

APIT - Java recap etc

Dr. Simon Rogers

29/12/2018

Overview

- ▶ Introduction
- ▶ Objects, interfaces etc
- ▶ Immutable objects
- ▶ Call by reference / value
- ▶ Final
- ▶ Testing
- ▶ Documenting
- ▶ Tools

Programming

Compiling and running Java from the command line

- ▶ I will do this in class
- ▶ In simplest case, it involves two steps:
 - ▶ Compiling: `javac MyClass.java`
 - ▶ Running: `java MyClass`
- ▶ We will see some more complex examples throughout the course
- ▶ Feel free to use Eclipse if you prefer
- ▶ Also, Visual Studio Code...

Organising projects

- ▶ All the programs in this course involve small numbers of classes
- ▶ For larger projects, it is important to organise all your files in a standard manner
 - ▶ Eclipse does this automatically
- ▶ If you want to do it manually, good description is available [here](#)

Classes

- ▶ Classes define objects
- ▶ Pet is a simple class used by PetTest
- ▶ Classes allow us to neatly combine related attributes and methods

Inheritance

- ▶ One of the big strengths of OOP is *inheritance*
 - ▶ Creating classes that *inherit* everything of another class and add more
 - ▶ e.g. Dog, Goldfish, PetInheritanceTest
- ▶ In this example we also see overridden methods
 - ▶ Dog and Goldfish override the description method
 - ▶ The loop does not care which subclass the objects belong to.
 - ▶ This is very useful in many applications - *polymorphism*

Abstract Classes

- ▶ Standard classes can be *instantiated*
 - ▶ i.e. we can create objects of their type (e.g. Pet, Dog, etc)
- ▶ Java allows you to define classes that cannot be instantiated:
Abstract classes
- ▶ Abstract classes can only be sub-classed
 - ▶ e.g. AbstractPet, Cat and AbstractPetTest
- ▶ There is no situation where you would *have* to use an abstract class but many where it's neater
- ▶ Note that sub-classes have to implement all abstract methods or be abstract themselves

Interfaces

- ▶ Interfaces are similar to abstract classes but:
 - ▶ Cannot have fields (unless they are `static` and `final`)
- ▶ See `InterfacePet`, `Parrot` and `TestInterfacePet`
- ▶ Interfaces are like contracts: they just specify the methods a class must implement
 - ▶ Note that methods in interfaces are abstract by default
- ▶ Note:
 - ▶ Classes can only sub-class one class...
 - ▶ ...but can implement many interfaces

Some odds and ends

public, private and protected

- ▶ Fields/attributes and methods are either public, private, or protected
 - ▶ Public: anything can access
 - ▶ Private: only objects of this type can access
 - ▶ e.g. `provideBone` method in `Dog`
 - ▶ Protected: only objects of this type, sub-classes (and other things within the same package)
 - ▶ e.g. `name` and `age` in `Pet` and `AbstractPet`
- ▶ In general, be as restrictive as possible.

static

- ▶ Fields and methods can also be declared `static`
- ▶ This means that they are accessible without an object being instantiated
- ▶ Useful for storing generic methods and constants
- ▶ e.g. `MyMath` and `MyMathTest`
 - ▶ `areaOfCircle` is used without creating a `MyMath` object
 - ▶ Another static thing is used here - what is it?

static attributes

- ▶ Static attributes within an object are *shared* by all instances
- ▶ Change the value in one, and it will change in all of the others. . .
 - ▶ Useful, but not always the neatest solution

Memory in Java

- ▶ Most data in Java is stored in Objects
- ▶ Objects are stored in an area of memory called the *heap*
 - ▶ There is one heap for the whole program
- ▶ Each thread has its own stack
 - ▶ All programs have at least one thread
 - ▶ In your programmes so far, there is one thread

The Stack

- ▶ The stack is used for three purposes:
 - ▶ Evaluating expressions
 - ▶ Storage of local variables (variables in the current *scope*)
 - ▶ Management of method calls
- ▶ Think of it as a stack of paper.
 - ▶ Pieces of paper are put on (pushed), and taken off (popped), the top of the pile
 - ▶ LIFO: Last In First Out

The Heap

- ▶ The heap is an area of memory used to store objects in Java
- ▶ Objects in the heap are accessible from any part of the program that has a local reference to the object
- ▶ Threads share a single heap
 - ▶ i.e. each thread can access objects in the heap
 - ▶ Useful, but causes all of the multi-threading problems we will see
- ▶ In Java, objects are stored in the heap, references to objects are stored in the stack
 - ▶ This is very important, and we will come back to it later. . .

