Chapter 7

Object-Oriented Programming
Part 2:
User-Defined Classes

Topics

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Why User-Defined Classes?

Primitive data types (*int*, *double*, *char*, ..) are great …

… but in the real world, we deal with more complex objects: products, Web sites, flight records, employees, students, ..

Object-oriented programming enables us to manipulate real-world objects.

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User-Defined Classes

- Combine data and the methods that operate on the data
- Advantages:
  - Class is responsible for the validity of the data.
  - Implementation details can be hidden.
  - Class can be reused.
- **Client** of a class
  - A program that instantiates objects and calls methods of the class

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Syntax for Defining a Class

```
accessModifier class ClassName
{
     // class definition goes here
}
```

- **Class or members can be referenced by**
  - methods of the same class,
  - methods of other classes
  - methods of subclasses,
  - methods of classes in the same package

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Software Engineering Tip

- Use a noun for the class name.
- Begin the class name with a capital letter.

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Important Terminology

- **Fields**
  - **instance variables**: data for each object
  - **class data**: *static* data that all objects share
- **Members**
  - fields and methods
- **Access Modifier**
  - determines access rights for the class and its members
  - defines where the class and its members can be used

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Access Modifiers

Access Modifier	Class or members can be referenced by…
public	methods of the same class, and methods of other classes
private	methods of the same class only
protected	methods of the same class, methods of subclasses, and methods of classes in the same package
No access modifier (**package** access)	methods in the same package only

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public VS. *private*

- Classes are usually declared to be ***public***
- Instance variables are usually declared to be ***private***

- Methods that will be called by the client of the class are usually declared to be *public*
- Methods that will be called only by other methods of the same class are usually declared to be ***private***

- APIs of methods are published (made known) so that clients will know how to instantiate objects and call the methods of the class

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Defining Instance Variables

Syntax:

```
accessModifier dataType identifierList;
```

dataType can be primitive date type or a class type
identifierList can contain:

- one or more variable names of the same data type
- multiple variable names separated by commas
- initial values

- Optionally, instance variables can be declared as *final*

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Examples of Instance Variable Definitions

```
private String name = "";

private final int PERFECT_SCORE = 100,
                  PASSING_SCORE = 60;

private int startX, startY,
            width, height;
```

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Software Engineering Tips

- Define instance variables for the data that all objects will have in common.
- Define instance variables as *private* so that only the methods of the class will be able to set or change their values.
- Begin the identifier name with a lowercase letter and capitalize internal words.

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The *Auto* Class

```
public class Auto
{
   private String model;
   private int milesDriven;
   private double gallonsOfGas;
}
```

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Writing Methods

Syntax:

```
accessModifier returnType methodName(
                parameter list ) // method header
{
  // method body
}
```

- *parameter list* is a comma-separated list of data types and variable names.
  - To the client, these are **arguments**
  - To the method, these are **parameters**
- Note that the method header is the method API.

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Software Engineering Tips

- Use verbs for method names.
- Begin the method name with a lowercase letter and capitalize internal words.

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Method Return Types

- The return type of a method is the data type of the value that the method returns to the caller. The return type can be any of Java's primitive data types, any class type, or *void*.
- Methods with a return type of *void* do not return a value to the caller.

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Method Body

- The code that performs the method's function is written between the beginning and ending curly braces {…}.
- Unlike *if* statements and loops, these curly braces are required, regardless of the number of statements in the method body.
- In the method body, a method can declare variables, call other methods, and use any of the program structures we've discussed, such as *if/else* statements, *while* loops, *for* loops, *switch* statements, and *do/while* loops.

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main is a Method

```
public static void main( String [] args )
{
   // application code
}
```

Let's look at *main*'s API in detail:

`public`	*main* can be called from outside the class. (The JVM calls *main*.)
`static`	*main* can be called by the JVM without instantiating an object.
`void`	*main* does not return a value
`String [] args`	*main*'s parameter is a *String* array

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Value-Returning Methods

- Use a *return* statement to return the value
- Syntax:

```
return expression;
```

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Constructors

- Special methods that are called when an object is instantiated using the *new* keyword.
- A class can have several constructors.
- The job of the class constructors is to initialize the instance variables of the new object.

