Chapter 7

Inheritance

- Inheritance Basics
- Programming with Inheritance
- Dynamic Binding and Polymorphism

Principles of OOP

- OOP - Object-Oriented Programming
- Principles discussed in previous chapters:
  - » Information Hiding
  - » Encapsulation
- In this chapter
  - » Inheritance

Why OOP?

- To try to deal with the complexity of programs
- To apply principles of abstraction to simplify the tasks of writing, testing, maintaining, and understanding complex programs
- To increase code reuse
  - » to 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 (superclass)*
- 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 (*subclass*)
- 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

<u>The base class: Display 7.1</u>

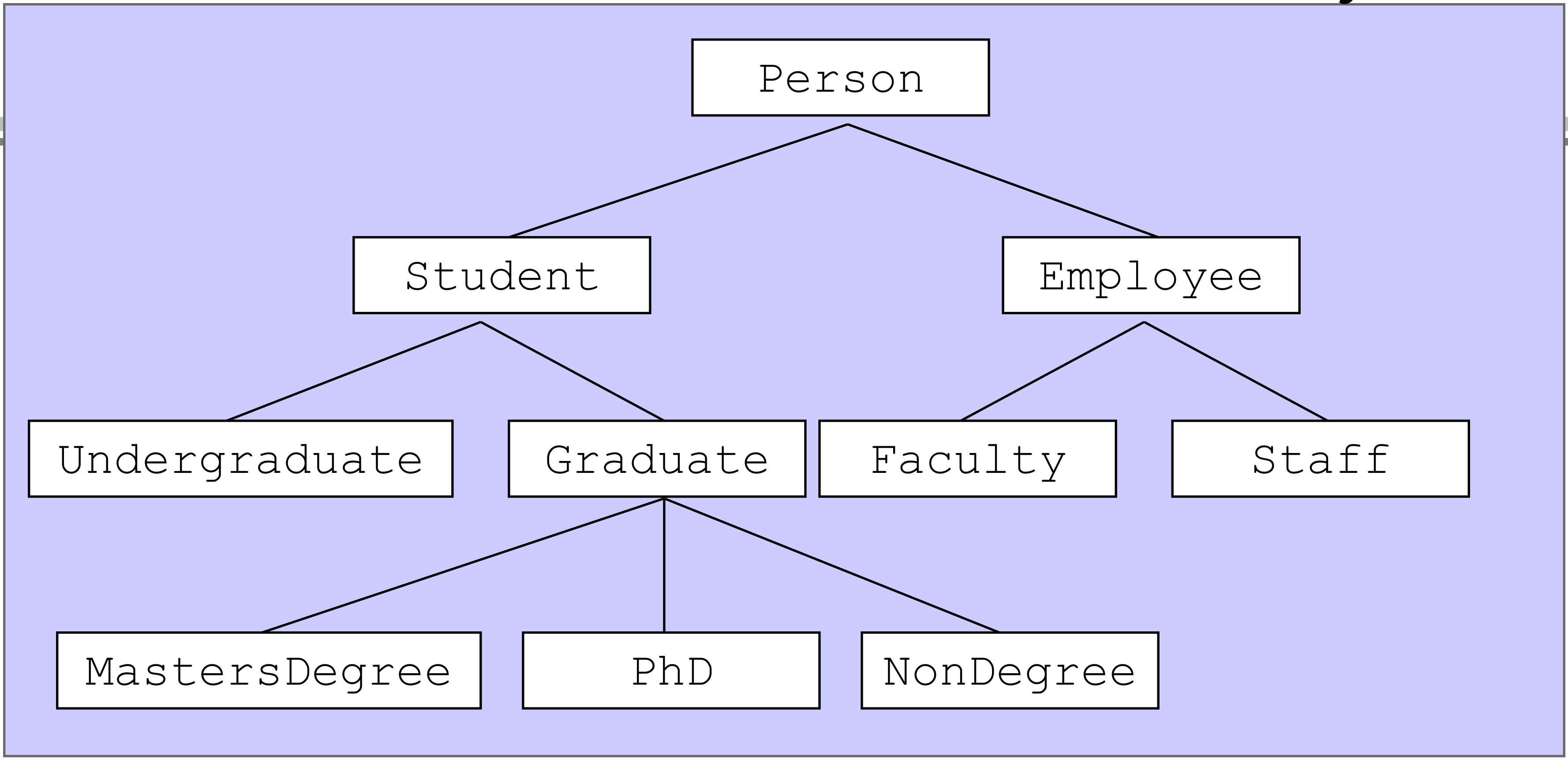
- Constructors:
  - » a default constructor
  - » one that initializes the `name` attribute (instance variable)
- Mutator and Accessor methods:
  - » `setName` to change the value of the `name` attribute
  - » `getName` to read the value of the `name` attribute
  - » `writeOutput` to display the value of the `name` attribute
- One other class method:
  - » `sameName` to compare the values of the `name` attributes for objects of the class
- Note: the methods are `public` and the `name` attribute `private`

