CHAPTER 8

Polymorphism

(Abstract Class and Interface)

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Introduction to Polymorphism

- There are three main programming mechanisms that constitute object-oriented programming (OOP)
  - Encapsulation
  - Inheritance
  - Polymorphism

Introduction to Polymorphism

❑ **Polymorphism**: A same operation can behave differently (be implemented by different methods).

Late Binding

- ***Early binding*** or ***static binding***
  - **which method is to be called** is decided at compile-time
    - ***Overloading***: *an invocation can be operated on arguments of more than one type*

- ***Late binding*** or ***dynamic binding***
  - **which method is to be called** is decided at run-time
    - ***Overriding***: a derived class inherits methods from the base class, it can change or override an inherited method

Lab: Early binding (through overloading)

```java
public class SayHello {

  public String sayHello(String name){
    return "Hello! "+ name;
  }

  public String sayHello(String name, String gender){
    if(gender.equals("boy")){
      return "Hello! Mr. "+ name;
    }
    else if(gender.equals("girl")){
      return "Hello! Miss. "+ name;
    }else{
      return "Hello! "+ name;
    }
  }

  public static void main(String[] args){
    SayHello hello = new SayHello();
    System.out.println(hello.sayHello("S.J.")); //decided at compile time
    System.out.println(hello.sayHello("S.J.","boy")); //decided at compile time
  }
}
```

Lab: Late binding (through overriding)

```
public class Payment {
  public void pay(){
    System.out.println("Pay in cash");
  }
  public void checkout(){
    pay();
  }
}
```

```
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();
  }
}
```

Lab: Late binding (through overriding)

```
public class CreditCardPayment extends Payment{
  public void pay() {
    System.out.println("Pay with credit card");
  }
}
```

```
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();

    Payment p2 = new CreditCardPayment();
    p2.checkout();
  }
}
```

Pitfall: No Late Binding for Static Methods

- Java uses **static binding** with **private**, **`final`**, and **static** methods
  - In the case of **`private`** and **`final`** methods, late binding would serve no purpose
  - However, in the case of a static method invoked using a calling object, it does make a difference

Lab

```java
public class Payment {
  public static void pay(){
    System.out.println("Pay in cash");
  }
  public void checkout(){
    pay();
  }
}
```

```java
public class CreditCardPayment extends Payment{
  public static void pay() {
    System.out.println("Pay with credit card");
  }
}
```

Then run Store again!

Lab

```java
public class Store {
  public static void main(String[] args) {
    Payment p1 = new Payment();
    p1.checkout();

    Payment p2 = new CreditCardPayment();
    p2.checkout();
  }
}
```

the type of **p2** is determined by its variable name, not the object that it references

Upcasting and Downcasting

- □ *Upcasting* is when an object of a derived class is assigned to a variable of a base class (or any ancestor class)

```
Payment p2 = new CreditCardPayment();
p2.checkout();
```

Upcasting and Downcasting

- *Downcasting* is when a type cast is performed from a base class to a derived class (or from any ancestor class to any descendent class)
  - Downcasting has to be done very carefully
  - In many cases it doesn't make sense, or is illegal:

```
Payment p1 = new Payment();
CreditCardPayment p2 = (CreditCardPayment)p1; //runtime error
```

Tip: Checking to See if Downcasting is Legitimate

- Downcasting to a specific type is only sensible if the object being cast is an instance of that type
  - This is exactly what the `instanceof` operator tests for:

    ```
    object instanceof ClassName
    ```

  - It will return true if ***`object`*** is of type ***`ClassName`***
  - In particular, it will return true if ***`object`*** is an instance of any descendent class of ***`ClassName`***

Lab (Downcasting)

Step1: Remove “static” in **CreditCardPayment and Payment**

Step2

```
 public class CreditCardPayment extends Payment{
   public void pay() {
     System.out.println("Pay with credit card");
   }
   public void sign(){
     System.out.println("Signing...");
   }
 }
```

Lab (Downcasting)

```
public class Store {

public static void main(String[] args) {
  Payment p1 = new Payment();
  p1.checkout();
  payProcess(p1);

  Payment p2 = new CreditCardPayment();
  p2.checkout();
  payProcess(p2);
}

public static void payProcess(Payment p){
  if(p instanceof CreditCardPayment){
    ((CreditCardPayment)p).sign();
  }
}

}
```

A First Look at the `clone` Method

- ❑ Creates and returns a copy of this object.
  - ➢ x.clone() != x

- ❑ The heading for the **`clone`** method defined in the **`Object`** class is as follows:

```
protected Object clone()
```

- ❑ A change to a more permissive access, such as from protected to public, is always allowed when overriding a method definition

