CMSC 131: Chapter 23 (Supplement)
Inheritance

Inheritance

Inheritance: is the process by which one new class, called the **derived class**, is created from another class, called the **base class**.

- The **derived class** is also called: **subclass** or **child class**.
- The **base class** is also called: **superclass** or **parent class**.

Motivation: In real life objects have a hierarchical structure: (figure omitted)

We want to do the same with our program objects.

Inheritance

Object Inheritance: What does inheritance mean within the context of object-oriented programming?

Suppose a **derived class**, **Circle**, comes from a **base class**, **Shape**:

- Circle should have **all the instance variables** that Shape has.
  (E.g., Shape stores a color, and thus, Circle stores a color.)
- Circle should have **all the methods** that Shape has (E.g.,
  Shape has an accessor, getColor( ), and thus, Circle has getColor( ).)
- Circle is allowed to define **new instance variables** and **new methods** that are particular to it:
  (New) Circle Instance variables: Center, radius.
  (New) Methods: draw( ), getArea( ), getPerimeter( ).

Code reuse: Code/Data that is common to all the derived classes can be stored in the base class. This allows us to **avoid code duplication**, and so makes development and maintenance easier.

Example: University People

Consider an example for a university database, which stores information on various people at the university. The various objects form a hierarchy: (figure omitted)

We will consider the design of the **Person**, **Student**, and **Faculty** classes.

These classes will be very simple (almost trivial). Watch for the relationships between these classes.

Base Class: Person (Part 1)

```
package university;

public class Person {
    private String name;        // person's name
    private String idNum;       // ID number

    public Person( ) {
        name = "No Name";
        idNum = "000-00-0000";
    }

    public Person( String n, String id ) {
        name = n;
        idNum = id;
    }

    public Person( Person p ) {
        name = p.name;
        idNum = p.idNum;
    }
    // …other methods in part 2
}
```

Base Class: Person (Part 2)

```
public class Person {
    private String name;        // person's name
    private String idNum;       // ID number

    // … constructors in part 1

    public String getName( ) { return name; }

    public String getIdNum( ) { return idNum; }

    public void setName( String n ) { name = n; }

    public void setIdNum( String id ) { idNum = id; }

    public String toString( ) {
        return "[" + name + "] " + idNum;
    }

    public boolean equals( Person p ) {
        return name.equals( p.name ) && idNum.equals( p.idNum );
    }
}
```

Derived Classes: Student and Faculty

We derive two classes Student and Faculty. Each class inherits all the data and methods from Person, and adds data and methods that are particular to its particular function. (figure omitted)

Student: In addition to name and ID, has **admission year** and **GPA**.
Faculty: In addition to name and ID, has the **year they were hired**.

Derived Class Structure

Person: (base class)

Instance Data: Name and ID-number.

String name
String idNum

Methods:

Constructors: default, standard, copy constructors.
Accessors/Setters: getname( ), setName( ), getIdNum( ), setIdNum( ).
Standard methods: toString( ), equals( ).

Student: (derived from **Person**)

Instance Data: Admission year and GPA.

int admitYear
double gpa

Methods: (same structure as Person)

Faculty: (derived from **Person**)

Instance Data: Year hired.

int hireYear

Methods: (same structure as Person)

Derived class: Student (Part 1)

```
package university;
public class Student extends Person  {
    private int admitYear;
    private double gpa;

    public Student( ) {
        super( );
        admitYear = -1;
        gpa = 0.0;
    }
    public Student( String n, String id, int yr, double g ) {
        super( n, id );
        admitYear = yr;
        gpa = g;
    }
    public Student( Student s ) {
        super( s );
        admitYear = s.admitYear;
        gpa = s.gpa;
    }
    // …other methods in part 2
}
```

Dissecting the Student Class

Extends: To specify that Student is a **derived class** (subclass) of Person we add the descriptor "extends" to the class definition:

```
public class Student extends Person { … }
```

super( ): When initializing a new Student object, we need to initialize its **base class** (or **superclass**). This is done by calling **super(…)**. For example, **super(name, id)** invokes the constructor **Person(name, id)**.

- super(…) must be the **first statement** of your constructor
- If you **do not** call super( ), Java will automatically invoke the base class's **default constructor**.
- What if the base class's default constructor is **undefined**? **Error**.
- You must use "**super(…)**", not "**Person(…)**".

Memory Layout and Initialization Order

When you create a new derived class object:

- Java allocates space for **both** the **base class** instance variables and the **derived class** variables.
- Java initializes the **base class variables first**, and then initializes the derived class variables.