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Defining a Constructor

Syntax:

```
public ClassName( parameter list )
{
  // constructor body
}
```

Note: no return value, not even *void*!

- Each constructor must have a different number of parameters or parameters of different types
- **Default constructor**: a constructor that takes no arguments.
- *See Examples 7.1 and 7.2, Auto.java and AutoClient.java*

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Default Initial Values

- If the constructor does not assign values to the instance variables, they are auto-assigned default values depending on the instance variable data type.

Data Type	Default Value
byte, short, int, long	0
float, double	0.0
char	space
boolean	*false*
Any object reference (for example, a *String*)	*null*

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Common Error Trap

Do not specify a return value for a constructor (not even *void*).

Doing so will cause a compiler error in the client program when the client attempts to instantiate an object of the class.

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Class Scope

- Instance variables have **class scope**
  - Any constructor or method of a class can directly refer to instance variables.
- Methods also have class scope
  - Any method or constructor of a class can call any other method of a class (without using an object reference).

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Local Scope

- A method's parameters have **local scope**, meaning that:
  - a method can directly access its parameters.
  - a method's parameters cannot be accessed by other methods.
- A method can define local variables which also have local scope, meaning that:
  - a method can access its local variables.
  - a method's local variables cannot be accessed by other methods.

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Summary of Scope

- A method in a class can access:
  - the instance variables of its class
  - any parameters sent to the method
  - any variable the method declares from the point of declaration until the end of the method or until the end of the block in which the variable is declared, whichever comes first
  - any methods in the class

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Accessor Methods

- Clients cannot directly access *private* instance variables, so classes provide *public* accessor methods with this standard form:

```
public returnType getInstanceVariable(  )
{
   return instanceVariable;
}
```

(*returnType* is the same data type as the instance variable)

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Accessor Methods

- Example: the accessor method for *model*.

```
public String getModel( )
{
   return model;
}
```

- *See Examples 7.3 Auto.java & 7.4 AutoClient.java*

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Mutator Methods

- Allow client to change the values of instance variables

```
public void setInstanceVariable(
                          dataType newValue )
{
   // validate newValue,
   // then assign to instance variable
}
```

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Mutator Methods

- Example: the mutator method for *milesDriven*

```
public void setMilesDriven( int newMilesDriven )
{
  if ( newMilesDriven >= 0 )
    milesDriven = newMilesDriven;
  else
  {
    System.err.println( "Miles driven "
            + "cannot be negative." );
    System.err.println( "Value not changed." );
  }
}
```

- *See Examples 7.5 Auto.java & 7.6 AutoClient.java*

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Software Engineering Tip

- Write the validation code for the instance variable in the mutator method and have the constructor call the mutator method to validate and set initial values
- This eliminates duplicate code and makes the program easier to maintain

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Common Error Trap

- Do not declare method parameters.
  - Parameters are defined already and are assigned the values sent by the client to the method.
- Do not give the parameter the same name as the instance variable.
  - The parameter has name precedence so it "**hides**" the instance variable.
- Do not declare a local variable with the same name as the instance variable.
  - Local variables have name precedence and hide the instance variable.

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Data Manipulation Methods

- Perform the "business" of the class.
- Example: a method to calculate miles per gallon:

```
public double calculateMilesPerGallon( )
{
  if ( gallonsOfGas != 0.0 )
     return milesDriven / gallonsOfGas;
  else
     return 0.0;
}
```

- See *Examples 7.7 Auto.java & 7.8 AutoClient.java*

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The Object Reference *this*

- How does a method know which object's data to use?
- ***this*** is an implicit parameter sent to methods and is an object reference to the object for which the method was called.
- When a method refers to an instance variable name, *this* is implied
- Thus:

variableName	*model*
is understood to be	is understood to be
this.variableName	*this.model*

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Using *this* in a Mutator Method

```
public void setInstanceVariable(
                dataType instanceVariableName )
{
  this.instanceVariableName = instanceVariableName;
}
```

- Example:

```
public void setModel( String model )
{
     this.model = model;
}
```

this.model refers to the instance variable.

model refers to the parameter.

