A Comprehensive Introduction to Object-Oriented Programming with **Java**™

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A COMPREHENSIVE INTRODUCTION TO OBJECT-ORIENTED PROGRAMMING WITH JAVA

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To my family

Contents

Preface

This book is an in-depth introduction to object-oriented programming using the Java programming language. In addition to covering traditional topics for a CS1 course, some of the more advanced topics such as recursion and linked lists are included to provide a comprehensive coverage of beginning to intermediate-level materials. There are more materials in the book than what are normally covered in a typical CS1 course. An instructor may want to teach some of the chapters on data structures in an advanced CS1 course. Topics covered in Chapters 16 to 20 are also suitable for use in a CS2 course.

Key Differences from the Standard Edition

This comprehensive edition is based on *An Introduction to Object-Oriented Programming with Java*, Fourth Edition. The key differences between this comprehensive version and the fourth edition standard version are as follows:

1. **Data Structures Chapters.** Chapter 16 covers topics on managing linked nodes. Using this as the foundation, Chapters 18 through 20 present three abstract data types (ADTs) List, Stack, and Queue, respectively. For all three ADTs, both array-based and linked-list implementations are shown, and their relative advantages and disadvantages are discussed.

2. **More Discussion on Java 5.0 Features.** Many of the new Java 5.0 features are explained and used in the sample programs. They include the enumerator type, the for-each loop construct, auto boxing and unboxing, and the generics. One complete chapter (Chapter 17) is dedicated to the generics.

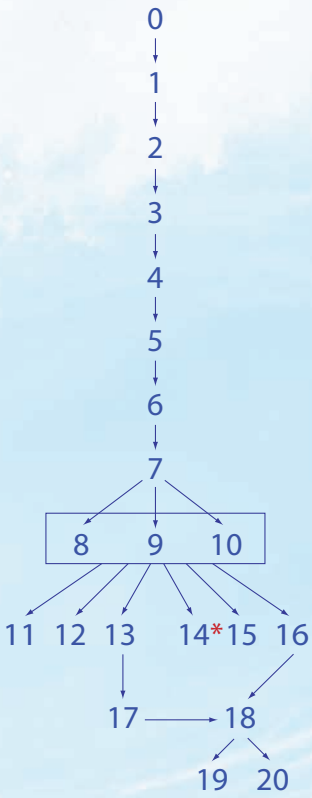
3. **Exclusive Use of Console Input and Output.** All the GUI related topics, including the `JOptionPane` class, are moved to Chapter 14. Sample programs before Chapter 14 use the standard console input (Scanner) and output (System.out). Those who want to use `JOptionPane` for simple input and output can do so easily by covering Section 14.1 before Chapter 3.

Book Organization

There are 21 chapters in this book, numbered from 0 to 20. The first 11 chapters cover the core topics that provide the fundamentals of programming. Chapters 11 to 15 cover intermediate-level topics such as sorting, searching, recursion, inheritance, polymorphism, and file I/O. And Chapters 16 to 20 cover topics related to data structures. There are more than enough topics for one semester. After the first 11 chapters (Ch 0 to Ch 10), instructors can mix and match materials from Chapters 11 to 20 to suit their needs. We first show the dependency relationships among the chapters and then provide a brief summary of each chapter.

Chapter Dependency

For the most part, chapters should be read in sequence, but some variations are possible, especially with the optional chapters. Here's a simplified dependency graph:



*Note: Some examples use arrays, but the use of arrays is not an integral part of the examples. These examples can be modified to those that do not use arrays. Many topics from the early part of the chapter can be introduced as early as after Chapter 2.

Brief Chapter Summary

Here is a short description of each chapter:

