Polymorphism

Object Orientated Programming in Java

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Quizzes/Labs

- **Every** single person should have done
  - Quiz 00 – Introduction
  - Quiz 01 - Java Basics

- Every single person should have at least submitted an attempt at the exercises

Outline

- Why use polymorphism?
- Upcast (and downcast)
- Static and dynamic type
- Dynamic binding
- Polymorphism
  - A polymorphic field (the state design pattern)Today's Practical
- Review/Discussion
- Summary

Question

- Which of these keyword must be used to inherit a class?

a) super

b) this

c) extent

d) extends

Answer

- d) extends

Question

- Which of these keywords is used to refer to member of base class from a sub class?

a) upper
b) super
c) this
d) None of the mentioned

Answer

- Answer: b)

Explanation: whenever a subclass needs to refer to its immediate superclass, it can do so by use of the keyword super.

Question

- A class member declared protected becomes member of subclass of which type?

a) public member
b) private member
c) protected member
d) static member

Answer

- Answer: b)

Explanation: A class member declared protected becomes private member of subclass.

Question

- Which of these is correct way of inheriting class A by class B?

a) class B + class A {}

b) class B inherits class A {}

c) class B extends A {}

d) class B extends class A {}

Answer

- Answer: c)

Question

- What is the output of this program?

```
class A {
    int i;
    void display() {
        System.out.println(i);
    }
}
class B extends A {
    int j;
    void display() {
        System.out.println(j);
    }
}
class inheritance_demo {
    public static void main(String args[])
    {
        B obj = new B();
        obj.i=1;
        obj.j=2;
        obj.display();
    }
}
```

a) 0
b) 1
c) 2
d) Compiler Error

Answer

- Answer: c

Explanation: class A & class B both contain display() method, class B inherits class A, when display() method is called by object of class B, display() method of class B is executed rather than that of Class A.

output:

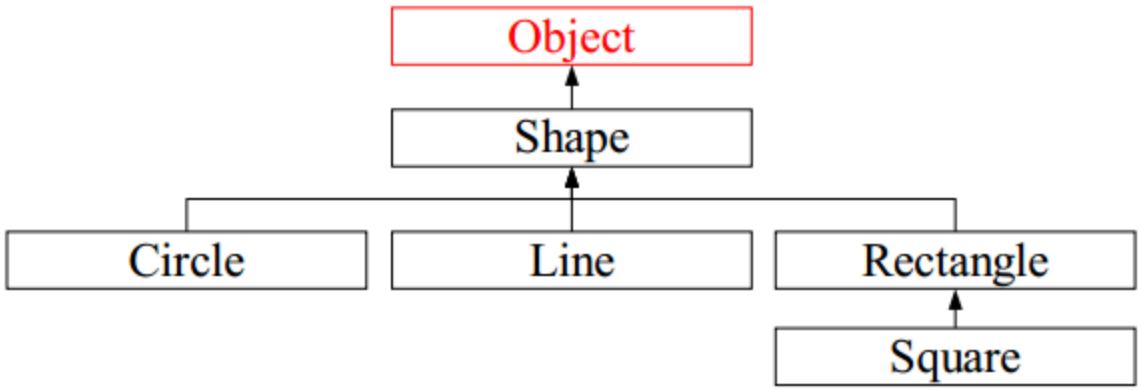
$ javac inheritanceDemo.java

$ java inheritanceDemo

2

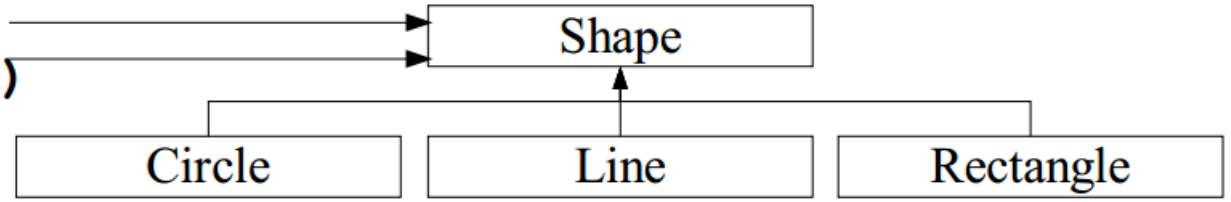
Review Class Hierarchies in Java

- Class Object is the root of the inheritance hierarchy in Java
- If no superclass is specified a class inherits implicitly from Object
- If a superclass is specified explicitly the subclass will inherit indirectly from Object

