Objects and Classes
(Part 2)

Introduction to Programming and Computational Problem Solving - 2
CSE 8B
Lecture 7
Announcements

• Assignment 3 is due Oct 20, 11:59 PM
• Quiz 3 is Oct 22
• Assignment 4 will be released Oct 20
  – Due Oct 27, 11:59 PM
• Educational research study
  – Oct 22, weekly survey
• Reading
  – Liang
    • Chapter 9
Object-oriented programming

• Object-oriented programming (OOP) involves programming using objects
• This is the focus of CSE 8B
Objects and classes

• An object represents an entity in the real world that can be distinctly identified

• Classes are constructs that define objects of the same type
Objects and Java classes

• The state of an object consists of a set of data fields (also known as properties) with their current values

• The behavior of an object is defined by a set of methods

• A Java class uses variables to define data fields and methods to define behaviors
Instance methods vs static methods

• An instance method can only be invoked from an object (i.e., a specific instance of a class)
  – The syntax to invoke an instance method is
    `objectReferenceVariable.methodName(arguments)`

• A static method (i.e., a non-instance method) can be invoked without using an object (i.e., they are not tied to a specific class instance)
  – The syntax to invoke a static method is
    `ClassName.methodName(arguments)`
Instance variables vs static variables

• An instance variable belongs to a specific instance of a class

• A static variable is shared by all objects of the class
  – Static variables are shared by all the instances of the class
  – Static constants are final variables shared by all the instances of the class
Static members

• In code using a class, the best practice is to make invocations of static methods and access of static data fields obvious

• Use
  ClassName.methodName(arguments)
  ClassName.variable

• Do not use
  objectReferenceVariable.methodName(arguments)
  objectReferenceVariable.variable
The static modifier

• To declare static variables, constants, and methods, use the static modifier
• static is a Java keyword
The static modifier

public class Circle {
    double radius; // The radius of the circle
    static int numberOfObjects = 0; // The number of objects created

    // Construct a circle of radius 1
    Circle() {
        radius = 1;
        numberOfObjects++;
    }

    // Construct a circle with a specified radius
    Circle(double newRadius) {
        radius = newRadius;
        numberOfObjects++;
    }

    // Return number of objects created
    static int getNumberOfObjects() {
        return numberOfObjects;
    }
}
The static modifier

```java
Circle circle1 = new Circle();
Circle circle2 = new Circle(5);
```
Limitations of static methods

• An instance method can
  – Invoke an instance or static method
  – Access an instance or static data field

• A static method can
  – Invoke a static method
  – Access a static data field

• A static method cannot access instance members
Static methods

• If a member method or data field is independent of any specific instance, then make it static

• Do not require those using your class to create instance unless it is absolutely necessary
Visibility modifiers

• Visibility modifiers can be used to specify the visibility of a class and its members

• By default, the class, variable, or method can be accessed by any class in the same package

• Packages can be used to organize classes
  – For example, classes C1 and C2 are placed in package p1, and class C3 is placed in package p2

```java
package p1;
class C1 {
}

package p1;
public class C2 {
}

package p2;
public class C3 {
}
```
Visibility modifiers

• There is no restriction on accessing data fields and methods from *inside* the class.

• A visibility modifier specifies how data fields and methods in a class can be accessed from *outside* the class.
Visibility modifiers

**public**
- The class, data, or method is visible to any class in any package

**private**
- Modifier cannot be applied to a class, only its members
- The data or methods can be accessed only by the declaring class

**protected**
- Used in inheritance (covered next week)
Packages and classes

• The default modifier on a class restricts access to within a package, and the public modifier enables unrestricted access

```java
package p1;

class C1 {
    ...
}

package p1;

public class C2 {
    can access C1
}

package p2;

public class C3 {
    cannot access C1;
    can access C2;
}
```
Packages, classes, and members

• The private modifier restricts access to within a class, the default modifier restricts access to within a package, and the public modifier enables unrestricted access

```java
package p1;

public class C1 {
    public int x;
    int y;
    private int z;

    public void m1() {
    }
    void m2() {
    }
    private void m3() {
    }
}

package p1;

public class C2 {
    void aMethod() {
        C1 o = new C1();
        can access o.x;
        can access o.y;
        cannot access o.z;

        can invoke o.m1();
        can invoke o.m2();
        cannot invoke o.m3();
    }
}

package p2;

public class C3 {
    void aMethod() {
        C1 o = new C1();
        can access o.x;
        cannot access o.y;
        cannot access o.z;

        can invoke o.m1();
        cannot invoke o.m2();
        cannot invoke o.m3();
    }
}
```
Visibility of own members

