Polymorphism and Abstract Classes

CHAPTER 8

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Introduction to Polymorphism

- There are three main programming mechanisms that constitute object-oriented programming (OOP)
  - Encapsulation
  - Inheritance
  - Polymorphism
- Polymorphism is the ability to associate many meanings to one method name
  - It does this through a special mechanism known as *late binding* or *dynamic binding*

Introduction to Polymorphism

- Inheritance allows a base class to be defined, and other classes derived from it
  - Code for the base class can then be used for its own objects, as well as objects of any derived classes
- Polymorphism allows changes to be made to method definitions in the derived classes, *and have those changes apply to the software written for the base class*

Example

- toString();

```
HourlyEmployee joe = new HourlyEmployee("Joe Worker",
                        new Date("January", 1, 2004), 50.50, 160);
Employee mike = new Employee("Mike Jordan", new
Date("March", 1, 1984));

System.out.println();
System.out.println("joe's record is as follows:");
System.out.println(joe);

Sstem.out.println();
System.out.println("mike's record is as follows:");
System.out.println(mike);
```

An example

```
public class Player{
        private health;
        public Player() {
                health = 100;
        }
        …
        public void attack(Player target){
                target.health -= 10;
        }
        …
}
```

An example

```
public class Warrior extends Player{
        public void attack(Player target){
                target.health -= 50;
        }
}
public class Wizard extends Player{
        public void attack(Player target){
                target.health -= 25;
        }
}
public class Doctor extends Player{
        public void attack(Player target){
                target.health += 25;
        }
}
```

An example

```
public class GameDemo{
        public static void main(String[ ] args) {
                Warrior player1 = new Warrior();
                Player player2 = new Wizard();
                Player player3 = new Doctor();
                player1.attack(player2);
                player2.attack(player3);
                player3.attack(player1);
        }
}
```

player1.health = ? player2.health = ? player3.health = ?

Late Binding

- The process of associating a method definition with a method invocation is called *binding*
- If the method definition is associated with its invocation when the code is compiled, that is called *early binding* or *static binding*
- If the method definition is associated with its invocation when the method is invoked (at run time), that is called *late binding* or *dynamic binding*

