants (2/2)

- Another good candidate for an *assertion* is a switch statement with no default case.

```
switch(suit) {
      case Suit.CLUBS:
            ...
            break;
      case Suit.DIAMONDS:
            ...
            break;
      case Suit.HEARTS:
            ...
            break;
      case Suit.SPADES:
            ...
}
```

The absence of a default case typically indicates that a programmer believes that one of the cases will always be executed

```
default:
 assert false: suit;
```

Control-Flow Invariants

- Place an assertion at any location you assume will not be reached
- For example, suppose you have a method that looks like this:

```
void foo() {
      for (...) {
            If (...)
                return;
      }
   // Execution should never
   // reach this point!!!
}
```

```
void foo() {
      for (...) {
            If (...)
                return;
      }
      assert false;
}
```

Use this technique with discretion

If a statement is unreachable as defined in the Java Language Specification, you will get a compile time error, if you try to assert that it is not reached.

Preconditions

Assert what must be true when a method is invoked. **BUT…**

- **Do not use** assertions to check the parameters of a public method…
  - Preconditions on public methods are enforced by explicit checks that throw particular, specified exceptions
  - It must check its arguments whether or not assertions are enabled
  - The assert construct does not throw an exception of the specified type. It can throw only an *AssertionError*

- **Use** an assertion to test a non-public method's precondition that you believe it will be true no matter what a client does with the class.

Postconditions

You **can** test postcondition with assertions in both public and non-public methods

```
/** Returns a BigInteger whose value is (this-1 mod m).
 *
 * @param  m the modulus.
 * @return this-1 mod m.
 * @throws ArithmeticException  m <= 0, or this BigInteger
 * has no multiplicative inverse mod m (that is, this BigInteger
 * is not relatively prime to m).
 */
public BigInteger modInverse (BigInteger m) {
     if (m.signum <= 0)
       throw new ArithmeticException("Modulus not positive: " + m);
            ... // Do the computation
     assert ( ((this-1)*result) % m ) == 0 : this;
      return result;
}
```

Class Invariants

- A class invariant is a type of internal invariant that applies to every instance of a class at all times, except when an instance is in transition from one consistent state to another.
- That is, a class invariant should be true before and after any method completes

- ex. implement a balanced tree data structure
  check that *insertObject()* method, after the end of an insertion and before the *return;* statement, keeps the tree in fact balanced.

```
// Returns true if this tree is properly balanced
private boolean balanced() {
      ...
}
assert balanced();
```

Where **not** to use assertions

- **DO NOT** use assertions for:
  - Argument checking in public methods
    - Correct arguments is part of the published specifications(or ***contract***) of a method and must be obeyed whether assertions are enabled or disabled
    - Erroneous arguments should result in an appropriate **runtime exception**
  - Doing any work that your application requires for correct operation
    - Assertions may be disabled, thus expression contained in an assertion may not be evaluated

```
// Broken! - Action is contained in assertion
assert names.remove(null);
```

```
// Fixed - Action precedes assertion boolean
nullsRemoved = names.remove(null);
assert nullsRemoved;
//Runs whether or not asserts are enabled
```

Compiling Files That Use Assertions

- For the javac compiler to accept code containing assertions, you must use the "**-source 1.4**" command-line option:

```
%> javac -source 1.4 MyClass.java
```

Enabling and Disabling Assertions

- By **default**, assertions are disabled at runtime
- **Enable** assertions at runtime:
  - `-enableassertions` or `-ea`
- **Disable** assertions at runtime:
  - `-disableassertions` or `-da`

Granularity

- You can specify the granularity:
  - ***no arguments***
    - enables or disables assertions in all classes except system classes
  - ***packageName***
    - enables or disables assertions in the named package and any subpackages
  - ***className***
    - *enables or disables assertions in the named class*
  - ***...***
    - enables or disables assertions in the unnamed package in the current working directory

```
java -ea:com.wombat.fruitbat...
-da:com.wombat.fruitbat.Brickbat BatTutor
```

The ADT Stack

- A stack is a LIFO queue of objects
- The elements of the stack have consecutive indices starting from 0 in the topmost element

- Assuming application requirements. It must be possible:
  - To make an empty stack
  - To add an element to the top of a stack
  - To remove the topmost element from a stack
  - To test whether a stack is empty
  - To access the element at the top of the stack without removing it
  - To find the position of an object in the stack

ADT Stack Operations

- The operations defined in a possible contract of ADT Stack are:

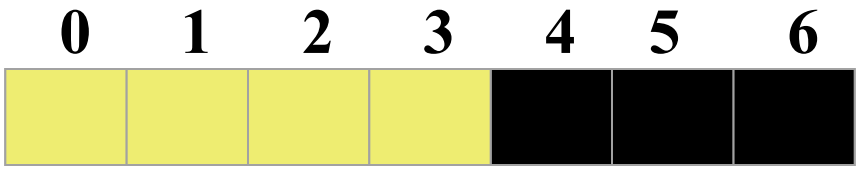
```
{ Stack():                    -> Stack
} isEmpty(): Stack -> Boolean
  peek():           Stack -> Object
  search(elem):     Stack x Object -> Int
  clear():          Stack -> Stack (void)
  push(elem):       Stack x Object -> Stack (void)
  pop():            Stack -> Stack (void)
```

Stack Interface

```
/**
 * Every Class that implements a Stack ADT should
 * implement this interface.
 *
 * @version 1.0
 */
public interface Stack {
 // Method headers and comments go here
 void push (Object item) throws IllegalArgumentException;
 Object pop () throws IllegalStateException;
 Object peek () throws IllegalStateException;
 boolean isEmpty ();
 void clear ();
 int search (Object item);
}
```

ArrayStack

- We implement the stack itself as an Array of Objects
- The top of the stack is an integer index to the last position of the array




```
top = 3
```

- Make the decision that the size of the array can change dynamically (Assumption: All stacks start with size 100)

ADT Stack Code

```
/**
 * A stack implementation using Array.
 * The capacity of the Array is set to default but it can
 * change dynamically if needed.
 *
 * @version 1.0
 * @author Nikos Armenatzoglou
 */
public class ArrayStack implements Stack {
  // The default capacity of the Array
  public final static int DEFAULT_CAPACITY = 100;

  private Object stack[];       // The stack itself
  private int top;              // index of the top of the
                                // stack.
```

ADT Stack Code

```
/**
 * Create a stack with Default Capacity
 */
public ArrayStack() {
    stack = new Object[DEFAULT_CAPACITY];
    top = -1; //No items:top can't point to anything useful
    assert stack != null;           //postcondition
}

/**
 * Tests if this stack is empty.
 *
 * @returns  true if and only if this stack contains no
 * items; false otherwise.
 */
public boolean isEmpty() {  return top == -1; }
```

ADT Stack Code

```
/**
 * Looks at the object at the top of this stack without
 * removing it from the stack.
 *
 * @return the object at the top of this stack
 * @throws IllegalStateException If this stack is empty.
 */

public Object peek() throws IllegalStateException  {
    if (isEmpty())
        throw new IllegalStateException ("Stack is empty");
    assert top != -1: top;
    assert stack[top] != null;                  // Invariant
    return stack[top]; // return a reference to the item
                       // on top of the stack
}
```

ADT Stack Code

```
/**
 * Adds an item to the top of the stack.
 *
 * @param  item the Object to be pushed onto the Stack
 * @return void
 * @throws IllegalArgumentException If item is null
 */
public void push(Object item) throws IllegalArgumentException{
   if (item == null)
      throw new IllegalArgumentException("item cant be null");
   if (isFull())
      resizeStack();       // resizeSatck would be a private
                           // arrayStack method
   top++;                  // Increment top index
   stack[top] = item;      // Add item to new top position
   assert stack[top] == item;          // postcondition
}
```

ADT Stack Code

```
/**
 * Removes the object at the top of this stack and
 * returns that object as the value of this function.
 *
 * @return The object at the top of this stack
 * @throws  IllegalStateException - If this stack is
 * empty.
 */
public Object pop() throws IllegalStateException {
      if (isEmpty()) {
         throw new IllegalStateException("Stack is empty");
      }
      Object topItem = stack[top];
      stack[top] = null; //Remove ref to item on stack
      top--;                // increment top
      return topItem;       // return the item that was popped
}
```

ADT Stack Code

```
/**
 * Searches for the specified object in the stack and
 * returns it's position.
 *
 * @param obj The object to find in the stack
 * @return The object's position in this stack, -1 if
 * object wasn't found
 * @throws  IllegalStateException If this stack is empty.
 */
public int search(Object obj) throws IllegalStateException {
      if (isEmpty())
         throw new IllegalStateException ("Stack is empty");
      for (int i = 0; i < top; i++) {
            if (stack[i] == obj)
                  return i;
      }
      assert i == top : i;
      return -1;
}
```