• There is no restriction on accessing data fields and methods from \textit{inside} the class

• However, an object cannot access its private members \textit{outside} the class

```java
public class C {
    private boolean x;
    
    public static void main(String[] args) {
        C c = new C();
        System.out.println(c.x);
        System.out.println(c.convert());
    }
    
    private int convert() {
        return x ? 1 : -1;
    }
}
```

(a) This is okay because object \texttt{c} is used inside the class \texttt{C}.

```java
public class Test {
    public static void main(String[] args) {
        C c = new C();
        System.out.println(c.x);
        System.out.println(c.convert());
    }
}
```

(b) This is wrong because \texttt{x} and \texttt{convert} are private in class \texttt{C}.
Constructors

• Use public constructors in most cases
• Use a private constructor if you want to prohibit users from creating an instance of a class
  – For example, in java.lang.Math, the constructor Math() is private
## Methods and data fields visibility

<table>
<thead>
<tr>
<th>Modifiers on Members in a Class</th>
<th>Accessed from the Same Class</th>
<th>Accessed from the Same Package</th>
<th>Accessed from a Subclass in a Different Package</th>
<th>Accessed from a Different Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Protected</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Default (no modifier)</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Private</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Covered next week
Data field encapsulation

• It is a best practice is to declare all data fields private

• Protects data
  – From being set to an arbitrary value mistakenly (i.e., tampering) outside of the class

• Makes class easier to maintain
  – Modify the implementation inside the class without modifying all existing code currently using the class outside of the class
Accessor and mutator

• Accessor
  – Provide a \textit{getter} method to read a private data field
  – Use syntax
    
    \begin{verbatim}
    public returnType getPropertyName()
    public boolean isPropertyName()
    \end{verbatim}

• Mutator
  – Provide a \textit{setter} method to modify a private data field
  – Use syntax
    
    \begin{verbatim}
    public void setPropertyName(datatype propertyValue)
    \end{verbatim}
Data encapsulation

<table>
<thead>
<tr>
<th>Circle</th>
<th>The radius of this circle (default: 1.0).</th>
</tr>
</thead>
<tbody>
<tr>
<td>-radius: double</td>
<td>The number of circle objects created.</td>
</tr>
<tr>
<td>-numberOfObjects: int</td>
<td></td>
</tr>
</tbody>
</table>

| +Circle()       | Constructs a default circle object.                                            |
| +Circle(radius: double) | Constructs a circle object with the specified radius.                            |
| +getRadius(): double | Returns the radius of this circle.                                              |
| +setRadius(radius: double): void | Sets a new radius for this circle.                                              |
| +getNumberOfObjects(): int | Returns the number of circle objects created.                                   |
| +getArea(): double | Returns the area of this circle.                                                |

The - sign indicates private modifier.
Pass by value

• Remember, Java uses **pass by value** to pass arguments to a method
• For a parameter of a primitive type, the *actual value* is passed
  – Changing the value of the local parameter inside the method does not affect the value of the variable outside the method
• For a parameter of an **array** or **object** type, the *reference value* is passed
  – Any changes to the array that occur inside the method body will affect the original array or object that was passed as the argument
Passing objects to methods

public static void main(String[] args) {
    Circle myCircle = new Circle(1);
    int n = 5;
    printAreas(myCircle, n);
}

public static void printAreas(Circle c, int times) {
    System.out.println("Radius | Area");
    while (times >= 1) {
        System.out.println(c.getRadius() + "| " + c.getArea());
        c.setRadius(c.getRadius() + 1);
        times--;
    }
}
Arrays of objects

• An array can hold objects as well as primitive type values
• An array of objects is actually an array of reference variables
Arrays of objects

- Create an array **and** each object in it
- When creating an array using `new`, each element in the array is a reference variable with a default value of `null`

```java
Circle[] circleArray = new Circle[10];
for (int i = 0; i < circleArray.length; i++)
{
    circleArray[i] = new Circle();
}
```
Arrays of objects

- Invoking `circleArray[1].getArea()` involves two levels of referencing
  - `circleArray` references to the entire array
  - `circleArray[1]` references to a Circle object
Immutable objects and classes

• Occasionally, it is desirable to create an object whose contents cannot be changed once the object has been created
• Such an object is called an *immutable object* and its class is called an *immutable class*
Immutable objects and classes

- For example, deleting the setRadius method in the Circle class would make it an immutable class because radius is private and cannot be changed without a mutator (i.e., set) method.