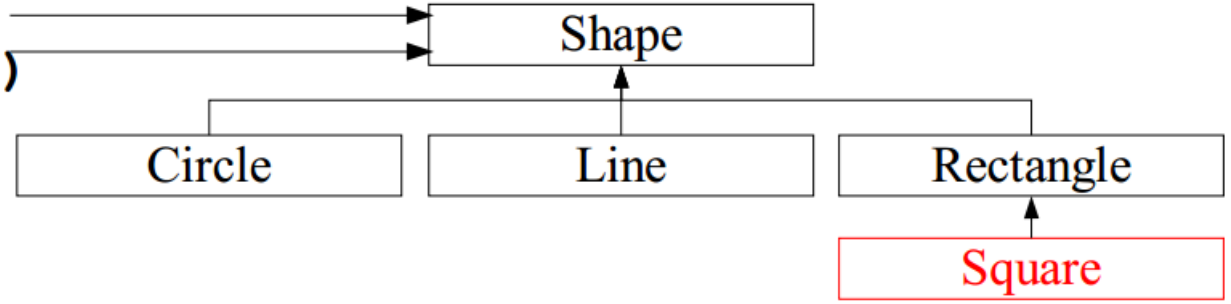


Why Polymorphism?

```
// substitutability
Shape s;
s.draw()
s.resize()
```

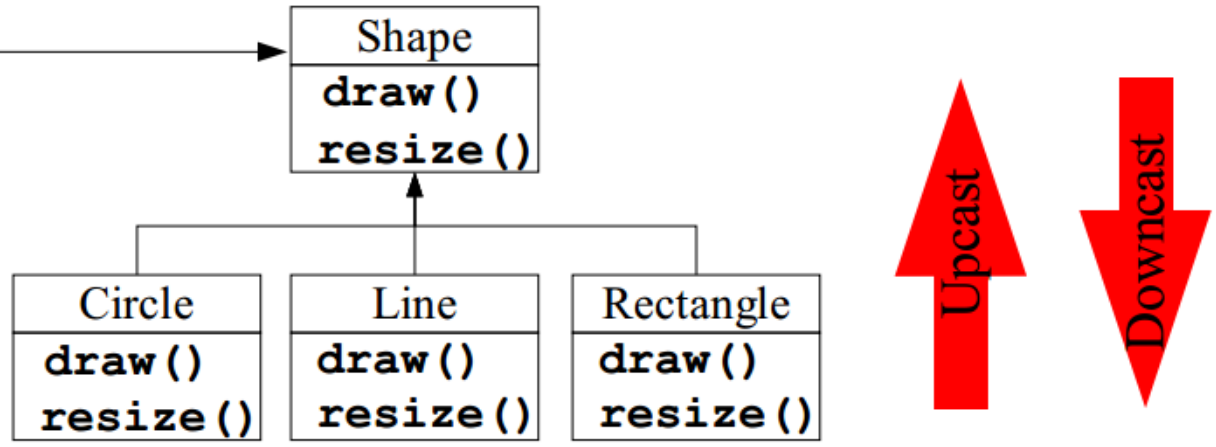



```
// extensibility
Shape s;
s.draw()
s.resize()
```



Why Polymorphism?, cont.

```
// common interface
Shape s;
s.draw()
s.resize()
```




```
// upcasting
Shape s = new Line();
s.draw()
s.resize()
```

