More About Classes – Instance Methods

Chap.6
Study Sections 6.1 – 6.4

Representing More Complex Objects

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Starting the Move from OCD to OOP

Characteristics of OOP:

Encapsulation: classes combine data and operations into self-contained units

Inheritance: classes can be defined as extensions of other classes

Later

Polymorphism: Poly–"many"; morph–"forms" different classes may implement the same operations in different ways

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Extending OCD

1. **Formulate behavior needed to solve problem**
2. **Identify objects in problem**
   For each object for which there is no type in the language:
   - ***Design and build a class to represent it.***
3. **Identify operations needed in problem**
   For each operation not provided in the language:
   - ***Design and build a method to perform it.***
   - ***Store the method in a class responsible for providing the operation.***

   Labs 4 & 5
4. **Organize objects and operations in an algorithm**

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Classes vs. Objects

Primary purpose of a class isn't to encapsulate methods.

It is to describe objects.

Classes are used to create objects.
We call objects *instances* of a class.

If a class is a:	An object is a:
factory	product
blueprint	building

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- A class is not an object; it *describes* an object.
- The *type* of an object is a class.
- *One class* can be used to create *many objects*. Each is an *instance* of the class.
- Each instance gets its *own* (instance) methods and (instance) variables that are described in the class.

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Example

What goes into a class usually arises out of a problem; so we begin with one.

Dealing with different systems of measurement is a nuisance and can be a very serious problem (e.g., Mars Climate Orbiter — 1999).

Here (and in the text) we consider the problem of processing temperatures in various scales (Fahrenheit, Celsius, Kelvin).

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Preliminary Analysis

We should be able to represent common objects with a *single type*.

But temperature objects have two attributes:

- *magnitude* (a double), and
- *scale* (a character)

When an object cannot be directly represented by any of the available types, *build a new type* (thus *extending the language*)!

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Behavior

Our program should display a prompt for a temperature (in either Fahrenheit, Celsius, or Kelvin) on the screen, read that temperature from the keyboard, compute and display corresponding temperatures in all three systems along with a descriptive label.

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Objects

Our program should display a prompt for a temperature (in either Fahrenheit, Celsius, or Kelvin) on the screen, read that temperature from the keyboard, compute and display corresponding temperatures in all three systems along with a descriptive label.

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Operations

Our program should display a prompt for a temperature (in either Fahrenheit, Celsius, or Kelvin) on the screen, read that temperature from the keyboard, compute and display corresponding temperatures in all three systems along with a descriptive label.

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Algorithm

1. Ask *the screen* to display *a prompt* for *the temperature*.

2. Ask the keyboard to read *the temperature*.

3. Compute *Fahrenheit, Celsius and Kelvin versions* of that temperature.

4. Ask *the screen* to display *the three versions*, plus an *informative label* on *the screen*.

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Representing Objects

Object	**Java Type**	**Name**
the program	--	--
a prompt	`String`	--
the input temperature	???	*temp*
the screen	`Screen`	*theScreen*
the keyboard	`Keyboard`	*theKeyboard*
a label	`String`	--

We need to create a `Temperature` type.

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Performing Operations

Operation	Library?	Name
Display a string	`ann.easyio`	`print()`
Read a temperature	???	*read*()
Compute fahrenheit	???	*inFahrenheit*()
Compute celsius	???	*inCelsius*()
Compute kelvin	???	*inKelvin*()
Display a temperature	???	*println*()???

We need to create a **`Temperature`** type that has input and output operations and converters from one scale to another (and perhaps other operations).


```
/** TemperatureConverter.java
 *  Input:  a temperature value (e.g., 0 C).
 *  Output: that temperature in Celsius, Fahrenheit and Kelvin.
 */

import ann.easyio.*;

class TemperatureConverter
{
 public static void main(String [] args)
 {
   Screen theScreen = new Screen();
   Keyboard theKeyboard = new Keyboard();
   Temperature temp = new Temperature();
   boolean inputOK;
   for (;;)
   {
     theScreen.print("\nTo perform a temperature conversion, enter\n"
                    + " a temperature (e.g., 0 C). Enter 0 A to stop: ");
     inputOK = temp.read(theKeyboard);

     if (!inputOK) break;

     theScreen.println( "--> " + temp.inFahrenheit()
                      + " = "  + temp.inCelsius()
                      + " = "  + temp.inKelvin() );
   }
 }
}
```

The Driver Code
(that we'd like to be able to write)

Using Classes
(External Perspective)

The program doesn't know how to:

- initialize the data stored for each temperature object
- read and write a temperature object
- convert a temperature object into various forms

The <u>temperature object itself is responsible</u> for these things.