ADT Stack Code

```
  /**
   * Clears this stack from all elements.
   */
  public void clear() {
      while (top !=-1) {
            stack[top--] = null;
      }
      assert top == -1 : top;          // postcondition
      return;
  }

} // end of class ArrayStack
```

JUnit

A tool for test-driven development

History

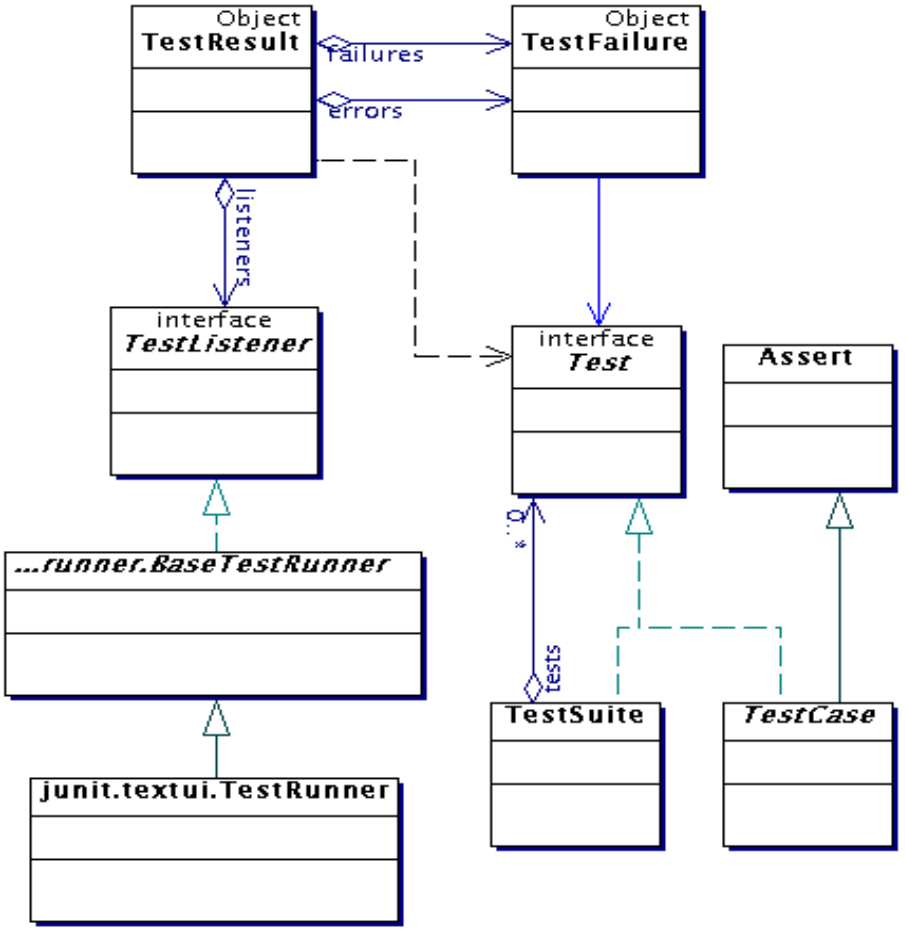
- Kent Beck developed the first xUnit automated test tool for Smalltalk in mid-90's
- Beck and Gamma (of design patterns Gang of Four) developed JUnit on a flight from Zurich to Washington, D.C.
- Martin Fowler: "Never in the field of software development was so much owed by so many to so few lines of code."
- Junit has become the standard tool for Test-Driven Development in Java (see Junit.org)
- Junit test generators now part of many Java IDEs (Eclipse, BlueJ, Jbuilder, DrJava)
- Xunit tools have since been developed for many other languages (Perl, C++, Python, Visual Basic, C#, …)

Why Create a Test Suite?

- Obviously you have to test your code—right?
  - You can do *ad hoc* testing (running whatever tests occur to you at the moment), or
  - You can build a test suite (a thorough set of tests that can be run at any time)
- Disadvantages of a test suite
  - It's a lot of extra programming
    - True, but use of a good test framework can help quite a bit
  - You don't have time to do all that extra work
    - *False!* Experiments repeatedly show that test suites reduce debugging time more than the amount spent building the test suite
- Advantages of a test suite
  - Reduces total number of bugs in delivered code
  - Makes code much more maintainable and refactorable

Architectural Overview

- JUnit test framework is a package of classes that lets yo write tests for each method, th easily run those tests
- **TestRunner** runs tests and reports **TestResult**s
- You test your class by extend abstract class ***TestCase***
- To write test cases, you need know and understand the **Assert** class