Garbage collection

- ▶ Java periodically deletes objects when they are not needed
- ▶ An object is not needed if it is *unreachable*
 - ▶ i.e. no references to it exist


```
public class Garbage {  
    public static class A {  
        B b;  
        public A(B b) {  
            this.b = b;  
        }  
    }  
    public class B {}  
    public static void main(String[] args) {  
        B b = new B();  
        A a = new A(b);  
        B b1 = new B();  
        B b2 = new B();  
        b = null;  
        b2 = null;  
    }  
}
```

Figure 1: Example program

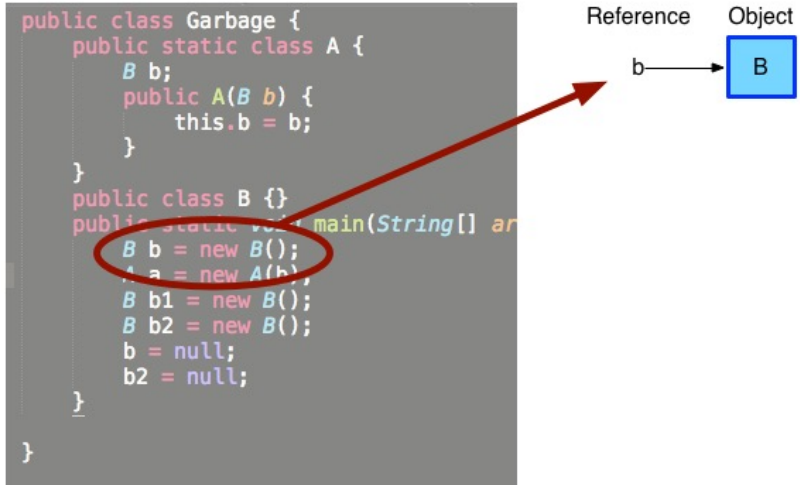


Figure 2: Object (B) and reference (b) created

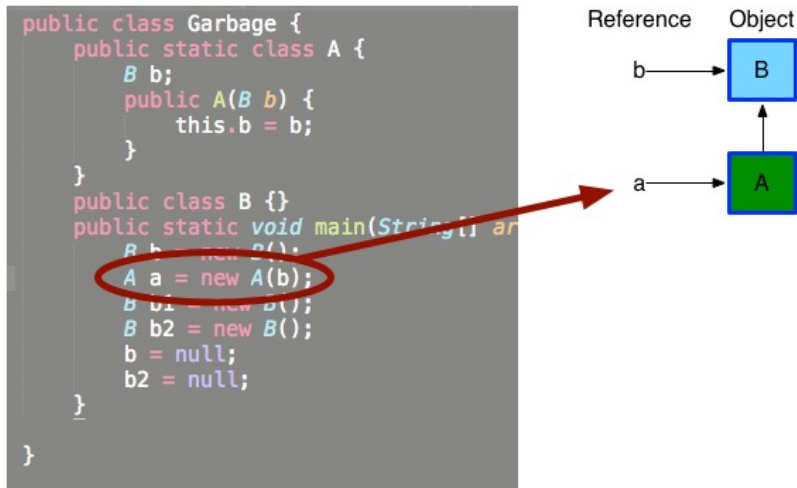


Figure 3: object (A) and reference (a) created. Note that A includes a reference to B)

```

public class Garbage {
    public static class A {
        B b;
        public A(B b) {
            this.b = b;
        }
    }
}

public class B {}

public static void main(String[] args) {
    B b = new B();
    A a = new A(b);
    B b1 = new B();
    B b2 = new B();
    b1 = null;
    b2 = null;
}
}

```

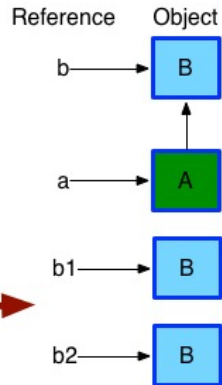


Figure 4: Two more B objects and references created

```

public class Garbage {
    public static class A {
        B b;
        public A(B b) {
            this.b = b;
        }
    }
    public class B {}
    public static void main(String[] args) {
        B b = new B();
        A a = new A(b);
        B b1 = new B();
        B b2 = new B();
        b = null;
        b2 = null;
    }
}