The <u>program sends messages</u> to temperature objects to execute methods for these operations.

Building Classes

Two phases:
1. Design
2. Implementation

"I can do it myself" principle

Best done from an internal perspective.
It puts you in the role of the object as you build its class:

```
"I am a Screen."
"I am a String."
"I am a Temperature object."
```

Design:

- Describe class' *behavior* — *operations* applied to class objects
- Identify its *attributes* — *data* stored to characterize a class object

Implementation:

- *Encapsulate* operations and attributes in a class declaration:

```
class ClassName
{
  // Method definitions for built-in operations
  // Data member declarations for data
}
```

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Design of Temperature Class

Behavior

Operations needed to solve problem:

- Construct myself with initial default values
- Read a temperature value from the keyboard and store it in myself
- Display myself on the screen
- Convert myself to Fahrenheit
- Convert myself to Celsius
- Convert myself to Kelvin

Other operations to increase reusability

- Construct myself with initial specified values
- Tell my degrees
- Tell my scale
- Increase myself by a given number of degrees
- Decrease myself by a given number of degrees
- Compare myself to another Temperature object
- Assign another Temperature value to me

Note the internal (*"I can do it myself"*) perspective

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Attributes

To find them, go through the operations and find information each of them requires.
If needed by several, make it an attribute.

- **my degrees**
- **my scale**

Note: Initial list may be incomplete.
But we can always add more later as we build (and maintain) the class

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Implementation of Temperature Class

Implement the attributes first.

Declare variables to hold the attributes. They determine the *state* of the object over time. They are called *attribute variables* or *instance variables*, or *fields*, or *data members*.

```
// Temperature.java

class Temperature
{
  double myDegrees;
  char myScale;
}
```

Not finished here yet!

Pretending that *we are* the Temperature object, we begin the name of each attribute with the prefix **my** to reinforce the *internal perspective*.

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Information Hiding

To prevent direct access to these attribute variables from outside the class, we declare them to be private:

```
// Temperature.java
class Temperature
{
  private double myDegrees;
  private char myScale;
}
```

This is known as *information hiding*.

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Why?

- They could be assigned invalid values (e.g., an 'X' scale).
- Software must often be updated. Updating a class may require that its data members be modified (e.g., make **myScale** a string), renamed, replaced, removed, added.
- If a program accesses class data members directly, then that program "breaks" if they are changed. This increases software maintenance costs! Programs that use a class should still work after the class has been updated.

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The principle of *information hiding* dictates that a class designer always distinguish between the:

- *External interface* to a class: Make *public* only those things that a class user really needs to know.
- *Internal implementation* of the class: Hide all other details by making them *private.*

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This is encapsulation!

```
// Temperature.java
class Temperature
{
  // Definitions of methods for reading,
     writing, & converting temperatures...
     (Most are public.)

  // Private declarations of attribute
     variables (also called instance
     variables, fields, or data members)
  private double myDegrees;
  private char myScale;
}
```

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Kinds of Methods

Static methods

- One definition is *shared* by all the objects in the class
- Declared with the keyword **`static`**
- *Invoked with a message to the class*

Instance methods

- Each object has its *own copy* of the method
- Declared by default (i.e., not static)
- *Invoked with a message to an instance of the class; i.e. to an object*

Static methods

- *Can access only static items in a class.*
- *Use if it doesn't need to access the instance variables of the class.*

Instance methods

- *Can access both instance and static items in a class.*
- *Most of the methods we write for a class are instance methods.*

Kinds of Instance Methods

Constructors	Initialize instance variables
Accessors	Retrieve values of instance variables
Mutators	Change values of instance variables
Convertors	Produces a different representation of an object
Utilities	Used to simplify other methods or to avoid redundant code