- **Chapter 0** is an optional chapter. We provide background information on computers and programming languages. This chapter can be skipped or assigned as an outside reading if you wish to start with object-oriented programming concepts.
- **Chapter 1** provides a conceptual foundation of object-oriented programming. We describe the key components of object-oriented programming and illustrate each concept with a diagrammatic notation using UML.
- **Chapter 2** covers the basics of Java programming and the process of editing, compiling, and running a program. From the first sample program presented in this chapter, we emphasize object-orientation. We will introduce the standard classes `String`, `Date`, and `SimpleDateFormat` so we can reinforce the notion of object declaration, creation, and usage. Moreover, by using these standard classes, students can immediately start writing practical programs.We describe and illustrate console input with `System.in` and the new `Scanner` class and output with `System.out`.
- **Chapter 3** introduces variables, constants, and expressions for manipulating numerical data. We explain the standard `Math` class from `java.lang` and introduce more standard classes (`GregorianCalendar` and `DecimalFormat`) to continually reinforce the notion of object-orientation. We describe additional methods of the `Scanner` class to input numerical values. Random number generation is introduced in this chapter. The optional section explains how the numerical values are represented in memory space.
- **Chapter 4** teaches the basics of creating programmer-defined classes. We keep the chapter accessible by introducting only the fundamentals with illustrative examples. The key topics covered in this chapter are constructors, visibility modifiers (`public` and `private`), local variables, and passing data to methods. We provide easy-to-grasp illustrations that capture the essence of the topics so the students will have a clear understanding of them.
- **Chapter 5** explains the selection statements `if` and `switch`. We cover boolean expressions and nested-`if` statements. We explain how objects are compared by using equivalence (`==`) and equality (the `equals` and `compareTo` methods). We use the `String` and the programmer-defined `Fraction` classes to make the distinction between the equivalence and equality clear. Drawing 2-D graphics is introduced, and a screensaver sample development program is developed. We describe the new Java 5.0 feature called *enumerated type* in this chapter.
- **Chapter 6** explains the repetition statements `while`, `do–while`, and `for`. Pitfalls in writing repetition statements are explained. One of the pitfalls to avoid is the use of float or double for the data type of a counter variable. We illustrate this pitfall by showing a code that will result in infinite loop. Finding the greatest common divisor of two integers is used as an example of a nontrivial loop statement. We show the difference between the straightforward (brute-force)

and the clever (Euclid's) solutions. We introduce the Formatter class (new to Java 5.0) and show how the output can be aligned nicely. The optional last section of the chapter introduces recursion as another technique for repetition. The recursive version of a method that finds the greatest common divisor of two integers is given.

- **Chapter 7** is the second part of creating programmer-defined classes. We introduce new topics related to the creation of programmer-defined classes and also repeat some of the topics covered in Chapter 4 in more depth. The key topics covered in this chapter are method overloading, the reserved word this, class methods and variables, returning an object from a method, and pass-by-value parameter passing. As in Chapter 4, we provide many lucid illustrations to make these topics accessible to beginners. We use the Fraction class to illustrate many of these topics, such as the use of this and class methods. The complete definition of the Fraction class is presented in this chapter.
- **Chapter 8** teaches exception handling and assertions. The focus of this chapter is the construction of reliable programs. We provide a detailed coverage of exception handling in this chapter. We introduce an assertion and show how it can be used to improve the reliability of finished products by catching logical errors early in the development.
- **Chapter 9** covers nonnumerical data types: characters and strings. Both the String and StringBuffer classes are explained in the chapter. Another string class named StringBuilder (new to Java 5.) is briefly explained in this chapter. An important application of string processing is pattern matching. We describe pattern matching and regular expression in this chapter. We introduce the Pattern and Matcher classes and show how they are used in pattern matching.
- **Chapter 10** teaches arrays. We cover arrays of primitive data types and of objects. An array is a reference data type in Java, and we show how arrays are passed to methods. We describe how to process two-dimensional arrays and explain that a two-dimensional array is really an array of arrays in Java. Lists and maps are introduced as a more general and flexible way to maintain a collection of data. The use of ArrayList and HashMap classes from the java.util package is shown in the sample programs. Also, we show how the WordList helper class used in Chapter 9 sample development program is implemented with another map class called TreeMap.
- **Chapter 11** presents searching and sorting algorithms. Both N^2 and $N\log_2 N$ sorting algorithms are covered. The mathematical analysis of searching and sorting algorithms can be omitted depending on the students' background.
- **Chapter 12** explains the file I/O. Standard classes such as File and JFileChooser are explained. We cover all types of file I/O, from a low-level byte I/O to a high-level object I/O. We show how the file I/O techniques are used to implement the helper classes—Dorm and FileManager—in Chapter 8 and 9 sample development programs. The use of the Scanner class for inputting data from a textfile is also illustrated in this chapter.