```

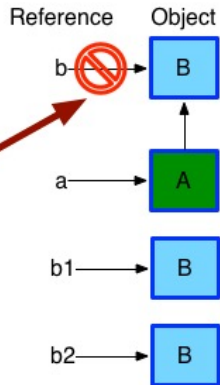


Figure 5: Reference b deleted

```

public class Garbage {
    public static class A {
        B b;
        public A(B b) {
            this.b = b;
        }
    }
    public class B {}
    public static void main(String[] args) {
        B b = new B();
        A a = new A(b);
        B b1 = new B();
        B b2 = new B();
        b = null;
        b2 = null;
    }
}

```

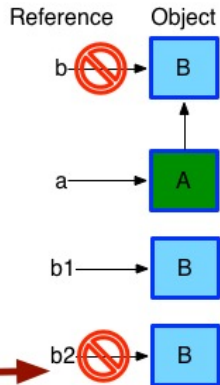


Figure 6: Reference `b2` deleted

```

public class Garbage {
    public static class A {
        B b;
        public A(B b) {
            this.b = b;
        }
    }
    public class B {}
    public static void main(String[] args) {
        B b = new B();
        A a = new A(b);
        B b1 = new B();
        B b2 = new B();
        b = null;
        b2 = null;
    }
}

```

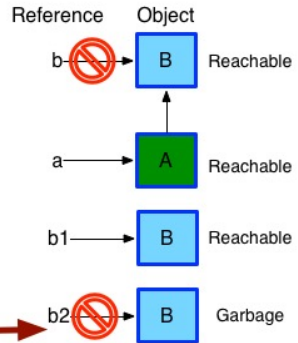


Figure 7: Objects with no reference are garbage. Note that the first B is still referenced from A so isn't garbage even though its original reference has been deleted

Immutable objects

- ▶ Some native Java objects are *immutable*
- ▶ Once they are created they cannot be changed
 - ▶ e.g. String, Double, Float, Integer, etc
- ▶ It looks like we can change them?

```
String a = "hello";  
a+=" simon";
```

- ▶ But, Java is creating a new object and storing the reference in a
 - ▶ Objects in heap, references in stack...
- ▶ See StringExample

Call by value and call by reference

- ▶ Call by value
 - ▶ Value of a variable is passed to a method
 - ▶ Changes to the local copy are not reflected in the calling space
- ▶ Call by reference (e.g. C++)
 - ▶ Object references are passed to method
 - ▶ Actual object can be modified

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}

```

Snapshot of
status here

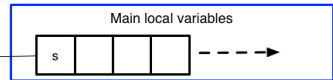
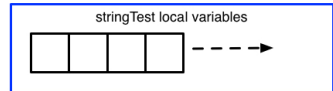
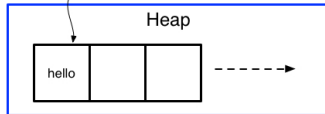


Figure 8:

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        system.out.println(s);
    }
}

```

Snapshot of
status here

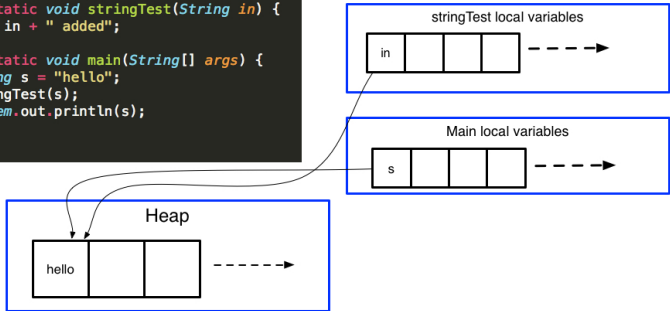


Figure 9:

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}

```

Snapshot of
status here

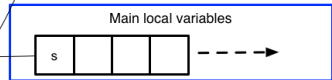
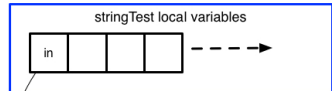
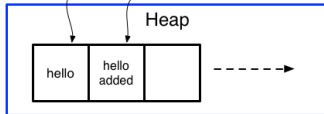


Figure 10:

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}

```

Snapshot of
status here

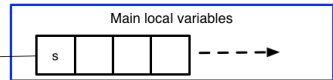
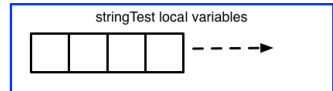
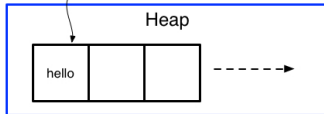


