Java - Inheritance/Polymorphism/Interfaces

Horstmann chapters 4.1-5 & 6.1

CS 4354
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Interface, 3 definitions used in this class

- (from cs2308): the mechanism that code outside the object uses to interact with the object; the object's public member functions.
- (graphical) **user interface** (sometimes shortened to "interface"): the means by which the user and a computer system interact, in particular the use of input devices and software.
- Java Interface: a reference type, similar to a class, that contains constants and/or method signatures (methods with empty bodies).

Goal: to separate the interface from the implementation

Example: The Icon interface in Java

- You can use javax.swing.JOptionPane to display message:

```
JOptionPane.showMessageDialog(null, "Hello, World!");
```

  ✦ Note the "i" icon on the left:

- To specify an arbitrary image file:

```
JOptionPane.showMessageDialog(
 null,
 "Hello, World!",
 "Message",
 JOptionPane.INFORMATION_MESSAGE,
 new ImageIcon("globe.gif"));
```

Example: The Icon interface in Java

- What if we want to draw the image using library methods? Here is the declaration of the showMessageDialog method:

```
public static void showMessageDialog(
  Component parent,
  Object message,
  String title,
  int messageType,
  Icon anIcon);
```

- You can use any class that implements the javax.swing.Icon interface type:

```
public interface Icon {
   int getIconWidth();
   int getIconHeight();
   void paintIcon(Component c, Graphics g, int x, int y);
}
```

Java Interfaces

- In the Java programming language, an Interface is a form or template for a class: the methods do no have implementations (they are like C++ prototypes).
- The methods are implicitly public.
- An interface may contain fields, but these are implicitly static and final (named constants).
- A class implements the interface type by providing an `implements` clause and supplying implementations for the methods that are declared in the interface type.
- An interface can be used as a type (for variables, parameters, etc)
  - ✦Java permits an object instance of a class that implements an Interface to be assigned to a variable or parameter of that type.

Example: A new class that implements Icon

- The javax.swing.ImageIcon class implements Icon (see the api)
- Let's design a class MarsIcon that implements the Icon interface type (see Horstmann for imports and detailed explanation):

```
public class MarsIcon implements Icon {
  public MarsIcon(int aSize) {
    size = aSize;
  }
  public int getIconWidth()  { return size; }
  public int getIconHeight() { return size; }

  public void paintIcon(Component c, Graphics g, int x, int y)  {
    Graphics2D g2 = (Graphics2D) g;
    Ellipse2D.Double planet = new Ellipse2D.Double(x, y, size, size);
    g2.setColor(Color.RED);
    g2.fill(planet);
  }

  private int size;
}
```

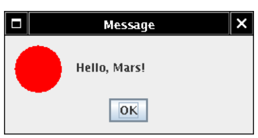
Note it provides definitions for the three Icon methods

Example: Using MarsIcon in showMessageDialog

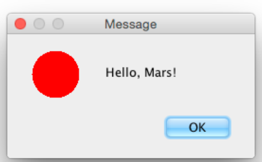
- This driver uses our MarsIcon class to make the dialog:

```
import javax.swing.*;

public class IconTester
{
    public static void main(String[] args)
    {
        JOptionPane.showMessageDialog(
           null,
           "Hello, Mars!",
           "Message",
           JOptionPane.INFORMATION_MESSAGE,
           new MarsIcon(50));
        System.exit(0);
    }
}
```

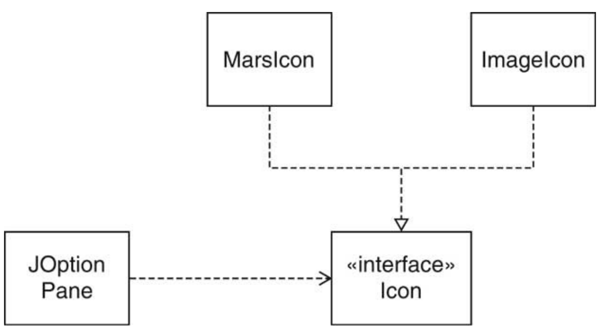


I got this when I ran the code on my mac:



Class diagram

- the Icon interface type and the classes that implement it:
  - ✦ A———|> B means class A implements interface B
  - ✦ A———>B means class A uses class/interface B



Polymorphism

- Upcasting:
  - ✦Permitting an object of a class type to be treated as an object of any interface type it implements:

```
Icon x = new MarsIcon(50);
```

- Polymorphism:
  - ✦The ability of objects belonging to different class types to respond to method calls of the same name, but with an appropriate type-specific behavior.
  - ✦It allows many types (implementing the same Interface) to be treated as if they were one type, and a single piece of code to work on all those different types equally, yet getting type-specific behavior for each one.

