Advanced Placement Computer Science

Inheritance and Polymorphism

What's past is prologue.

Don't write it twice — write it once and reuse it.

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Main Tenants of OO Programming

- Encapsulation
  - abstraction, information hiding, responsibility driven programming
- Inheritance
  - code reuse, specialization "New code using old code."
- Polymorphism
  - do X for a collection of various types of objects, where X is ***different*** depending on the type of object
  - "Old code using new code."

Explanation of Inheritance

- 1 of the fundamental principles of OOP
  - allows code reuse
- Models the *IS-A* relationship
  - a student is-a person
  - an undergraduate is-a student
  - a rectangle is-a shape
  - a rook is-a piece
- Contrast with the *Has-A* relationship (or uses a)
  - a student has-a name
  - a rook has-a position
  - a Stack uses a List
- Is-a relationships indicate inheritance, has-a relationships indicate composition (fields)

Nomenclature of Inheritance

- The `extends` keyword is used to specify which preexisting class a new class is inheriting from

```
public class Student extends Person
```

- Person is said to be
  - the parent class of Student
  - the super class of Student
  - the base class of Student
  - an ancestor of Student
- Student is said to be
  - a child class of Person
  - a sub class of Person
  - a derived class of Person
  - a descendant of Person

The Mechanics of Inheritance

- Java is a pure object oriented language
- all code is part of some class
- all classes, except one, must inherit from exactly one other class
- The `Object` class is the *cosmic super class*
  - The `Object` class does not inherit from any other class
  - The `Object` class has several important methods: `toString`, `equals`, `hashCode`, `clone`, `getClass`
- implications:
  - all classes are descendants of `Object`
  - all classes, and thus all objects, have a `toString`, `equals`, `hashCode`, `clone`, and `getClass` method
    - `toString`, `equals`, `hashCode`, `clone` normally overridden

Inheriting from a Class

- If a class header does not include the extends clause the class extends the `Object` class by default

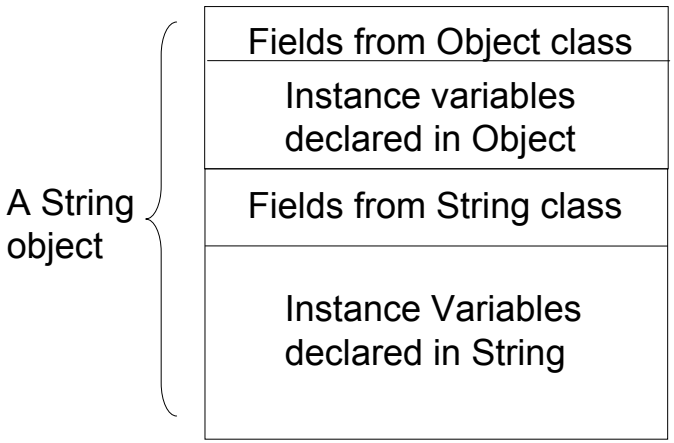
```
public class Card
```

  - `Object` is an ancestor to all classes
  - it is the only class that does not extend some other class
- A class extends exactly one other class
  - extending two or more classes is *multiple inheritance.* Java does not support this directly, rather it uses *Interfaces*.

Implications of Inheritance

- The sub class gains all of the behavior (methods) and data regarding state (instance variables) of the super class *and all ancestor classes*
- Sub classes can:
  - add new fields
  - add new methods
  - *override* existing methods (change behavior)
- Sub classes may not
  - remove fields
  - remove methods
- Note, even though an object may have instance variables from its parent they may not be accessible by the code of the child class if the fields are private

The Real Picture



Behaviors (methods) from String class and Object class.

Access Modifiers and Inheritance

- public
  - accessible to all classes
- private
  - accessible only within that class. Hidden from all sub classes.
- protected
  - accessible by classes within the same *package* and all descendant classes
- Instance variables *should* be private
- protected methods are used to allow descendant classes to modify instance variables in ways other classes can't

Instance Variables - Private or Protected

- Why is it good design to make the instance variables of an object private instead of protected?
- protected also allows classes in the same package to access the data
  - a class in a package does not necessarily inherit from other classes in the same package
- What if when the data changes something else must be done? How would the descendant classes know to do the required changes?
  - Excellent example in the MBCS

MBCS Example

```
public class Fish
{       private Location myLoc;
        // Why private?
        // What if subclasses override move() and need to change
        // the Location? Don't subclasses need access to it?
        private Environment theEnv;
        // If a Fish changes its location theEnv must be updated

        protected void changeLocation(Location newLoc)
        {       // Change location and notify Environment
                Location oldLoc = location();
                myLoc = newLoc;
                environment().recordMove(this, oldLoc);

                // object is again at location myLoc in environment
        }
}
```

Making myLoc private and forcing sub classes to call changeLocation to alter the location of a fish guarantees the environment is correctly updated with the now location.