Output

- Add an output operation early so we can check other operations.
- When **`print()`** and **`println()`** are asked to display an object, they send it a message to *convert* itself to a **`String`** using its **`toString()`** method. So we need only add this method to our class:

```
/** toString converter (used by print(), println(), ...
 *  Return a string representation of myself.
 */
public String toString()
{
  return myDegrees + " " + myScale;
}
```

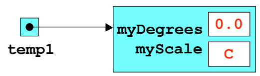
Constructor Methods

Users should be able to construct new Temperature objects in two ways:

- default initial values

*Calling the **default** constructor*

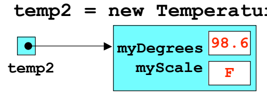
```
Temperature temp1 = new Temperature();
```



- explicitly specified values

*Calling the **explicit-value** constructor*

```
Temperature temp2 = new Temperature(98.6, 'F');
```



This is the role of the class constructors.

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Default-Value Constructor

```
/** Default-value constructor.
 *  Postcondition: myDegrees == 0.0 && myScale == 'C'.
 */
public Temperature()
{
  myDegrees = 0.0;
  myScale = 'C';
}
```

- The name of a constructor is always the *name of the class* (in this case **`Temperature()`**).
- Since it returns nothing, a constructor has *no return type* (not even **`void`**).
- Specification is usually a postcondition describing the state of the constructed object.

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Explicit-Value Constructor

```
/** Explicit-value constructor.
 *  Receive:       double degrees, char scale
 *  Precondition:  scale is one of 'f', 'F', 'c', 'C', 'k', or 'K'
 *                 degrees is a valid number of degrees for scale.
 *  Postcondition: myDegrees == degrees &&
 *                 myScale == (uppercase) scale.
 */

public Temperature(double degrees, char scale)
{
  // we'll add more later

    myDegrees = degrees;
    myScale = Character.toUpperCase(scale);

  // more later
}
```

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pp. 284-5, 222-3

Overloading Methods

Our constructors are two different methods with the same name **`Temperature`**. Such a name is said to be overloaded.

When is this permitted? First, a definition: A method's name and the list of its parameter types is known as the method's signature.

> *The name of a method can be overloaded provided no two definitions of the method have the same signature.*

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Incremental (Unit) Testing

We can now begin a driver program that will be used to test our class (and add to it as we develop more methods):

Output:

```
temp1 = 0.0 C
temp2 = 98.6 F
```

```
import ann.easyio.*;

class TempDriver
{
  public static void main(String [] args)
  {
    Screen theScreen = new Screen();
    Keyboard theKeyboard = new Keyboard();
    Temperature temp1 = new Temperature(),
                temp2 = new Temperature(98.6, 'F');
    theScreen.println(  "temp1 = " + temp1 +
                      "\ntemp2 = " + temp2 );
  }
}
```

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Class Invariants

PROBLEM: *Objects must maintain the integrity of their internal data*. However, the explicit-value constructor can assign invalid values to the class' instance variables. (e.g., 0 X, -10 K)

A *class invariant* is a condition that must be true throughout the class. The most important one is that the *instance variables always contain valid values.*

Example: For the Temperature class:

- the scale can only be 'C', 'F', or 'K'
- the degrees should be greater than absolute zero

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Any method that modifies instance variables – called a *mutator* method – must ensure that the class invariant will be true.

We can express our class invariant as a boolean expression:

```
       myScale == 'C'
         && myDegrees >= ABSOLUTE_ZERO_CELSIUS
    || myScale == 'F'
         && myDegrees >= ABSOLUTE_ZERO_FAHRENHEIT
    || myScale == 'K'
         && myDegrees >= ABSOLUTE_ZERO_KELVIN
```

It's good practice to include the class invariant in the class' opening documentation.

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We begin by adding definitions of the absolute-zero constants at the beginning of our class:

```
class Temperature
{
  public final static double
          ABSOLUTE_ZERO_FAHRENHEIT = -459.67,
          ABSOLUTE_ZERO_CELSIUS    = -273.15,
          ABSOLUTE_ZERO_KELVIN     =    0.0;
  . . .
}
```

Why public?

They're probably useful in other temperature programs, so we make them accessible outside the class (e.g., **`Temperature.ABSOLUTE_ZERO_KELVIN`**)

Why static??????