Figure 11:

```

public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }
    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}

```

Snapshot of
status here

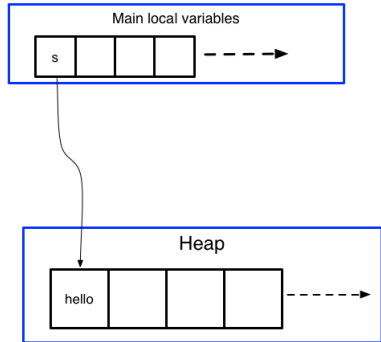


Figure 12:

```

public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }

    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}

```

Snapshot of
status here

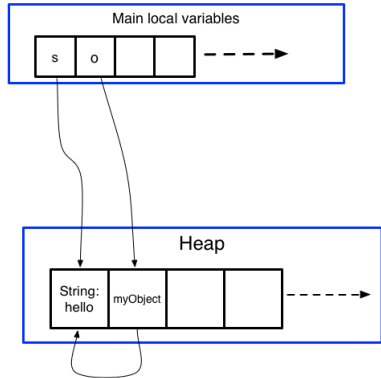


Figure 13:

```

public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }

    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}

```

Snapshot of status here

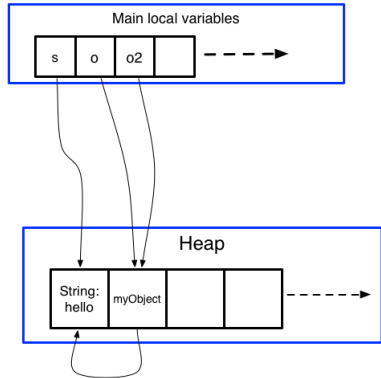


Figure 14:


```

public class ObjectThing {
    public static class myObject {
        private String s;
        public myObject(String s) {
            this.s = s;
        }
        public void setString(String s) {
            this.s = s;
        }
        public String getString() {
            return this.s;
        }
    }

    public static void main(String[] args) {
        String s = "hello";
        myObject o = new myObject(s);
        myObject o2 = o;
        o.setString("blah");
        System.out.println(o2.getString());
        System.out.println(s);
    }
}

```

Snapshot
of status
here

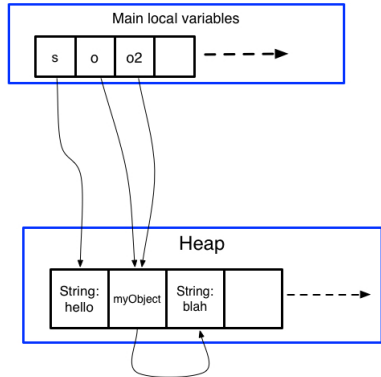


Figure 15:

- ▶ In Java, numbers and object references are call by value. Note that there is a difference between:
 - ▶ Objects are passed by reference
 - ▶ Object references are passed by value
- ▶ Objects passed to a method can be modified, but creating new ones will not be reflected in the calling scope (the reference cannot change)
 - ▶ CallExamples
- ▶ Objects are stored in the heap, references to objects are stored in the stack

```
public class StringThing {  
    public static void stringTest(String in) {  
        in = in + " added";  
    }  
    public static void main(String[] args) {  
        String s = "hello";  
        stringTest(s);  
        System.out.println(s);  
    }  
}
```

Reference
(main)

Object

Reference
(stringTest)

Figure 16: Example program

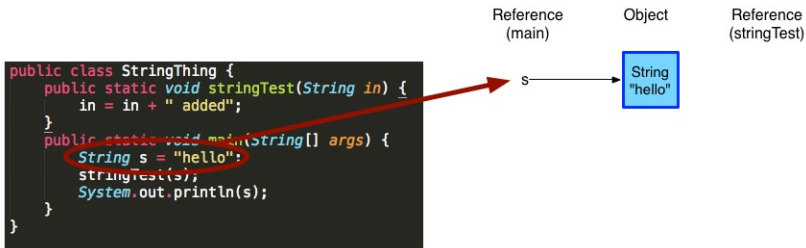


Figure 17: Main makes a String object and a reference (s)

```
public class StringThing {  
    public static void stringTest(String in) {  
        in = in + " added";  
    }  
    public static void main(String[] args) {  
        String s = "hello";  
        stringTest(s);  
        System.out.println(s);  
    }  
}
```

