CITS2200 Data Structures and Algorithms

Topic 0

# Java Primer

- Review of Java basics
- Primitive vs Reference Types
- Classes and Objects
- Class Hierarchies and Interfaces
- Exceptions
- Generics

Reading: Lambert and Osborne, Appendix A & Sections 1.2 and 2.1–2.7



## 1. Review of Java Basics

### 1.1 Primitive Data Types

| Type | default value | size | range |
|---|---|---|---|
| byte | 0 | 8 bits | $-128$ to $127$ |
| short | 0 | 16 bits | $-2^{15}$ to $2^{15}-1$ |
| int | 0 | 32 bits | $-2^{31}$ to $2^{31}-1$ |
| long | 0L | 64 bits | $-2^{63}$ to $2^{63}-1$ |
| float | 0.0f | 32 bits | ? |
| double | 0.0d | 64 bits | ? |
| char | '\u0000' | 16 bits | $0-2^{16}$ |
| boolean | false | ? | {true, false} |



### 1.2 Local Variables

**Scope**: block in which defined

```
for (int i=0; i<4; i++) {
  // do something with i
  }
System.out.println(i);
```

Result?



### 1.3 Expressions

Built from variables, values, and *operators*.

arithmetic: `+, -, *, /, %,...`

logical: `&&, ||, !,...`

relational: `=, !=, <, >, <=, >=,...`
`==, !=, equals`
`instanceOf`

ternary: `?` (e.g. `x > 0 ? x : -x`)

## 1.4 Control Statements

### if and if-else

```
if (<boolean expression>)
  <statement>

if (<boolean expression>)
  <statement>
else
  <statement>
```

where `<statement>` is a single or compound statement.



### while, do-while, and for

```
while (<boolean expression>)
  <statement>

do
  <statement>
while (<boolean expression>)

for (<initialiser list>; <termination list>; <update list>)
  <statement>
```



### Example

```
for (int i=0; i<4; i++) System.out.println(i);
```

0
1
2
3

```
for (String s=""; !s.equals("aaaa"); s=s+"a")
  System.out.println(s.length());
```

In Java 5 we also have an enhanced for loop:

```
int[] array = {0,2,4};
for (int i : array)
  System.out.println("i is: " + i);
```



### Arrays

Declaration

```
<type>[] <name>;
<type>[]...[] <name>;
```

Instantiation

```
<name> = new <type>[<int-exp>];
<name> = new <type>[<int-exp>]...[<int-exp>];
```

Example

```
int[][] matrixArray;

matrixArray = new int[rows][columns];

int[] array = {0,2,4};
```

## 1.5 Methods

Methods have the form (ignoring access modifiers for the moment)

```
<return type> <name> (<parameter list>) {
  <local data declarations and statements>
}
```

Example

```
void set (int i, int j, int value) {
  matrixArray[i][j]=value;
}

int get (int i, int j) {return matrixArray[i][j];}
```

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Parameters are *passed by value*:

```
// a method...
void increment (int i) {i++;}

// some code that calls it...
i=7;
increment(i);
System.out.println(i);
```

Result?

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## 2. Primitive Types vs Reference Types

Primitive types

- fixed size
- size doesn't change with reassignment

⇒ store *value* alongside variable name

Reference types (eg. Arrays, Strings, Objects)

- size may not be known in advance
- size may change with reassignment

⇒ store *address* alongside variable name

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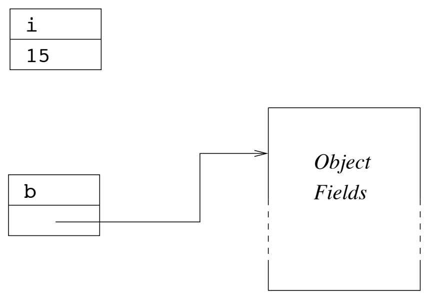
```
integer i = 15;

Object b = new Object();
```




The variable holds a pointer or *reference* to the object's data

⇒ *reference types*

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```
int[] a = {0,1,2,3};
int[] b = a;
b[0]++;
System.out.println(a[0]);
```

Result?

