

CMSC 131: Chapter 27 (Supplement)

Inheritance II

Inheritance: Quick Recap

Recap:

- Inheritance is when one class (**derived class** or **subclass**) is defined from another class (the **base class** or **superclass**).
- The derived class **inherits** all the instance variables and the methods from the base class. It can also:
 - define its own instance variables and methods.
 - redefine methods from the base class, which is called **overriding**.
- A derived class can explicitly refer to entities from the base class using **super**.
- A reference to a derived class can be used anywhere where a reference to the base class is expected.
- By declaring members to be **protected**, a base class makes them accessible to derived classes and further descendents.

The Class Hierarchy and Object

Class inheritance defines a hierarchy:

- **GradStudent** is a **Student**
- **Student** is a **Person**
- **Person** is a ???

There is a class at the top of the hierarchy, called **Object**. Every class is derived (either directly or indirectly) from **Object**.

- If a class is not explicitly derived from some class, it is **automatically derived from Object**. The following are equivalent:

```
public class FooBar { ... } ↔ public class FooBar extends Object { ... }
```

- This means that if you write a method with a parameter of type **Object**, you can call this method with an object reference of **any class**.
- **Object** is defined in **java.lang**, and so it is available to all programs.

Object

The class **Object** has no instance variables, but defines the a number of methods. These include:

toString(): returns a String representation of this object.
equals(Object o): test for equality with another object o.

Every class you define can, and probably should, override these two methods with something that makes sense for your class.

Early and Late Binding

Consider the following example:

```
Faculty carol = new Faculty( "Carol Tuffteacher",  
                             "999-99-9999", 1995 );  
Person p = carol;  
System.out.println( p.toString( ) );
```

Q: Should this call **Person's** toString or **Faculty's** toString?

A: There are good arguments for either choice:

Early (static) binding: The variable p is **declared** to be of type **Person**. Therefore, we should call the Person's toString.

Late (dynamic) binding: The object to which p refers was **created** as a "new **Faculty**". Therefore, we should call the Faculty's toString.

Pros and cons: Early binding is more efficient, since the decision can be made at compile time. Late binding provides more flexibility.

Java uses late binding (by default): so Faculty toString is called.
(Note: C++ uses early binding by default.)

Polymorphism

Java's **late binding** makes it possible for a single reference variable to refer to objects of many different types. Such a variable is said to be **polymorphic** (meaning having many forms).

Example: Create an array of various university people and print.

```
Person[ ] list = new Person[3];
list[0] = new Person( "Col. Mustard", "000-00-0000" );
list[1] = new Student ( "Ms. Scarlet", "111-11-1111", 1998, 3.2 );
list[2] = new Faculty ( "Prof. Plum", "222-22-2222", 1981 );
for ( int i = 0; i < list.length; i++ )
    System.out.println( list[i].toString( ) );
```

Output:

```
[Col. Mustard] 000-00-0000
[Ms. Scarlet] 111-11-1111 1998 3.2
[Prof. Plum] 222-22-2222 1981
```

What type is list[i]? It can be a reference to any object that is derived from Person. The appropriate toString will be called.

Disabling Overriding with "final"

Sometimes you do not want to allow method overriding.

Correctness: Your method only makes sense when applied to the base class. Defining it for a derived class might break things.

Efficiency: Late binding is less efficient than early binding. You know that no subclass will redefine your method. You can force early binding by disabling overriding.

Example: The class Object defines the following method:

getClass(): returns a description of a class. You can test whether two objects x and y are of the same class with:

```
if ( x.getClass( ) == y.getClass( ) ) ...
```

This is a very useful function. But clearly we do not want arbitrary classes screwing around with it.

We can disable overriding by declaring a method to be **"final"**.

Disabling Overriding with "final"

final: Has two meanings, depending on context:

- To define **symbolic constants**:

```
public static final int MAX_BUFFER_SIZE = 1000;
```

- It means that a method **cannot be overridden by derived classes**.

```
public class Parent {  
    ...  
    public final void someMethod( ) { ... } // subclasses cannot override  
}  
  
public class Child extends Parent {  
    ...  
    public void someMethod( ) { ... } // Illegal!  
}
```

Polymorphism and Abstract Methods

Polymorphism: is allows us to write generic methods that leave the low-level details for the subclasses to implement.