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The *toString* Method

- Returns a *String* representing the data of an object
- Client can call *toString* explicitly by coding the method call.
- Client can call *toString* implicitly by using an object reference where a *String* is expected.
- Example client code:

```
Auto compact = new Auto( );

// explicit toString call
System.out.println( compact.toString( ) );
// implicit toString call
System.out.println( compact );
```

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The *toString* API

Return value	Method name and argument list
`String`	`toString( )` returns a *String* representing the data of an object

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Auto Class *toString* Method

```
public String toString( )
{
   DecimalFormat gallonsFormat =
      new DecimalFormat( "#0.0" );
   return "Model: " + model
      + "; miles driven: " + milesDriven
      + "; gallons of gas: "
      + gallonsFormat.format( gallonsOfGas );
}
```

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The *equals* Method

- Determines if the data in another object is equal to the data in this object

Return value	Method name and argument list
`boolean`	`equals( Object obj )` returns *true* if the data in the Object *obj* is the same as in this object; *false* otherwise.

- Example client code using *Auto* references *auto1* and *auto2*:

```
if ( auto1.equals( auto2 ) )
   System.out.println( "auto1 equals auto2" );
```

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Auto Class *equals* Method

```
public boolean equals( Auto autoA )
{
  if ( model.equals( autoA.model )
     && milesDriven == autoA.milesDriven
     && Math.abs( gallonsOfGas -
                  autoA.gallonsOfGas ) < 0.0001 )
       return true;
  else
       return false;
}
```

- *See Examples 7.10 Auto.java & 7.11 AutoClient.java*

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static Variables

- Also called **class variables**
- One copy of a *static* variable is created per class
- *static* variables are not associated with an object
- *static* constants are often declared as *public*
- To define a *static* variable, include the keyword *static* in its definition:
- Syntax:

```
accessSpecifier static dataType variableName;
```

- Example:

```
public static int countAutos = 0;
```

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static Methods

- Also called **class methods**
- Often defined to access and change *static* variables
- *static* methods cannot access instance variables:
  - *static* methods are associated with the class, not with any object.
  - *static* methods can be called before any object is instantiated, so it is possible that there will be no instance variables to access.

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Rules for *static* and Non-*static* Methods

	static Method	Non-*static* Method
Access instance variables?	no	yes
Access *static* class variables?	yes	yes
Call *static* class methods?	yes	yes
Call non-*static* instance methods?	no	yes
Use the object reference *this*?	no	yes

- *See Examples **7.12 and 7.13***

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Reusable Graphical Objects

- In Chapter 4, the applet code and the Astronaut were **tightly coupled**; we couldn't draw the Astronaut without running the applet.
- To separate the Astronaut from the applet, we can define an *Astronaut* class.
  - The starting x and y values become instance variables, along with a new scaling factor.
  - We move the code for drawing the Astronaut into a *draw* method.
- The applet instantiates an *Astronaut* object in *init* and calls *draw* from the *paint* method.
- *See Examples **7.14, 7.15, and 7.16.***

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enum Types

- Special class definition designed to increase the readability of code
- Allows you to define a set of objects that apply names to ordered sets
- Examples of ordered sets:
  - Days of the week
  - Months of the year
  - Playing cards

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enum

- Built into *java.lang* (no *import* statement needed)
- Syntax:

```
enum EnumName { obj1, obj2,… objn };
```

- Example

```
enum Days { Sun, Mon, Tue, Wed,
            Thurs, Fri, Sat };
```

- When this statement is executed A constant object is instantiated for each name in the list. Thus, each name is a reference to an object of type *Days*

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Using an *enum* Object

- Referring to an *enum* object reference
  - Syntax:
    `EnumType.enumObject`
  - Example:
    `Days.Mon`
- Declaring an object reference of an *enum* type
  - Syntax:
    `EnumType referenceName`
  - Example:

```
Days d;  // d is null initially
d = Days.Thurs;
```

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Useful *enum* Methods

Return value	Method name and argument list
`int`	`compareTo( Enum eObj )` compares two *enum* objects and returns a negative number if *this* object is less than the argument, a positive number if *this* object is greater than the argument, and 0 if the two objects are the same.
`int`	`ordinal( )` returns the numeric value of the *enum* object. By default, the value of the first object in the list is 0, the value of the second object is 1, and so on.

