CSE 1030

Yves Lespérance

Lecture Notes

Week 7 — Inheritance

Recommended Readings:
Van Breugel & Roumani Ch. 6 and Savitch Ch. 7, 8, and 9 and Sec. 13.1

Inheritance

Often, we need to define a class that is similar to an existing class; it just adds a few new attributes or methods, or implements existing methods differently.

Instead of having to define the new class from scratch, OOP supports declaring the new class as a *subclass* or *specialization* of the old one.

Then the subclass *inherits* all the attributes and methods of the original class, can add new ones, as well as *override* the implementation of existing methods.

This is called *inheritance*.

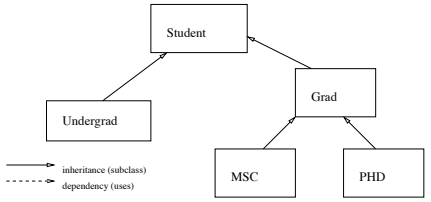
We say that the subclass *is a* the superclass.

Code reuse is important in software engineering. This saves time and you don't have to keep track of all the places where the same code appears so you keep them "in sync".

E.g. `RewardCard` *is a* `CreditCard`.

Can represent is-a/subclass relationships in UML class diagrams.

E.g. a hierarchy of related classes:



The class `Undergrad` is a subclass or specialization of `Student`. Inversely, we say that `Student` is a *superclass* or *generalization* of `Undergrad`.

Every instance of a class is also an instance of all it superclasses (similar to sets). So an instance of `Undergrad` is also an instance of `Student`. An instance of `MSC` is also an instance of `Grad` and `Student`.

```
public class Student
{  // instance attributes
   private String name;
   private long number;
   //constructor
   public Student(String aName, long aNumber)
   {  this.setName(aName);
      this.setNumber(aNumber);
   }
   // instance methods
   public void setName(String aName)
   {  this.name = aName;
   }
   public String getName()
   {  return this.name;
   }
   public void setNumber(long aNumber)
   {  this.number = aNumber;
   }
   public long getNumber()
   {  return this.number;
   }
   public String toString()
   {  return "Student[name=" + this.getName() +
           ",number=" + this.getNumber() + "]";
   }
}
```



```
public class Undergrad extends Student
{  // instance attributes
   // name and number are inherited from Student
   private String major;
   private int year;
   //constructor
   public Undergrad(String aName, long aNumber,
      String aMajor, int aYear)
   {  ...
   }
   // instance methods
   // setName, getName, setNumber, & getNumbers
   // are inherited from superclass Student
   // new methods
   public void setMajor(String aMajor)
   {  this.major = aMajor;
   }
   public String getMajor()
   {  return this.major;
   }
   public void setYear(int aYear)
   {  this.year = aYear;
   }
   public int getYear()
   {  return this.year;
   }
   // need to override toString method from Student

}
```



```
public class Eg
{  public static void main(String[] args)
   {  Student s1 = new Student("John",202123456);
      System.out.println("s1 is " + s1.getName());
      Undergrad s2 = new Undergrad(
         "Mary",201234567,"compsci",1);
      System.out.println("s2 is "+s2.getName());//inherited
      s2.setName("Mary Ellen");//inherited
      System.out.println("s2's year is " +
                  s2.getYear());//new method
   }
}
```


Overriding Methods

Sometimes when we define a subclass, a method inherited from the superclass is inappropriate and we want to change it (e.g., `toString`). We can do this by providing a new definition for the method in the subclass. The new definition *overrides*, i.e. replaces the inherited one. E.g.

```
public class Undergrad extends Student
{  ...
   // override toString method from Student
   public String toString()
   {  return "Undergrad[name=" + this.getName() +
             ",number=" + this.getNumber() +
             ",major=" + this.getMajor() +
             ",year=" + this.getYear() + "]";
   }
   ...
}
```

```
public class Eg
{  public static void main(String[] args)
   {  Student s1 = new Student("John",202123456);
      System.out.println(s1.toString());//calls Student's
      Undergrad s2 = new Undergrad(
         "Mary",201234567,"compsci",1);
      System.out.println(s2.toString());//calls Undergrad's
   }
}
```

Note that the *private* attributes of the superclass, e.g. `name`, are *not visible* in the subclass; you must use a public method to retrieve their value, e.g. `getName()`.

The keyword `super` refers to the object as an instance of the superclass. It can be used to invoke overridden methods. E.g. another way to define `toString` in `Undergrad`:

```
public class Undergrad extends Student
{  ...
   // override toString method from Student
   public String toString()
   {  // call superclass's method
      String s = super.toString();
      // make appropriate changes & return
      s = s.substring(s.indexOf("["),s.length()-1);
      return "Undergrad" + s +
             ",major=" + this.getMajor() +
             ",year=" + this.getYear() + "]";
   }
   ...
}
```


Overloaded vs Overridden Methods

It is important to distinguish between overloaded and overridden methods. As we have seen earlier, we can define several versions of a method that work with different types of arguments. This is called *overloading* the methods. E.g. the overloaded constructors:

```
public Person(){...}
public Person(String n, int a){...}
```

Another e.g.: we already have

```
public void setYear(int aYear)
{  this.year = aYear;
}
```


We could add:

```
public void setYear(){
  this.setYear(1); // default value
}
```

Then the user can write:

```
s1.setYear(); // sets year to 1
s1.setYear(n); // sets year to n
```

The *signature* of a method is the number and types of its parameters and their ordering. E.g.