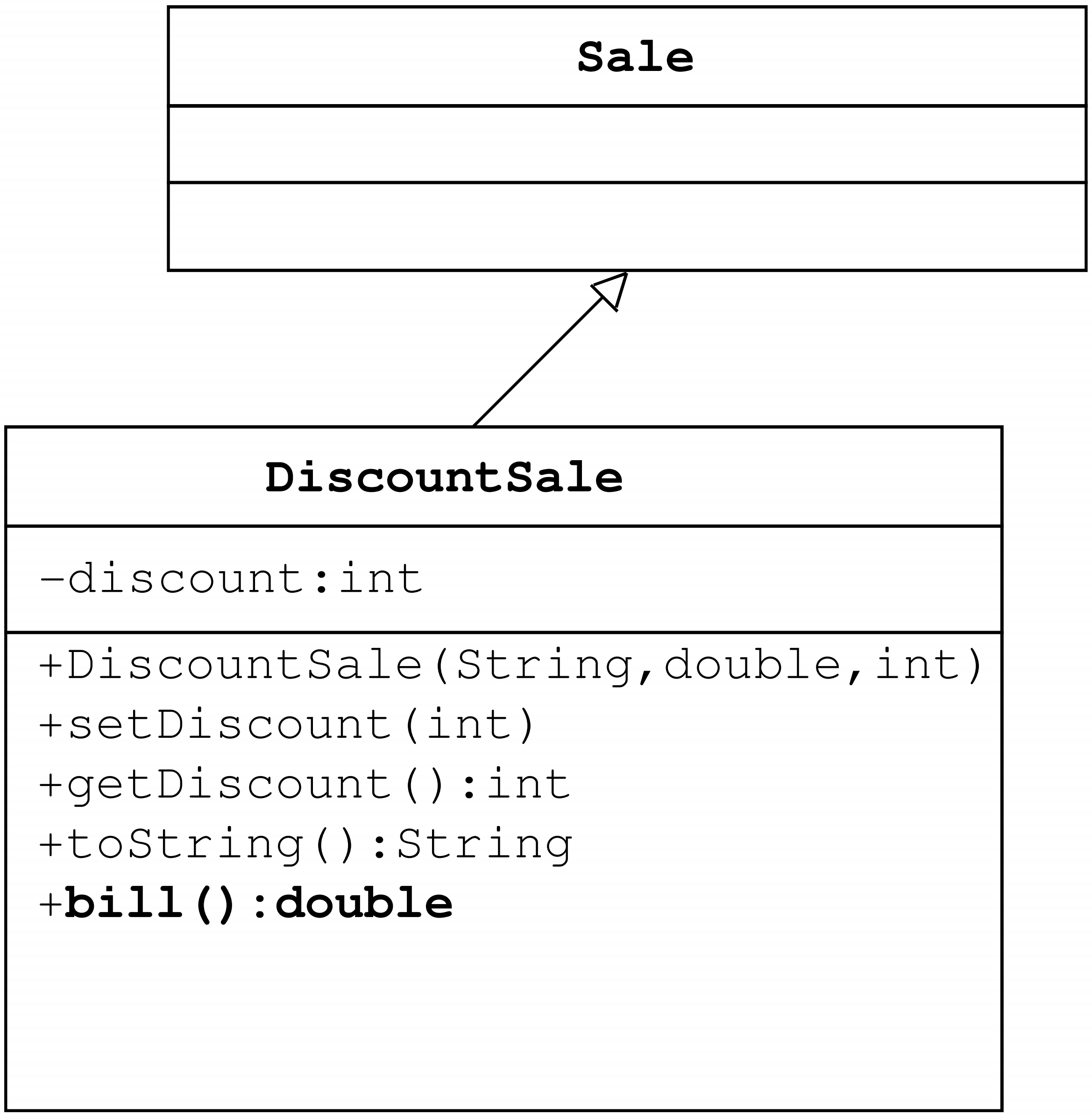
Late Binding

- Java uses late binding for all methods (except private, `final,` and static methods)
- Because of late binding, a method can be written in a base class to perform a task, even if portions of that task aren't yet defined
- For an example, the relationship between a base class called `Sale` and its derived class `DiscountSale` will be examined

Sale class

Sale
-name :String -price:double
+Sale() +Sale(String,double) +Sale(Sale) +setName(String) +getName():String +setPrice(double) +getPrice():double +toString():String +**bill():double** +**equalDeals(Sale):boolean** +**lessThan(Sale):boolean**

DiscountSale class



The `Sale` and `DiscountSale` Classes

- The `Sale` class contains two instance variables
  - `name`: the name of an item (`String`)
  - `price`: the price of an item (`double`)
- It contains three constructors
  - A no-argument constructor that sets `name` to `"No name yet"`, and price to `0.0`
  - A two-parameter constructor that takes in a `String` (for `name`) and a `double` (for `price`)
  - A copy constructor that takes in a `Sale` object as a parameter

The `Sale` and `DiscountSale` Classes

- The `Sale` class also has a set of accessors (`getName`, `getPrice`), mutators (`setName`, `setPrice`), overridden `equals` and `toString` methods, and a static `announcement` method
- The `Sale` class has a method `bill`, that determines the bill for a sale, which simply returns the price of the item
- It has two methods, `equalDeals` and `lessThan`, each of which compares two sale objects *by comparing their bills* and returns a `boolean` value

The `Sale` and `DiscountSale` Classes

- The `DiscountSale` class inherits the instance variables and methods from the `Sale` class
- In addition, it has its own instance variable, `discount` (a percent of the `price`), and its own suitable constructor methods, accessor method (`getDiscount`), mutator method (`setDiscount`), overriden `toString` method, and static `announcement` method
- The `DiscountSale` class has its own `bill` method which computes the bill as a function of the `discount` and the `price`

