Topic 4
Inheritance

"Question: What is the object oriented way of getting rich?
Answer: Inheritance."

Features of OO Programming

- Encapsulation
  - abstraction
  - information hiding
  - breaking problem up based on data types

- Inheritance
  - code reuse
  - specialization
  - "New code using old code."

Encapsulation

- Create a program to allow people to play the game Monopoly
  - Create classes for money, dice, players, the bank, the board, chance cards, community chest cards, pieces, etc.

- Some class use other classes:
  - the board consists of spaces
  - a player has money
  - a piece has a position
  - also referred to as composition

Inheritance

- Another kind of relationship exists between data types

- There are properties in Monopoly
  - a street is a kind of property
  - a railroad is a kind of property
  - a utility is a kind of property

<table>
<thead>
<tr>
<th>B. &amp; O. RAILROAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent: $26</td>
</tr>
<tr>
<td>If 3 railcars are owned:</td>
</tr>
<tr>
<td>$100.</td>
</tr>
<tr>
<td>If 4 railcars are owned:</td>
</tr>
<tr>
<td>$200.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>TITLEOWNED ILLINOIS AVE.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent: $250</td>
</tr>
<tr>
<td>With 1 house: $100</td>
</tr>
<tr>
<td>With 2 houses: $300</td>
</tr>
<tr>
<td>With 3 houses: $500</td>
</tr>
<tr>
<td>With 4 houses: $925</td>
</tr>
<tr>
<td>With hotel: $1,000</td>
</tr>
<tr>
<td>Mortgage Value: $1,000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WATER WORKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rent: $100</td>
</tr>
<tr>
<td>Mortgage Value: $875</td>
</tr>
</tbody>
</table>
Inheritance

- In Monopoly there is the concept of a Property
- All properties have some common traits
  - they have a name
  - they have a position on the board
  - they can be owned by players
  - they have a price to buy
- But some things are different for each of the three kinds of property
  - How to determine money I owe

What to Do?

- If we have a separate class for Street, Railroad, and Utility there is going to be a lot of code copied
  - hard to maintain
  - an anti-pattern
- Inheritance is a programming feature to allow data types to build on pre-existing data types without repeating code

Inheritance in Java

- Java is designed to encourage object oriented programming
- 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**

Nomenclature of Inheritance

- In Java the `extends` keyword is used in the class header to specify which preexisting class a new class is inheriting from
  ```java
  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
**Clicker Question 1**

What is the primary reason for using inheritance when programming?

A. To make a program more complicated
B. To duplicate code between classes
C. To reuse pre-existing code
D. To hide implementation details of a class
E. To ensure pre-conditions of methods are met.

**Clicker Question 2**

What is output when the `main` method is run?

```java
public class Foo{
    public static void main(String[] args){
        Foo f1 = new Foo();
        System.out.println(f1.toString());
    }
}
```

A. 0
B. null
C. Unknown until code is actually run.
D. No output due to a syntax error.
E. No output due to a runtime error.

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**Simple Code Example**

- Create a class named `Shape`
  - what class does `Shape` inherit from
  - what methods can we call on `Shape` objects?
  - add instance variables for a position
  - `override` the `toString` method
- Create a `Circle` class that extends `Shape`
  - add instance variable for radius
  - debug and look at contents
  - try to access instance var from `Shape`
  - constructor calls
  - use of key word `super`

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**Overriding methods**

- any method that is not `final` may be overridden by a descendant class
- same signature as method in ancestor
- may not reduce visibility
- may use the original method if simply want to add more behavior to existing
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 call a one of the parent’s constructors
  - 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

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 ClosedShapes toString

A New Class

- Assume we want to have a list of ints, but that the ints must always be maintained in ascending order
  
  [-7, 12, 37, 212, 212, 313, 313, 500]

  sortedList.get(0) returns the min
  sortedList.get( list.size() – 1 )
  returns the max
Implementing SortedIntList

- Do we have to write a whole new class?
- Assume we have an IntList class.
- Which of the following methods would have to be changed?
  - add(int value)
  - int get(int location)
  - String toString()
  - int size()
  - int remove(int location)

Overriding the add Method

- First attempt
- Problem?
- solving with insert method
  - double edged sort
- solving with protected
  - What protected really means

Problems

- What about this method?
  - void insert(int location, int val)
- What about this method?
  - void insertAll(int location, IntList otherList)
- SortedIntList is not a good application of inheritance given the IntList we developed

More Example Code

ClosedShape and Rectangle classes
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

```java
public class ClosedShape {
    private double myX;
    private double myY;

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

    public ClosedShape(double x, double y) {
        myX = x;
        myY = y;
    }

    public String toString() {
        return "x: " +getX() + " y: " + getY(); }

    public double getX() { return myX; }
    public double getY() { return myY; }
}
// Other methods not shown
```

A Rectangle Constructor

```java
public class Rectangle extends ClosedShape {
    private double myWidth;
    private double myHeight;

    public Rectangle(double x, double y, double width, double height) {
        super(x, y);
        // calls the 2 double constructor in
        // ClosedShape
        myWidth = width;
        myHeight = height;
    }

    // other methods not shown
}
```

A Rectangle Class

```java
public class Rectangle extends ClosedShape {
    private double myWidth;
    private double myHeight;

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

    public Rectangle(double width, double height) {
        myWidth = width;
        myHeight = height;
    }

    public Rectangle(double x, double y, double width, double height) {
        super(x, y);
        myWidth = width;
        myHeight = height;
    }

    public String toString() {
        return super.toString() + " width " + myWidth
            + " height " + myHeight;
    }
}
```
Initialization method

```java
public class Rectangle extends ClosedShape {
    private double myWidth;
    private double myHeight;

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

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

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

    private void init(double width, double height) {
        myWidth = width;
        myHeight = height;
    }
}
```

Result of Inheritance

Do any of these cause a syntax error?

What is the output?

```java
Rectangle r = new Rectangle(1, 2, 3, 4);
ClosedShape s = new CloseShape(2, 3);
System.out.println(s.getX());
System.out.println(s.getY());
System.out.println(s.toString());
System.out.println(r.getX());
System.out.println(r.getY());
System.out.println(r.toString());
```

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

The Real Picture

<table>
<thead>
<tr>
<th>Fields from Object class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instance variables declared in Object</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fields from ClosedShape class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instance Variables declared in ClosedShape</td>
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</tbody>
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<tr>
<th>Fields from Rectangle class</th>
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<tr>
<td>Instance Variables declared in Rectangle</td>
</tr>
</tbody>
</table>
Why private Vars and not protected?

- In general it is good practice to make instance variables private
  - hide them from your descendants
  - if you think descendants will need to access them or modify them provide protected methods to do this

- Why?
- Consider the following example

```java
public class GamePiece {
    private Board myBoard;
    private Position myPos;

    // whenever my position changes I must
    // update the board so it knows about the change

    protected void alterPos(Position newPos) {
        Position oldPos = myPos;
        myPos = newPos;
        myBoard.update(oldPos, myPos);
    }
}
```