Lab

```java
public class A implements Cloneable{
  int num = 1;
  B b = new B();

  public Object clone(){
    try{
      return super.clone();
    }catch(Exception e){
      return null;
    }
  }
}


public class B implements Cloneable{
  int speed = 100;
}
```

Lab (Shallow Copy)

```
public class Test {

  public static void main(String[] args) {
    A a = new A();
    System.out.println(a.num);             //1
    System.out.println(a.b.speed);         //100

    A clone_a = (A) a.clone();
    System.out.println(clone_a.num);       //1
    System.out.println(clone_a.b.speed);   //100

    clone_a.num = 2;
    clone_a.b.speed = 200;
    System.out.println(a.num);             //1
    System.out.println(a.b.speed);         //200

  }

}
```

A First Look at the `clone` Method

- ❑ If a class has a copy constructor, the `clone` method for that class can use the *copy constructor* to create the copy returned by the `clone` method

```
public Sale clone()
{
  return new Sale(this);
}
```

Lab (Deep Copy)

```
public class A implements Cloneable{
  int num = 1;
  B b = new B();

  public A(A a){
    num = a.num;
    b.speed = a.b.speed;
  }
  public A(){}

  public Object clone(){
    return new A(this);
  }
}
```

Lab (Deep Copy)

```java
public class Test {

  public static void main(String[] args) {
    A a = new A();
    System.out.println(a.num);               //1
    System.out.println(a.b.speed);           //100

    A clone_a = (A) a.clone();
    System.out.println(clone_a.num);         //1
    System.out.println(clone_a.b.speed);     //100

    clone_a.num = 2;
    clone_a.b.speed = 200;
    System.out.println(a.num);               //1
    System.out.println(a.b.speed);           //100

  }

}
```

Introduction to Abstract Classes

- In order to postpone the definition of a method, Java allows an *abstract method* to be declared
  - An abstract method has a heading, but no method body
  - The body of the method is defined in the derived classes
- The class that contains an abstract method is called an *abstract class*

Abstract Method

- An abstract method is like a placeholder for a method that will be fully defined in a descendent class
- It has a complete method heading, to which has been added the modifier `abstract`
- **It cannot be private**
- It has no method body, and ends with a semicolon in place of its body

```
public abstract double getPay();
public abstract void doIt(int count);
```

Abstract Class

- A class that has at least one abstract method is called an *abstract class*
  - An abstract class must have the modifier **`abstract`** included in its class heading:

```
public abstract class Employee
{
  private instanceVariables;
  . . .
  public abstract double getPay();
  . . .
}
```

Abstract Class

- An abstract class can have any number of abstract and/or fully defined methods
- If a derived class of an abstract class adds to or does not define all of the abstract methods, then it is abstract also, and must add **`abstract`** to its modifier

❑ A class that has no abstract methods is called a *concrete class*

Pitfall: You Cannot Create Instances of an Abstract Class

- ❑ An abstract class can only be used to derive more specialized classes
  - ➢ While it may be useful to discuss employees in general, in reality an employee must be a salaried worker or an hourly worker
- ❑ **An abstract class constructor cannot be used to create an object of the abstract class**

