HST 952

Computing for Biomedical Scientists

Lecture 6

Designing Methods: Top-Down Design

- In pseudocode, write a list of subtasks that the method must perform
- If you can easily write Java statements for a subtask, you are finished with that subtask
- If you cannot easily write Java statements for a subtask, treat it as a new problem and break it up into a list of subtasks
- Eventually, all of the subtasks will be small enough to easily design and code
- Solutions to subtasks might be implemented as private helper methods
- Top-down design is also known as *divide-and-conquer* or *stepwise refinement*

Designing Methods: Top-Down Design

- Person class has attributes of type String and GregorianCalendar corresponding to a person's first name, last name, and date of birth: firstName, lastName, and dateOfBirth
- Create a new method:
  `double ageOfPerson()`
  for the Person class that returns the approximate age (with respect to year and month of birth) of a person. Approximate in this case means that if a person was born in September of 1965 and the current month and year are September 2002, the age returned should be 37.0 (the actual day of the month on which the person was born is ignored).

  What tasks should this method perform?

Designing Methods: Top-Down Design

Some tasks this method should perform:

- find out the current year
- find out the current month
- find out the birth year
- find out the birth month
- find out the age using these values

- subtract the birth year and month from the current year and month
- return the value obtained as the age

ageOfPerson() method

```
public double ageOfPerson()
   {
     // The GregorianCalendar class default constructor creates
     // a new date and time corresponding to the date and time
     // the program in which it is called is executed
     GregorianCalendar today = new GregorianCalendar();
     // Calendar is a parent class to GregorianCalendar
     // YEAR is a static named constant of the Calendar class
     int thisYear = today.get(Calendar.YEAR);
     int birthYear = dateOfBirth.get(Calendar.YEAR);
     // Java Gregorian Calendar month is zero based -- Jan==0
     int thisMonth = today.get(Calendar.MONTH);
     int birthMonth = dateOfBirth.get(Calendar.MONTH);
     double age = (thisYear - birthYear) + ((thisMonth - birthMonth)/12.0);
     return(age);
   }
```

ageOfPerson() method

```
public double ageOfPerson()
   {
      // The GregorianCalendar class default constructor creates
      // a new date and time corresponding to the date and time
      // the program in which it is called is executed
      GregorianCalendar today = new GregorianCalendar();
      // Calendar is a parent class to GregorianCalendar
      // YEAR is a static named constant of the Calendar class
      int thisYear = today.get(Calendar.YEAR);
      int birthYear = dateOfBirth.get(Calendar.YEAR);
      // Java Gregorian Calendar month is zero based -- Jan==0
      int thisMonth = today.get(Calendar.MONTH);
      int birthMonth = dateOfBirth.get(Calendar.MONTH);
      double age = (thisYear - birthYear) +
                              ((thisMonth - birthMonth)/12.0);
      return(age);
   }
```

The Person class definition would need to include the following line at the top of the Person.java file:

`import java.util.*;`

This import statement tells the java compiler where to find the GregorianCalendar and Calendar built-in classes

Wrapper Classes

- Used to wrap primitive types in a class structure
- All primitive types have an equivalent class
- The class includes useful constants and static methods, including one to convert back to the primitive type

Primitive type	Class type	Method to convert back
`int`	`Integer`	`intValue()`
`long`	`Long`	`longValue()`
`float`	`Float`	`floatValue()`
`double`	`Double`	`doubleValue()`
`char`	`Character`	`charValue()`

Wrapper class example: Integer

- Declare an `Integer` class variable:

```
Integer n = new Integer();
```

- Convert the value of an `Integer` variable to its primitive type, `int`:

```
int i = n.intValue();
//method intValue()returns an int
```

- Some useful `Integer` constants:
  - `Integer.MAX_VALUE` - the maximum integer value the computer can represent
  - `Integer.MIN_VALUE` - the smallest integer value the computer can represent