Example: Typical graphics drawing program.

- Define a **base class, Shape**, and derive various **subclasses for specific shapes**. Each subclass defines it own method `drawMe( )`.

```
public class Shape {  
    public void drawMe( ) { ... }    // generic drawing method  
}  
  
public class Circle extends Shape {  
    public void drawMe( ) { ... }    // draws a Circle  
}  
  
public class Rectangle extends Shape {  
    public void drawMe( ) { ... }    // draws a Rectangle  
}
```

Polymorphism and Abstract Methods

Example: Graphics drawing program.

- The entire picture consists of an array **shapes** of type `Shape[ ]`.
- To draw the **picture**, we invoke `drawMe( )` for all the shapes.

```
Shape[ ] shapes = new Shape[...];
shapes[0] = new Circle( ... );
shapes[1] = new Rectangle( ... );
...
for ( int i = 0; i < shapes.length; i++ )
    shapes[i].drawMe( );
```

Polymorphism and Abstract Methods

Problem: The `Shape` object does not represent a specific shape. So how do we implement `Shape's drawMe( )` method?

- Draw some special "**undefined shape**".
- Just **ignore** the operation.
- Issue an **error message** or exception.

None of these solutions is very natural.

Better solution: Abstract methods/classes

- What you really want is for the compiler to know that `Shape` is **incomplete class**.
- It **declares but does not define** some methods. These must be implemented in the derived classes.

Abstract Method: a method that contains no body. It is just a **placeholder**. The derived classes will provide the actual implementation.

Polymorphism and Abstract Methods

Abstract Method:

- It behaves much like a method in an **interface**. You give a signature, but no body. The class descendents provide the implementation.
- An abstract method **cannot be final**. (Obviously...since it must be overridden by a descendent class, and final would prevent this.)

Abstract Class:

- A class with at least one abstract method is an **abstract class**.
- You must include the modifier **abstract** in the class heading.
`public abstract class Shape { ... }`
- An abstract class is a **incomplete**:
 - It **cannot be created** using "new"
`Shape s = new Shape( ... );` // Illegal! Shape is abstract
 - ...but you can create concrete shapes (Circle, Rectangle) and assign them to variables of type Shape.
`Shape s = new Circle( ... );`

Example: Shapes

```
public abstract class Shape {
    private int color;
    Shape ( int c ) { color = c; }
    public abstract void drawMe( );
}

public class Circle extends Shape {
    private double radius;
    public Circle( int c, double r ) { ... details omitted ... }
    public void drawMe( ) { ... Circle drawing code goes here ... }
}

public class Rectangle extends Shape {
    private double height;
    private double width;
    public Rectangle( int c, double h, double w ) { ... details omitted ... }
    public void drawMe( ) { ... Rectangle drawing code goes here ... }
}
```

Inheritance: Yet Another Quick Recap

Recap:

- Inheritance is when one class (**derived class** or **subclass**) is defined from another class (the **base class** or **superclass**). The derived class **inherits** variables and methods from the base class and can **override** their definitions or define its own.
- A reference to a **derived class** can be used anywhere where a reference to the **base class** is **expected**.
- All objects are derived (directly or indirectly) from **Object**.
- Java uses **late (or dynamic) binding**, which means that the method that is called depends on an **object's actual type**, and not the **declared type** of the referring variable.
- Late binding and inheritance allows you to create **polymorphic variables**. The behavior (based on method calls) depends on what the variable refers to.
- When a method in a base class is not provided, the method and class are said to be **abstract**. It must be implemented in a derived class.

getClass and instanceof

Objects in Java can access their type information dynamically.

getClass(): Returns a representation of the class of any object.

```
Person bob = new Person( ... );
Person ted = new Student( ... );

if ( bob.getClass( ) == ted.getClass( ) ) // false (ted is really a Student)
```

instanceof: You can determine whether one object is an instance of (e.g., derived from) some class using **instanceof**. Note that it is a **operator (!)** in Java, and not a method call.

```
if ( bob instanceof Person )           // true
if ( ted instanceof Student )          // true
if ( ted instanceof Person )           // true
if ( bob instanceof Student )          // false

Faculty carol = new Faculty( ... );
if ( carol instanceof Person )          // true
if ( carol instanceof Student )         // Illegal! Doesn't compile
```

Up-casting and Down-casting

We have already seen that we can assign a derived class reference anywhere that a base class is expected.