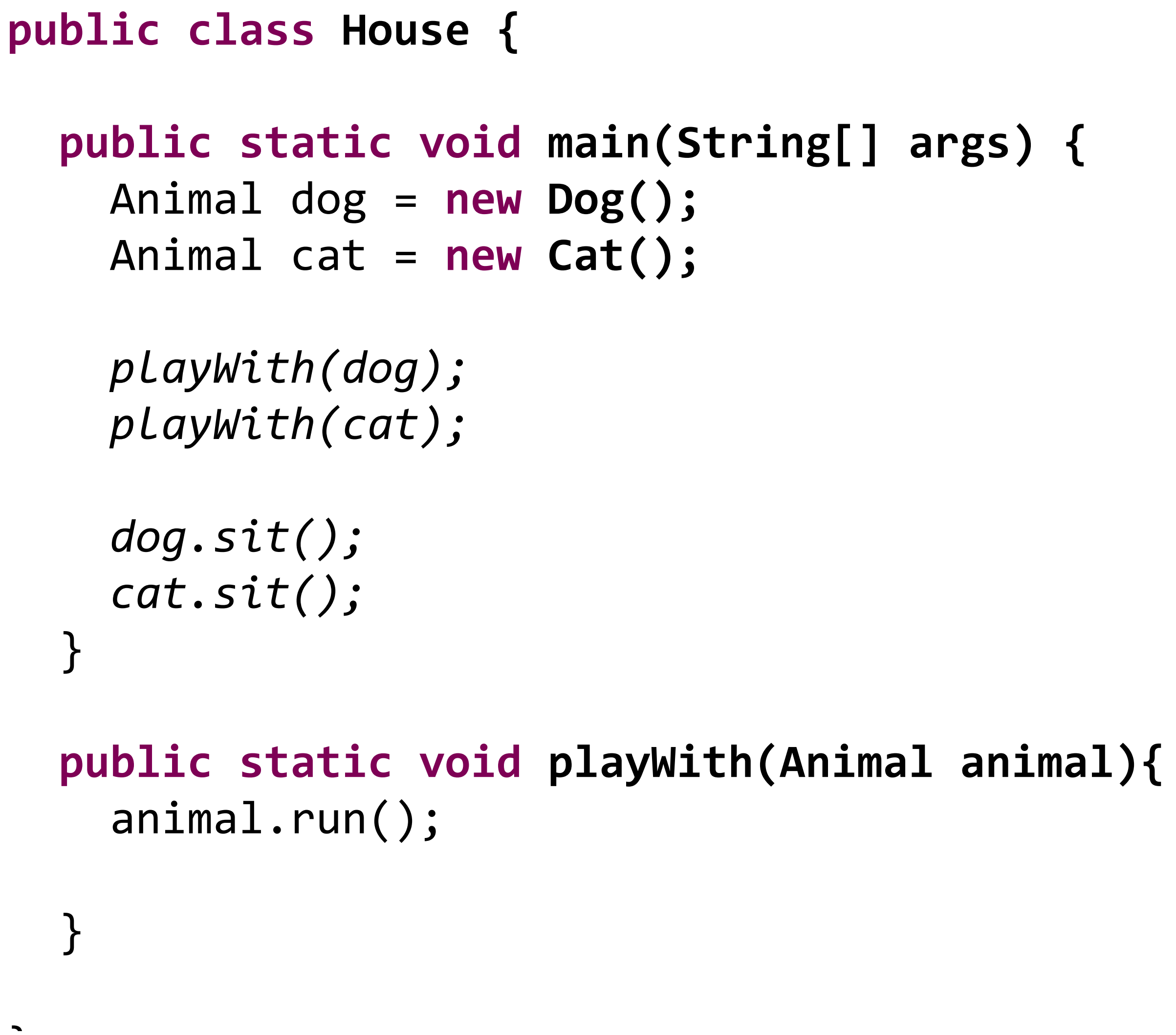
Lab

```
public abstract class Animal {
  public abstract void run();
  public void sit(){ System.out.println(“Sit down…”); }
}
```

```
public class Dog extends Animal {
  public void run(){
    System.out.println("The dog is running");
  }
}
```

```
public class Cat extends Animal{
  public void run(){
    System.out.println("The cat is running");
  }
}
```

Lab



```
public class House {

  public static void main(String[] args) {
    Animal dog = new Dog();
    Animal cat = new Cat();

    playWith(dog);
    playWith(cat);

    dog.sit();
    cat.sit();
  }

  public static void playWith(Animal animal){
    animal.run();

  }
```

Lab

___________ binding refers to the method definition being associated with the method invocation when the code is compiled.

(a)Dynamic

(b)Late

[✓ (c)Early]

(d)None of the above

Lab

Java does not use late binding for methods marked as:

(a)final

(b)static

(c)private

[✓ (d)all of the above]

Lab

Assigning an object of a derived class to a variable of a base class is called:

(a)static binding

(b)dynamic binding

[✓ (c)Upcasting]

(d)downcasting

Lab

Assigning an object of an ancestor class to a descendent class is called:

(a)static binding

(b)dynamic binding

(c)Upcasting

[✓ (d)downcasting]

Lab

If you choose to use the method clone in your code, you must ____________ the clone method.

(a)overload

(b)encapsulate

[✓ (c)override]

(d)protect

Lab

You cannot create an object using a/an:

(a)superclass constructor

(b)subclass constructor

(c)ancestor class constructor

[✓ (d)abstract class constructor]

Lab

An abstract method cannot be modified by:

(a)public

(b)protected

[✓ (c)private]

(d)none of the above

Lab

A class that has at least one abstract method is called an:

(a)concrete class

(b)encapsulated class

[✓ (c)abstract class]

(d)private class

Lab

A class with no abstract methods is called a

[✓ (a)concrete class]

(b)encapsulated class

(c)abstract class

(d)private class

Interfaces

- An *interface* is something like an extreme case of an abstract class
  - However, *an interface is not a class*
  - *It is a type that can be satisfied by any class that implements the interface*
- The syntax for defining an interface is similar to that of defining a class
  - Except the word `interface` is used in place of `class`