Wrapper class example: Integer

- Some useful `Integer` methods:
  - `Integer.parseString("123")` to convert a string of numerals to an integer
  - `Integer.toString(123)` to convert an `Integer` to a `String`
- The other wrapper classes have similar constants and functions

Wrapper classes

There are some important differences in the code to use wrapper classes and that for the primitive types

Wrapper Class

- variables contain the *address* of the object
- variable declaration example: `Integer n;`
- variable declaration & init: `Integer n = new Integer(0);`
- assignment: `n = new Integer(5);`

Primitive Type

- variables contain a value
- variable declaration example: `int n;`
- variable declaration & init.: `int n = 0;`
- assignment: `n = 99;`

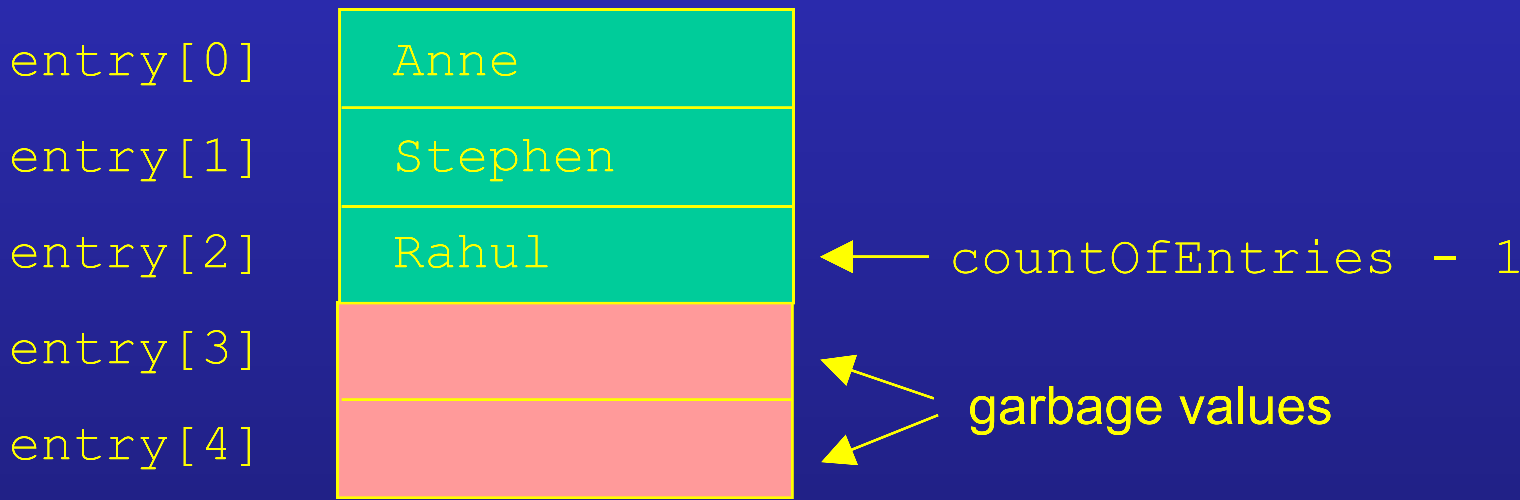
Outline

- Arrays continued
- Packages
- Inheritance

Partially Filled Arrays

- Sometimes only part of an array has been filled with data
- Array elements always contain something, whether you have written to them or not
  - elements which have not been written to/filled contain unknown (*garbage*) data so you should avoid reading them
- There is no automatic mechanism to detect how many elements have been filled - *you*, need to keep track...

Example of a Partially Filled Array



`countOfEntries` has a value of `3`.

`entry.length` has a value of `5`.