```
// a method...
void incrementAll (int[] a) {
  for (int i=0; i<a.length; i++) a[i]++;
}

// some code that calls it...
int[] b = {0,1,2,3};
incrementAll(b);
System.out.println(b[0]);
```

Result?



## 3. Classes and Objects

### 3.1 What are they?

Aside from a few built-in types (arrays, strings, etc) all reference types are defined by a *class*.

A class is a chunk of software that defines a type, its attributes or *instance variables* (also known as *member variables*), and its *methods*. . .



```
class Box {

  // instance variables
  double width, length, height;

  // constructor method
  Box (double w, double l, double h) {
    width = w;
    length = l;
    height = h;
  }

  // additional method
  double volume () {return width * length * height;}
}
```



### 3.2 Constructors

The runtime engine creates an *object* or *instance* of the class each time the `new` keyword is executed:

```
Box squareBox, rectangularBox;
...
squareBox = new Box(20,20,20);
rectangularBox = new Box(20,30,10);
```

## 3.3 Different Kinds of Methods

**constructor** — tells the runtime engine how to initialise the object

**accessor** — returns information about an object's state without modifying the object

**mutator** — changes the object's state



## 3.4 Packages

A collection of related classes. E.g. `java.io`

In Java:

- must be in same directory
- directory name matches package name

Specifying your own package

```
package myMaths;

class Matrix {
  ...
```

If you don't specify a package Java will make a default package from all classes in the directory.



Using someone else's package

```
package myMaths;
import java.io.*;

class Matrix {
  ...
```

Note that `java.lang.*` is automatically imported.



## 3.5 Access Modifiers

Specify access to classes, variables, and methods.

**public** — accessible by all

**private** — access restricted to within class

**(none)** — access restricted to within package

**protected** — access to package and subclasses

## 3.6 The `static` Keyword

Used for methods and variables in classes that *don't* create objects, or for variables *shared* by all instances of a class.

**Example:**

```
public class MatrixTest {

   static Matrix m;

  public static void main (String[] args) {
    m = new Matrix(2,2);
    m.set(0,0,1);
    ...
```

Called *class variables* and *class methods*.



Also used for "constants".

**Example:**

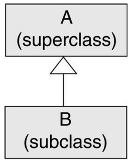
```
public class Matrix {

  static final int MAX_SIZE=100;

  private int[][] matrixArray;
  ...
```

Keyword `final` means the value cannot be changed at runtime.

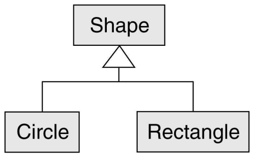


# 4. Class Hierarchies

Classes can be built from, or *extend* other classes.




**Example:**






```
public class Shape {

  private double xPos, yPos;

  public void moveTo (double xLoc, double yLoc) {
    xPos = xLoc;
    yPos = yLoc;
  }

  ...
}
```

(More detail: see Lambert and Osborne, Section 2.5)

```
public class Circle extends Shape {

  private double radius;

  public double area () {
    return Math.PI * radius * radius;
  }
}
```

While we will not be using hierarchies extensively in this unit, we will be using some *very important features of them*...



1. Any superclass reference (variable) can hold and access a subclass object.

**Example:**

```
public class ShapeTest {

  public static void main (String[] args) {
    Shape sh;             // declare reference of type Shape
    sh = new Circle();    // hold a Circle object in sh
    sh.moveTo(2.0,3.0);   // access a Shape method
    double a=sh.area();   // access a Circle method
    ...
```



2. All Java classes are (automatically) subclasses of `Object`

**Example:**

```
Object holdsAnything;
holdsAnything = new Circle();
holdsAnything = new Rectangle();
holdsAnything = new Shape();
```

**Example:**

```
Object[] arrayOfAnythings = new Object[10];
arrayOfAnythings[0] = new Circle();
arrayOfAnythings[1] = new Rectangle();
arrayOfAnythings[2] = new Shape();
```



Java provides *wrappers* for all primitives to allow them to be treated as `Object`s:

⇒ `Character, Boolean, Integer, Float, ...`

See the Java API for details.

Note: A new feature in Java 1.5 is *autoboxing* — automatic wrapping and unwrapping of primitives.

⇒ Compile time feature — doesn't change what is "really" happening.

## 4.1 Casting

While a superclass variable can be assigned a subclass object, a subclass variable cannot be assigned an object held in a superclass, *even if that object is a subclass object*.

**Example:**