Upcasting: Casting a reference to a **base class** (casting up the inheritance tree). This is done **automatically** and is always safe.

Downcasting: Casting a reference to a **derived class**. This may not be legal (depending on the actual object type). You can **force** it by performing an explicit cast.

```
Person bob = new Person( ... );
Person ted = new Student( ... );
Student carol = new Student( ... );
GradStudent alice = new GradStudent( ... );

bob = ted;                // okay: ted is a Person
carol = ted;              // compile error! ted may not be a Student
carol = ( Student ) ted;  // okay: ted is a Student
alice = ( GradStudent ) ted; // run-time error! ted isn't a GradStudent
```

Safe Downcasting

Illegal downcasting results in a `ClassCastException` run-time error.

Q: Can we check for the **legality** of a cast before trying it?

A: Yes, using `instanceof`.

Example: Suppose that we want to store a list of university people references in an `ArrayList`. We then want to print the *GPA's* of all the students.

Recall: the following `ArrayList` methods:

```
int size( ): Returns the size of the list.
void add( Object x ) : Adds x to the end of the list.
Object get( int i ) : Returns a reference to the object at position i.
```

As elements are removed from the list they must be **downcast** from **Object** to **Student**, but this can only be done if the object really is a `Student`.

Safe Downcasting

```
ArrayList list = new ArrayList( );

list.add( new Person( "Bender", "000" ) );
list.add( new Student( "Fry", "111", 1999, 1.2 ) );
list.add( new Student( "Leela", "222", 2999, 3.8 ) );
list.add( new Faculty( "Farnsworth", "333", 2841 ) );
list.add( new Student( "Nibbler", "444", 1000, 4.0 ) );

for ( int i = 0; i < list.size( ); i++ ) {
    Object o = list.get( i );
    if ( o instanceof Student ) {
        Student s = (Student) o;
        System.out.println( s.getName( ) + "'s GPA is " + s.getGpa( ) );
    }
}
```

Fry's GPA is 1.2
Leela's GPA is 3.8
Nibbler's GPA is 4.0

equals: The Right Way

We defined an **equals** methods for our various classes. Here is an example from Student:

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

Although this will correctly compare two students, there will be problems if you try to compare a **Student** with **other members** of the Person hierarchy.

equals: The Right Way

Example: Write a method that looks up a person (Person, Student, or Faculty) in an ArrayList containing university person objects.

```
public static boolean find( Person p, ArrayList list ) {  
    for ( int i = 0; i < list.size( ); i++ ) {  
        if ( p.equals ( list.get( i ) ) ) return true;  
    }  
    return false;  
}
```

Suppose that we have: Person p = new Student(...); find(p, list); Which **equals** method will be called here?

Person equals() ? p is declared to be type Person
Student equals() ? Late binding uses actual object type (Student)
Object equals() ? ArrayList.get() returns an Object reference

equals: The Right Way

Answer: Object equals() is called (Surprise!)

Huh? Isn't this a case of method overriding? Since p is a Student, we should call Student equals?

What are Java's options?

- class Student { ... boolean equals(Student s) ... }
- class Person { ... boolean equals(Person p) ... }
- ...
- class Object { ... boolean equals(Object o) ... }

All of these methods take different parameter types.

- This is **not** a case of method **overriding**.
- This is a case of method **overloading**.