1st `Person` constructor:	`Person()`
2nd `Person` constructor:	`Person(String,int)`
original `setYear`:	`setYear(int)`
2nd `setYear`:	`setYear()`
perhaps a 3rd `setYear`:	`setYear(String)`

When overloading methods, you are defining several methods with the same name that will be available *in the same class*. This is only possible when the signatures of the methods are *different*.

To decide which overloaded method to call, the compiler looks at the number and types of the arguments. If the signatures are the same, it cannot determine which method is called.

In contrast, *overridden* methods have the *same signature*. The method in the subclass replaces that in the superclass (even though the superclass's version is still available using `super`). E.g.

```
public class Parent
{  public void meth() // #1
   {  ...
   }
   public void meth(int n) // #2, overloads #1
   {  ...
   }
   ...
}
public class Offspring extends Parent
{  public void meth(int n) // #3, overrides #2
   {  ...
   }
   ...
}
...
// in main
Parent o1 = new Parent();
Offspring o2 = new Offspring();
o1.meth();   // calls #1
o1.meth(31); // calls #2
o2.meth();   // calls #1
o2.meth(29); // calls #3
```


Inheritance and Attributes

As we saw previously, attributes defined in a superclass are inherited by the subclass, but are not directly accessible (assuming they are `private`). They can only be accessed through inherited `public` methods.

You can also redefine an attribute in the subclass, but unlike for methods, the new attribute does not replace the original one. Instead, you will have two attributes with the same name, with the one defined in the subclass *shadowing* the one defined in the superclass. E.g.


```
public class Parent
{  ...
   public setAtt(int n)
   {  att = n;
   }
   private int att;
}
public class Offspring extends Parent
{  public void meth()
   {  att = 4;// sets Offspring's att
      setAtt(3);// sets Parent's att
   }
   private int att;
}
// in main
Offspring o = new Offspring();
o.meth();
```

If the superclass's attribute is not private, you can refer to it as `super.att`.

Constructors and Inheritance

An instance of a class C in a hierarchy is also an instance of all of C's superclasses (all the way to the top). This fits with the view of classes as sets and the specialization relation as subset.

If an object is to be an instance of a class, then the class's constructor should be called when the object is created. For an instance of a class C in a hierarchy, the constructor of C *and the constructors of all of C's superclasses should be called*. Java *requires* this.

You can call a constructor of C's superclass by putting `super(...)` in C's constructor. This must be the first statement in C's constructor. E.g.


```
public class Student
{
   private String name;
   ptivate long number;

   public Student()
   {  this("UNKNOWN",-1);
   }
   public Student(String aName, long aNumber)
   {  this.setName(aName);
      this.setNumber(aNumber);
   }
   ...
}
```



```
public class Undergrad extends Student
{  private String major;
   private int year;

   public Undergrad()
   {  super();// calls Student's 0 args constructor
      this.setMajor("general");
      this.setYear(1);
   }
   public Undergrad(String aName, long aNumber,
      String aMajor, int aYear)
   {  super(aName, aNumber);// calls Student's
                            // 2 args constructor
      this.setMajor(aMajor);
      this.setYear(aYear);
   } ...
}

// in main
Undergrad u = new Undergrad(
   "John", 201234567, "compsci", 1);
```


If you leave out the call to the superclass's constructor, Java automatically inserts `super()` at the beginning of the subclass's constructor, i.e. a call to the superclass's 0 arguments constructor.

If there are more than one superclass, each ancestor class's constructor is called in turn. E.g.

```
public class PartTimeUndergrad extends Undergrad
{  private double courseLoad;
   //constructors
   public PartTimeUndergrad()
   {  super();// calls Undergrad's 0 args constructor
      this.setCourseLoad(2.5);
   }
   public PartTimeUndergrad(String aName, long
      aNumber, String aMajor, int aYear, double aLoad)
   {  super(aName, aNumber, aMajor, aYear);
         // calls Undergrad's 4 args constructor
      this.setCourseLoad(aLoad);
   }
   ...
}
// in main
PartTimeUndergrad p = new PartTimeUndergrad(
   "John", 201234567, "compsci", 1, 3.5);
```


Constructors are never inherited.

However, if you don't define a constructor for a class, Java automatically provides a default 0 arguments constructor that initializes the attributes to default values, 0 for numbers, `false` for `boolean`, and `null` for objects.