- **Chapter 13** discusses inheritance and polymorphism and how to use them effectively in program design. The effect of inheritance for member accessibility and constructors is explained. We also explain the purpose of abstract classes and abstract methods.
- **Chapter 14** covers GUI and event-driven programming. Only the Swing-based GUI components are covered in this chapter. We show how to use the JOptionPane class for a very simple GUI-based input and output. GUI components introduced in this chapter include JButton, JLabel, ImageIcon, JTextField, JTextArea, and menu-related classes. We describe the effective use of nested panels and layout managers. Handling of mouse events is described and illustrated in the sample programs. Those who do not teach GUI can skip this chapter altogether. Those who teach GUI can introduce the beginning part of the chapter as early as after Chapter 2.
- **Chapter 15** covers recursion. Because we want to show the examples where the use of recursion really shines, we did not include any recursive algorithm (other than those used for explanation purposes) that really should be written nonrecursively.
- **Chapter 16** covers contiguous and noncontiguous memory allocation schemes and introduces the concept of linked lists. Ample examples are provided to illustrate the manipulation of linked lists of primitive data types and linked lists of objects. This chapter lays the necessary foundation for the students to learn different techniques for implementing the abstract data types covered in Chapters 18 through 20.
- **Chapter 17** covers new Java 5.0 generics in detail. The chapter describes how generic classes are defined and how the type safety is supported by generics. A concrete example of using generics is shown by defining a simple linked list with generic nodes.
- **Chapter 18** introduces the concept of abstract data types (ADT) and covers the List ADT. Key features of the List ADT are explained and two implementations using an array and a linked list are shown. The iterator pattern to traverse the elements in the List ADT is introduced.
- **Chapter 19** covers the Stack ADT. Key features of the Stack ADT are explained and two implementations using an array and a linked list are shown. Sample applications that use stacks are described.
- **Chapter 20** covers the Queue ADT. Key features of the Stack ADT are explained and two implementations using an array and a linked list are shown. A special type of queue called a *priority queue* is also intoduced in this chapter.

Walkthrough Hallmark Features of the Text

Problem Solving

2.5 Sample Development

Printing the Initials

Now that we have acquired a basic understanding of Java application programs, let's write a new application. We will go through the design, coding, and testing phases of the software life cycle to illustrate the development process. Since the program we develop here is very simple, we can write it without really going through the phases. However, it is extremely important for you to get into a habit of developing a program by following the software life cycle stages. Small programs can be developed in a haphazard manner, but not large programs. We will teach you the development process with small programs first, so you will be ready to use it to create large programs later.

We will develop this program by using an incremental development technique, which will develop the program in small incremental steps. We start out with a bare-bones program and gradually build up the program by adding more and more code to it. At each incremental step, we design, code, and test the program before moving on to the next step. This methodical development of a program allows us to focus our attention on a single task at each step, and this reduces the chance of introducing errors into the program.

Problem Statement

We start our development with a problem statement. The problem statement for our sample programs will be short, ranging from a sentence to a paragraph, but the problem statement for complex and advanced applications may contain many pages. Here's the problem statement for this sample development exercise:

> *Write an application that asks for the user's first, middle, and last names and replies with the user's initials.*

Overall Plan

Our first task is to map out the overall plan for development. We will identify classes necessary for the program and the steps we will follow to implement the program. We begin with the outline of program logic. For a simple program such as this one, it is kind of obvious; but to practice the incremental development, let's put down the outline of program flow explicitly. We can express the program flow as having three tasks:

program tasks

1. Get the user's first, middle, and last names.
2. Extract the initials to formulate the monogram.
3. Output the monogram.

Having identified the three major tasks of the program, we will now identify the classes we can use to implement the three tasks. First, we need an object to handle the input. At this point, we have learned about only the **Scanner** class, so we will use it here. Second, we need an object to display the result. Again, we will use **System.out**, as it is the only one we know at this point for displaying a string value. For the string

Sample Development Programs
Most chapters include a sample development section that describes the process of incremental development.

Development Exercises
give students an opportunity to practice incremental development.

Development Exercises

For the following exercises, use the incremental development methodology to implement the program. For each exercise, identify the program tasks, create a design document with class descriptions, and draw the program diagram. Map out the development steps at the start. Present any design alternatives and justify your selection. Be sure to perform adequate testing at the end of each development step.

8. In the sample development, we developed the user module of the keyless entry system. For this exercise, implement the administrative module that allows the system administrator to add and delete `Resident` objects and modify information on existing `Resident` objects. The module will also allow the user to open a list from a file and save the list to a file. Is it proper to implement the administrative module by using one class? Wouldn't it be a better design if we used multiple classes with each class doing a single, well-defined task?
9. Write an application that maintains the membership lists of five social clubs in a dormitory. The five social clubs are the Computer Science Club, Biology Club, Billiard Club, No Sleep Club, and Wine Tasting Club. Use the `Dorm`

Object-Oriented Approach

We take the object-first approach to teaching object-oriented programming with emphasis on proper object-oriented design. The concept of objects is clearly illustrated from the very first sample program.

```
/*
    Chapter 2 Sample Program: Displaying a Window
    File: Ch2Sample1.java
*/
import javax.swing.*;
class  Ch2Sample1 {
   public static void main(String[] args) {
       JFrame    myWindow;
       myWindow = new JFrame();
       myWindow.setSize(300, 200);
       myWindow.setTitle("My First Java Program");
       myWindow.setVisible(true);
   }
}
```

Good practices on object-oriented design are discussed throughout the book and illustrated through numerous sample programs.