Shape Classes

- Declare a class called ClosedShape
  - assume all shapes have x and y coordinates
  - override Object's version of `toString`
- Possible sub classes of ClosedShape
  - Rectangle
  - Circle
  - Ellipse
  - Square
- Possible hierarchy

  ClosedShape -> Rectangle -> Square

A ClosedShape class

```
public class ClosedShape
{  private int iMyX;
   private int tMyY;

   public ClosedShape()
   {  this(0,0);  }

   public ClosedShape (int x, int y)
   {  iMyX = x;
      iMyY = y;
   }

   public String toString()
   { return "x: " + iMyX + " y: " + iMyY; }

   public int getX(){ return iMyX; }
   public int getY(){ return iMyY; }
}
// Other methods not shown
```


Constructors

- Constructors handle initialization of objects
- When creating an object with one or more ancestors (every type except Object) a chain of constructor calls takes place
- The reserved word `super` may be used in a constructor to specify which of the parent's constructors to call
  - must be first line of constructor
- if no parent constructor is explicitly called the default, 0 parameter constructor of the parent is called
  - if no default constructor exists a syntax error results
- If a parent constructor is called another constructor in the same class may no be called
  - no `super();this();` allowed. One or the other, not both
  - good place for an initialization method

A Rectangle Constructor

```
public class Rectangle extends ClosedShape
{  private int iMyWidth;
   private int iMyHeight;

   public Rectangle(int width, int height,
          int x, int y)
   {   super(x,y);
       // calls the 2 int constructor in
       // ClosedShape
       iMyWidth = width;
       iMyHeight = height;

   }

    // other methods not shown
}
```


A Rectangle Class

```
public class Rectangle extends ClosedShape
{  private int iMyWidth;
   private int iMyHeight;

   public Rectangle()
   {  this(0, 0);
   }

   public Rectangle(int width, int height)
   {  this(width, height, 0, 0);
   }

   public Rectangle(int width, int height,
              int x, int y)
   {   super(x, y);
       iMyWidth = width;
       iMyHeight = height;
   }

   public String toString()
   {  return super.toString() + " width: " + iMyWidth
         + " height: " + iMyHeight;
   }
}
```

Initialization method

```
public class Rectangle extends ClosedShape
{  private int iMyWidth;
   private int iMyHeight;

   public Rectangle()
   {  init(0, 0);
   }

   public Rectangle(int width, int height)
   {  init(width, height);
   }

   public Rectangle(int width, int height,
       int x, int y)
   {  super(x, y);
      init(width, height);
   }

   private void init(int width, int height)
   {  iMyWidth = width;
      iMyHeight = height;
   }
```


Overriding methods

- any method that is not `final` may be overridden by a descendant class
  - overriding is a replacement of a behavior
  - overloading is the addition of a behavior
- same signature as method in ancestor
- may not reduce visibility
- may use the original method if simply want to add more behavior to existing
  - also called *partial overriding*
- The Rectangle class
  - adds data, partially overrides `toString`

The Keyword `super`

- `super` is used to access something (any protected or public field or method) from the super class that has been overridden
- Rectangle's `toString` makes use of the `toString` in ClosedShape my calling `super.toString()`
- without the super calling `toString` would result in infinite recursive calls
- Java does not allow nested supers

  `super.super.toString()`

  results in a syntax error even though technically this refers to a valid method, Object's `toString`
- Rectangle *partially* overrides ClosedShape's `toString`

What Can Rectangles Do?

```
Rectangle r1 = new Rectangle();
Rectangle r2 = new Rectangle(10, 15);
Rectangle r3 = new Rectangle(10, 15, 2, 3);
System.out.println( r1 );
System.out.println( r2 );
System.out.println( r3 );
int a = r1.getX() + r1.getY();
ClosedShape s = new Rectangle(5, 10, 3, 4);
System.out.println( s.toString() );
a += s.getX();
ClosedShape[] sList = new ClosedShape[3];
sList[0] = new ClosedShape(5, 10);
sList[1] = new Rectangle(10, 25, 10, 7);
sList[2] = r2;
for(int i = 0; i < sList.length; i++)
      System.out.println( sList[i].toString() );
```

Abstract Classes and Methods

- An abstract class is used to define a class to gather together behaviors but:
  - an object of that type never exists and can never be created or *instantiated*.
  - a Shape or a Mammal
- a method may be declared abstract in its header, after visibility modifier
  - no body to the method
  - all derived classes must eventually implement this method (or they must be abstract as well)
  - any class with 1 or more abstract methods must be an abstract class

An Abstract ClosedShape Class

```
public abstract class ClosedShape
{  private int iMyX;
   private int iMyY;

   public ClosedShape()
   {  this(0,0);
   }

   public ClosedShape (int x, int y)
   {  iMyX = x;
      iMyY = y;
   }

   public String toString()
   { return "x: " + iMyX + " y: " + iMyY;
   }

   public abstract int getArea();

   public int getX(){ return iMyX; }
   public int getY(){ return iMyY; }
}
```


Classes that Inherit from ClosedShape

- `Rectangle` inherits from `ClosedShape`
- What if `Rectangle` is unchanged
- Problem: If I have a Rectangle object what happens when I call:

```
Rectangle r = new Rectangle(10, 5, 0, 0);
System.out.println( r.getArea(); )
```

