Abstract Classes and Interfaces

CSE 114, Computer Science 1
Stony Brook University
http://www.cs.stonybrook.edu/~cse114
Abstract Classes and Abstract Methods

Abstract class GeometricObject
- color: String
- filled: boolean
- dateCreated: java.util.Date

# GeometricObject()
#GeometricObject(color: string, filled: boolean)
+ getColor(): String
+ setColor(color: String): void
+ isFilled(): boolean
+ setFilled(filled: boolean): void
+ getDateCreated(): java.util.Date
+ toString(): String
+ getArea(): double
+ getPerimeter(): double

Methods getArea and getPerimeter are overridden in Circle and Rectangle. Superclass abstract methods are generally omitted in the UML diagram for subclasses.

Abstract classes are italicized
The # sign indicates protected modifier

GeometricObject

Circle
- radius: double
+ Circle()
+ Circle(radius: double)
+ Circle(radius: double, color: string, filled: boolean)
+ getRadius(): double
+ setRadius(radius: double): void
+ getDiameter(): double

Rectangle
- width: double
- height: double
+ Rectangle()
+ Rectangle(width: double, height: double)
+ Rectangle(width: double, height: double, color: string, filled: boolean)
+ getWidth(): double
+ setWidth(width: double): void
+ getHeight(): double
+ setHeight(height: double): void

The # sign indicates protected modifier
Abstract methods are italicized
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public abstract class GeometricObject {
    private String color = "white";
    private boolean filled;
    private java.util.Date dateCreated;
    protected GeometricObject() {
        dateCreated = new java.util.Date();
    }
    protected GeometricObject(String color, boolean filled) {
        dateCreated = new java.util.Date();
        this.color = color;
        this.filled = filled;
    }
    public String getColor() {   return color;  }
    public void setColor(String color) {  this.color = color;  }
    public boolean isFilled() {   return filled;  }
    public void setFilled(boolean filled) {  this.filled = filled;  }
    public java.util.Date getDateCreated() {   return dateCreated;  }
    public String toString() {   return "created on " + dateCreated + "ncolor: " + color + " and filled: " + filled;
    }
    /** Abstract method getArea */
    public abstract double getArea();
    /** Abstract method getPerimeter */
    public abstract double getPerimeter();
}
public class Circle extends GeometricObject {
    private double radius;
    public Circle() {} 
    public Circle(double radius) {
        this.radius = radius;
    }
    public double getRadius() {
        return radius;
    }
    public void setRadius(double radius) {
        this.radius = radius;
    }
    public double getArea() {
        return radius * radius * Math.PI;
    }
    public double getDiameter() {
        return 2 * radius;
    }
    public double getPerimeter() {
        return 2 * radius * Math.PI;
    }
    /* Print the circle info */
    public void printCircle() {
        System.out.println("The circle is created " + getDateCreated() + ", and the radius is " + radius);
    }
}
public class Rectangle extends GeometricObject {
    private double width;
    private double height;
    public Rectangle() {
    }
    public Rectangle(double width, double height) {
        this.width = width;
        this.height = height;
    }
    public double getWidth() {
        return width;
    }
    public void setWidth(double width) {
        this.width = width;
    }
    public double getHeight() {
        return height;
    }
    public void setHeight(double height) {
        this.height = height;
    }

    public double getArea() {
        return width * height;
    }

    public double getPerimeter() {
        return 2 * (width + height);
    }
}

public class TestGeometricObject {
    public static void main(String[] args) {
        // Declare and initialize two geometric objects
        GeometricObject geoObject1 = new Circle(5);
        GeometricObject geoObject2 = new Rectangle(5, 3);
        System.out.println("The two objects have the same area? " +
            equalArea(geoObject1, geoObject2));
        // Display circle
        displayGeometricObject(geoObject1);
        // Display rectangle
        displayGeometricObject(geoObject2);
    }

    /** A method for comparing the areas of two geometric objects */
    public static boolean equalArea(GeometricObject object1,
        GeometricObject object2) {
        return object1.getArea() == object2.getArea();
    }

    /** A method for displaying a geometric object */
    public static void displayGeometricObject(GeometricObject object) {
        System.out.println();
        System.out.println("The area is " + object.getArea());
        System.out.println("The perimeter is " + object.getPerimeter());
    }
}
abstract method in abstract class

• An abstract method cannot be contained in a nonabstract class.