Interfaces

- An interface specifies a set of methods that any class that implements the interface must have
  - It contains **method headings** and **constant definitions** only
    - Any variables defined in an interface must be public, static, and final
  - It contains **no instance variables nor any complete method definitions**

Lab (Constants)

```java
public interface Shape {
  int color = 1; // => public static final int color = 1;
}
```

```java
public class Paint {
  public static void main(String[] args) {
    System.out.println(Shape.color);
  }
}
```

Interfaces

- All methods in an interface are **implicitly public and abstract**, so you can omit the public modifier.
  - They cannot be given private or protected

```
public interface ISpec1 {
        private void run(); //Not allowed
        protected void run(); //Not allowed

        void run(); // Allowed. Equal to the following definition
        public abstract void run(); //Allowed

}
```

Lab

```
public interface Shape {

  int color = 1; // => public static final int color = 1;

  public abstract double area(); //=> double area();
}
```

Interfaces

- ❑ *Multiple inheritance* is not allowed in Java
- ❑ Instead, Java's way of approximating multiple inheritance is through interfaces

```
public class ConcreteClass implements ISpec1, ISpec2, ISpec3{
        …
}
```

Interfaces

- To *implement an interface*, a concrete class must do two things:

1. `implements` ***`Interface_Name`***

2. The class must implement *all* the method headings listed in the definition(s) of the interface(s)

Lab

```
public class Rectangle implements Shape{
  int x1=0;
  int y1=0;
  int x2=10;
  int y2=10;
  public double area(){
    return (x2-x1)*(y2-y1);
  }
}


public class Circle implements Shape{

  double radius = 3;
  public double area(){
    return radius*radius*3.14;
  }
}
```

Lab

```
public class Paint {

  public static void main(String[] args) {
    System.out.println(Shape.color);

    Shape shape1 = new Rectangle();
    printArea(shape1);

    Shape shape2 = new Circle();
    printArea(shape2);
  }

  public static void printArea(Shape shape){
    System.out.println(shape.area());
  }
}
```

Abstract Classes Implementing Interfaces

❑ Abstract classes may implement one or more interfaces

- ➢ Any method headings given in the interface that are not given definitions are made into abstract methods

❑ A concrete class must give definitions for all the method headings given in the abstract class *and the interface*

Abstract Class vs. Interface

```
public abstract class Animal {
  public abstract void run();
  public void sit(){ System.out.println(“Sit down…”); }
}
```

vs.

```
public interface Shape {

  int color = 1; // => public static final int color = 1;

  public abstract double area(); //=> double area();
}
```

Derived Interfaces

- ❑ Like classes, an interface may be derived from a base interface
  - ➢ This is called *extending* the interface
  - ➢ The derived interface must include the phrase `extends` ***`BaseInterfaceName`***
- ❑ A concrete class that implements a derived interface must have definitions for any methods in the derived interface as well as any methods in the base interface

Lab

```java
public interface Drawing {

  public abstract void drawBorder();
}
```

```java
public interface Shape extends Drawing{

  int color = 1; // => public static final int color = 1;

  public abstract double area();
}
```

Lab

```
public class Rectangle implements Shape{

  int x1=0;
  int y1=0;
  int x2=10;
  int y2=10;

  public double area(){
    return (x2-x1)*(y2-y1);
  }
  public void drawBorder(){
    System.out.println("Drawing the border of the rectangle...");
  }
}
```

Lab

```
public class Circle implements Shape{

  double radius = 3;
  public double area(){
    return radius*radius*3.14;
  }

  public void drawBorder(){
    System.out.println("Drawing the border of the circle...");
  }
}
```

Lab

A class that uses an interface must use the keyword:

(a)Extends

(b)Inherits

(c)Super

[✓ (d)Implements]

Lab

An interface and all of its method headings are normally declared to be:

[✓ (a)public]

(b)private

(c)Protected

(d)package access

Lab

An interface may contain:

(a)instance variables

(b)primitive variables

(c)constant variables

(d)all of the above

Lab

```java
public interface Printable {
  void printAll();
}


class Person implements Printable {
  private String name = new String("Bill");
  private int age = 22;

  public void printAll() {
    System.out.println("Name is " + name + ", age is " + age);
  }
}


public class PrintableTest {
  public static void main(String[] args) {
    Printable p = new Person();
    p.printAll();
  }
}
```

Reference

- ❑ “Absolute Java”. Walter Savitch and Kenrick Mock. Addison-Wesley; 5 edition. 2012
- ❑ “Java How to Program”. Paul Deitel and Harvey Deitel. Prentice Hall; 9 edition. 2011.
- ❑ “A Programmers Guide To Java SCJP Certification: A Comprehensive Primer 3rd Edition”. Khalid Mughal, Rolf Rasmussen. Addison-Wesley Professional. 2008