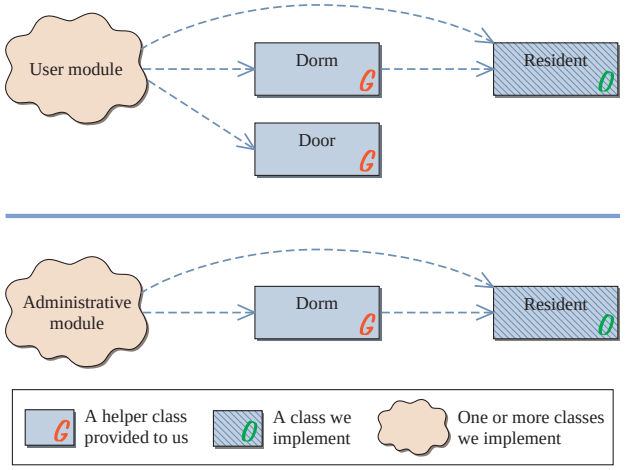


Figure 8.8 Program diagrams for the user and administrative modules. Notice the same **Dorm** and **Resident** classes are used in both programs. User and administrative modules will include one or more classes (at least one is programmer-defined).

Illustrative Diagrams

Illustrative diagrams are used to explain all key concepts of programming such as the difference between object declaration and creation, the distinction between the primitive data type and the reference data type, the call-by-value parameter passing, inheritance, and many others.

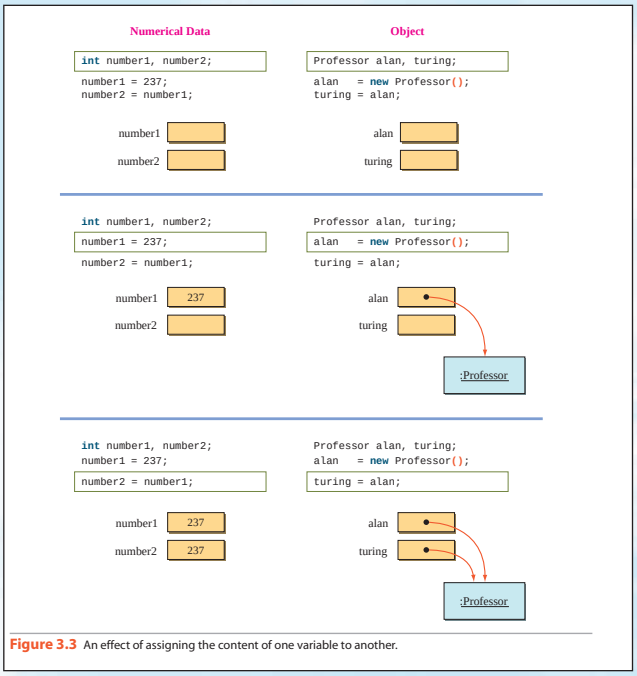


Figure 3.3 An effect of assigning the content of one variable to another.

Lucid diagrams are used effectively to explain data structures and abstract data types.

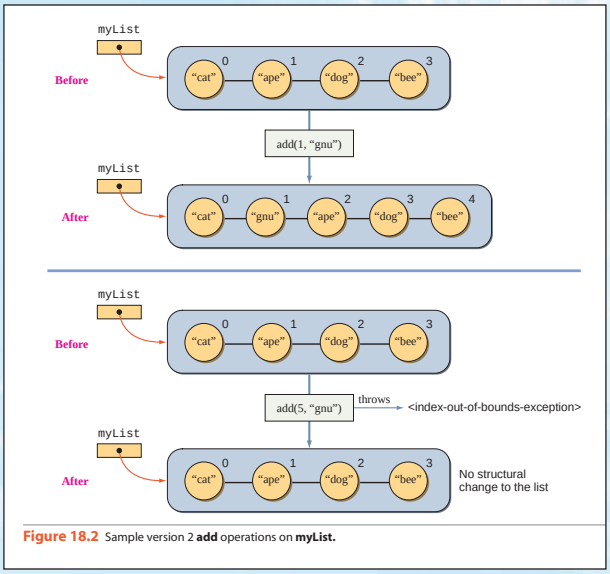


Figure 18.2 Sample version 2 **add** operations on **myList.**