Advantages of Upcasting

- Advantages
  - Code is simpler to write (and read)
  - Uniform interface for clients, i.e., type specific details only in class code, not in the client code
  - Change in types in the class does not effect the clients
    - If type changed within the inheritance hierarchy
  - Popular in object-oriented programs
    - Many upcast to Object in the standard library

Disadvantages of Upcasting

- Disadvantages
  - Must explicitly downcast if type details needed in client after object has been handled by the standard library (very annoying sometimes).

```
Shape s = new Line();
Line l = (Line) s; // downcast
```

Static and Dynamic Type

- The static type of a variable/argument is the declaration type
- The dynamic type of a variable/argument is the type of the object the variable/argument refers to

```
class A{
  // body
}
class B extends A{
  // body
}
public static void main(String args[]){
   A x;              // static type A
   B y;              // static type B

   x = new A();      // dynamic type A
   y = new B();      // dynamic type B
   x = y;            // dynamic type B
}
```

Polymorphism Informal Example

- In a bar you say “I want a beer!”
  - What ever beer you get is okay because your request was very generic
- In a bar you say “I want a Samuel Adams Cherry Flavored beer!”
  - If you do not exactly get this type of beer you are allowed to complain
- In chemistry they talk about polymorph materials as an example
  - H20 is polymorph (ice, water, and steam)

Polymorphism

- *Polymorphism:* **"The ability of a variable or argument to refer at run-time to instances of various classes"**

```
Shape s = new Shape();
Circle c = new Circle();
Line l = new Line();
Rectangle r = new Rectangle();

s = l;          // is this legal?
l = s;          // is this legal?
l  = (Line)s    // is this legal?
```

- The assignment s = l is legal if the static type of l is Shape or a subclass of Shape
- This is *static type checking* where the type comparison rules can be done at compile-time
- Polymorphism is constrained by the inheritance hierarchy

Dynamic Binding

```
class A {
   void doSomething(){
      ...
   }
}
```

```
class B extends A {
   void doSomething (){
      ...
   }
}
```

```
A x = new A();
B y = new B();
x = y;
x.doSomething(); // on class A or class B?
```

- Binding: Connecting a method call to a method body
- **Dynamic binding**: The dynamic type of x determines which method is called (also called *late binding*)
  - ▷ Dynamic binding is not possible without polymorphism
- **Static binding**: The static type of x determines which method is called (also called early binding)

Dynamic Binding, Example

```
class Shape {
   void draw() { System.out.println ("Shape"); }
}
class Circle extends Shape {
   void draw() { System.out.println ("Circle"); }
}
class Line extends Shape {
   void draw() { System.out.println ("Line"); }
}
class Rectangle extends Shape {
   void draw() {System.out.println ("Rectangle"); }
}
public static void main(String args[]){
   Shape[] s = new Shape[3];
   s[0] = new Circle();
   s[1] = new Line();
   s[2] = new Rectangle();
   for (int i = 0; i < s.length; i++){
      s[i].draw(); // prints Circle, Line, Rectangle
   }
}
```

Polymorphism and Constructors

```
class A { // example from inheritance lecture
    public A(){
        System.out.println("A()");
        // when called from B the B.doStuff() is called
        doStuff();
    }
    public void doStuff(){System.out.println("A.doStuff()"); }
}
class B extends A{
    int i = 7;
    public B(){System.out.println("B()");}
    public void doStuff(){System.out.println("B.doStuff() " + i);
    }

}
public class Base{
    public static void main(String[] args){
        B b = new B();
        b.doStuff();
    }
}
```

```
//prints
A()
B.doStuff() 0
B()
B.doStuff() 7
```