- Undefined behavior = BAD
- As is the Rectangle class would not compile
- If a class inherits from an abstract class that has abstract methods those methods must be defined in the child or the child must be abstract as well

Implementing getArea()

```
public class Rectangle extends ClosedShape
{  private int iMyWidth;
   private int iMyHeight;

   public int getArea()
   {   return iMyWidth * iMyHeight; }

   // other methods not shown
}

public class Square extends Rectangle
{  public Square()
   { }

   public Square(int side)
   { super(side, side); }

   public Square(int side, int x, int y)
   { super(side, side, x, y); }
}
```

A Circle Class

```
public class Circle extends ClosedShape
{   int iMyRadius;

    public Circle()
    {   this(1); }

    public Circle(int radius)
    {   iMyRadius = radius;
    }

    public Circle(int radius, int x, int y)
    {   super(x,y);
        iMyRadius = radius;
    }

    public int getArea()
    {   return Math.PI * iMyRadius * iMyRadius; }

    public String toString()
    { return super.toString() + " radius: " + iMyRadius; }
}
```


Polymorphism in Action

```
public class UsesShapes
{   public static void go()
    {   ClosedShape[] sList = new ClosedShape[10];
        int a, b, c, d;
        int x;
        for(int i = 0; i < 10; i++)
        {   a = (int)(Math.random() * 100);
            b = (int)(Math.random() * 100);
            c = (int)(Math.random() * 100);
            d = (int)(Math.random() * 100);
            x = (int)(Math.random() * 3 );
            if( x == 0 )
                sList[i] = new Rectangle(a,b,c,d);
            else if(x == 1)
                sList[i] = new Square(a,c,d);
            else
                sList[i] = new Circle(a,c,d);
        }
        int total =0;
        for(int i = 0; i < 10; i++)
        {   total += sList[i].getArea();
            System.out.println( sList[i] );
        }
    }
}
```


The Kicker

- We want to expand our pallet of shapes
- Triangle could also be a sub class of ClosedShape.
  - it would *inherit* from ClosedShape

```
public int getArea()
{ return 0.5 * iMyWidth * iMyHeight;}
```

- What changes do we have to make to the code on the previous slide for totaling area so it will now handle Triangles as well?
- Power.

Object Variables

```
Rectangle r = new Rectangle(10, 20);
ClosedShape s = r;
System.out.println("Area is " + s.getArea());
```

- The above code works if Rectangle extends ClosedShape
- An object variable may point to an object of its base type or a descendant in the inheritance chain
  - The is-a relationship is met. A Rectangle object is-a shape so `s` may point to it
- This is a form of *polymorphism* and is used extensively in the Java *Collection* classes
  - Vector, ArrayList are lists of Objects

Type Compatibility

```
Rectangle r = new Rectangle(5, 10);
ClosedShape s = r;
s.changeWidth(20); // syntax error
```

- polymorphism allows s to point at a Rect object but there are limitations
- The above code will not compile
- Statically, `s` is declared to be a shape
  - no changeWidth method in Shape class
  - must *cast* `s` to a `Rectangle`

```
Rectangle r = new Rectangle(5, 10);
Shape s = r;
((Rectangle)s).changeWidth(20); //Okay
```


Problems with Casting

- The following code compiles but a Class Cast Exception is thrown at runtime

```
Rectangle r = new Rectangle(5, 10);
Circle c = new Circle(5);
Shape s = c;
((Rectangle)s).changeWidth(4);
```

- Casting must be done carefully and correctly
- If unsure of what type object will be the use the `instanceof` operator or the `getClass()` method

```
expression instanceof ClassName
```


Multiple Inheritance

- Inheritance models the "is-a" relationship between real world things
- one of the benefits is code reuse, completing programs faster, with less effort
- in the real world a thing can have "is-a" relationships with several other things
  - a Graduate Teaching Assistant is-a Graduate Student. Graduate Teaching Assistant is-a Faculty Member
  - a Student is-a Person. a Student is a SortableObject

Interfaces

- A Java `interface` is a "pure abstract class".
  - Design only, no implementation.
- Interfaces are declared in a way similar to classes but
  - consist only of public abstract methods
  - public final static fields
- A Java class extends exactly one other class, but can implement as many interfaces as desired

Common Interfaces in Java

- One of the most interesting interfaces is: `Comparable`

```
package java.lang

public interface Comparable
{
     public int compareTo( Object other );
}
```

- compareTo should return an int <0 if the calling object is less than the parameter, 0 if they are equal, and an int >0 if the calling object is greater than the parameter

Implementing an Interface

```
public class Card implements Comparable
{
      public int compareTo(Object otherObject)
      {     Card other = (Card)otherObject;
            int result = iMySuit - other.iMySuit;
            if(result == 0)
                  result = iMyValue - other.iMyValue;
      }
      // other methods not shown
}
```

- unlike the equals method no steps to prevent a miscast
- If a class declares that it will implement an interface, but does not provide an implementation of all the methods in that interface, that class must be abstract