• In a nonabstract subclass extended from an abstract class, all the abstract methods must be implemented, even if they are not used in the subclass.

• If a subclass of an abstract superclass does not implement all the abstract methods, the subclass must be defined abstract.
abstract classes

• An object cannot be created from abstract class
• An abstract class cannot be instantiated using the \texttt{new} operator
• We can still define its constructors, which are invoked in the constructors of its subclasses.
  • For instance, the constructors of \texttt{GeometricObject} are invoked in the \texttt{Circle} class and the \texttt{Rectangle} class.
abstract classes

• A class that contains abstract methods must be abstract
• An abstract class without abstract method:
  • It is possible to define an abstract class that contains no abstract methods.
  • We cannot create instances of the class using the `new` operator.
  • This class is used as a base class for defining new subclasses
abstract classes

- A subclass can be abstract even if its superclass is concrete.
- For example, the `Object` class is concrete, but a subclass, `GeometricObject`, is abstract.
abstract classes

• A subclass can override a method from its superclass to define it abstract
  • rare, but useful when the implementation of the method in the superclass becomes invalid in the subclass.
  • the subclass must be defined abstract
abstract classes as types

- You cannot create an instance from an abstract class using the `new` operator, but an abstract class can be used as a data type:

```java
GeometricObject c = new Circle(2);
```

- The following statement, which creates an array whose elements are of `GeometricObject` type, is correct:

```java
GeometricObject[] geo=new GeometricObject[10];
```
- There are only `null` elements in the array!!!
The abstract Calendar class and its GregorianCalendar subclass

- An instance of `java.util.Date` represents a specific instant in time with millisecond precision
- `java.util.Calendar` is an abstract base class for extracting detailed information such as year, month, date, hour, minute and second from a `Date` object for a specific calendar
  - Subclasses of `Calendar` can implement specific calendar systems such as Gregorian calendar, Lunar Calendar and Jewish calendar.
    - `java.util.GregorianCalendar` is for the Gregorian calendar
The GregorianCalendar Class

- Java API for the GregorianCalendar class: [http://docs.oracle.com/javase/8/docs/api/java/util/GregorianCalendar.html](http://docs.oracle.com/javase/8/docs/api/java/util/GregorianCalendar.html)
- `new GregorianCalendar()` constructs a default `GregorianCalendar` with the current time
- `new GregorianCalendar(year, month, date)` constructs a `GregorianCalendar` with the specified year, month, and date
  - The `month` parameter is 0-based, i.e., 0 is for January.
The **abstract** Calendar class and its GregorianCalendar subclass

### java.util.Calendar

- `#Calendar()`: Constructs a default calendar.
- `+get(field: int): int`: Returns the value of the given calendar field.
- `+set(field: int, value: int): void`: Sets the given calendar to the specified value.
- `+set(year: int, month: int, dayOfMonth: int): void`: Sets the calendar with the specified year, month, and date. The month parameter is 0-based, that is, 0 is for January.
- `+getActualMaximum(field: int): int`: Returns the maximum value that the specified calendar field could have.
- `+add(field: int, amount: int): void`: Adds or subtracts the specified amount of time to the given calendar field.
- `+getTime(): java.util.Date`: Returns a Date object representing this calendar’s time value (million second offset from the Unix epoch).
- `+setTime(date: java.util.Date): void`: Sets this calendar’s time with the given Date object.

### java.util.GregorianCalendar

- `+GregorianCalendar()`: Constructs a GregorianCalendar for the current time.
- `+GregorianCalendar(year: int, month: int, dayOfMonth: int)`: Constructs a GregorianCalendar for the specified year, month, and day of month.
- `+GregorianCalendar(year: int, month: int, dayOfMonth: int, hour:int, minute: int, second: int)`: Constructs a GregorianCalendar for the specified year, month, day of month, hour, minute, and second. The month parameter is 0-based, that is, 0 is for January.
The get Method in Calendar Class

- The get(int field) method defined in the Calendar class is useful to extract the date and time information from a Calendar object.
- The fields are defined as constants, as shown in the following.