Polymorphism and private Methods

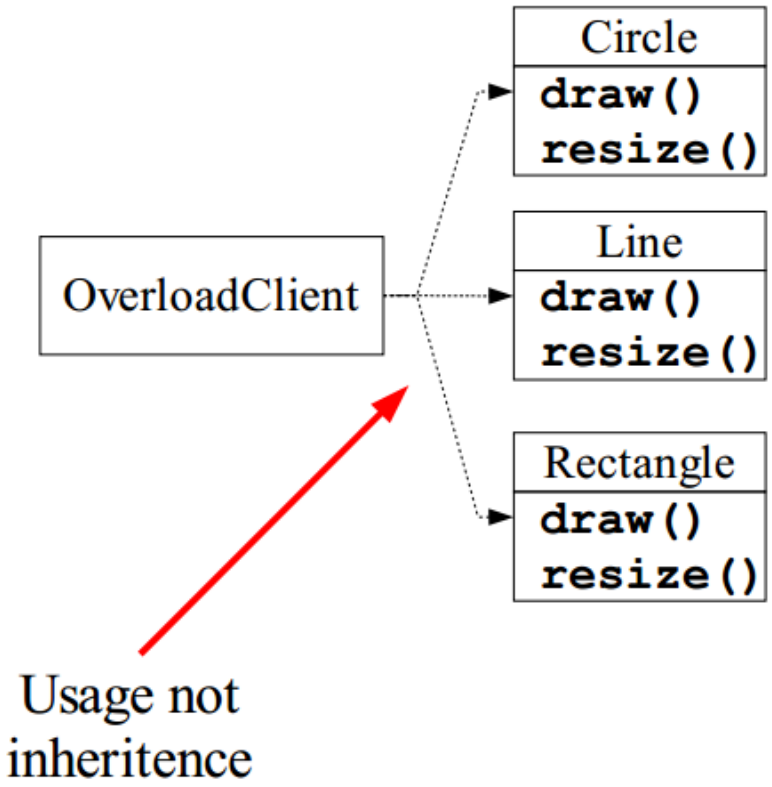
```
class Shape {
   void draw() { System.out.println ("Shape"); }
   private void doStuff() {
      System.out.println("Shape.doStuff()");
   }
}
class Rectangle extends Shape {
   void draw() {System.out.println ("Rectangle"); }
   public void doStuff() {
      System.out.println("Rectangle.doStuff()");
    }
}

public class PolymorphShape {
   public static void polymorphismPrivate(){
      Rectangle r = new Rectangle();
      r.doStuff();   // okay part of Rectangle interface
      Shape s = r;   // up cast
      s.doStuff();   // not allowed, compiler error
   }
}
```

Why Polymorphism and Dynamic Binding?

- Separate interface from implementation
  - What we are trying to achieve in object-oriented programming!
- Allows programmers to isolate type specific details from the main part of the code
  - Client programs only use the method provided by the Shape class in the shape hierarchy example.
- Code is simpler to write and to read
- Can change types (and add new types) with this propagates to existing code

Overloading vs. Polymorphism (1)

- Has not yet discovered that the Circle, Line and Rectangle classes are related. (not very realistic but just to show the idea)