A **`Person`** Base Class

Display 7.1

```
public class Person
{
    private String name;
    public Person()
    {
        name = "No name yet.";
    }
    public Person(String initialName)
    {
        name = initialName;
    }
    public void setName(String newName)
    {
        name = newName;
    }
    public String getName()
    {
        return name;
    }
   public void writeOutput()
   {
        System.out.println("Name: " + name);
   }
    public boolean sameName(Person otherPerson)
    {
        return (this.name.equalsIgnoreCase(otherPerson.name));
    }
}
```

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*

Derived Classes

```
public class Student extends Person
```

- The keyword **`extends`** in first line indicates inheritance.
  - » Creates derived class `Student` from base class `Person`
- A derived class inherits the instance variables and methods of the base class that it extends.
  - » The `Person` class has a `name` instance variable so the `Student` class will also have a `name` instance variable.
  - » Can call the `setName` method with a `Student` object even though `setName` is defined in `Person` and not in `Student`:

```
Student s = new Student();
s.setName("Warren Peace");
```

Extending the Base Class

- A derived class can add instance variables and/or methods to those it inherits from its base class.
- Note that an instance variable for the student number has been added
  - » `Student` has this attribute in addition to `name`, which is inherited from `Person`

```
private int studentNumber;
```

- Student also adds several methods that are not in Person:
  - » `reset`, `getStudentNumber`, `setStudentNumber`, `writeOutput`, `equals`, and some constructors
- Should I create a subclass or just change an existing class???

Example of Adding Constructor in a Derived Class: **`Student`**

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

The first few lines of `Student` class (Display 7.3):

- Two 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 `newName` 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 newName, int newStudentNumber)
    {
        super(newName);
        studentNumber = newStudentNumber;
    }
...
```

More lines of `Student` class (Display 7.3):

More about Constructors in a Derived Class

- Constructors can call other constructors
- Use `super` to invoke a constructor in parent class
  - » as shown on the previous slide
- Use `this` to invoke a constructor within the class
  - » shown on the next slide
- Whichever is used must be the first action taken by the constructor
- Only one of them can be first, so if you want to invoke both:
  - » Use a call with `this` to call a constructor with `super`

Example of a constructor using `this`

`Student` class has a constructor with two parameters: `String` for the `name` attribute and `int` for the `studentNumber` attribute

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

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

» calls the constructor with two arguments, initialName (`String`) and 0 (`int`), within the same class

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

Overriding Methods

- When a child class has a method with the same signature as the parent class, the method in the child class ***overrides*** the one in the parent class.
- This is *overriding*, not *overloading*.
- Example:
  - » Both `Person` and `Student` have a `writeOutput` method with no parameters (same signature).
  - » When `writeOutput` is called with a `Student` calling object, the `writeOutput` in `Student` will be used, not the one in `Person`.

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
- Can be called from anywhere in the method