```
Object o1 = new Object();           // OK
Object o2 = new Character('a');     // OK
Character c1 = new Character('a');  // OK
Character c2 = new Object();        // Error

o1 = c1;                            // OK
c1 = o1;                            // Error
```



In the last statement, even though `o1` is now "holding" something that was created as a `Character`, its reference (ie its class) is `Object`.

To get the "`Character`" back, we have to *cast* it back down the hierarchy:

```
o1 = c1;                     // OK
c1 = (Character) o1;         // OK - casted back to Character
```



## 4.2 Object Oriented Programming in Java

Some object oriented features worth remembering are:

- **Abstraction**: the ability to treat different types of object as a common type.
- **Polymorphism**: how one method can change its behavior in different classes.
- **Inheritance**: reusing methods and variables from super classes.
- **Encapsulation**: information hiding, and containing other classes.



To demonstrate these properties, let's reconsider the `Shape` example. This time, we first define a class `Point`...

```
public class Point {

  private double xPos, yPos;

  public Point(double x, double y){
    xPos = x;
    yPos = y;
  }

  public void moveTo (double xLoc, double yLoc) {
    xPos = xLoc;
    yPos = yLoc;
  }
}
```

...and use Point to define Shape. This is **encapsulation**.

```
public abstract class Shape {

  private Point p;

  public Shape(double x, double y) {
    p = new Point(x,y);
  }

  public void moveTo (double xLoc, double yLoc) {
    p.moveTo(xLoc, yLoc)
  }

  public double area();     //an abstract method - more later
}
```



Circle inherits from Shape...

```
public class Circle extends Shape {

  private double radius;

  public Circle(double x, double y, double radius) {
    super(x,y);
    this.radius = radius;
  }

  public double area() {
    return Math.PI * radius * radius;
  }
}
```



as does Rectangle. This demonstrates **inheritance**.

```
public class Rectangle extends Shape {

  private double height;
  private double width;

  public Rectangle(double x, double y, double height, double width)
    super(x,y);
    this.height = height;
    this.width = width;
  }

  public double area() {
    return width * height;
  }
}
```



We can now treat Rectangles and Circles as the more general type Shape:

**Example:**

```
public class ShapeTest {

  public static void main (String[] args) {
    Shape[] sA = new Shape[2];
    sA[0] = new Circle(1,1,1);
    sA[1] = new Rectangle(1,1,1,1);    // This is abstraction
    for(int i = 0; i < 2; i++)
      sA[i].moveTo(0,0);
    int totArea = 0;
    for(int i = 0; i < 2; i++)
       totArea += sA[i].area();        // This is polymorphism
  }
}
```

**Note:**

- We did not need to specify how a `Shape`'s area is calculated. This means that we are never able to construct *just* a `Shape`.
- We chose to encapsulate a `Point`, rather than inherit from it (*a shape is not a point*). Inheritance should be used sparingly. Always consider composition first.
- Once `Circles` and `Rectangles` can be treated as shapes we can have an array that contains both.
- The method `area()` was different for both shapes, but we did not need to cast. The Java virtual machine will determine which method is called.
- A good example of inheritance in the API is `java.awt` (e.g., a `Window` is a `Container` which is a `Component` which is an `Object`). However, in general inheritance hierarchies should be fairly shallow.



## 5. Interfaces and Abstract Classes

An interface:

- looks much like a class, but uses the keyword `interface`
- contains a list of method headers — name, list of parameters, return type (and exceptions)
- no method contents (they are called *abstract*, but abstract classes may have some methods specified)
- can only have constant variables declared
- no `public/private` necessary — they are implicitly `public`
- can implement multiple interfaces

Effectively, interfaces present all the OO advantages above, *except* inheritance.



**Example:**

```
public interface Matrix {

  public void set (int i, int j, int value);

  public int get (int i, int j);

  public void transpose ();
}
```



Classes can *implement* an interface:

Implementation 1:

```
public class MatrixReloaded implements Matrix {
  private int[][] matrixArray;
  public void transpose () {
    // do it one way
  }
  ...
```

Implementation 2:

```
public class MatrixRevolutions implements Matrix {
  private int[][] somethingDifferent;
  public void transpose () {
    // do it yet another way
  }
```

### Why use interfaces?

1. Can be used like a superclass:

   **Example:**

```
Matrix[] myMatrixHolder = new Matrix[10];
myMatrixHolder[0] = new MatrixReloaded(2,2);
myMatrixHolder[1] = new MatrixRevolutions(20,20);
...
myMatrixHolder[0] = myMatrixHolder[1];
```



2. Specifies the methods that any implementation *must implement*.

   **Example:**

```
Matrix[] myMatrixHolder = new Matrix[10];
myMatrixHolder[0] = new MatrixReloaded(2,2);
myMatrixHolder[1] = new MatrixRevolutions(20,20);
...
for (int i=0; i<10; i++)
  myMatrixHolder[i].transpose();
```

   Note: this doesn't mean the methods are implemented *correctly*.



This is an important software engineering facility

- follows on from Information Hiding in Topic 1
  — allows independent development and maintenance of libraries and programs that use them
- will be used extensively in this unit to specify ADTs
- also used to add common functionality to all objects, eg *Serializable*, *Cloneable*

More examples — see the Java API

eg. the *Collection* interface, also *Runnable*, *Throwable*, *Iterable*, and *List*.



## 6. Exceptions

- special built-in classes
- used by Java to determine what to do when something goes wrong
- *thrown* by the Java virtual machine (JVM)

Example program

```
int[] myArray = {0,1,2,3};
System.out.println("The last number is:");
System.out.println(myArray[4]);
```

Output

```
The last number is:
Exception in thread "main"
java.lang.ArrayIndexOutOfBoundsException: 4
at Test.main(Test.java:31)

Process Test exited abnormally with code 1
```

See the Java API for ArrayIndexOutOfBoundsException.



We can throw exceptions ourselves.

```
if (<condition>)
  throw new <exception type> (<message string>);
```

Example:

```
double squareRoot (double x) {
  if (x < 0)
    throw new ArithmeticException("Can't find square root
                                        of -ve number.");
  else {
    // calculate and return result
  }
}
```

Have a look for `ArithmeticException` in the Java API.



Two types of exceptions:

**checked** — most Java exceptions
— must be *caught* by the method, or passed (thrown) to the calling method

**unchecked** — `RuntimeException` and its subclasses
— don't need to be handled by programmer (JVM will halt)

To catch an exception, we use the code:

```
try {
  codeThatThrowsException();
}
catch(Exception e) {
  codeThatDealsWithException(e);
}
```

For simplicity, we will primarily use unchecked exceptions in this unit.



## Compiling and running Java

There are various ways to compile and run Java, but the command line is the most ubiquitous. The command:

```
> javac myClass.java
```

will create the file `myClass.class` in the current directory. The command:

```
> java myClass
```

will execute the main method of the class `myClass`.

## Objects and Generic Data Structures

```
/**
 * Block representation of a queue (of objects).
 */
public class QueueBlock {

  private Object[] items;                    // array of Objects
  private int first;
  private int last;

  public Object dequeue() throws Underflow {  // returns an Object
    if (!isEmpty()) {
      Object a = items[first];
      first++;
      return a;
    }
    else throw new Underflow("dequeuing from empty queue");
  }
```



## 6.1 Wrappers

The above queue is able to hold any type of object — that is, an instance of any subclass of the class `Object`. (More accurately, it can hold any reference type.)

But there are some commonly used things that are not objects — the primitive types.

In order to use the queue with primitive types, they must be "wrapped" in an object.

Recall from Topic 4 that Java provides wrapper classes for all primitive types.



## Autoboxing — Note for Java 1.5

Java 1.5 provides *autoboxing* and *auto-unboxing* — effectively, automatic wrapping and unwrapping done by the compiler.