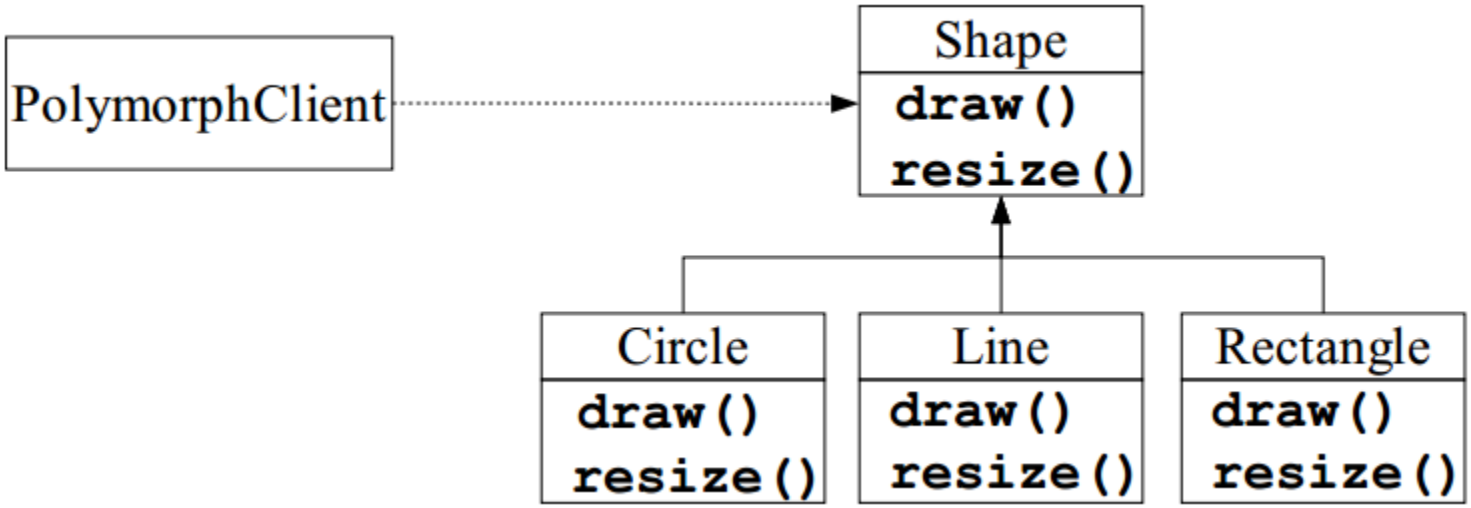


Overloading vs. Polymorphism (2)

```
class Circle {
    void draw() { System.out.println("Circle"); }}
class Line {
    void draw() { System.out.println("Line"); }}
class Rectangle {
    void draw() { System.out.println("Rectangle"); }}

public class OverloadClient{
    // make a flexible interface by overload and hard work
    public void doStuff(Circle c){ c.draw(); }
    public void doStuff(Line l){ l.draw(); }
    public void doStuff(Rectangle r){ r.draw(); }

    public static void main(String[] args){
        OverloadClient oc = new OverloadClient();
        Circle ci = new Circle();
        Line li = new Line();
        Rectangle re = new Rectangle();
        // nice encapsulation from client
        oc.doStuff(ci); oc.doStuff(li); oc.doStuff(re);
   }
}
```

Overloading vs. Polymorphism (3)

- Discovered that the Circle, Line and Rectangle class are related are related via the general concept Shape
- Client only needs access to base class methods