The **`Sale`** and **`DiscountSale`** Classes

- The **`Sale`** class **`lessThan`** method
  - Note the **`bill()`** method invocations:

```
public boolean lessThan (Sale otherSale)
{
  if (otherSale == null)
  {
    System.out.println("Error: null object");
    System.exit(0);
  }
  return (bill( ) < otherSale.bill( ));
}
```

The **`Sale`** and **`DiscountSale`** Classes

- The **`Sale`** class **`bill()`** method:

```
public double bill( )
{
  return price;
}
```

- The **`DiscountSale`** class **`bill()`** method:

```
public double bill( )
{
  double fraction = discount/100;
  return (1 - fraction) * getPrice( );
}
```

The `Sale` and `DiscountSale` Classes

- Given the following in a program:

```
   . . .
Sale simple = new sale("floor mat", 10.00);
DiscountSale discount = new
           DiscountSale("floor mat", 11.00, 10);
   . . .
if (discount.lessThan(simple))
  System.out.println("$" + discount.bill() +
                " < " + "$" + simple.bill() +
                " because late-binding works!");
   . . .
```

  - Output would be:

```
$9.90 < $10 because late-binding works!
```

The `Sale` and `DiscountSale` Classes

- In the previous example, the `boolean` expression in the `if` statement returns `true`
- As the output indicates, when the `lessThan` method in the `Sale` class is executed, it knows which `bill()` method to invoke
  - The `DiscountSale` class `bill()` method for `discount`, and the `Sale` class `bill()` method for `simple`
- Note that when the `Sale` class was created and compiled, the `DiscountSale` class and its `bill()` method did not yet exist
  - These results are made possible by late-binding

Pitfall: No Late Binding for Static Methods

- When the decision of which definition of a method to use is made at compile time, that is called *static binding*
  - This decision is made based on the *type of the variable naming the object*
- 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

Late Binding with **`toString`**

- If an appropriate **`toString`** method is defined for a class, then an object of that class can be output using **`System.out.println`**

```
Sale aSale = new Sale("tire gauge", 9.95);
System.out.println(aSale);
```

  – Output produced:

```
tire gauge Price and total cost = $9.95
```

- This works because of late binding

Late Binding with `toString`

- One definition of the method `println` takes a single argument of type `Object`:

```
public void println(Object theObject)
{
  System.out.println(theObject.toString());
}
```

  - In turn, It invokes the version of `println` that takes a `String` argument
- Note that the `println` method was defined before the `Sale` class existed
- Yet, because of late binding, the `toString` method from the `Sale` class is used, not the `toString` from the `Object` class

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)

```
Sale saleVariable; //Base class
DiscountSale discountVariable = new
   DiscountSale("paint", 15,10); //Derived class
saleVariable = discountVariable; //Upcasting
System.out.println(saleVariable.toString());
```

- Because of late binding, `toString` above uses the definition given in the `DiscountSale` class

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:

```
discountVariable =                    //will produce
     (DiscountSale)saleVariable;//run-time error
discountVariable = saleVariable //will produce
                                //compiler error
```

  - There are times, however, when downcasting is necessary, e.g., inside the **`equals`** method for a class:

```
Sale otherSale = (Sale)otherObject;//downcasting
```

Pitfall: Downcasting

- It is the responsibility of the programmer to use downcasting only in situations where it makes sense
  - The compiler does not check to see if downcasting is a reasonable thing to do
- Using downcasting in a situation that does not make sense usually results in a run-time 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`***

A First Look at the `clone` Method (SKIP)

- Every object inherits a method named `clone` from the class `Object`
  - The method `clone` has no parameters
  - It is supposed to return a deep copy of the calling object
- However, the inherited version of the method was not designed to be used as is
  - Instead, each class is expected to override it with a more appropriate version

A First Look at the `clone` Method (SKIP)