Example:

```
Person ted = new Person( "Ted Goodman", "111-22-3333" );
Student bob = new Student( "Bob Goodstudent", "123-45-6789",
                           2004, 4.0 );
```

(figure omitted)

Derived class: Student (Part 2)

```
public class Student extends Person  {
    private int admitYear;
    private double gpa;

    // … constructors in part 1

    public int getAdmitYear( ) { return admitYear; }
    public double getGpa( ) { return gpa; }

    public void setAdmitYear( int yr ) { admitYear = yr; }
    public void setGpa( double g ) { gpa = g; }

    public String toString( ) {
        return super.toString( ) + " " + admitYear + " " + gpa;
    }

    public boolean equals( Student s ) {
        return super.equals( s ) &&
                admitYear == s.admitYear &&
                gpa == s.gpa;
    }
}
```

Inheritance

Inheritance: Since Student is derived from Person, a Student object can invoke any of the Person methods, it **inherits** them.

```
Student bob = new Student( "Bob Goodstudent", "123-45-6789", 2004, 4.0 );
System.out.println( "Bob's name is " + bob.getName( ) );
bob.setName( "Robert Goodstudent" );
System.out.println( "Bob's new info: " + bob.toString( ) );
```

A Student "is a" Person:

- By inheritance a Student object is also a Person object. We can use a Student reference anywhere that a Person reference is needed.

```
Person robert = bob;            // Okay: A Student is a Person
```

- However, we cannot do it the other way around. (A Person need not be a Student.)

```
Student bob2 = robert;          // Error! Cannot convert Person to Student
```

Inheritance

Inheritance and private members:

- Student objects inherit all the private data (name and idNum).
- However, **private members** of the base class **cannot** be accessed directly.

Example:

```
public class Student extends Person {
    …
    public void someMethod( ) { name = "Mr. Foobar"; }  // Illegal!
    public void someMethod2( ) { setName( "Mr. Foobar" ); } // Okay
}
```

Why is this? After you have gone to all the work of setting up privacy, it wouldn't be fair to allow someone to simply extend your class and now have direct access to all the private information.

Inheritance: Quick Recap

Recap:

- Inheritance is when one class (**derived class** or **subclass**) is defined from another class (the **base class** or **superclass**).
- To derive a class D from a base class B, we use the declaration:
  public class D extends B { … }
- The derived class **inherits** all the instance variables and the methods from the base class. It can also define new instance variables and new methods.
- When a derived class is initialized, it can use **super(…)** to invoke the constructor for the base class.
- A derived class can explicitly refer to entities from the base class using **super**. For example, super.toString( ) invokes the base class's toString method.
- A reference to a derived class can be used anywhere where a reference to the base class is expected.

  Remember: A Student "is a" Person.

Derived Class: Faculty

```
package university;
public class Faculty extends Person {
    private int hireYear;                           // year when hired

    public Faculty( ) { super( ); hireYear = -1; }

    public Faculty( String n, String id, int yr ) {
        super(n, id);
        hireYear = yr;
    }
    public Faculty( Faculty f ) {
        this( f.getName( ), f.getIdNum( ), f.hireYear );
    }
    int getHireYear( ) { return hireYear; }
    void setHireYear( int yr ) { hireYear = yr; }

    public String toString( ) {
        return super.toString( ) + " " + hireYear;
    }
    public boolean equals( Faculty f ) {
         return super.equals( f ) && hireYear == f.hireYear;
    }
}
```

Overriding Methods

New Methods: A derived class can define **entirely new** instance variables and new methods (e.g. hireYear and getHireYear( )).

Overriding: A derived class can also **redefine existing** methods.

```
public class Person {
    …
    public String toString( ) { … }
}
public class Student extends Person {
    …
    public String toString( ) { … }
}

Student bob = new Student( "Bob Goodstudent", "123-45-6789",  2004, 4.0 );
System.out.println( "Bob's info: " + bob.toString( ) );
```

Overriding and Overloading

Don't confuse method **overriding** with method **overloading**.

Overriding: occurs when a derived class defines a method with the **same name** and **parameters** as the base class.

Overloading: occurs when two or more methods have the **same name**, but have **different parameters** (different signature).

Example:

```
public class Person {
    public void setName( String n ) { name = n; }
    …
}
public class Faculty extends Person {
    public void setName( String n ) {
        name = "The Evil Professor " + n;
    }
    public void setName( String first, String last ) {
        name = first + " " + last;
    }
}
```

Overriding Variables: Shadowing

We can override methods, can we override instance variables too?

Answer: Yes, it is possible, but **not recommended**.

- Overriding an instance variable is called **shadowing**, because it makes the base instance variables of the base class inaccessible. (We can still access it explicitly using **super.varName**).

```
public class Person {          public class Staff extends Person {
    String name;                   String name;
    // …                           // …  name refers to Staff's name
}                              }
```

- This can be **confusing** to readers, since they may not have noticed that you redefined name. Better to just pick a new variable name.

super and this

super: refers to the base class object.

- We can invoke any base class constructor using **super(…)**.
- We can access data and methods in the base class (Person) through **super**. E.g., toString( ) and equals( ) invoke the corresponding methods from the Person base class, using **super.toString( )** and **super.equals( )**.

this: refers to this object.