<table>
<thead>
<tr>
<th>Constant</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR</td>
<td>The year of the calendar.</td>
</tr>
<tr>
<td>MONTH</td>
<td>The month of the calendar with 0 for January.</td>
</tr>
<tr>
<td>DATE</td>
<td>The day of the calendar.</td>
</tr>
<tr>
<td>HOUR</td>
<td>The hour of the calendar (12-hour notation).</td>
</tr>
<tr>
<td>HOUR_OF_DAY</td>
<td>The hour of the calendar (24-hour notation).</td>
</tr>
<tr>
<td>MINUTE</td>
<td>The minute of the calendar.</td>
</tr>
<tr>
<td>SECOND</td>
<td>The second of the calendar.</td>
</tr>
<tr>
<td>DAY_OF_WEEK</td>
<td>The day number within the week with 1 for Sunday.</td>
</tr>
<tr>
<td>DAY_OF_MONTH</td>
<td>Same as DATE.</td>
</tr>
<tr>
<td>DAY_OF_YEAR</td>
<td>The day number in the year with 1 for the first day of the year.</td>
</tr>
<tr>
<td>WEEK_OF_MONTH</td>
<td>The week number within the month.</td>
</tr>
<tr>
<td>WEEK_OF_YEAR</td>
<td>The week number within the year.</td>
</tr>
<tr>
<td>AM_PM</td>
<td>Indicator for AM or PM (0 for AM and 1 for PM).</td>
</tr>
</tbody>
</table>

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import java.util.*;
public class TestCalendar {
    public static void main(String[] args) {
        // Construct a Gregorian calendar for the current date and time
        Calendar calendar = new GregorianCalendar();
        System.out.println("Current time is " + new Date());
        System.out.println("YEAR:	" + calendar.get(Calendar.YEAR));
        System.out.println("MONTH:	" + calendar.get(Calendar.MONTH));
        System.out.println("DATE:	" + calendar.get(Calendar.DATE));
        System.out.println("HOUR:	" + calendar.get(Calendar.HOUR));
        System.out.println("HOUR_OF_DAY:	" + calendar.get(Calendar.HOUR_OF_DAY));
        System.out.println("MINUTE:	" + calendar.get(Calendar.MINUTE));
        System.out.println("SECOND:	" + calendar.get(Calendar.SECOND));
        System.out.println("DAY_OF_WEEK:	" + calendar.get(Calendar.DAY_OF_WEEK));
        System.out.println("DAY_OF_MONTH:	" + calendar.get(Calendar.DAY_OF_MONTH));
        System.out.println("DAY_OF_YEAR: 	" + calendar.get(Calendar.DAY_OF_YEAR));
        System.out.println("WEEK_OF_MONTH: 	" + calendar.get(Calendar.WEEK_OF_MONTH));
        System.out.println("WEEK_OF_YEAR: 	" + calendar.get(Calendar.WEEK_OF_YEAR));
        System.out.println("AM_PM: 	" + calendar.get(Calendar.AM_PM));
        // Construct a calendar for January 1, 2020
        Calendar calendar1 = new GregorianCalendar(2020, 0, 1);
        System.out.println("January 1, 2020 is a 	" + dayNameOfWeek(calendar1.get(Calendar.DAY_OF_WEEK)));
    }
    
    public static String dayNameOfWeek(int dayOfWeek) {
        switch (dayOfWeek) {
            case 1: return "Sunday";
            case 2: return "Monday";
            case 3: return "Tuesday";
            ...
            case 7: return "Saturday";
            default: return null;
        }
    }
}
Interfaces

- What is an interface?
  - An interface is a class-like construct that contains only constants and abstract methods.

- Why is an interface useful?
  - An interface is similar to an abstract class, but the intent of an interface is to specify behavior for objects.
    - For example: specify that the objects are comparable, edible, cloneable, ...
  - Allows multiple inheritance.
Define an Interface

- Declaration:

```java
public interface InterfaceName {
    // constant declarations;
    // method signatures;
}
```

- Example:

```java
public interface Edible {
    /** Describe how to eat */
    public abstract String howToEat();
}
```
Interface is a Special Class

- An interface is treated like a special class in Java:
  - Each interface is compiled into a separate bytecode file, just like a regular class.
  - Like an abstract class, you cannot create an instance from an interface using the `new` operator.