Polymorphism Example (using an Interface):

- Wind, Stringed and Percussion are Instruments

```
public interface Instrument {
  void play(String n);
}

public class Wind implements Instrument {
  public void play(String n) {
    System.out.println("Wind.play() " + n);
  }
}
public class Stringed implements Instrument {
  public void play(String n) {
    System.out.println("Stringed.play() " + n);
  }
}
public class Percussion implements Instrument {
  public void play(String n) {
    System.out.println("Percussion.play() " + n);
  }
}
```


Polymorphism Example continued

```
public class Music {
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    tune(flute);  //upcasting to Instrument
    tune(violin); //upcasting to Instrument
  }
}
```

What is output?

```
Wind.play() Middle C
Stringed.play() Middle C
```

Polymorphism:
in tune, i is an Instrument, but it calls the play method based on the specific type of the object it receives.

What if we didn't have polymorphism?

- We could overload tune to work for each type of Instrument
- **If we add a new instrument, we have to add a new tune function**

```
public class Music {
  public static void tune(Wind i) {
    i.play("Middle C");
  }
  public static void tune(Stringed i) {
    i.play("Middle C");
  }
  public static void tune(Percussion i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    tune(flute); // No upcasting necessary
    tune(violin);
  }
}
```

Output:

```
Wind.play() Middle C
Stringed.play() Middle C
```

But we do have upcasting and polymorphism:

- We can get the same effect with just one tune method

```
public class Music {
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    Percussion snaredrum = new Percussion();
    tune(flute); // upcasting
    tune(violin);
    tune(snaredrum);  }
}
```

Output: polymorphism

```
Wind.play() Middle C
Stringed.play() Middle C
Percussion.play() Middle C
```


Polymorphism in JOptionPane.showMessageDialog

- Consider implementing the showMessageDialog method:

```
public static void showMessageDialog( . . .  Icon anIcon);
```

- The width of the dialog box depends on the width of `anIcon`.
- But `anIcon` could refer to a `MarsIcon` or to an `ImageIcon`, how do we call the proper method?
- Since the type of `anIcon` must be a class that implements `Icon`, we know it must have a `getIconWidth()` method that returns the width of the Icon, so we can use that: `anIcon.getIconWidth()`
- During run-time, the Java interpreter determines the class type of the object `anIcon` is referring to, and uses the implementation of `getIconWidth` from that class.

Implementing the Java **Comparable** Interface

- Assume you want to sort an ArrayList of custom objects (instances of some class you created).
- The following static method is available in the Java API:

```
void Collections.sort(List<T> list)    // for ArrayLists
```

- All elements in the ArrayList must implement the java.lang.Comparable<T> interface:

```
int compareTo(T o);     //T is your custom class
```

The call object1.compareTo(object2) is expected to return a negative number if object1 should come before object2, zero if the objects are equal, and a positive number otherwise

Sorting with Comparable, example

```
import java.util.*;

public class Student implements Comparable<Student> {
    private String name;
    private String major;
    private int idNumber;
    private float gpa;
    public Student(String name, String major,
                   int idNumber, float gpa) {
        this.name = name;  this.major = major;
        this.idNumber = idNumber; this.gpa = gpa;
    }
    public String getName() { return name; }
    public float getGpa() { return gpa; }
    public String toString() {
        return "Student: " + name + " " +major + " "
                           + idNumber + " " + gpa;
    }
    public int compareTo(Student rhs) {
       return name.compareTo(rhs.name);
    }
```

This will sort by name

compareTo is already defined in String, so we can reuse it.