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Static (Class) vs. Instance Data

Static data

- One definition is *shared* by all the objects in the class
- Declared with the keyword `static`
- *Constants* are usually static; e.g., absolute zero constants

Instance data

- Each object has its *own copy*
- Declared by default (i.e., not static)
- *Variables* are usually instance ; e.g., `myDegrees, myScale`

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Utility Methods

To help the explicit-value constructor and other mutators with checking a complex class invariant, we can add a *utility method* like the following to our class to save having to write an if statement each time:

```
public static boolean isValidTemperature(double degrees,
                                         char scale)
{
  if (scale == 'C' || scale == 'c')
     return degrees >= ABSOLUTE_ZERO_CELSIUS;
  else if (scale == 'F' || scale == 'f')
     return degrees >= ABSOLUTE_ZERO_FAHRENHEIT;
  else if (scale == 'K' || scale == 'k')
     return degrees >= ABSOLUTE_ZERO_KELVIN;
  else
     return false;
}
```

Why static?

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If the class invariant fails, we might call another utility method like the following to display an error message and halt execution:

User need not know about this method

Doesn't need to access instance variables

```
private static void fatal(String methodName,
                          String diagnostic)
{
  System.err.println("\n*** " + methodName + ": "
                     + diagnostic);
  System.err.flush();
  System.exit(1);
}
```

Ensure that output gets to the screen.

Halt execution

Note: `fatal()` is useful in other classes, so it was added to `ann.util.Controller`.

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Safe Explicit-Value Constructor

```
/** Explicit-value constructor.
 *  Receive:       double degrees, char scale
 *  Precondition:  scale is one of 'f', 'F', 'c', 'C', 'k', or 'K'
 *                 degrees is a valid number of degrees for scale.
 *  Postcondition: myDegrees == degrees &&
 *                 myScale == (uppercase) scale.
 */
public Temperature(double degrees, char scale)
{
  if (isValidTemperature(degrees, scale))
  {
    myDegrees = degrees;
    myScale = Character.toUpperCase(scale);
  }
  else
    fatal("Temperature(degrees, scale)",
          "invalid args: " + degrees + scale);
}
```

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Accessor Methods

```
/** degrees accessor
 *  Return:  myDegrees
 */
public double getDegrees()
{
  return myDegrees;
}

/** scale accessor
 *  Return:  myDegrees
 */
public char getScale()
{
  return myScale;
}
```


Mutator Methods

```
/** raise a temperature
 *  Receive: double amount
 *  Precondition: myDegrees + amount is valid for myScale
 *  Return:  the raised Temperature object
 */
public Temperature raise(double amount)
{
  double newDegrees = myDegrees + amount;

  if (!isValidTemperature(newDegrees, myScale))
    fatal("raise(double)", newDegrees + " "
             + myScale + " is not a valid temperature");
  return new Temperature(newDegrees, myScale);
}
```

Temperature-lowering method is similar.


```
/** read a temperature
 * Receive: Keyboard object in
 * Input:   inDegrees (double), inScale (char)
 * Return:  true if valid temperature read, else false
 * Postcondition: myDegrees == inDegrees &&
 *                myScale == inScale (if valid)
 */
public boolean read(Keyboard in)
{
  double inDegrees = in.readDouble();
  char inScale     = in.readChar();

  if (isValidTemperature(inDegrees, inScale))
  {
    myDegrees = inDegrees;
    myScale   = Character.toUpperCase(inScale);
    return true;
  }
  else
    return false;
}
```

Usage:

```
boolean ok = temp.read(theKeyboard);
if (ok)
{  . . .
```


An alternative (ala Lab 6):

```
import java.util.StringTokenizer;
  . . .
public void read(Keyboard in)
{
  Keyboard.EatWhiteSpace();
  String tempStr = in.readLine();
  StringTokenizer parser = new StringTokenizer(tempStr);
  if (parser.countTokens() != 2)
    fatal("read(Keyboard in)",
          " -- Bad format for temperature");
  //else
  double inDegrees = Double.parseDouble(parser.nextToken());
  char inScale = parser.nextToken().charAt(0);
  if (!isValidTemperature(inDegrees, inScale))
    fatal("read(Keyboard in)",
          " -- Bad format for temperature");
  //else
  myDegrees = inDegrees;
  myScale   = Character.toUpperCase(inScale);
}
```