- We can refer to our own data and methods using "**this.**" but this usually is not needed.
- We can invoke any of our own constructors using **this(…)**. As with the super constructor, this can only be done **within a constructor**, and must be the **first statement** of the constructor.

- Example:

```
public Faculty( Faculty f ) {
    this( f.getName( ), f.getIdNum( ), f.hireYear );
}
```

Inheritance and Private

Inheritance and private members:

- Student objects inherit all the private data (name and idNum).
- However, **private members** of the base class **cannot** be accessed directly.

Example: (Recall that name is a private member of Person.)

```
public class Student extends Person {
    …
    public void someMethod( ) { name = "Mr. Foobar"; }  // Illegal!
    public void someMethod2( ) { setName( "Mr. Foobar" ); } // Okay
}
```

Why is this? After you have gone to all the work of setting up privacy, it wouldn't be fair to allow someone to simply extend your class and now have direct access to all the private information.

Protected and Package Access

The derived class cannot access private base elements. So can a base class grant any special access to its derived classes?

Special Access for Derived Classes:

Protected: When a class element (instance variable or method) is declared to be **protected** (rather than public or private) it is accessible:

- to any **derived class** (and hence to all descendents), and
- to any class in the **same package**.

Example:

```
protected void someMethod( ) { … }  // has protected access
```

Package: When a class element **not given any** access modifier (private, public, protected) it is said to have **package access**. It is accessible:

- to any class in the **same package**.

Example:

```
void someOtherMethod( ) { … }    // has package access
```

Access to Base Class Elements

Which should I use? : private, protected, package, or public

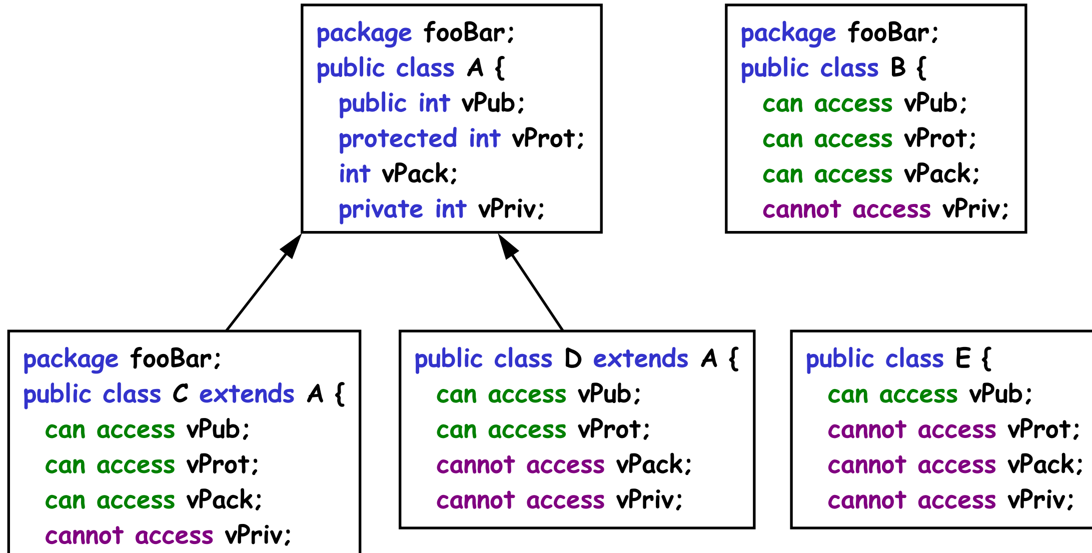
Public:
- Methods of the object's **public interface**.
- **Constant** instance variables (static final).

Private:
- **Instance variables** (other than constants).
- Internal **helper/utility methods** (not intended for use except in this class).

Protected/Package:
- Internal **helper/utility methods** (for use in this class and related classes).

Note: Some style gurus **discourage the use of protected**. Package is safer, since any resulting trouble can be localized to the current package.

Access Modifiers



Inheritance versus Composition

Inheritance is but one way to create a complex class from another. The other way is to explicitly have an instance variable of the given object type. This is called **composition**:

Common Object:
```
public class ObjA {
    public methodA( ) { … }
}
```

Inheritance:
```
public class ObjB extends ObjA {
    …
    // call methodA( );
}
```

Composition:
```
public class ObjB {
    ObjA a;
   // call a.methodA( )
}
```

When should I use inheritance vs. Composition?

ObjB "is a" ObjA: in this case use **inheritance**.
ObjB "has a" ObjA: in this case use **composition**.

Inheritance versus Composition

University parking lot permits: A parking permit object involves a university Person and a lot name ("4", "11", "XX", "Home Depot").

Inheritance:
```
public class Permit extends Person {
    String lotName;

    // …
}
```

Composition:
```
public class Permit {
    Person p;
    String lotName;
   // …
}
```

Which to use?

A parking permit "is a" person? Clearly no.
A parking permit "has a" person? Yes, because a Person is one of the two entities that is constitutes a permit object.
So **composition** is the better design choice here.