Sorting with Comparable, example (p2)

```
public static void main(String[] args) {
    ArrayList<Student>a = new ArrayList<Student>();
    a.add(new Student("Doe, J","Math",1234,3.6F));
    a.add(new Student("Carr, M","CS",1000,2.7F));
    a.add(new Student("Ames, D","Business",2233,3.7F));
    System.out.println("Before: ");
    for (Student s : a)
        System.out.println(s);
    Collections.sort(a);
    System.out.println("After: ");
    for (Student s : a)
        System.out.println(s);
}
```

Output:

```
Before:
Student: Doe, J Math 1234 3.6
Student: Carr, M CS 1000 2.7
Student: Ames, D Business 2233 3.7
After:
Student: Ames, D Business 2233 3.7
Student: Carr, M CS 1000 2.7
Student: Doe, J Math 1234 3.6
```


Implementing the Java **Comparator** Interface

- Assume you want to sort the ArrayList of students by gpa, but you don't want to reimplement compareTo.
- The following static method is available in the Java API:

```
void Collections.sort(List<T> list, Comparator<T> c)
```

- The java.lang.Comparator<T> interface:

```
int compare(T obj1, T obj2); //T is your custom class
```

Compares obj1 to obj2 for order. Returns a negative number, zero, or a positive number depending on whether obj1 is less than, equal to, or greater than obj2 in the particular sort order

Sorting with Comparator, sort by gpa

- To sort by gpa, define a new class that implements Comparator as follows:

```
public class StudentByGpa implements Comparator<Student> {
    public int compare(Student lhs, Student rhs) {
        float lhsGpa = lhs.getGpa();
        float rhsGpa = rhs.getGpa();
        if (lhsGpa < rhsGpa) return -1;
        if (lhsGpa == rhsGpa) return 0;
        return 1;
    }
}
```

- To sort by name, define another Comparator as follows:

```
public class StudentByName implements Comparator<Student> {
    public int compare(Student lhs, Student rhs) {
        return lhs.getName().compareTo(rhs.getName());
    }
}
```


Sorting with Comparator, example (p2)

```
public static void main(String[] args) {
    ArrayList<Student>a = new ArrayList<Student>();
    a.add(new Student("Doe, J","Math",1234,3.6F));
    a.add(new Student("Carr, M","CS",1000,2.7F));
    a.add(new Student("Ames, D","Business",2233,3.7F));
    System.out.println("Before: ");
    for (Student s : a)
        System.out.println(s);
    Comparator<Student> comp = new StudentByGpa();
    Collections.sort(a, comp);
    System.out.println("After: ");
    for (Student s : a)
        System.out.println(s);
}
```

Output:

```
Before:
Student: Doe, J Math 1234 3.6
Student: Carr, M CS 1000 2.7
Student: Ames, D Business 2233 3.7
After:
Student: Carr, M CS 1000 2.7
Student: Doe, J Math 1234 3.6
Student: Ames, D Business 2233 3.7
```

Anonymous objects and classes

- **Anonymous objects**: no need to name an object used only once:

```
Collections.sort(a, new StudentByGpa());
```

- **Anonymous classes**: no need to name a class used only once:

```
Comparator<Student> comp = new
  Comparator<Student>() {
    public int compare(Student lhs, Student rhs) {
        return lhs.getName().compareTo(rhs.getName());
    }
  };
```

- The right-hand side expression defines a temporary class with no name that implements Comparator<Student>, and constructs one object of that class.

Anonymous classes

- Anonymous classes can be returned by a function:

```
public class Student {
. . .
public static Comparator<Student> compByName() {
  return new
  Comparator<Student>() {
    public int compare(Student lhs, Student rhs) {
       return lhs.getName().compareTo(rhs.getName());
    }
  };
public static Comparator<Student> compByGpa() {
  return new
  Comparator<Student>() {
    public int compare(Student lhs, Student rhs) {
       return Math.round(lhs.getGpa() - rhs.getGpa());
    }
  };
}
Collections.sort(a, Student.compByGpa());
```


Inheritance

- A way to reuse code from existing classes by extending an existing class with new fields and methods
- Classes can inherit attributes and behavior from pre-existing classes called base classes, superclasses, or parent classes. The resulting classes are known as derived classes, subclasses or child classes.
- The relationships of classes through inheritance gives rise to a hierarchy.
- In Java, each class has exactly one superclass. If none are specified, then java.lang.Object is the superclass.
- Note: In Java, constructors are NOT inherited.