Conversion Methods

We've written one converter -- `toString()`. Now we look at one of the converters from one scale to another; the others are similar.

```
/** Fahrenheit converter
 *  Return: the Fahrenheit equivalent to myself
 */
public Temperature inFahrenheit()
{
  Temperature result = null;

  if (myScale == 'F')
    result = new Temperature(myDegrees, 'F');
  else if (myScale == 'C')
    result = new Temperature(myDegrees*1.8 + 32.0, 'F');
  else if (myScale == 'K')
    result = new Temperature((myDegrees-273.15)*1.8 + 32.0,'F');

  return result;
}
```

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Comparison Methods

We can't compare new types with:

```
if (temp1 < temp2)
```

Unlike C++, Java doesn't allow operator overloading.

Thus, we must write methods for comparison.

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```
/** less-than
 * Receive: another Temperature object otherTemp
 * Return:  true if-f I am less than otherTemp
 */
public boolean lessThan(Temperature otherTemp)
{
  Temperature localTemp = null;

  if (myScale == 'C')
    localTemp = otherTemp.inCelsius();
  else if (myScale == 'F')
    localTemp = otherTemp.inFahrenheit();
  else if (myScale == 'K')
    localTemp = otherTemp.inKelvin();

  return myDegrees < localTemp.getDegrees();
}
```

Other comparison methods are basically the same.

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```
public int compareTo(Temperature otherTemp)
{
  Temperature localTemp = null;
  if (myScale == 'C')
    localTemp = otherTemp.inCelsius();
  else if (myScale == 'F')
    localTemp = otherTemp.inFahrenheit();
  else if (myScale == 'K')
    localTemp = otherTemp.inKelvin();

  if (myDegrees < localTemp.getDegrees())
    return -1;
  else if (myDegrees > localTemp.getDegrees())
    return 1;
  else
    return 0;
}
```

Another way to compare

```
public boolean lessThan(Temperature otherTemp)
{
  return compareTo(otherTemp) < 0;
}
```

Other comparison methods are basically the same.

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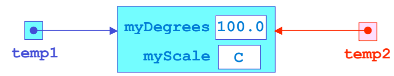
Copy (or Clone) Operation

Picture what the following code will do:

```
Temperature temp1 = new Temperature(100, 'C');
Temperature temp2 = temp1;
```



`Temperature` is a reference type; "reference" = "address";

Value of **`temp1`** is an *address* that refers ("points") to the actual temperature object; we call it a *handle*.

Second declaration gives **`temp2`** the same value (i.e., the *same address*, so it refers to the same temperature object; changing one changes both!

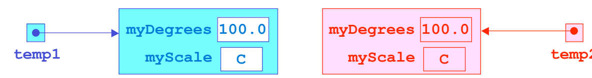
This is called the *aliasing problem*.

To avoid it, add a copy operation to the class:

```
/** copy operation
 *  Return:  A distinct copy of myself
 */
public Temperature copy()
{
  return Temperature(myDegrees, myScale);
}
```

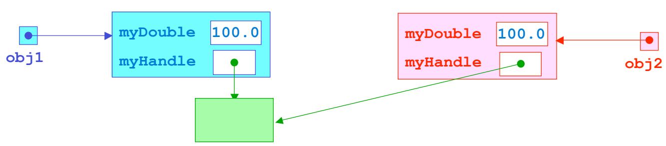
Now picture:

```
Temperature temp1 = new Temperature(100, 'C');
Temperature temp2 = temp1.copy();
```

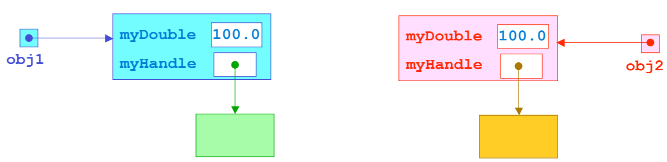


`temp2` refers to a *distinct copy* of the object referred to by **`temp1.`**

But . . .
we still have an aliasing problem when some data members are of a reference type with no copy operation:



This is a *shallow copy*; we need a *deep copy*.



Have every class provide a copy operation.