Problem: define a method

```
public double calculateFees(
     double courseload)
```

for `Student` and `Undergrad` which returns the fees to be paid by the student depending on on his/her courseload.

Suppose that for students generally, the fees are $800 per course and that for undergraduates, there is an additional incidental charge of $100 for first year students and $150 for students in later years.


```
public class Student
{  ...
   public double calculateFees(double courseload)
   {  final double FEE_PER_COURSE = 800;
      return FEE_PER_COURSE * courseload;
   }
   ...
}
public class Undergrad extends Student
{  ...
   // override Student's calculateFees method
   public double calculateFees(double courseload)
   {  final double INCIDENTAL_FEE_Y1 = 100;
      final double INCIDENTAL_FEE_Y_GT_1 = 150;
      double fee = super.calculateFees(courseload);
      if (year == 1)
      {  fee = fee + INCIDENTAL_FEE_Y1;
      } else
      {  fee = fee + INCIDENTAL_FEE_Y_GT_1;
      }
      return fee;
   }
   ...
}
// in main
Student s = new Student("Mary", 202345678);
System.out.println(s + " fees: " + s.calculateFees(4.5));
Undergrad u = new Undergrad(
   "John", 201234567, "compsci", 1);
System.out.println(u + " fees: " + u.calculateFees(4.5));
```

Polymorphism

In OOP, classes correspond to types. When a class `Co` is a subclass of a class `Cp`, then the type `Co` is a subtype of `Cp`. If you have a reference to an instance of `Co`, it can be assigned to a variable of type `Cp` and manipulated as if it were an instance of the class `Cp`. E.g.

```
Student s1;
s1 = new Undergrad(
  "Mary",201234567,"compsci",1);
```

The ability to use a value of a more specific type where one of a more general type is expected is called *polymorphism*, since the general type comes in “many forms”.

You can also assign a reference to an instance of superclass (a supertype) to a variable of a subclass (a subtype) provided you perform a type cast. E.g.


```
Student s1;
s1 = new Undergrad(
  "Mary",201234567,"compsci",1);
Undergrad u1;
u1 = (Undergrad) s1;
```

Note that if the object being cast does not belong to the type given (e.g. `s1` is not an instance of `Undergrad` or one of it’s subclasses) an exception will be thrown when the program is run.

To be safe, you can check whether the object belongs to the right class using the `instanceof` operator before you perform the cast, e.g.

```
if (s1 instanceof Undergrad)
   u1 = (Undergrad) s1;
```


Dynamic Method Binding

When you call an overridden method on a reference of polymorphic type (e.g. `s1.toString()`), the version of the method that gets called depends on the actual type of the object referred to at run time; it is not necessarily that of the declared type. E.g.

```
Student s1;
s1 = new Student("John",202123456);
System.out.println(s1.toString());// calls Student's
s1 = new Undergrad(
  "Mary",201234567,"compsci",1);
System.out.println(s1.toString());// calls Undergrad's
```

This approach to selecting which version of an overridden method to call is named *dynamic* or *late method binding*. The term polymorphism is often used to refer to this specific feature of polymorphic method calls.

Dynamic method binding searches for method signature determined at compilation time, so it may not get the expected version of a method. E.g.

`CreditCard` provides `isSimilar(CreditCard)`

`RewardCard` overloads this with `isSimilar(RewardCard)`

```
CreditCard c1 = new RewardCard(9, "adam");
CreditCard c2 = new RewardCard(9, "adam");
c1.charge(100);
c1.pay(100);
System.out.println(c1.isSimilar(c2)); // CreditCard version
System.out.println(c1.isSimilar((RewardCard)c2)); // CreditCard version!!
System.out.println(((RewardCard)c1).isSimilar(c2)); // CreditCard version
System.out.println(((RewardCard)c1).isSimilar((RewardCard)c2)); // RewardCard versi
```

See Java By Abstraction p. 344.

Abstract Classes

Abstract classes are “incompletely defined” classes. They contain a partial definition, a sort of template, that will be completed when we define concrete subclases. This is often useful to avoid code duplication.

Abstract classes can contain `abstract` methods, i.e. methods for which we only provide the signature, not the code. The code will be provided by the subclasses. Abstract classes can also contain normal method definitions and attribute declarations like ordinary classes. If a class contains even one abstract methods, the class must be declared `abstract`.

Because they are “incomplete”, abstract classes *cannot have any direct instances,* i.e. instances that are not also instances of some concrete subclass.

Inheritance and Preconditions/Postcontitions

In a subclass, if we override a method from the superclass, we can weaken its precondition, but not strenghten it. The method of the subclass should work whenever the superclass’s version would because an instance of the subclass is an instance of the superclass.

For a postcondition, we have the opposite: if in a subclass we override a method from the superclass, we can strenghten its precondition, but not weaken it. The new verson should achieve all the effects guaranteed by the superclass’s version and possibly more.