Simple Example of Inheritance

```
public class Cleanser {
  private String s = new String("Cleanser");
  public void append(String a) { s += a; }
  public void dilute() { append(" dilute()"); }
  public void apply() { append(" apply()"); }
  public void scrub() { append(" scrub()"); }
  public String toString() { return s; }
}
public class CleanserTester {
  public static void main(String[] args) {
    Cleanser x = new Cleanser();
    x.dilute(); x.apply(); x.scrub();
    System.out.println(x);
  }
}
```

toString is a method of java.lang.Object

Output:

```
Cleanser dilute() apply() scrub()
```

Simple Example of Inheritance

```
public class Detergent extends Cleanser {
  // Change (override) a method:
  public void scrub() {
    append(" Detergent.scrub()");
    super.scrub();  // Call superclass version
  }
  public void foam() { append(" foam()"); } // Added method
}
public class DetergentTester {
  public static void main(String[] args) {
    Detergent x = new Detergent();
    x.dilute();  x.apply();  x.scrub();  x.foam();
    System.out.println(x);
    CleanserTester.main(args);
  }
}
```

extends is used to specify the superclass

Output:

```
Cleanser dilute() apply() Detergent.scrub() scrub() foam()
Cleanser dilute() apply() scrub()
```


General convention

- Fields are private
  - ✦Not even subclasses should access these directly
- Methods are public
  - ✦This is so other classes, including subclasses can access them.
- Overriding a method:
  - ✦Writing a new instance method in the subclass that has the same signature as the one in the superclass.
  - ✦Any instance of the subclass will use the method from the subclass
  - ✦Any instance of the superclass will use the method from the superclass
  - ✦The subclass can call the superclass method using “super.method()”

Invoking Superclass Fields and Methods

- Cannot access superclass fields if they are private:

```
public class Detergent extends Cleanser {
 public String toString() { return “Detergent: ” + s; }
                             //ERROR: s is private
}
```

- But be careful when calling superclass method:

```
public class Detergent extends Cleanser {
 public String toString() {return “Detergent: ” + toString(); }
                             //ERROR: recursive call!!
}
```

- Correct:

```
public class Detergent extends Cleanser {
 public String toString() {
        return “Detergent: ” + super.toString(); }
}
```


Initialization

- Java automatically inserts calls to the (default) superclass constructor at the beginning of the subclass constructor.

```
class Art {
  Art() {
    System.out.println("Art constructor");
  }
}
class Drawing extends Art {
  Drawing() {
    System.out.println("Drawing constructor");
  }
}
public class Cartoon extends Drawing {
  public Cartoon() {
    System.out.println("Cartoon constructor");
  }
}
public class CartoonTester {
  public static void main(String[] args) {
    Cartoon x = new Cartoon();
  }
}
```

Output:

```
Art constructor
Drawing constructor
Cartoon constructor
```

So constructors are not inherited, they are called from the constructors of the subclass.

Initialization

- If your class doesn't have default (no arg) constructors, or if you want to call a superclass constructor that has an argument, you must explicitly write the calls to the superclass constructor using the super keyword and the appropriate argument list

```
class Game {
  int x;
  Game(int i) {
    x = i;
    System.out.println("Game constructor");
  }
}
class BoardGame extends Game {
  BoardGame(int i) {
    super(i);
    System.out.println("BoardGame constructor");
  }
}
public class Chess extends BoardGame {
  Chess() {
    super(11);
    System.out.println("Chess constructor");
  }
}
```


Access specifiers

- keywords that control access to the definitions they modify
  - ✦**public**: accessible to all other classes
  - ✦**private**: accessible only from within the class in which it is defined
  - ✦**package** (unspecified, default): accessible only to other classes in the same package
  - ✦**protected**: accessible to all classes derived from (subclasses of) the class containing this definition, even if the class is in another package. Note: protected also provides package access!!!
- Classes can only be public or unspecified (which is package)

java.lang.Object

- some commonly used and/or overridden methods:
  - ✦**toString**: Returns a string representation of the object. You should override this if you want a displayable version of the objects of your class.
  - ✦**equals**: Indicates whether some other object is "equal to" this one. For your class, it will use ==, unless you override it.
  - ✦**clone**: Creates and returns a copy of this object. Make your class implement Cloneable to use a default version of this method.