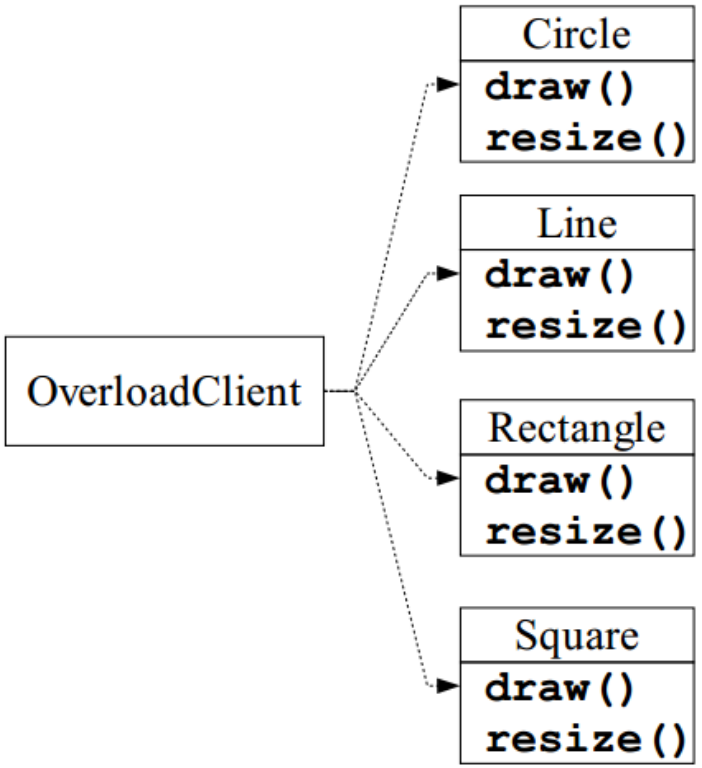


Overloading vs. Polymorphism (4)

```
class Shape {
   void draw() { System.out.println("Shape"); }}
class Circle extends Shape {
    void draw() { System.out.println("Circle"); }}
class Line extends Shape {
    void draw() { System.out.println("Line"); }}
class Rectangle extends Shape {
    void draw() { System.out.println("Rectangle"); }}

public class PolymorphClient{
    // make a really flexible interface by using polymorphism
    public void doStuff(Shape s){ s.draw(); }

    public static void main(String[] args){
        PolymorphClient pc = new PolymorphClient();
        Circle ci = new Circle();
        Line li = new Line();
        Rectangle re = new Rectangle();
        // still nice encapsulation from client
        pc.doStuff(ci); pc.doStuff(li); pc.doStuff(re);
   }
}
```

Overloading vs. Polymorphism (5)

- Must extend with a new class Square and the client has still not discovered that the Circle, Line, Rectangle, and Square classes are related