Multidimensional Arrays

- Arrays with more than one index
  - number of dimensions = number of indexes
- Arrays with more than two dimensions are a simple extension of two-dimensional (2-D) arrays
- A 2-D array corresponds to a table or grid
  - one dimension is the row
  - the other dimension is the column
  - cell: an intersection of a row and column
  - an array element corresponds to a cell in the table

Multidimensional Arrays

Example of usage:

Store the different possible ending balances corresponding to $1000 saved at 6 different interest rates over a period of 10 years

Table as a 2-D Array

Column Index 4
(5th column)

Row Index 3
(4th row)

Indexes	0	1	2	3	4	5
0	$1050	$1055	$1060	$1065	$1070	$1075
1	$1103	$1113	$1124	$1134	$1145	$1156
2	$1158	$1174	$1191	$1208	$1225	$1242
3	$1216	$1239	$1262	$1286	$1311	$1335
4	$1276	$1307	$1338	$1370	$1403	$1436
É	É	É	É	É	É	É

- Generalizing to two indexes: [row][column]
- First dimension: row index
- Second dimension: column index
- Cell contains balance for the year/row and percentage/column
- All indexes use zero-numbering
  - Balance[*3*][*4*] = cell in 4th row (year = 4) and 5th column (7.00%)
  - Balance[3][4] = $1311 (shown in yellow)

Java Code to Create a 2-D Array

- Syntax for 2-D arrays is similar to 1-D arrays
- Declare a 2-D array of `int`s named `table`
  - the array table should have ten rows and six columns

```
int[][] table = new int[10][6];
```

Calculating the Cell Values

Each array element corresponds to the balance for a specific number of years and a specific interest rate (assuming a starting balance of $1000):

$$\text{balance(start-balance, years, rate)} = \text{(start-balance)} \times (1 + \text{rate})^{\text{years}}$$

The repeated multiplication by (1 + rate) can be done in a `for` loop that repeats `years` times.

```
public static int balance(double startBalance, int years, double rate)
   {
      double runningBalance = startBalance;
      int count;
      for (count = 0; count < years; count++)
         runningBalance = runningBalance*(1 + rate/100);
      return (int) (Math.round(runningBalance));
   }
```

Processing a 2-D Array: for Loops Nested 2-Deep

- Arrays and `for` loops are a natural fit
- To process all elements of an *n*-dimensional array nest *n* for loops
  - each loop has its own counter that corresponds to an index

Processing a 2-D Array: for Loops Nested 2-Deep

- For example: calculate and enter balances in interest table (10 rows and 6 columns)
  - inner loop repeats 6 times (six rates) for every outer loop iteration
  - the outer loop repeats 10 times (10 different values of `years`)
  - so the inner repeats 10 x 6 = 60 times = # cells in `table`

```
int[][] table = new int[10][6];
int row, column;
for (row = 0; row < 10; row++)
    for (column = 0; column < 6; column++)
        table[row][column] = balance(1000.00, row + 1, (5 + 0.5*column));
```

Multidimensional Array Parameters and Returned Values

- Methods may have multi-dimensional array parameters
- Methods may return a multi-dimensional array as the value returned
- The situation is similar to 1-D arrays, but with more brackets
- Example: a 2-D `int` array as a method argument

Multidimensional Array Parameters and Returned Values

Number of rows of a 2D array is: *nameOfArray.length*

Number of columns for each row is:

nameOfArray[row-index].length

```
public static void showTable(int[][] displayArray)
 {
   int row, column;
   for (row = 0; row < displayArray.length; row++)
   {
      System.out.print((row + 1) + "      ");
      for (column = 0; column < displayArray[row].length; column++)
         System.out.print("$" + displayArray[row][column] + "  ");
      System.out.println();
   }
 }
```

Notice how the number of rows is obtained

Notice how the number of columns is obtained

Ragged Arrays

- Ragged arrays have rows of unequal length
  - each row has a different number of columns, or entries
- Ragged arrays are allowed in Java
- Example: create a 2-D `int` array named `b` with 5 elements in the first row, 7 in the second row, and 4 in the third row:

```
int[][] b;
b = new int[3][];
b[0] = new int[5];
b[1] = new int[7];
b[2] = new int[4];
```

Packages

- A way of grouping and naming a collection of related classes
  - the classes in a package serve as a *library* of classes
  - they do not have to be in the same directory as the code for your program

- The first line of each class in the package must be the keyword `package` followed by the name of the package