Polymorphism

- Upcasting:
  - ✦Permitting an object of a subclass type to be treated as an object of any superclass type.

```
Cleanser x = new Detergent();
```

- Polymorphism:
  - ✦The ability of objects belonging to different types to respond to method calls of the same name, each one according to an appropriate type-specific behavior.
  - ✦It allows many types (derived from the same superclass) to be treated as if they were one type, and a single piece of code to work on all those different types equally, yet getting type-specific behavior for each one.

Very similar to polymorphism with Interfaces

Polymorphism Example (using Inheritance):

- Wind, Stringed and Percussion are Instruments

```
public class Instrument {
  void play(String n) {
    System.out.println("Instrument.play() " + n);
  }
}
public class Wind extendsInstrument {
  void play(String n) {
    System.out.println("Wind.play() " + n);
  }
}
public class Stringed extends Instrument {
  void play(String n) {
    System.out.println("Stringed.play() " + n);
  }
}
public class Percussion extends Instrument {
  void play(String n) {
    System.out.println("Percussion.play() " + n);
  }
}
```


Example continued

```
public class Music {
  public static void tune(Instrument i) {
    i.play("Middle C");
  }
  public static void main(String[] args) {
    Wind flute = new Wind();
    Stringed violin = new Stringed();
    tune(flute);  //upcasting to Instrument
    tune(violin); //upcasting to Instrument
  }
}
```

What is output?

```
Wind.play() Middle C
Stringed.play() Middle C
```

or

```
Instrument.play() Middle C
Instrument.play() Middle C
```

Polymorphism:
in tune, i is an Instrument, but it calls the play method based on the specific type of the object it receives.

Dynamic (run-time) binding

- Given the definition of tune, how does the **compiler** know which definition of the play method to call? Instrument? Wind? Stringed?

```
public static void tune(Instrument i) {
    i.play("Middle C");
  }
```

  - ✦It will differ depending on the specific type of each argument passed to i.
  - ✦This cannot be determined at compile time.
- Binding: connecting the method call to a method definition.
  - ✦Static binding: done at compile time (play binds to Instrument.play)
  - ✦Dynamic binding: at run-time, the JVM determines the actual type of i and uses its play() definition. It can vary for each invocation of tune.
  - ✦If the actual type of i does not define "play()", the JVM looks for the nearest definition in its superclass hierarchy.

Abstract methods and classes

- An abstract class is a class that cannot be instantiated, but it can be subclassed
- It may or may not include abstract methods:
- An abstract method is a method that is declared in a class without a method body, like this:

```
abstract void f(int x);
```

- If a class contains an abstract method, it **must** be declared to be an abstract class.

Abstract methods and classes, example

- Any class that inherits from an abstract class must provide method definitions for all the abstract methods in the base class.
  - ✦Unless the derived class is also declared to be abstract
- The Instrument class can be made abstract:
  - ✦No longer need "dummy" definitions for abstract methods
  - ✦Common code (shared by subclasses) can be put in the abstract superclass

```
abstract class Instrument {
  private int i; // Storage allocated in each subclass
  abstract void play(String n); //subclass must define
  String what() {
    return "Instrument";       //when would this be executed?
  }
  abstract void adjust();      //subclass must define
}
```


Interface or Abstract class?

- Interface
  - ✦Pro: can be implemented by any number of classes
  - ✦Con: each class **must** have its own code for the methods, common method implementations must be duplicated in each class
- Abstract Class
  - ✦Pro: subclasses do not have to repeat common method implementations, common code is in the abstract superclass
  - ✦Con: Cannot be multiply inherited.