Java selects the option that **best matches** the parameter type, which is **Object**. So Object equals() is called.

equals: The Right Way

What is the **right way** to define equals? It should:

- take an argument of type **Object**, not **Student**.
- check that the argument is **non-null** (just for robustness).
- check that the argument refers to an actual **Student**. (We could define equals less strictly, but we won't.)
- proceed with the other equality checks.

```
public boolean equals( Object o ) {
    if ( o == null ) return false;
    else if ( getClass( ) != o.getClass( ) ) return false;
    else {
        Student s = (Student) o;
        return super.equals( s ) &&
               admitYear == s.admitYear &&
               gpa == s.gpa;
    }
}
```

Copying and Inheritance

We have seen how to make copies of objects using the copy constructor:

```
Student amy = new Student( "Amy", "555", 3002, 3.5 );
Student amyCopy = new Student( amy );

public Student( Student s ) {
    super( s );
    admitYear = s.admitYear;
    gpa = s.gpa;
}
```

As with equals, we will run into **problems** if we try to use this to copy **other types of Person objects**, but the problems are of a different nature here.

Copying and Inheritance

Let's suppose that we want to construct an array of `Person` objects (of various types) and write general purpose copy method.

```
Person list[ ] = new Person[5];
list[0] = new Person( "Bender", "000" );
list[1] = new Student( "Fry", "111", 1999, 1.2 );
// ... (also Leela and Farnsworth)
list[4] = new Student( "Nibbler", "444", 1000, 4.0 );
Person list2[ ] = copy( list );

public static Person[ ] badCopy( Person[ ] list ) {
    Person[ ] list2 = new Person[ list.length ];
    for ( int i = 0; i < list.length; i++ ) {
        list2[i] = new Person( list[i] );
    }
    return list2;
}
```

Copying and Inheritance

Problem: The constructor call "`Person ( list[i] )`" invokes the **Person** constructor, irrespective of the actual type of `list[i]`.

```
public static Person[ ] badCopy( Person[ ] list ) {
    Person[ ] list2 = new Person[ list.length ];
    for ( int i = 0; i < list.length; i++ ) {
        list2[i] = new Person( list[i] );
    }
    return list2;
}
```

Huh? Isn't Java smart enough to know that I really wanted it to apply the copy constructor of the **actual type** of `list[i]`?

Of course not: If you call a method, it is not Java's job to read your mind and change the call to an **entirely different method**. (Overriding is different, because the methods have the same name and same argument types, so it must pick one.)

Copying: The Right Way

Solution: We use **inheritance** and method **overriding**, so Java will call the correct copying method.

clone:

- We define a method **clone**, which will be overridden for each class.
- The job of clone is to return a **duplicate copy** of this object.
- clone is overridden from class Object and returns an Object. Thus, we will need to **downcast** its result to Person.
- This works because (by late binding) each type (Person, Student, Faculty) calls its **own clone**, and so makes the proper copy.

```
public static Person[ ] goodCopy( Person[ ] list ) {  
    Person[ ] list2 = new Person[ list.length ];  
    for ( int i = 0; i < list.length; i++ ) {  
        list2[i] = ( Person ) list[i].clone( );  
    }  
    return list2;  
}
```

Defining Clone

How to define clone?

- There is an **officially sanctioned** way to define clone, but it will take too long to explain. (It involves the Cloneable interface.)
- Instead, we will just define it in a **quick-and-dirty** manner, using our copy constructors.

```
public class Person {  
    ...  
    public Object clone( ) {  
        return new Person( this );  
    }  
}  
  
public class Student extends Person {  
    ...  
    public Object clone( ) {  
        return new Student( this );  
    }  
}
```

Summary of equals and clone

General Warning:

- When dealing with class inheritance, you **may not know** the **actual types** of objects that you are manipulating. This complicates your job as a programmer.
- Set up your method parameters to be of the **most general type** that is **applicable** to your method (e.g. Object or Person rather than Student or Faculty).
- Whenever dealing with references to objects in the class hierarchy, use **method overriding** to produce the proper behavior. (E.g. using clone rather than calling a copy constructor directly).
- **Avoid downcasting**, but if you need to downcast to a particular type, use **getClass** and/or **instanceof** to make sure your cast is valid.

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 (continued)

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 constitutes a permit object.

So **composition** is the better design choice here.