Packages

Example -- a group of related classes that represent shapes and methods for drawing them:

```
package graphics;
public class Circle extends Graphic {
        . . .
} // in Circle.java

package graphics;
public class Rectangle extends Graphic {
        . . .
} // in Rectangle.java

package graphics;
public class Ellipse extends Graphic {
        . . .
} // in Ellipse.java
```

Packages

- To use classes from a package in program source code, can put an `import` statement at the start of the file, e.g.:

  ```
  import graphics.*;
  ```

  - note the "`.*`" notation, "`*`" is a *wild-card* that matches all class names in the `graphics` package; in our example, it is shorthand for graphics.Circle, graphics.Rectangle, and graphics.Ellipse
- Class descriptions with no `package` statement are automatically placed in a *default* package (a package with no name)

Packages

- Use lowercase letters for the package name
- By using packages if we write a new class description that has the same name as a built-in Java class, we can avoid problems
- java.awt has a Rectangle class
  - to refer to it by its full name: java.awt.Rectangle
- graphics package has a Rectangle class
  - to refer to it by its full name: graphics.Rectangle
- To use java.awt and graphics Rectangle packages in the same code, can use their full names (which includes their package name)

Packages

- In directory `c:jdk\lib\examples\graphics` have

```
package graphics;

public class Rectangle {

    private double length=5.5;
    private double width=4.0;

    public double getArea()
    {
        return length*width;
    }
} // Rectangle.java
```

```
package graphics;

public class Circle {

    private double radius=5;

    public double getArea()
    {
        return Math.PI *
          radius * radius;
    }
} // Circle.java
```

Packages

- In directory `c:jdk\lib\examples\test` have

```
package test;
import graphics.*; // import graphics.Rectangle and graphics.Circle

public class TestGraphics
{
   public static void main (String[] args) {
         Rectangle r1 = new Rectangle();
         System.out.println("Rectangle area is " + r1.getArea());
         Circle c1 = new Circle();
         System.out.println("Circle area is " + c1.getArea());
   } // end of main ()
}
```

Packages

- Pathnames are usually relative and use the `CLASSPATH` environment variable

DOS

- If: `CLASSPATH=c:jdk\lib\examples`, and the classes in your `graphics` package are in `c:jdk\lib\examples\graphics\`, and your test program is in package `test` in `c:jdk\lib\examples\test\TestGraphics.java`

  From the DOS command line in `c:jdk\lib\examples`, can type `javac test\TestGraphics.java` to compile and `java test.TestGraphics` to run

  Output:

  Rectangle area is 22.0

  Circle area is 78.53981633974483

Packages

Unix/Linux

- If: `CLASSPATH=/name/lib/examples`, and the classes in your `graphics` package are in `/name/lib/examples/graphics/`, and your test program is in package `test` in `/name/lib/examples/test/TestGraphics.java`

  From the unix/linux command line in `/name/lib/examples`, you can type

  `javac test/TestGraphics.java` to compile

  and `java test.TestGraphics` to run

  Output:

  Rectangle area is 22.0

  Circle area is 78.53981633974483

Inheritance

- OOP is one paradigm that facilitates managing the complexity of programs
- OOP applies principles of abstraction to simplify the tasks of writing, testing, maintaining and understanding complex programs
- OOP aims to increase code reuse
  - reuse classes developed for one application in other applications instead of writing new programs from scratch ("Why reinvent the wheel?")
- Inheritance is a major technique for realizing these objectives

Inheritance Overview

- Inheritance allows you to define a very general class then later define more specialized classes by adding new detail
  - the general class is called the *base* or *parent class*
- The specialized classes *inherit* all the properties of the general class
  - specialized classes are *derived* from the base class
  - they are called *derived* or *child* classes

Inheritance Overview

- After the general class is developed you only have to write the "difference" or "specialization" code for each derived class
- A *class hierarchy:* classes can be derived from derived classes (child classes can be parent classes)
  - any class higher in the hierarchy is an *ancestor class*
  - any class lower in the hierarchy is a *descendent class*