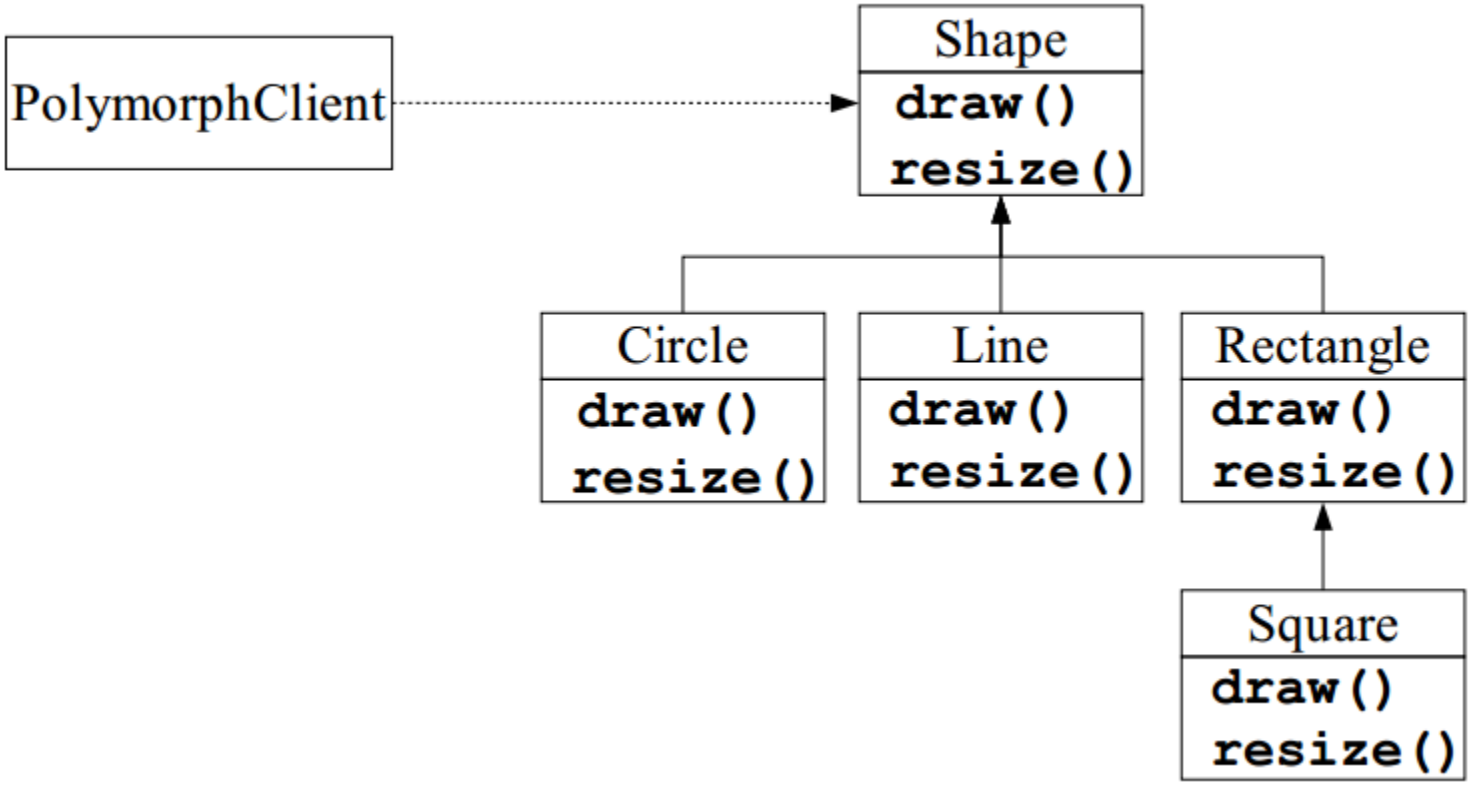


Overloading vs. Polymorphism (6)

```
class Circle {
    void draw() { System.out.println("Circle"); }}
class Line {
    void draw() { System.out.println("Line"); }}
class Rectangle {
    void draw() { System.out.println("Rectangle"); }}
class Square {
    void draw() { System.out.println("Square"); }}

public class OverloadClient{
    // make a flexible interface by overload and hard work
    public void doStuff(Circle c){ c.draw(); }
    public void doStuff(Line l){ l.draw(); }
    public void doStuff(Rectangle r){ r.draw(); }
    public void doStuff(Square s){ s.draw(); }

    public static void main(String[] args){
        <snip>
        // nice encapsulation from client
        oc.doStuff(ci); oc.doStuff(li); oc.doStuff(re);
   }
}
```

Overloading vs. Polymorphism (7)

- Must extend with a new class Square that is a subclass to Rectangle



Overloading vs. Polymorphism (8)

```
class Shape {
   void draw() { System.out.println("Shape"); }}
class Circle extends Shape {
    void draw() { System.out.println("Circle"); }}
class Line extends Shape {
    void draw() { System.out.println("Line"); }}
class Rectangle extends Shape {
    void draw() { System.out.println("Rectangle"); }}
class Square extends Rectangle {
    void draw() { System.out.println("Square"); }}

public class PolymorphClient{
    // make a really flexible interface by using polymorphism
    public void doStuff(Shape s){ s.draw(); }

    public static void main (String[] args){
        <snip>
        // still nice encapsulation from client
        pc.doStuff(ci); pc.doStuff(li); pc.doStuff(re);
   }
}
```

The Opened/Closed Principle

- Open
  - The class hierarchy can be extended with new specialized classes
- Closed
  - The new classes added do not affect old clients
  - The superclass interface of the new classes can be used by old clients
- This is made possible via
  - Polymorphism
  - Dynamic binding

Abstract Class and Method

- An abstract class is a class with an abstract method.
- An abstract method is method with out a body, i.e., only declared but not defined.
- It is not possible to make instances of abstract classes.
- Abstract method are defined in subclasses of the abstract class

Abstract Classes in Java

```
abstract class ClassName {
    // <class body>
}
```

- Classes with abstract methods must declared abstract
- Classes without abstract methods can be declared abstract
- A subclass to a concrete superclass can be abstract
- Constructors can be defined on abstract classes.
- Instances of abstract classes cannot be made

- Abstract fields not possible

Abstract Class in Java, Example

```
public abstract class Stack{

  abstract public void push(Object el);
  abstract public void pop(); // note no return value
  abstract public Object top();
  abstract public boolean full();
  abstract public boolean empty();
  abstract public int size();
  public void toggleTop(){
    if (size() >= 2){
      Object topEl1 = top();  pop();
      Object topEl2 = top();  pop();
      push(topEl1); push(topEl2);
    }
  }
  public String toString(){
    return "Stack";
  }
}
```

Abstract Methods in Java

```
abstract [access modifier] return type
                           methodName([parameters]);
```

- A method body does not have be defined
- Abstract method are overwritten in subclasses
- Idea taken directly from C++
  - ▷pure virtual function
- You are saying: “The object should have this properties I just do not know how to implement the property at this level of abstraction.”