Writing a TestCase

- To start using JUnit, create a subclass of *TestCase*, to which you add test methods
- Here's a skeletal test class:

```
import junit.framework.TestCase;
public class TestBowl extends TestCase {
} //Test my class Bowl
```

- Name of class is important – should be of the form ***Test***MyClass or MyClass***Test***
- This naming convention lets TestRunner automatically find your test classes

Writing methods in TestCase

- Pattern follows ***programming by contract*** paradigm:
  - Set up **preconditions**
  - Exercise functionality being tested
  - Check **postconditions**
- Example:

```
public void testEmptyList() {
  Bowl emptyBowl = new Bowl();
  assertEquals("Size of an empty list should be zero.",
        0, emptyBowl.size());
  assertTrue("An empty bowl should report empty.",
              emptyBowl.isEmpty());
}
```

- Things to notice:
  - Specific method signature – public void ***test***Whatever()
    - Allows them to be found and collected automatically by JUnit
  - Coding follows pattern
  - Notice the assert-type calls…

Assert methods

- Each assert method has parameters like these:
  message, expected-value, actual-value
- Assert methods dealing with floating point numbers get an additional argument, a tolerance
- Each assert method has an equivalent version that does not take a message – however, this use is not recommended because:
  - messages helps documents the tests
  - messages provide additional information when reading failure logs

Assert methods

- assertTrue(String *message*, Boolean *test*)
- assertFalse(String *message*, Boolean *test*)
- assertNull(String *message*, Object *object*)
- assertNotNull(String *message*, Object *object*)
- assertEquals(String *message*, Object *expected*, Object *actual*)
  - (uses equals method)
- assertSame(String *message*, Object *expected*, Object *actual*)
  - (uses == operator)
- assertNotSame(String *message*, Object *expected*, Object *actual*)

More stuff in test classes

- Suppose you want to test a class `Counter`
- `public class CounterTest extends junit.framework.TestCase {`
  - This is the unit test for the `Counter` class
- `public CounterTest() { } //Default constructor`
- `protected void setUp()`
  - Test *fixture* creates and initializes instance variables, etc.
- `protected void tearDown()`
  - Releases any system resources used by the test fixture
- `public void testIncrement(), public void testDecrement()`
  - These methods contain tests for the `Counter` methods `increment()`, `decrement()`, etc.
  - Note capitalization convention

JUnit tests for Counter

```
public class CounterTest extends junit.framework.TestCase {
 Counter counter1;
 public CounterTest() { } // default constructor
 protected void setUp() {// creates a (simple) test fixture
    counter1 = new Counter();
 }
 public void testIncrement() {
    assertTrue(counter1.increment()==1);
    assertTrue(counter1.increment()==2);
 }

 public void testDecrement() {
    assertTrue(counter1.decrement()==-1);
 }
}
```

Note that each test begins with a *brand new* counter

This means you don't have to worry about the order in which the tests are run

TestSuites

- TestSuites collect a selection of tests to run them as a unit
- Collections automatically use TestSuites, however to specify the order in which tests are run, write your own:

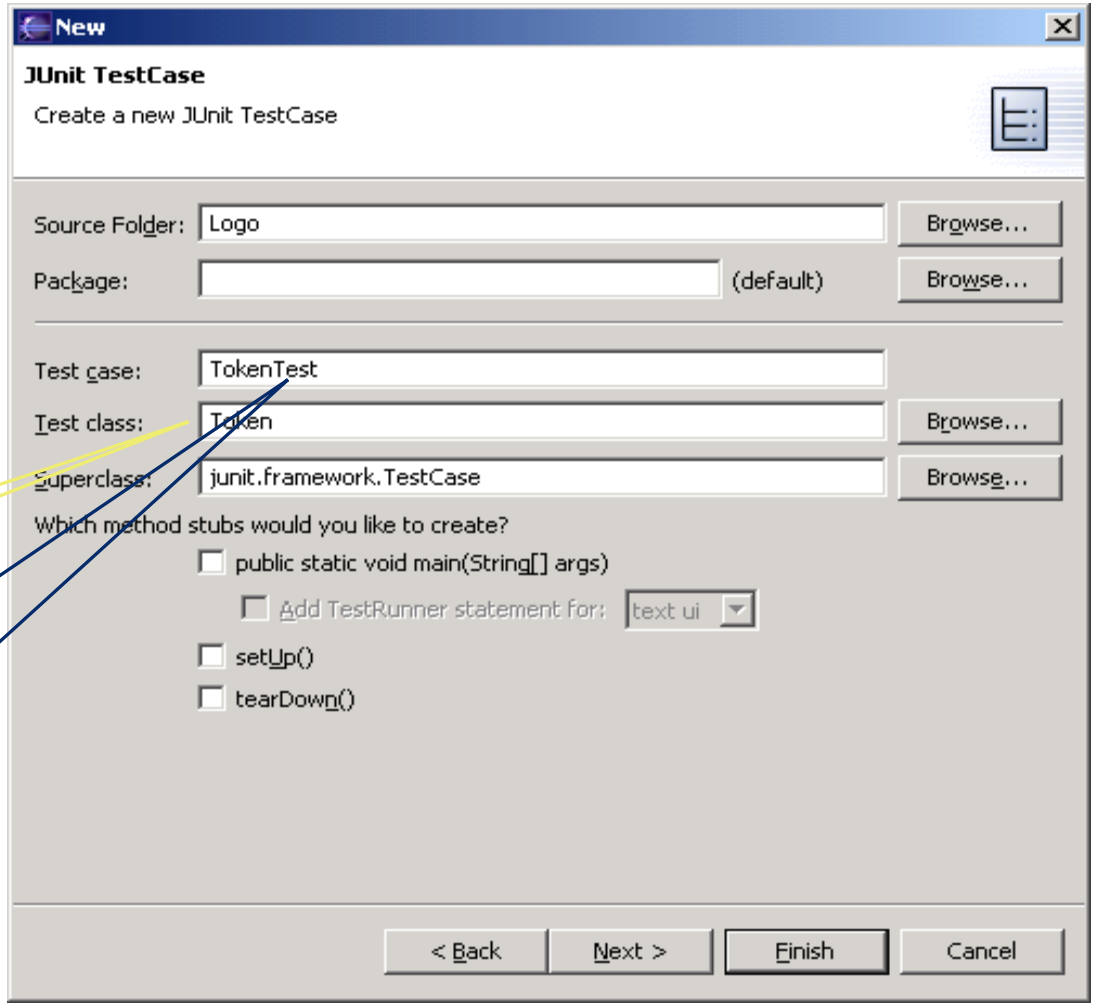
```
public static Test suite() {
      suite.addTest(new TestBowl("testBowl"));
      suite.addTest(new TestBowl("testAdding"));
      return suite;
}
```

- Should seldom have to write your own TestSuites as each method in your TestCase should be independent of all others
- Can create TestSuites that test a whole package:

```
public static Test suite() {
      TestSuite suite = new TestSuite();
      suite.addTestSuite(TestBowl.class);
      suite.addTestSuite(TestFruit.class);
      return suite;
}
```

JUnit in Eclipse

- To create a test class, select File→ New→ Other… → Java, JUnit, TestCase and enter the name of the *class* you will test