An Example of Inheritance: a Person Class

The base class:

- Constructors:
  - a default constructor
  - three others that initialize the `firstName`, `lastName`, and `dateOfBirth` attributes (instance variables)
- Accessor methods:
  - `setFirstName` to change the value of the `firstName` attribute
  - `getFirstName` to read the value of the `firstName` attribute
  - same for `lastName`

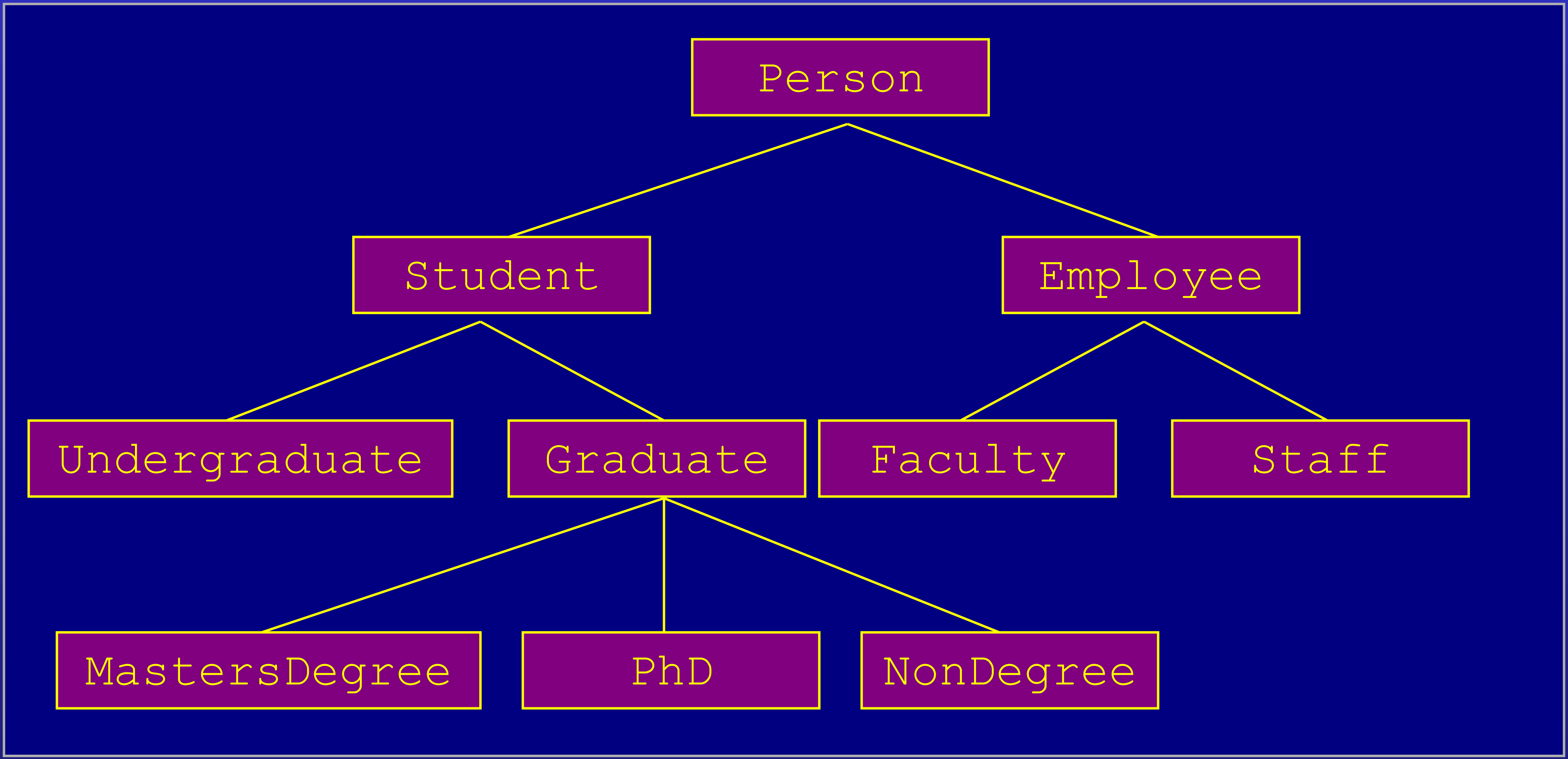
An Example of Inheritance: a Person Class