- Uses:
  - as a data type for a variable
  - as the result of casting
Interface Example

• The **Edible** interface specifies whether an object is edible

```java
public interface Edible {
    public abstract String howToEat();
}
```

• The class **Chicken** implements the **Edible** interface:

```java
class Chicken extends Animal implements Edible {
    public String howToEat() {
        return "Chicken: Fry it";
    }
}
```
interface Edible {
    public abstract String howToEat();  /** Describe how to eat */
}
class Animal {
}
class Chicken extends Animal implements Edible {
    public String howToEat() {
        return "Chicken: Fry it";
    }
}
class Tiger extends Animal {  /** Does not extend Edible */
}
abstract class Fruit implements Edible {
}
class Apple extends Fruit {
    public String howToEat() {
        return "Apple: Make apple cider";
    }
}
class Orange extends Fruit {
    public String howToEat() {
        return "Orange: Make orange juice";
    }
}
public class TestEdible {
    public static void main(String[] args) {
        Object[] objects = {new Tiger(), new Chicken(), new Apple()};
        for (int i = 0; i < objects.length; i++)
            if (objects[i] instanceof Edible)
                System.out.println(((Edible)objects[i]).howToEat());
    }
}
Omitting Modifiers in Interfaces

- All data fields are `public static final` in an interface
- All methods are `public abstract` in an interface
- These modifiers can be omitted:

```java
public interface T1 {
  public static final int K = 1;
  public abstract void p();
}
```

Equivalent

```java
public interface T1 {
  int K = 1;
  void p();
}
```

- A constant defined in an interface can be accessed using `InterfaceName.CONSTANT_NAME`, for example: `T1.K`
Example: The **Comparable** Interface

```java
package java.lang;

public interface Comparable {
    public int compareTo(Object o);
}
```
String and Date Classes

• Many classes (e.g., String and Date) in the Java library implement Comparable to define a natural order for the objects

```java
public class String extends Object implements Comparable {
  // class body omitted
}

public class Date extends Object implements Comparable {
  // class body omitted
}
```

new String() instanceof String    true
new String() instanceof Comparable true
new java.util.Date() instanceof java.util.Date true
new java.util.Date() instanceof Comparable true
In UML, the interface and the methods are italicized. Dashed lines and triangles are used to point to the interface.
Generic \texttt{max} Method

The \texttt{return} value from the \texttt{max} method is of the \texttt{Comparable} type. So, we need to cast it to \texttt{String} or \texttt{Date} explicitly.
We cannot use the `max` method to find the larger of two instances of `Rectangle`, because `Rectangle` does not implement `Comparable`.

We can define a new rectangle class `ComparableRectangle` that implements `Comparable`: the instances of this new class are comparable.
public class ComparableRectangle extends Rectangle implements Comparable {
    /** Construct a ComparableRectangle with specified properties */
    public ComparableRectangle(double width, double height) {
        super(width, height);
    }

    /** Implement the compareTo method defined in Comparable */
    public int compareTo(Object o) {
        if (getArea() > ((ComparableRectangle)o).getArea())
            return 1;
        else if (getArea() < ((ComparableRectangle)o).getArea())
            return -1;
        else
            return 0;
    }

    public static void main(String[] args) {
        ComparableRectangle rectangle1 = new ComparableRectangle(4, 5);
        ComparableRectangle rectangle2 = new ComparableRectangle(3, 6);
        System.out.println(Max.max(rectangle1, rectangle2));
    }
}
The Cloneable Interface

- Marker Interface: an empty interface
  - Does not contain constants or methods
  - It is used to denote that a class possesses certain desirable properties
- A class that implements the Cloneable interface is marked cloneable: its objects can be cloned using the clone() method defined in the Object class

```java
package java.lang;
public interface Cloneable {
}
```
The Cloneable Interface

