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

- http://www.boutiques.com/
  - Sponsored by Google
- Game Class Recommendations
  - 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

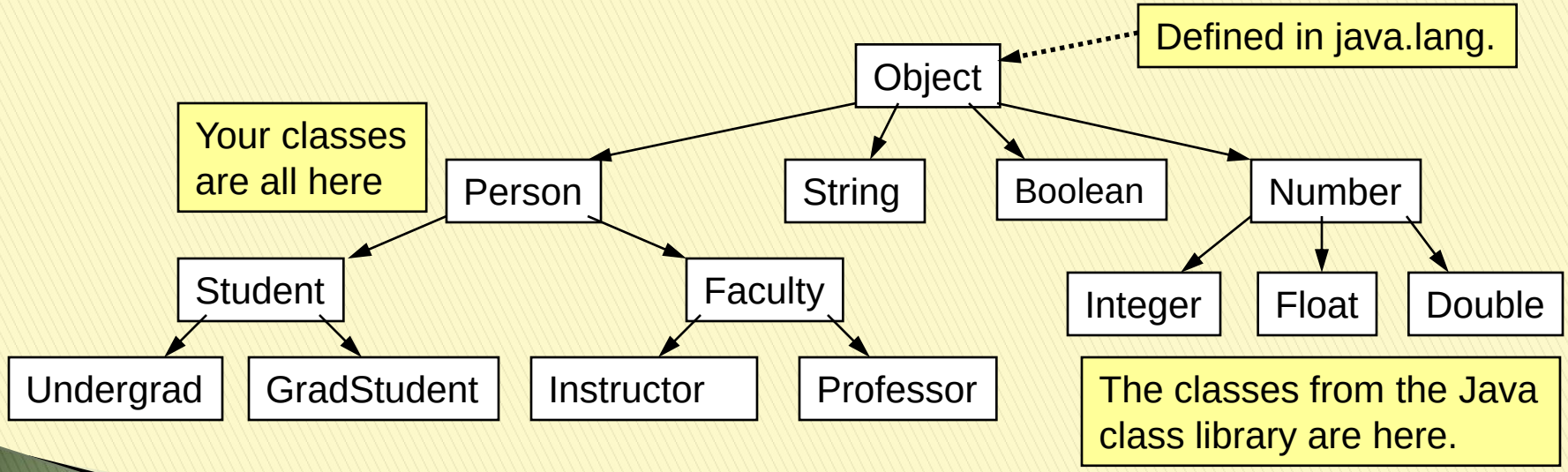
Object

- 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( ) { ... }
}

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

Subclasses cannot override this method

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 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  cmsc131) */
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 */
}
```

The are some cases where they may produce different results.