Accessor methods contd.:

- `setDateOfBirth` to change the value of the `dateOfBirth` attribute
- `getDateOfBirth` to read the value of the `dateOfBirth` attribute
- `writeOutput` to display the values of the `firstName`, and `lastName` attributes

- One other class method:
  - `sameName` to compare the values of the `firstName` and `lastName` attributes for objects of the class
- Note: the methods are `public` and the attributes `private`

Derived Classes: a Class Hierarchy



- The base class can be used to implement specialized classes
  - For example: student, employee, faculty, and staff
- Classes can be derived from the classes derived from the base class, etc., resulting in a *class hierarchy*

Example of Adding Constructor in a Derived Class: Student

- Keyword *extends* in first line
  - » creates derived class from base class
  - » this is inheritance

```
public class Student extends Person
{
     private int studentNumber;
     public Student()
     {
          super();
          studentNumber = 0;
     }
…
```

- Four new constructors (one on next slide)
  - – default initializes attribute `studentNumber` to 0
- *super* must be first action in a constructor definition
  - – Included automatically by Java if it is not there
  - – *super()* calls the parent default constructor

Example of Adding Constructor in a Derived Class: Student

- Passes parameter `fName` to constructor of parent class
- Uses second parameter to initialize instance variable that is not in parent class.

```
public class Student extends Person
{
. . .
    public Student(String fName, int newStudentNumber)
    {
        super(fName);
        studentNumber = newStudentNumber;
    }
. . .
```

More about Constructors in a Derived Class

- Constructors can call other constructors
- Use `super` to invoke a constructor that is defined in the parent class
  - as shown on the previous slide
- Use `this` to invoke a constructor that is defined within the derived class itself
  - shown on the next slide

Example of a constructor using this

`Student` class has a constructor with three parameters: `String` for the `firstName` and `lastName` attributes and `int` for the `studentNumber` attribute

```
public Student(String fName, String lName,
               int newStudentNumber)
  {
      super(fName, lName);
      studentNumber = newStudentNumber;
  }
```

Another constructor within `Student` takes two `String` arguments and initializes the `studentNumber` attribute to a value of 0:

- calls the constructor with three arguments, fName, lName (`String`) and 0 (`int`), within the same class

```
public Student(String first, String last)
{
   this(first, last, 0);
}
```

Example of Adding an Attribute in a Derived Class: Student

A line from the `Student` class:

```
private int studentNumber;
```

- Note that an attribute for the student number has been added
  - `Student` has this attribute in addition to `firstName`, `lastName`, and `dateOfBirth`, which are inherited from `Person`

Example of Overriding a Method in a Derived Class: Student

- Both parent and derived classes have a `writeOutput` method
- Both methods have the same parameters (none)
  - they have the same *signature*
- The method from the derived class *overrides* (replaces) the parent's
- It will not override the parent if the parameters are different (since they would have different signatures)
- This is *overriding*, **not** overloading

```
public void writeOutput()
{
   System.out.println(“Name: “ + getFirstName() + “ “ +
                               getLastName());
   System.out.println("Student Number : " +
                                          studentNumber);
}
```

Call to an Overridden Method

- Use `super` to call a method in the parent class that was overridden (redefined) in the derived class
- Example: `Student` redefined the method `writeOutput` of its parent class, `Person`
- Could use `super.writeOutput()` to invoke the overridden (parent) method

```
public void writeOutput()
{
   super.writeOutput(); // prints first and last name
   System.out.println("Student Number : " +
                                        studentNumber);
}
```