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

  ```
  protected Object clone()
  ```

- The heading for a `clone` method that overrides the `clone` method in the `Object` class can differ somewhat from the heading above
  - A change to a more permissive access, such as from protected to public, is always allowed when overriding a method definition
  - Changing the return type from `Object` to the type of the class being cloned is allowed because every class is a descendent class of the class `Object`
  - This is an example of a covariant return type

A First Look at the `clone` Method (SKIP)

- 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);
}
```

and another example:

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

Pitfall: Sometime the `clone` Method Return Type is `Object` (SKIP)

- Prior to version 5.0, Java did not allow covariant return types
  - There were no changes whatsoever allowed in the return type of an overridden method
- Therefore, the `clone` method for all classes had `Object` as its return type
  - Since the return type of the clone method of the `Object` class was `Object`, the return type of the overriding clone method of any other class was `Object` also

Pitfall: Sometime the `clone` Method Return Type is `Object` (SKIP)

- Prior to Java version 5.0, the `clone` method for the `Sale` class would have looked like this:

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

- Therefore, the result must always be type cast when using a `clone` method written for an older version of Java

```
Sale copy = (Sale)original.clone();
```

Pitfall: Sometime the `clone` Method Return Type is `Object` (SKIP)

- It is still perfectly legal to use Object as the return type for a clone method, even with classes defined after Java version 5.0
  - When in doubt, it causes no harm to include the type cast
  - For example, the following is legal for the clone method of the Sale class:

```
Sale copy = original.clone();
```

  - However, adding the following type cast produces no problems:

```
Sale copy = (Sale)original.clone();
```

Pitfall: Limitations of Copy Constructors (SKIP)

- Although the copy constructor and **`clone`** method for a class appear to do the same thing, there are cases where only a **`clone`** will work
- For example, given a method **`badcopy`** in the class **`Sale`** that copies an array of sales
  - If this array of sales contains objects from a derived class of **`Sale`**(i.e., **`DiscountSale`**), then the copy will be a plain sale, not a true copy