- Calendar (in the Java library) implements Cloneable:

  ```java
  Calendar calendar = new GregorianCalendar(2020, 1, 1);
  Calendar calendarCopy = (Calendar)(calendar.clone());
  System.out.println("calendar == calendarCopy is " + (calendar == calendarCopy));
  System.out.println("calendar.equals(calendarCopy) is " + calendar.equals(calendarCopy));
  ```

Displays:

- `calendar == calendarCopy` is `false`
- `calendar.equals(calendarCopy)` is `true`
Implementing the Cloneable Interface

- If we try to create a clone of an object instance of a class that does not implement the Cloneable interface, it throws `CloneNotSupportedException`.
- We can override the `clone()` method from the `Object` class to create custom clones.
  - The clone method in the `Object` class creates a new instance of the class of this object and initializes all its fields with exactly the contents of the corresponding fields of this object, as if by assignment; the contents of the fields are not themselves cloned.
  - The `clone()` method returns an `Object` that needs to be casted.
public class House implements Cloneable, Comparable {
    private int id;
    private double area;
    private java.util.Date whenBuilt;
    public House(int id, double area) {this.id = id; this.area = area;
            whenBuilt = new java.util.Date();}
    public double getId() { return id;}
    public double getArea() { return area;}
    public java.util.Date getWhenBuilt() { return whenBuilt;}
    /** Override the protected clone method defined in the Object
     * class, and strengthen its accessibility */
    public Object clone() {
        try {
            return super.clone();
        }catch (CloneNotSupportedException ex) {
            return null;
        }
    }
    /** Implement the compareTo method defined in Comparable */
    public int compareTo(Object o) {
        if (area > ((House)o).area)
            return 1;
        else if (area < ((House)o).area)
            return -1;
        else
            return 0;
    }
}
Shallow vs. Deep Copy

- House house1 = new House(1, 1750.50);
- House house2 = (House)(house1.clone());

**Shallow Copy**: if the field is of reference type, the object’s reference is copied rather than its content.
public class House implements Cloneable {
    ...
    public Object clone() { // deep copy
        try {
            House h = (House)(super.clone());
            h.whenBuilt = (Date)(whenBuilt.clone());
            return h;
        } catch (CloneNotSupportedException ex) {
            return null;
        }
    }
    ...
}
 Interfaces vs. Abstract Classes

- In an interface, the data must be constants; an abstract class can have all types of data.
- Each method in an interface has only a signature without implementation; an abstract class can have concrete methods.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Constructors</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract class</td>
<td>No restrictions</td>
<td>Constructors are invoked by subclasses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>through constructor chaining.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An abstract class cannot be instantiated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>using the new operator.</td>
</tr>
<tr>
<td>Interface</td>
<td>All variables must be public static final</td>
<td>No constructors.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>An interface cannot be instantiated</td>
</tr>
<tr>
<td></td>
<td></td>
<td>using the new operator.</td>
</tr>
</tbody>
</table>
Interfaces vs. Abstract Classes

- A class can implement any number of interfaces
- An interface can extend another interface
- There is no root for interfaces
Caution: conflict interfaces

- Errors detected by the compiler:
  - If a class implements two interfaces with conflict information:
    - two same constants with different values, or
    - two methods with same signature but different return type
Whether to use an interface or a class?

- **Strong is-a**: a relationship that clearly describes a parent-child relationship - **should be modeled using classes and class inheritance**
  - For example: a staff member is a person

- **Weak is-a (is-kind-of)**: indicates that an object possesses a certain property - **should be modeled using interfaces**
  - For example: all strings are comparable, so the String class implements the Comparable interface

- You can also use interfaces to circumvent single inheritance restriction if multiple inheritance is desired
Wrapper Classes

- Primitive data types in Java ➔ **Better performance**
- Each primitive has a wrapper class: Boolean, Character, Short, Byte, Integer, Long, Float, Double
  - The wrapper classes do not have no-arg constructors
  - The instances of all wrapper classes are immutable: their internal values cannot be changed once the objects are created
Wrapper Classes

- Each wrapper class overrides the `toString`, `equals`, and `hashCode` methods defined in the `Object` class.
- Since these classes implement the `Comparable` interface, the `compareTo` method is implemented in these classes.
The Number Class