Overriding Verses Overloading

Overriding

- Same method name
- Same signature
- One method in ancestor, one in descendant

Overloading

- Same method name
- Different signature
- Both methods can be in same class

The final Modifier

- Specifies that a method definition cannot be overridden with a new definition in a derived class
- Example:

```
public final void specialMethod()
{
   . . .
}
```

- Used in specification of some methods in standard libraries
- Allows the compiler to generate more efficient code
- An entire class can be declared final, which means it cannot be used as a base class to derive another class

private & public Instance Variables and Methods

- `private` instance variables from the parent class are not available by name in derived classes
  - "Information Hiding" says they should not be
  - use accessor methods to change them, e.g. can call parent's `setFirstName` method for a `Student` object to change the `firstName` attribute
- `private` methods are **not** inherited!
  - use `public` to allow methods to be inherited
  - only helper methods should be declared `private`

What is the "Type" of a Derived class?

- Derived classes have more than one type
- They have the type of the derived class (the class they define)
- They also have the type of every ancestor class
  - all the way to the top of the class hierarchy
- *All* classes derive from the original, predefined Java class `Object`
- That is, `Object` is the original ancestor class for all other Java classes (including user-defined ones)

Assignment Compatibility

- **Can** assign an object of a derived class to a variable of any ancestor type

```
Person josephine;
Employee boss = new Employee();
josephine = boss;        OK
```

- Can **not** assign an object of an ancestor class to a variable of a derived class type

```
Person josephine = new Person();
Employee boss;
boss = josephine;        Not allowed
```