Abstract Methods in Java, Example

```
public abstract class Number {
    public abstract int intValue();
    public abstract long longValue();
    public abstract double doubleValue();
    public abstract float floatValue();
    public byte byteValue(){
        // method body
    }
    public short shortValue(){
        // method body
    }
}
```

Today

- Exercises
  - [14.1-14.3]
  - Submit online your java implementations (single .zip with your student number)

- Ensure you're totally comfortable with object orientated principles
  - e.g., inheritance, polymorphism, up/down casting, types, classes, objects, interfaces, abstract classes, …

This Week

- Read Associated Chapters
- Review Slides
- Java Exercises
- Online Quizzes

Summary

- Polymorphism an object-oriented “switch” statement
- Polymorphism should strongly be preferred over overloading
  - Must simpler for the class programmer
  - Identical (almost) to the client programmer
- Polymorphism is a prerequest for dynamic binding and central to the object-oriented programming paradigm
  - Sometimes polymorphism and dynamic binding are described as the same concept (this is inaccurate).
- Abstract classes
  - Complete abstract class no methods are abstract but instancing does not make sense.
  - Incomplete abstract class, some method are abstract

Questions/Discussion

- Revision Questions

Question

- What is the output of this program?

```
class A {
    int i;
}
class B extends A {
    int j;
    void display() {
        super.i = j + 1;
        System.out.println(j + " " + i);
    }
}
class inheritance {
    public static void main(String args[])
    {
        B obj = new B();
        obj.i=1;
        obj.j=2;
        obj.display();
    }
}
```

a) 2 2
b) 3 3
c) 2 3
d) 3 2

Answer

- Answer: c

output:

$ javac inheritance.java

$ java inheritance

2 3

Question

- What is the output of this program?

```
class A {
    public int i;
    private int j;
}
class B extends A {
    void display() {
        super.j = super.i + 1;
        System.out.println(super.i + " " + super.j);
    }
}
class inheritance {
    public static void main(String args[])
    {
        B obj = new B();
        obj.i=1;
        obj.j=2;
        obj.display();
    }
}
```

a) 2 2
b) 3 3
c) Runtime Error
d) Compilation Error

Answer

- Answer: d)

Explanation: class contains a private member variable j, this cannot be inherited by subclass B and does not have access to it.

output:

$ javac inheritance.java

Exception in thread “main” java.lang.Error: Unresolved compilation problem:

The field A.j is not visible

Question

- What is the output of this program?

```
class A {
    public int i;
    public int j;
    A() {
        i = 1;
        j = 2;
    }
}
class B extends A {
    int a;
    B() {
        super();
    }
}
class super_use {
    public static void main(String args[])
    {
        B obj = new B();
        System.out.println(obj.i + " " + obj.j)
    }
}
```

a) 1 2
b) 2 1
c) Runtime Error
d) Compilation Error

Answer

- Answer: a)

Explanation: Keyword super is used to call constructor of class A by constructor of class B. Constructor of a initializes i & j to 1 & 2 respectively.

output:

$ javac superExample.java

$ java superExample

1 2

Question

- What is the output of this program?

```
class A {
    public int i;
    protected int j;
}
class B extends A {
    int j;
    void display() {
        super.j = 3;
        System.out.println(i + " " + j);
    }
}
class Output {
    public static void main(String args[])
    {
        B obj = new B();
        obj.i=1;
        obj.j=2;
        obj.display();
    }
}
```

a) 1 2
b) 2 1
c) 1 3
d) 3 1

Answer

- Answer: a)

Explanation: Both class A & B have member with same name that is j, member of class B will be called by default if no specifier is used. I contains 1 & j contains 2, printing 1 2.

output:

$ javac Output.java

$ java Output

1 2