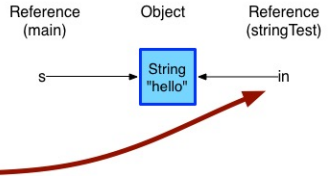


Figure 18: `stringTest` makes its own reference to the `String` object (`in`)

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}

```

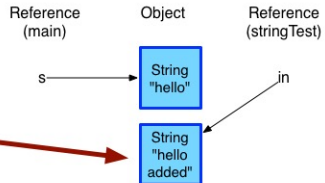


Figure 19: String is an immutable type so when we change it, a new String is made

```

public class StringThing {
    public static void stringTest(String in) {
        in = in + " added";
    }
    public static void main(String[] args) {
        String s = "hello";
        stringTest(s);
        System.out.println(s);
    }
}

```

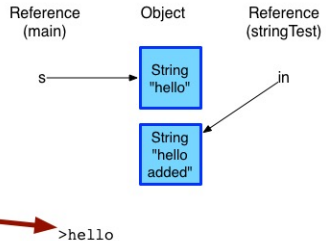


Figure 20: Back in main, s is still a reference to the original object. What happens to the “hello added” string when we return to main?

Final

- ▶ It is good practice to make as many things `final` as possible
- ▶ Make as many attributes `final` as possible
- ▶ Stops other people doing bad things to your code
 - ▶ `final` classes can not be sub-classed
 - ▶ `final` methods can not be overloaded
 - ▶ `final` variables cannot be modified once declared
- ▶ `final` is not the same as `immutable`
- ▶ `FinalTest` and `FinalTestFixed`

Some useful Java objects

ArrayList

- ▶ Java arrays are of fixed length
- ▶ ArrayList gives you an object that can handle arrays of any object that change length

```
ArrayList<Integer> a = new ArrayList();  
a.add(3);  
a.add(5);  
System.out.println(a.contains(4)); // Checks if 4 is in a
```

HashSet

- ▶ Useful way of keeping a set of objects together (not ordered)

```
HashSet<String> h = new HashSet<String>();  
h.add("hello");  
h.add("simon");  
h.add("hello"); // Wont add as already in there  
h.contains("hello"); // returns true  
h.remove("simon"); // removes this one
```

- ▶ Very fast for checking if an item is in the set

HashMap

- Useful way of storing key,value pairs

```
HashMap<String,Double> h = new HashMap<String,Double>()  
h.put("banana",3.0);  
h.put("apple",2.0);  
System.out.println(h.get("apple")); //print 2  
h.keySet(); // Returns a set of the keys
```

- Very fast for obtaining items for a particular key

Hashing

- ▶ Hashing solves the problem of *efficiently* finding items in some collection
- ▶ We'll use the example of storing a phonebook. E.g. we want to store the following:
 - ▶ Simon, 0777777777
 - ▶ Jennifer, 0666677889
 - ▶ Ravi, 056782776
 - ▶ Ken, 0447838827
 - ▶ Hannah, 066848382

- ▶ The simplest solution would be to create two arrays (forget the problem of parallel arrays for now)
- ▶ Then, to find the number for a particular person, we loop through the array of names
- ▶ PhoneBook1.java

- ▶ In general looping over all entries will be slow (if lots of entries)
- ▶ A solution:
 - ▶ Assume no name longer than 15 characters
 - ▶ Create two arrays as before
 - ▶ Store the name and number in the n th position, where $n = \text{length of the name}$
 - ▶ PhoneBook2.java
- ▶ This is much quicker as we can jump directly to the correct array position.
- ▶ It is a simple example of *hashing*
- ▶ In general, hashing is a way of mapping an object to a position in an array that enables finding it quickly
- ▶ A *hash function* is the function used to map from the object to the position
- ▶ In this example, the object is a `String` and the function simply computes its length

Collisions

- ▶ What will happen if we have two names of the same length?
- ▶ A *collision*, and our simple program will fail
- ▶ Solution: maintain a list at each array position
- ▶ PhoneBook3.java
- ▶ Final problem is what to do if a name is longer than 15?
- ▶ Solution:
 - ▶ Fix the max length of array (e.g. 6)
 - ▶ Store entries in the position $\text{length} \% 6$
 - ▶ PhoneBook4.java
- ▶ This is the basics of hashing
- ▶ Length isn't a great hash function
 - ▶ Want something that will spread the objects fairly evenly over the array

hashCode()

- ▶ All objects have a hashCode() method
- ▶ Here's equivalent code to Java's String hashCode function:

```
public int hashCode() {  
    int hash = 0;  
    for (int i = 0; i < length(); i++) {  
        hash = hash * 31 + charAt(i);  
    }  
    return hash;  
}
```


- ▶ You can overwrite `hashCode()` for your own objects
- ▶ By default the `hashCode` returns (roughly) the memory location of the object
- ▶ Note:
 - ▶ Two objects that are equal *must* have the same hash.
 - ▶ I.e. if `obj1.equals(obj2)` then `obj1.hashCode()` must equal `obj2.hashCode()`
 - ▶ Why? Think about our hashing examples...

Generics

ArrayList

- ▶ What is the `<Double>` for in `ArrayList`?
- ▶ It is a generic
- ▶ i.e. `ArrayList` can work with any type (specified when you create it)
- ▶ You can make classes with generics too...

Creating generic objects

```
public class MyClass<T> {  
    private T t;  
    public MyClass(T t) {  
        this.t = t;  
    }  
}
```

- ▶ In the code above T can be any class
- ▶ Can also have multiple types in the definition (<A,B,C,D>)
- ▶ See Dictionary.java

Testing

Unit testing

- ▶ Testing individual components (e.g. classes, methods) to see if they are fit for use
- ▶ Design a suite of tests that can be run every time objects are changed
- ▶ Separates testing from the classes themselves

JUnit

- ▶ JUnit is a popular Java unit test framework
- ▶ A *test class* is created for each normal class
- ▶ We can then run JUnit and it will automatically perform the tests
- ▶ Easiest to do this directly in Eclipse

Assertions

- ▶ Unit testing is done at compile time
- ▶ We might also want *runtime* checks
 - ▶ to catch runtime errors (e.g. based on input that is unknown at compile time)
- ▶ The naive way is through the use of `if` statements

```
public class AssertionExample {  
    private int myInt;  
    public AssertionExample(int n) {  
        myInt = n;  
    }  
    public void decrement(int d) {  
        if(d>myInt) {  
            // Cannot decrement!  
            System.out.println("Can't decrement!!");  
        }else {  
            myInt = myInt - d;  
        }  
    }  
    public static void main(String[] args) {  
        new AssertionExample(5).decrement(10);  
    }  
}
```

- ▶ Assertions are a neater way to achieve this
 - ▶ Cause the program to exit if the condition is not met
 - ▶ Can be switched on or off at runtime
 - ▶ e.g. switch between runtime and debugging

```
public class AssertionExample2 {  
    private int myInt;  
    public AssertionExample2(int n) {  
        myInt = n;  
    }  
    public void decrement(int d) {  
        assert myInt >= d;  
        myInt = myInt - d;  
    }  
    public static void main(String[] args) {  
        new AssertionExample2(5).decrement(10);  
    }  
}
```


- ▶ Running:

```
java -enableassertions AssertionExample2
```

- ▶ can also use `-ea`
- ▶ Try running with and without
- ▶ An alternative is to explicitly throw exceptions but..
 - ▶ Takes longer to write
 - ▶ Exceptions cannot be switched off at runtime (slows things down)

JavaDoc

- ▶ It's very important to properly document your code
- ▶ Standard comments `//` `/*` are good
- ▶ Javadoc is better!
- ▶

[This]{<http://agile.csc.ncsu.edu/SEMaterials/tutorials/javadoc/>}
is quite a good tutorial

Things we are not covering here

Testing

- ▶ We have only touched upon testing. It's very important! Those of you doing SE will cover it more there.
- ▶ Much software engineering is now done in a *test driven* manner.
 - ▶ First write test cases and then write code.
 - ▶ Stop coding when the test cases are finished.
 - ▶ Writing a good set of test cases is hard!

Data structures

- ▶ We make use of Java objects (e.g. `ArrayList`) but we don't worry about how Java implements this
- ▶ We also don't worry too much about the efficiency of different data structures and algorithms
- ▶ Those of you in ADS will do lots of this

Build systems

- ▶ Compiling from the command line is fine for simple projects
- ▶ But..when you have a more complex project with lots of *dependencies* things get very complex
- ▶ Systems exist to help you with this
- ▶ Examples:
 - ▶ Maven (the current standard for Java)
 - ▶ ANT (older but still popular)
- ▶ See Tim Storer's ANT guide on Moodle

Software Engineering

- ▶ Programming is only a small part of building software
- ▶ Engineering large software projects is hard (evidenced by the number of times they end badly)
- ▶ Youll get lots of SE in, erm, SE