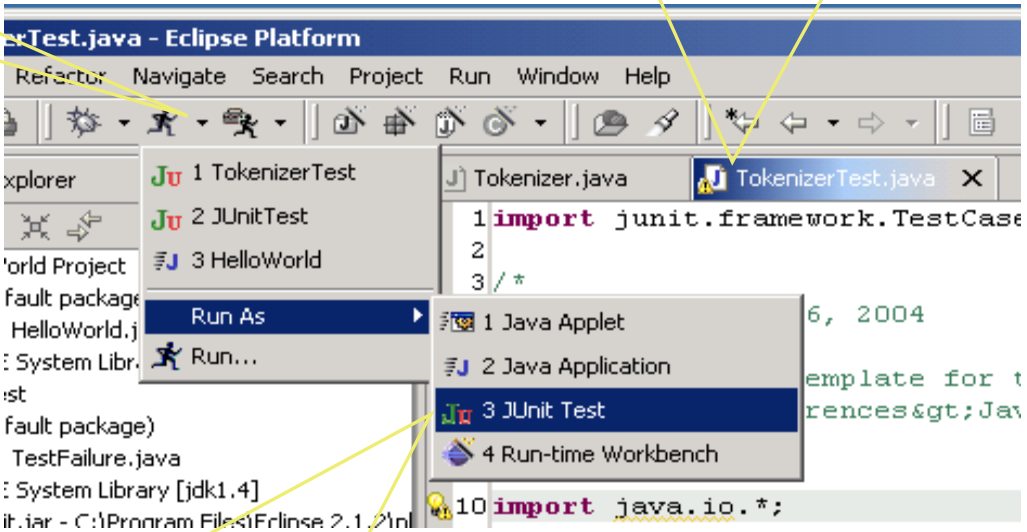
Fill this in

This will be filled in *automatically*

Running JUnit

Second, use this pulldown menu

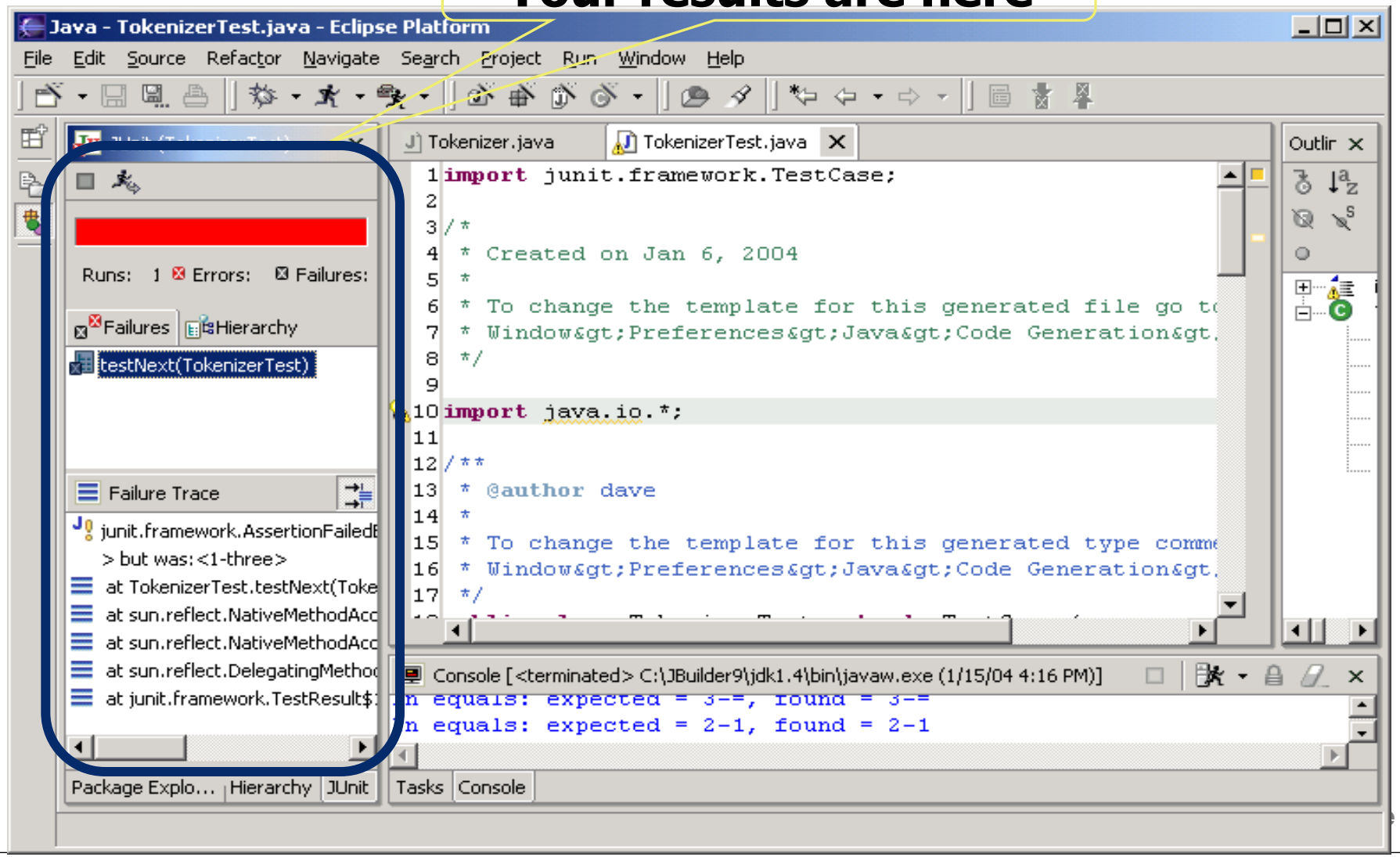
First, select a *Test* class



Third, Run As → JUnit Test

Results

Your results are here



More Information

- http://www.junit.org
  - Download of JUnit
  - Lots of information on using JUnit
- http://www.thecoadletter.com
  - Information on Test-Driven Development