• Each numeric wrapper class extends the abstract Number class:
  • The abstract Number class contains the methods doubleValue, floatValue, intValue, longValue, shortValue, and byteValue to “convert” objects into primitive type values
  • The methods doubleValue, floatValue, intValue, longValue are abstract
  • The methods byteValue and shortValue are not abstract, which simply return (byte)intValue() and (short)intValue(), respectively
  • Each numeric wrapper class implements the abstract methods doubleValue, floatValue, intValue and longValue
The **Integer and Double Classes**

### java.lang.Number

- `byteValue()`: byte
- `shortValue()`: short
- `intValue()`: int
- `longValue()`: long
- `floatValue()`: float
- `doubleValue()`: double

### java.lang.Comparable

- `compareTo(o: Object)`: int

### java.lang.Integer

- `value`: int
- `MAX_VALUE`: int
- `MIN_VALUE`: int
- `Integer(value: int)`
- `Integer(s: String)`
- `valueOf(s: String): Integer`
- `valueOf(s: String, radix: int): Integer`
- `parseInt(s: String): int`
- `parseInt(s: String, radix: int): int`

### java.lang.Double

- `value`: double
- `MAX_VALUE`: double
- `MIN_VALUE`: double
- `Double(value: double)`
- `Double(s: String)`
- `valueOf(s: String): Double`
- `valueOf(s: String, radix: int): Double`
- `parseDouble(s: String): double`
- `parseDouble(s: String, radix: int): double`
You can construct a wrapper object either from a primitive data type value or from a string representing the numeric value.

The constructors for Integer and Double are:

```java
public Integer(int value)
public Integer(String s)
public Double(double value)
public Double(String s)
```
Numeric Wrapper Class Constants

- Each numerical wrapper class has the constants `MAX_VALUE` and `MIN_VALUE`:
  - `MAX_VALUE` represents the maximum value of the corresponding primitive data type
  - For `Float` and `Double`, `MIN_VALUE` represents the minimum positive float and double values
  - The maximum integer: 2,147,483,647
  - The minimum positive float: 1.4E-45
  - The maximum double floating-point number: 1.79769313486231570e+308d
The Static `valueOf` Methods

- The numeric wrapper classes have a static method `valueOf(String s)` to create a new object initialized to the value represented by the specified string:

```java
Double doubleObject = Double.valueOf("12.4");
Integer integerObject = Integer.valueOf("12");
```

- Each numeric wrapper class has overloaded parsing methods to parse a numeric string into an appropriate numeric value:

```java
double d = Double.parseDouble("12.4");
int i = Integer.parseInt("12");
```
public class GenericSort {
    public static void main(String[] args) {
        Integer[] intArray={new Integer(2),new Integer(4),new Integer(3)};
        sort(intArray);
        printList(intArray);
    }
    public static void sort(Object[] list) {
        Object currentMax;
        int currentMaxIndex;
        for (int i = list.length - 1; i >= 1; i--) {
            currentMax = list[i];
            currentMaxIndex = i; // Find the maximum in the list[0..i]
            for (int j = i - 1; j >= 0; j--) {
                if (((Comparable)currentMax).compareTo(list[j]) < 0) {
                    currentMax = list[j];
                    currentMaxIndex = j;
                }
            }
            list[currentMaxIndex] = list[i];
            list[i] = currentMax;
        }
    }
    public static void printList(Object[] list) {
        for (int i=0;i<list.length;i++) System.out.print(list[i]+" ");
    }
}

The objects are instances of the Comparable interface and they are compared using the compareTo method.
Sorting an Array of Objects

- Java provides a static `sort` method for sorting an array of `Object` in the `java.util.Arrays` class:
  ```java
  java.util.Arrays.sort(intArray);
  ```
Arrays of Objects

- Arrays are objects:
  - An array is an instance of the `Object` class
  - If A is a subclass of B, every instance of A[] is an instance of B[]

```java
new int[10] instanceof Object    true
new GregorianCalendar[10] instanceof Calendar[]; true
new Calendar[10] instanceof Object[] true
new Calendar[10] instanceof Object true
```