```
Integer i = 5;
int j = i;
```

However:

- Not a change to the underlying language — the *compiler* recognises the mismatch and substitutes code for you:

  ```
  Integer i = Integer.valueOf(5)
  int j = i.intValue();
  ```



- Can lead to unintuitive behaviour. Eg:

  ```
  Long w1 = 1000L;
  Long w2 = 1000L;
  if (w1 == w2) {
    // do something
  }
  ```

  may not work. Why?
- Can be slow. Eg. if a, b, c, d are Integers, then

  ```
  d = a * b + c
  ```

  becomes

  ```
  d.valueOf(a.intValue() * b.intValue() + c.intValue())
  ```

For more discussion see:

http://chaoticjava.com/posts/autoboxing-tips/

## 6.2 Casting

Recall that in Java we can assign "up" the hierarchy — a variable of some class (which we call its reference) can be assigned an object whose reference is a subclass.

However the converse is not true — a subclass variable cannot be assigned an object whose reference is a superclass, even if that object is a subclass object.

In order to assign back down the hierarchy, we must use *casting*.

This issue occurs more subtly when using ADTs. Recall our implementation of a queue. . .



```
public class QueueBlock {
  private Object[] items;                        // array of Objects
  ...
  public Object dequeue() throws Underflow {  // returns an Object
    if (!isEmpty()) {
      Object a = items[first];
      first++;
      return a;
    }
    else...
```

Consider the calling program:

```
QueueBlock q = new QueueBlock();
String s = "OK, I'm going in!";
q.enqueue(s);                                // put it in the queue
s = q.dequeue();                             // get it back off ???
```

The last statement fails. Why?



The queue holds `Object`s. Since `String` is a subclass of `Object`, the queue can hold a `String`, but its reference in the queue is `Object`. (Specifically, it is an element of an array of `Object`s.)

`dequeue()` then returns the "`String`" with reference `Object`.

The last statement therefore asks for something with reference `Object` (the superclass) to be assigned to a variable with reference `String` (the subclass), which is illegal.

We have to cast the `Object` back "down" the hierarchy:

```
s = (String) q.dequeue();        // correct way to dequeue
```



## 6.3 Generics

Java 1.5 provides an alternative approach. *Generics* allow you to specify the type of a collection class:

```
Stack<String> ss = new Stack<String>();
String s = "OK, I'm going in!";
ss.push(s);
s = ss.pop()
```

Like autoboxing, generics are handled by compiler rewrites — the compiler checks that the type is correct, and substitutes code to do the cast for you.

## Writing Generic Classes

```
/**
* A simple generic block stack for
* holding object of type E
**/
class Stack<E> {

  private Object[] block;
  private int size;

  public Stack(int size) {block = new Object[size];}

  public E pop() {return (E) block[--size];}

  public void push(E el) {block[size++] = el;}
}
```



## Using Generic Classes

```
public static void main(String[] args){
  //create a Stack of Strings
  Stack<String> s = new Stack<String>(10);
  s.push("abc");
  System.out.println(s.pop());

  //create a stack of Integers
  Stack<Integer> t = new Stack<Integer>(1);
  t.push(7);
  System.out.println(t.pop());
}
```



## How Generics Work

The program:

```
Stack<String> ss = new Stack<String>(10);
String s = "OK, I'm going in!";
ss.push(s);
s = ss.pop();
```

is converted to:

```
Stack<Object> ss = new Stack<Object>(10);
String s = "OK, I'm going in!";
ss.push(s);
s = (String) ss.pop();
```

at compile time. Generics allow the compiler to ensure that the casting is correct, rather than the runtime environment.



## Some Tricks with Generics...

Note that `Stack<String>` is not a subclass of `Stack<Object>` (because you can't put an `Integer` on a stack of `Strings`).

Therefore, polymorphism won't allow you to define methods for all stacks of sub-classes of String. e.g.

```
public int printAll(Stack<Object>);
```

Java 5 allows *wildcards* to overcome this problem:

```
public int printAll(Stack<?>);
```

or even

```
public int printAll(Stack<? extends Object>);
```

Generics in Java are complex and are the subject of considerable debate. While you may not need to write them often, it is important you understand them as the Java Collection classes all use generics.

Some interesting articles:

http://www-128.ibm.com/developerworks/java/library/
j-jtp01255.html

http://weblogs.java.net/blog/arnold/archive/2005/06/
generics_consid_1.html

http://java.sun.com/j2se/1.5/pdf/generics-tutorial.pdf