```
public void writeOutput()
{
   super.writeOutput();
   System.out.println("Student Number : "
                      + studentNumber);
}
```

Overriding Versus Overloading

Overriding	**Overloading**
• Same method name	• Same method name
• Same signature • One method in ancestor, one in descendant	• 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
- Can also declare an entire class to be 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 mutator methods to change them, e.g. `reset` for a `Student` object to change the `name` 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
- Of course 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 class `Object`
- `Object` is called the *Eve* class since it is the original class for all other classes

Assignment Compatibility

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

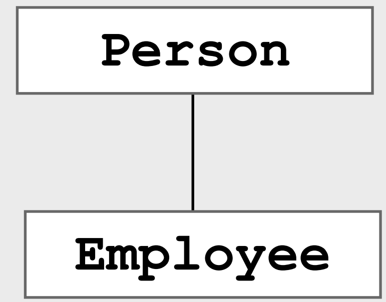
```
Person josephine;
Employee boss = new Employee();
josephine = boss;
```

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

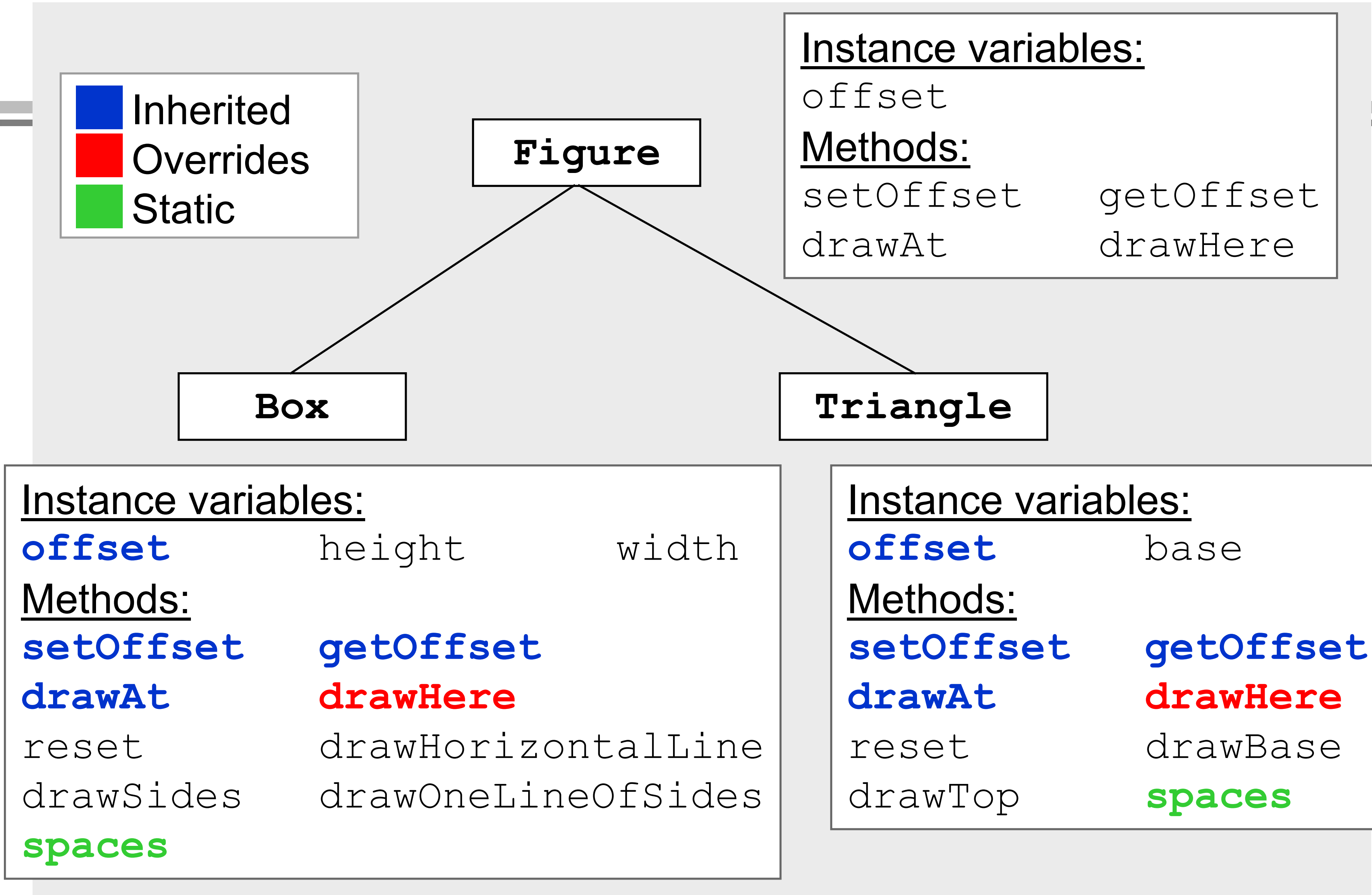


`Person` is the parent class of `Employee` in this example.

"Is a" and "Has a" Relationships

- Inheritance is useful for "is a" relationships.
  - » A student "is a" person.
  - » `Student` inherits from `Person`.
- Inheritance is usually **not** useful for "has a" relationships.
  - » A student "has a(n)" enrollment date.
  - » Add a `Date` object as an instance variable of `Student` instead of having `Student` inherit from `Date`.
- If it makes sense to say that an object of `Class1` "is a(n)" object of `Class2`, then consider using inheritance.

Character Graphics Example



Abstract Classes

- Cannot create objects of an ***abstract class***
  - » Example: `Figure` class in character graphics program
  - » An abstract class is used as a base for inheritance instead of being used to create objects.
- Abstract classes simplify program design by not requiring you to supply methods that would always be overridden.
  - » Example: `drawHere` method is overridden in all classes derived from `Figure`.
- Specify that a method is abstract if you don't want to implement it:

```
public abstract void drawHere();
```

- Any class that has an abstract method must be declared as an abstract class:

```
public abstract class Figure
```

Interfaces

- An ***interface*** is a type that specifies method headings.

  Example:

```
public interface Writeable
{
        public String toString();
        public void writeOutput();
    }
```

- You can make a method more general by using an interface as a type for a parameter.
  - » An object of any class that ***implements*** the interface (see the next slide) can be passed as the parameter.

```
public void display(Writeable displayObj)
{
        displayObj.writeOutput();
    }
```

Implementing an Interface

- A class that implements an interface must
  - » contain complete definitions for all of the methods specified in the interface
  - » be declared as implementing the interface

    `implements` *`Interface_Name`*
- Any class that implements the `Writeable` interface must have complete definitions of `toString` and `writeOutput`.
- There can be many different classes that implement an interface.

How do Programs Know Where to Go Next?

- 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
- *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

- Derived classes call a method in their parent class which calls a method that is overridden (defined) in each of the derived classes
  - » the parent class is compiled separately and before the derived classes are 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

<u>Parent class</u>: `Figure`

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

<u>Derived class</u>: `Box extends Figure`

- » Inherits `drawAt`
- » Redefines (overrides) `drawHere`
- » Calls `drawAt`
  - – uses the parent's `drawAt` method
  - – which must call this, 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

- Using the process of dynamic binding to allow different objects to use different method actions for the same method name
- Originally overloading was considered to be polymorphism
- Now the term usually refers to use of dynamic binding

Summary

- A derived 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, than A is both a member of both classes, A and B
  - » the type of A is both A and B