<table>
<thead>
<tr>
<th>Circle</th>
<th>Description</th>
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<tr>
<td>-radius: double</td>
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<td>+Circle()</td>
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<tr>
<td>+Circle(radius: double)</td>
<td>Constructs a circle object with the specified radius.</td>
</tr>
<tr>
<td>+getRadius(): double</td>
<td>Returns the radius of this circle.</td>
</tr>
<tr>
<td>+setRadius(radius: double): void</td>
<td>Sets a new radius for this circle.</td>
</tr>
<tr>
<td>+getNumberOfObjects(): int</td>
<td>Returns the number of circle objects created.</td>
</tr>
<tr>
<td>+getArea(): double</td>
<td>Returns the area of this circle.</td>
</tr>
</tbody>
</table>
Immutable objects and classes

public class Student {
    private int id;
    private BirthDate birthDate;

    public Student(int ssn, int year, int month, int day) {
        id = ssn;
        birthDate = new BirthDate(year, month, day);
    }

    public int getId() {
        return id;
    }

    public BirthDate getBirthDate() {
        return birthDate;
    }
}

public class BirthDate {
    private int year;
    private int month;
    private int day;

    public BirthDate(int newYear, int newMonth, int newDay) {
        year = newYear;
        month = newMonth;
        day = newDay;
    }

    public void setYear(int newYear) {
        year = newYear;
    }
}

public class Test {
    public static void main(String[] args) {
        Student student = new Student(111233333, 1970, 5, 3);
        BirthDate date = student.getBirthDate();
        date.setYear(2010); // Now the student birth year is changed!
    }
}
Immutable class

• Requirements of an immutable class
  – All data fields must be private
  – There cannot be any mutator methods for data fields
  – No accessor methods can return a reference to a data field that is mutable
Scope of variables revisited

• The scope of class variables (instance and static data fields) is the entire class
  – They can be declared anywhere inside a class
    • Best practice is to declare them at the beginning of the class
  – They have default values

• The scope of a local variable starts from its declaration and continues to the end of the block that contains the variable
  – Java assigns no default value to a local variable inside a method
  – A local variable must be initialized explicitly before it can be used
Scope of variables revisited

• If a local variable has the same name as a class variable, then the local variable takes precedence (i.e., the class variable is hidden)

```java
public class F {
    private int x = 0; // Instance variable
    private int y = 0;

    public F() {
    }

    public void p() {
        int x = 1; // Local variable
        System.out.println("x = " + x); // Uses local variable
        System.out.println("y = " + y);
    }
}
```
this reference

• The *this* keyword is the name of a reference that refers to an object itself

• One common use of the *this* keyword is to reference a hidden class variable

```java
public void p() {
    int x = 1; // Local variable
    System.out.println("x = " + this.x);
    System.out.println("y = " + y);
}
```
Use this to reference data fields

• Best practice is to use the data field name as the parameter name in the setter method or a constructor
• For a hidden static variable, use ClassName.staticVariable

```java
public class F {
    private int i = 5;
    private static double k = 0;

    void setI(int i) {
        this.i = i;
    }

    static void setK(double k) {
        F.k = k;
    }
}
```

Suppose that f1 and f2 are two objects of F.
F f1 = new F();
F f2 = new F();

Invoking f1.setI(10) is to execute
   this.i = 10, where this refers f1

Invoking f2.setI(45) is to execute
   this.i = 45, where this refers f2
public class Circle {
    private double radius;

    public Circle(double radius) {
        this.radius = radius;
    }

    public Circle() {
        this(1.0);
    }

    public double getArea() {
        return this.radius * this.radius * Math.PI;
    }
}

• The this keyword is the name of a reference that refers to an object itself
• One common use of the this keyword is to reference a hidden class variable
• It can also be used inside a constructor to invoke another constructor of the same class

public class Circle {
    private double radius;
    
    public Circle(double radius) {
        this.radius = radius;
    } 

    public Circle() {
        this(1.0);
    } 

differentiation of data field radius of the object being constructed

this is used to invoke another constructor
Next Lecture

• Object-oriented thinking
• Reading
  – Liang
    • Chapter 10