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More Useful *enum* Methods

Return value	Method name and argument list
`boolean`	`equals( Enum eObj )` returns *true* if *this* object is equal to the argument *eObj*; returns *false* otherwise.
`String`	`toString( )` returns the name of the *enum* constant
`Enum`	`valueOf( String enumName )` Convert a string to an object *static* method that returns the *enum* object whose name is the same as the *String* argument *enumName*.

- *See Example **7.17** EnumDemo.java*

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Using *enum* Objects with *switch*

- Using *enum* objects for *case* constants makes the code more readable.
- Use the *enum* object reference without the *enum* type
  - Example:

```
case Fri:
```

- *See Example **7.18** DailySpecials.java*

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Creating Packages

- A **package** is a collection of related classes that can be imported into a program.
- Packages allow reuse of classes without needing the class in the same directory as the other source files.
- To include a class in a package, precede the class definition with the *package* statement:

```
package packageName;
```

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A Reusable Class

- For example, we can create a class that provides type-safe reading of input from the console that can be reused by our programs.
- We will name this class *ConsoleIn.java*
- ***See Example 7.20***

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Naming Packages

- To avoid **name collisions**, which can occur when multiple programmers define packages, we use this naming convention:
  - Use the reverse of the domain name, excluding "`www`".
- For example, for a domain name:

  `www.jbpub.com`

  the package name would begin with:

  `com.jbpub`

  then add the package name:

  `com.jbpub.af`

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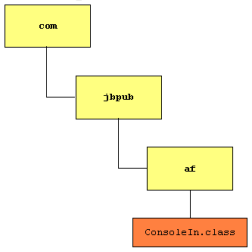
Create the Directory Structure

- For the package `com.jbpub.af`, we create three directories and place *ConsoleIn.java* into the *af* directory and compile it:



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Modify the CLASSPATH

- The CLASSPATH environment variable tells the compiler where to look for packages.
- Set the CLASSPATH to include the directory in which you created the *com* directory for your package.
- On Windows, if *com* is created in *My Documents*, the CLASSPATH might be:

```
.;c:\documents and settings\user\My Documents
```

- On Linux, if *com* is created in *myClasses* in your home directory, the CLASSPATH might be:

```
.;/usr/local/java/jre/lib;/home/user/myClasses
```

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Client Use of Package

- To reuse the classes in a package, use the *import* statement.

```
import com.jbpub.af.ConsoleIn;
```

- *See Example 7.21 ConsoleInClient.java*

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Javadoc Documentation

- The Java class library documentation on Sun's Web site (www.java.sun.com) helps us learn how to instantiate objects and call methods for the classes.
- This documentation was generated using Javadoc, a tool provided in the Java Software Development Toolkit (SDK).
- We can also use Javadoc to generate Web pages that provide documentation on our class's fields and methods.

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To Use Javadoc

- We need to add Javadoc comments and special tags to our classes.
- Javadoc comments begin with `/**` and end with `*/` (Note that this is similar to a Java block comment, but with an extra * in the opening syntax.)
- Example:

```
/** Auto class
*   Anderson, Franceschi
*/
```

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Block Tags

- Identify parameters and return values

Tag	Common syntax
`@param`	`@param variableName description`
`@return`	`@return description`

- HTML tags can be used in the descriptions
  - For example, `<BR>` to insert a new line

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Sample *equals* Method Documentation

```
/**
* equals method:<BR>
* Compares the fields of two Auto objects
* @param a1 another Auto object
* @return a boolean, true if this object
* has the same field values as the parameter a1
*/
public boolean equals( Auto a1 )
{
   return ( model.equals( a1.model ) &&
      milesDriven == a1.milesDriven &&
      Math.abs( gallonsOfGas - a1.gallonsOfGas )
              < 0.001 );
}
```

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Executing Javadoc

- *javadoc.exe* is located in the *bin* directory of the Java SDK
- To generate documentation for a class:

```
javadoc Class.java
```

  Example:

```
javadoc Auto.java
```

- To generate documentation for all classes in a directory:

```
javadoc *.java
```

- *See Example 7.22*

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Sample Javadoc Documentation