```
b[i] = new Sale(a[i]); //plain Sale object
```

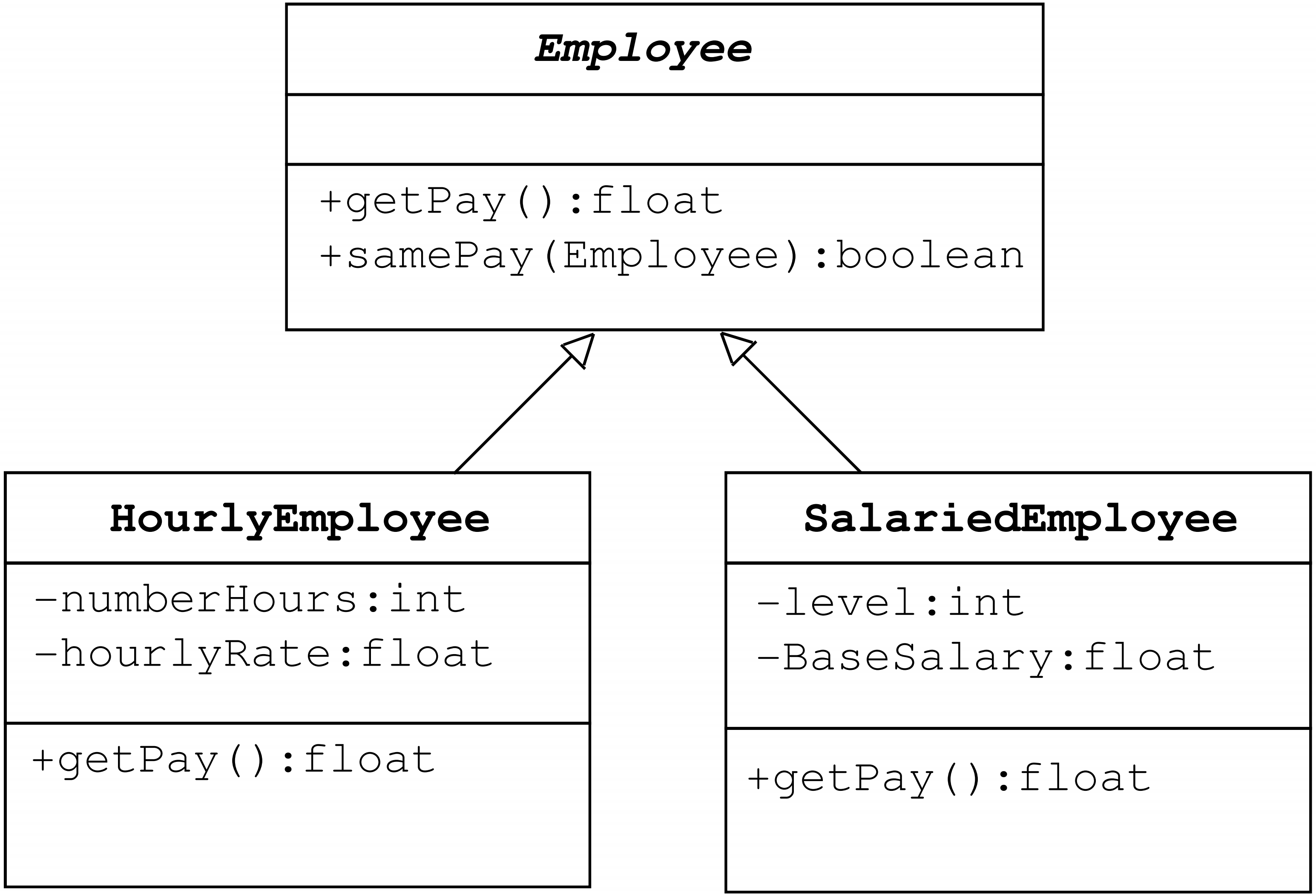
Pitfall: Limitations of Copy Constructors (SKIP)

- However, if the **`clone`** method is used instead of the copy constructor, then (because of late binding) a true copy is made, even from objects of a derived class (e.g., **`DiscountSale`**):

```
b[i] = (a[i].clone());//DiscountSale object
```

  - The reason this works is because the method **`clone`** has the same name in all classes, and polymorphism works with method names
  - The copy constructors named **`Sale`** and **`DiscountSale`** have different names, and polymorphism doesn't work with methods of different names

Introduction to Abstract Classes



Introduction to Abstract Classes

- In Chapter 7, the **`Employee`** base class and two of its derived classes, **`HourlyEmployee`** and **`SalariedEmployee`** were defined
- The following method is added to the **`Employee`** class
  - It compares employees to to see if they have the same pay:

```
public boolean samePay(Employee other)
{
  return(this.getPay() == other.getPay());
}
```

Introduction to Abstract Classes

- There are several problems with this method:
  - The `getPay` method is invoked in the `samePay` method
  - There are `getPay` methods in each of the derived classes
  - There is no `getPay` method in the `Employee` class, nor is there any way to define it reasonably without knowing whether the employee is hourly or salaried

Introduction to Abstract Classes

- The ideal situation would be if there were a way to
  - Postpone the definition of a `getPay` method until the type of the employee were known (i.e., in the derived classes)
  - Leave some kind of note in the `Employee` class to indicate that it was accounted for
- Surprisingly, Java allows this using abstract classes and methods

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
  - However, a derived class constructor will include an invocation of the abstract class constructor in the form of `super`
  - The constructor in an abstract class is only used by the constructor of its derived classes

Tip: An Abstract Class Is a Type

- Although an object of an abstract class cannot be created, it is perfectly fine to have a parameter of an abstract class type
  - This makes it possible to **plug in** an object of any of its **descendent** classes
- It is also fine to use a variable of an abstract class type, as long as it names objects of its concrete descendent classes only