- Although an int value can be assigned to a double type variable, int[] and double[] are two incompatible types:
  - We cannot assign an int[] array to a variable of double[] array
Wrapper Classes

- Automatic Conversion Between Primitive Types and Wrapper Class Types:

  - JDK 1.5 allows primitive type and wrapper classes to be converted automatically = boxing

```
Integer[] intArray = {new Integer(2), new Integer(4), new Integer(3)};
```

(a) Equivalent to:
```
Integer[] intArray = {2, 4, 3};
```

(b) New JDK 1.5 boxing

```
Integer[] intArray = {1, 2, 3};
System.out.println(intArray[0] + intArray[1] + intArray[2]);
```

Unboxing
BigInteger and BigDecimal

• BigInteger and BigDecimal classes in the java.math package:
  • For computing with very large integers or high precision floating-point values
    • BigInteger can represent an integer of any size
    • BigDecimal has no limit for the precision (as long as it’s finite=terminates)
  • Both are immutable
  • Both extend the Number class and implement the Comparable interface.
BigInteger and BigDecimal

BigInteger a = new BigInteger("9223372036854775807");
BigInteger b = new BigInteger("2");
BigInteger c = a.multiply(b); // 9223372036854775807 * 2
System.out.println(c);
18446744073709551614

BigDecimal a = new BigDecimal(1.0);
BigDecimal b = new BigDecimal(3);
BigDecimal c = a.divide(b, 20, BigDecimal.ROUND_UP);
System.out.println(c);
0.33333333333333333334
import java.math.*;
public class LargeFactorial {
    public static void main(String[] args) {
        System.out.println("50! is 
" + factorial(50));
    }
    public static BigInteger factorial(long n) {
        BigInteger result = BigInteger.ONE;
        for (int i = 1; i <= n; i++)
            result = result.multiply(new BigInteger(i+""));
        return result;
    }
}

30414093201713378043612608166064768844377641
56896051200000000000000000
Case Study: The **Rational** Class

```
java.lang.Number
+byteValue(): byte
+shortValue(): short
+intValue(): int
+longValue(): long
+floatValue(): float
+doubleValue(): double
```

```
java.lang.Comparable
compareTo(Object): int
```

```
Rational

-numerator: long
-denominator: long

+Rational()
+Rational(numerator: long, denominator: long)
+getNumerator(): long
+getDenominator(): long
+add(secondRational: Rational): Rational
+multiply(secondRational: Rational): Rational
+subtract(secondRational: Rational): Rational
+divide(secondRational: Rational): Rational
+toString(): String
-gcd(n: long, d: long): long
```

add, subtract, multiply, divide
public class Rational extends Number implements Comparable
{
    private long numerator = 0;
    private long denominator = 1;
    public Rational() { this(0, 1); }
    public Rational(long numerator, long denominator) {
        long gcd = gcd(numerator, denominator);
        this.numerator = ((denominator > 0) ? 1 : -1) * numerator / gcd;
        this.denominator = Math.abs(denominator) / gcd;
    }
    public Rational add(Rational secondRational) {
        long n = numerator * secondRational.getDenominator() +
                denominator * secondRational.getNumerator();
        long d = denominator * secondRational.getDenominator();
        return new Rational(n, d);
    }
    private static long gcd(long n, long d) {
        long n1 = Math.abs(n);
        long n2 = Math.abs(d);
        int gcd = 1;
        for (int k = 1; k <= n1 && k <= n2; k++) {
            if (n1 % k == 0 && n2 % k == 0)
                gcd = k;
        }
        return gcd;
    }
}
```java
/** Override the abstract intValue method in java.lang.Number */
public int intValue() {   return (int)doubleValue();  }
// ... Override all the abstract *Value methods in java.lang.Number

/** Override the compareTo method in java.lang.Comparable */
public int compareTo(Object o) {
    if (((this.subtract((Rational)o)).getNumerator() > 0) return 1;
    else if (((this.subtract((Rational)o)).getNumerator() < 0) return -1;
    else return 0;
}
public static void main(String[] args) {
    Rational r1 = new Rational(4, 2);
    Rational r2 = new Rational(2, 3);
    System.out.println(r1 + " + " + r2 + " = " + r1.add(r2));
}
```