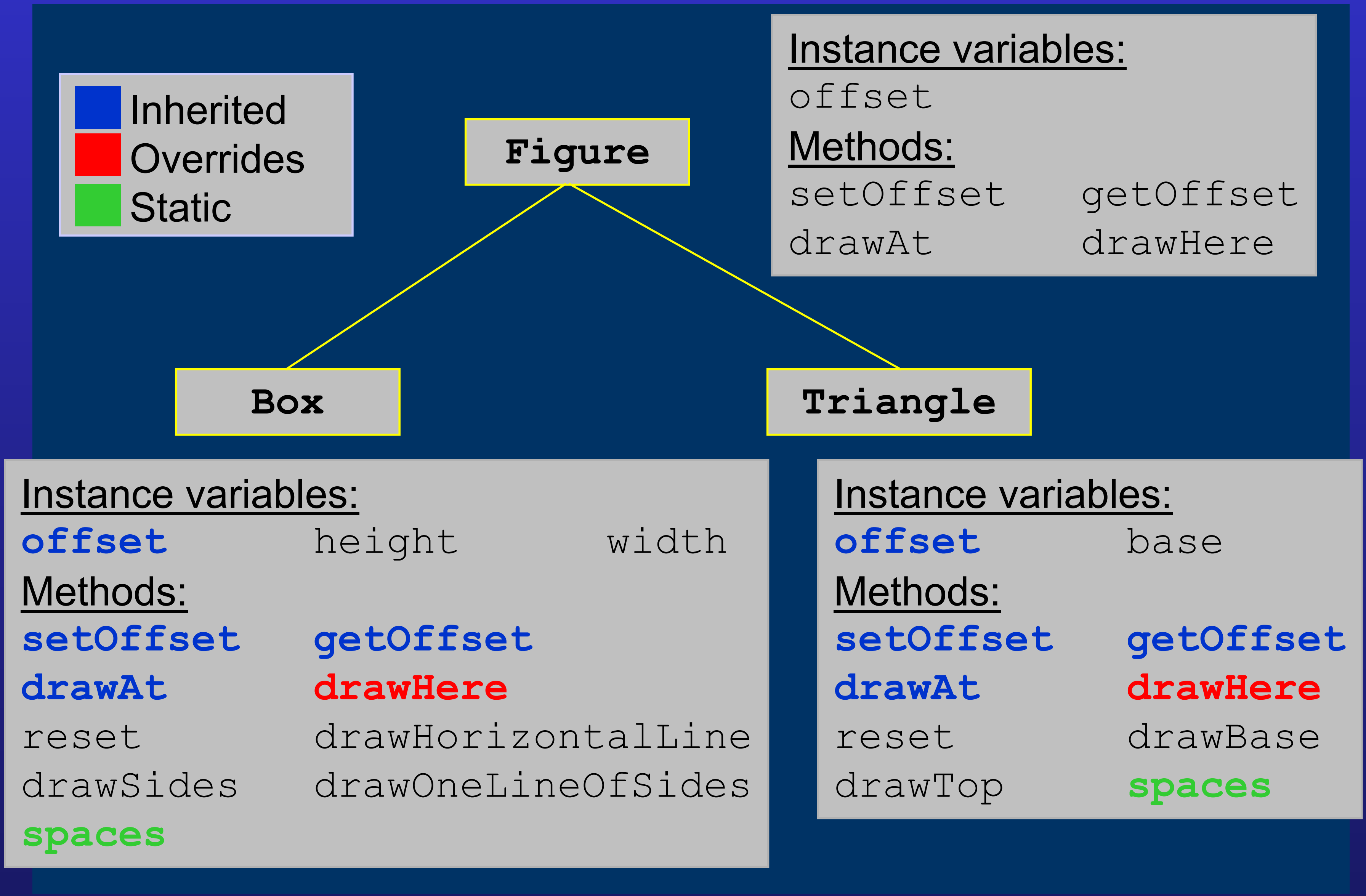
Person

Employee

`Person` is the parent class of `Employee` in this example.

An employee is a person but a person is not necessarily an employee

Character Graphics Example



Java program execution order

- Programs normally execute in sequence
- Non-sequential execution occurs with:
  - selection (if/if-else/switch) and repetition (while/do-while/for)
    (depending on the test it may not go in sequence)
  - method calls, which jump to the location in memory that contains the method's instructions and returns to the calling program when the method is finished executing
- One job of the compiler is to try to figure out the memory addresses for these jumps
- The compiler cannot always know the address
  - sometimes it needs to be determined at run time

Static and Dynamic Binding

- *Binding*: determining the memory addresses for jumps (calls to class methods, etc.)
- *Static*: done at compile time
  - also called *offline*
- *Dynamic*: done at run time
- Compilation is done *offline*
  - it is a separate operation done before running a program
- Binding done at compile time is, therefore, static
- Binding done at run time is dynamic
  - also called *late binding*

Example of Dynamic Binding: General Description

- A derived class calls a method in its parent class which calls a method that is overridden (defined) in the derived class
  - the parent class is compiled separately; in some cases before the derived class is even written
  - the compiler cannot possibly know which address to use
  - therefore the address must be determined (bound) at run time

Dynamic Binding: Specific Example

Parent class: `Figure`

- Defines methods: `drawAt` and `drawHere`
- `drawAt` calls `drawHere`

Derived class: `Box extends Figure`

- Inherits `drawAt`
- redefines (overrides) `drawHere`
- Calls `drawAt`
  - uses the parent's `drawAt` method
  - which must call the derived class's, `drawHere` method

- `Figure` is compiled before `Box` is even written, so the address of `drawHere`(in the derived class `Box`) cannot be known then
  - it must be determined during run time, i.e. dynamically

Polymorphism revisited

- Using the process of dynamic binding to allow different objects to use different method actions for the same method name
- Method overloading is an example of polymorphism
- However, the term polymorphism is most often used in reference to dynamic binding

Summary

- A derived class inherits the instance variables & methods of the base class
- A derived class can create additional instance variables and methods
- The first thing a constructor in a derived class normally does is call a constructor in the base class
- If a derived class redefines a method defined in the base class, the version in the derived class *overrides* that in the base class
- Private instance variables and methods of a base class cannot be accessed directly in the derived class
- If A is a derived class of class B, then an instance of A (object) is both a member of classes A and B
  - the type of the object is both A and B

Read

- Sections 6.3 - 6.5