



CMSC 131

Object-Oriented Programming I

Inheritance III

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Overview

- ▶ Object class
- ▶ Early/Late Binding
- ▶ getClass(), instanceof
- ▶ Up-casting, down-casting
- ▶ equals method

News

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 - <http://www.cs.umd.edu/~nelson/announcements/GameClassRecommendations.pdf>

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

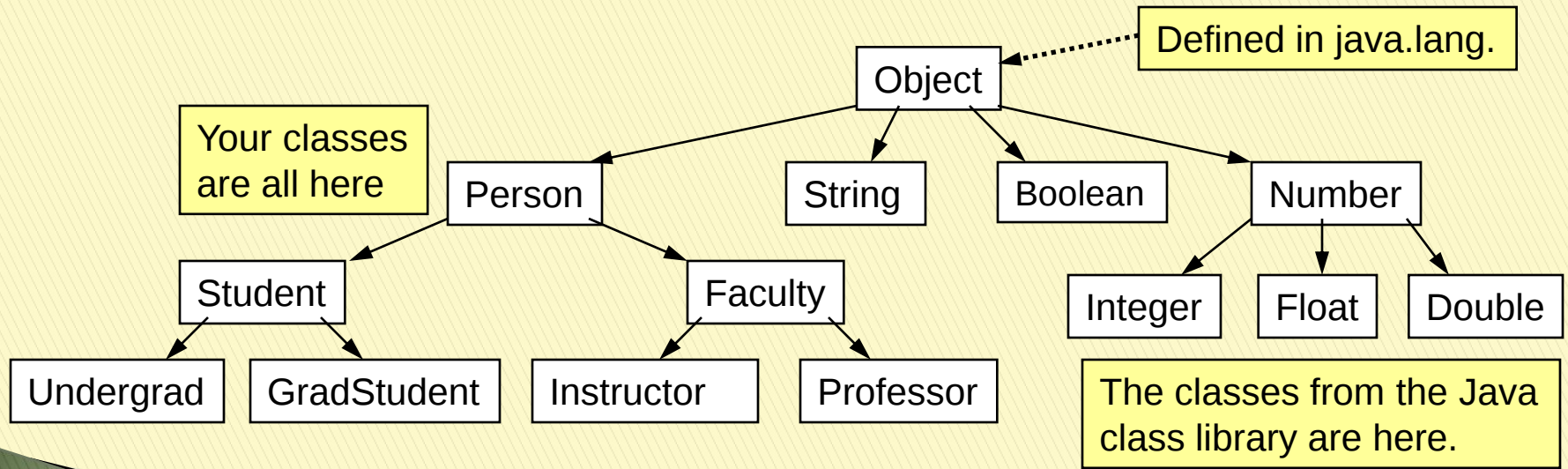
Object

- ▶ The class **Object** has no instance variables, but defines 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, overrides these two methods with something that makes sense for your class (hashCode method is also included in the group)
- ▶ <http://download.oracle.com/javase/6/docs/api/java/lang/Object.html>



Early and Late Binding

- ▶ **Motivation:** 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. Redefining 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:
 - Define **symbolic constants**:

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

- Indicate that a method **cannot be overridden by derived classes**

```
public class Parent {  
    ...  
    public final void someMethod() { ... }  
}
```

Subclasses cannot
override this method

```
public class Child extends Parent {  
    ...  
    public void someMethod() { ... }  
}
```

Illegal! someMethod is final
in base class.

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

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 an **operator** (!) in Java, 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:
 - size()**: Returns the size of the list
 - add()** : Adds element to the end of the list
 - get()**: Returns a reference to the object at position i
- ▶ As elements are removed from the list, they must be **downcast** from **Person** to **Student**, but this can only be done if the object really is a Student

Safe Downcasting

```
ArrayList<Person> list = new ArrayList<Person>();  
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++) {  
    Person obj = list.get(i);  
    if (obj instanceof Student) {  
        Student s = (Student) obj;  
        System.out.println(s.getName() + "'s GPA is " + s.getGpa());  
    }  
}
```

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<Person> 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() ?

equals: The Right Way

- ▶ **Answer:** **Person equals** is called
- ▶ **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 **Person** so Person 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;  
    }  
}
```

equals: Options

```
/* Option 1 (we use in cmisc131) */  
public boolean equals(Object o) {  
    if (o == null)  
        return false;  
    if (getClass() != o.getClass())  
        return false;  
    A s = (A) o;  
    /* Comparison based on A fields */  
}
```

```
/* Option 2 */  
public boolean equals(Object o) {  
    if (o == this)  
        return true;  
    if (!(o instanceof A))  
        return false;  
    A s = (A) o;  
    /* Comparison based on A fields */  
}
```

There are some cases where they may produce different results.