

Data Structures and Abstractions with Java TM

FOURTH EDITION

Frank M. Carrano • Timothy M. Henry

ONLINE ACCESS

Thank you for purchasing a new copy of *Data Structures and Abstractions with JavaTM*, Fourth Edition, Global Edition. Your textbook includes twelve months of prepaid access to the book's Premium Content. This prepaid subscription provides you with full access to the following student support areas:

- VideoNotes are step-by-step video tutorials specifically designed to enhance the programming concepts presented in this textbook
- Premium Web Chapters

Use a coin to scratch off the coating and reveal your student access code. Do not use a knife or other sharp object as it may damage the code.

To access the *Data Structures and Abstractions with JavaTM*, Fourth Edition, Global Edition, Premium Content for the first time, you will need to register online using a computer with an Internet connection and a web browser. The process takes just a couple of minutes and only needs to be completed once.

- 1. Go to www.pearsonglobaleditions.com/Carrano
- 2. Click on Companion Website.
- 3. Click on the **Register** button.
- 4. On the registration page, enter your student access code* found beneath the scratch-off panel. Do not type the dashes. You can use lower- or uppercase.
- 5. Follow the on-screen instructions. If you need help at any time during the online registration process, simply click the **Need Help?** icon.
- 6. Once your personal Login Name and Password are confirmed, you can begin using the *Data Structures and Abstractions with Java*TM Companion Website!

To log in after you have registered:

You only need to register for this Companion Website once. After that, you can log in any time at **www.pearsonglobaleditions.com/Carrano** by providing your Login Name and Password when prompted.

*Important: The access code can only be used once. This subscription is valid for twelve months upon activation and is not transferable.

Data Structures and Abstractions with Java, Global Edition

Table of Contents

Cover

Title Page

Copyright

Contents

Introduction: Organizing Data

Prelude: Designing Classes

Encapsulation

Specifying Methods

Comments

Preconditions and Postconditions

Assertions

Java Interfaces

Writing an Interface

Implementing an Interface

An Interface as a Data Type

Extending an Interface

Named Constants Within an Interface

Choosing Classes

Identifying Classes

CRC Cards

The Unified Modeling Language

Reusing Classes

Chapter 1: Bags

The Bag

A Bags Behaviors

Specifying a Bag



An Interface

Using the ADT Bag

Using an ADT Is Like Using a Vending Machine

The ADT Set

Java Class Library: The Interface set

Java Interlude 1: Generics

Generic Data Types

Generic Types Within an Interface

Generic Classes

Chapter 2: Bag Implementations That Use Arrays

Using a Fixed-Size Array to Implement the ADT Bag

An Analogy

A Group of Core Methods

Implementing the Core Methods

Making the Implementation Secure

Testing the Core Methods

Implementing More Methods

Methods That Remove Entries

Using Array Resizing to Implement the ADT Bag

Resizing an Array

A New Implementation of a Bag

The Pros and Cons of Using an Array to Implement the ADT Bag

Java Interlude 2: Exceptions

The Basics

Handling an Exception

Postpone Handling: The throws Clause

Handle It Now: The try-catch Blocks

Multiple catch Blocks

Throwing an Exception

Chapter 3: A Bag Implementation That Links Data

Linked Data

Forming a Chain by Adding to Its Beginning

A Linked Implementation of the ADT Bag



The Private Class Node

An Outline of the Class LinkedBag

Defining Some Core Methods

Testing the Core Methods

The Method getFrequencyOf

The Method contains

Removing an Item from a Linked Chain

The Methods remove and clear

A Class Node That Has Set and Get Methods

The Pros and Cons of Using a Chain to Implement the ADT Bag

Chapter 4: The Efficiency of Algorithms

Motivation

Measuring an Algorithms Efficiency

Counting Basic Operations

Best, Worst, and Average Cases

Big Oh Notation

The Complexities of Program Constructs

Picturing Efficiency

The Efficiency of Implementations of the ADT Bag

An Array-Based Implementation

A Linked Implementation

Comparing the Implementations

Chapter 5: Stacks

Specifications of the ADT Stack

Using a Stack to Process Algebraic Expressions

A Problem Solved: Checking for Balanced Delimiters in an Infix Algebraic Expression

A Problem Solved: Transforming an Infix Expression to a Postfix Expression

A Problem Solved: Evaluating Postfix Expressions
A Problem Solved: Evaluating Infix Expressions

The Program Stack

Java Class Library: The Class Stack

Chapter 6: Stack Implementations

A Linked Implementation

An Array-Based Implementation

A Vector-Based Implementation



Java Class Library: The Class Vector
Using a Vector to Implement the ADT Stack

Chapter 7: Recursion

What Is Recursion?

Tracing a Recursive Method

Recursive Methods That Return a Value

Recursively Processing an Array

Recursively Processing a Linked Chain

The Time Efficiency of Recursive Methods

The Time Efficiency of countDown

The Time Efficiency of Computing xn

A Simple Solution to a Difficult Problem

A Poor Solution to a Simple Problem

Tail Recursion

Indirect Recursion

Using a Stack Instead of Recursion

Java Interlude 3: More About Generics

The Interface Comparable

Generic Methods

Bounded Type Parameters

Wildcards

Bounded Wildcards

Chapter 8: An Introduction to Sorting

Organizing Java Methods That Sort an Array

Selection Sort

Iterative Selection Sort

Recursive Selection Sort

The Efficiency of Selection Sort

Insertion Sort

Iterative Insertion Sort

Recursive Insertion Sort

The Efficiency of Insertion Sort

Insertion Sort of a Chain of Linked Nodes

Shell Sort



The Algorithm

The Efficiency of Shell Sort

Comparing the Algorithms

Chapter 9: Faster Sorting Methods

Merge Sort

Merging Arrays

Recursive Merge Sort

The Efficiency of Merge Sort

Iterative Merge Sort

Merge Sort in the Java Class Library

Quick Sort

The Efficiency of Quick Sort

Creating the Partition

Implementing Quick Sort

Quick Sort in the Java Class Library

Radix Sort

Pseudocode for Radix Sort

The Efficiency of Radix Sort

Comparing the Algorithms

Java Interlude 4: More About Exceptions

Programmer-Defined Exception Classes

Inheritance and Exceptions

The finally Block

Chapter 10: Queues, Deques, and Priority Queues

The ADT Queue

A Problem Solved: Simulating a Waiting Line

A Problem Solved: Computing the Capital Gain in a Sale of Stock

Java Class Library: The Interface Queue

The ADT Deque

A Problem Solved: Computing the Capital Gain in a Sale of Stock

Java Class Library: The Interface Deque Java Class Library: The Class ArrayDeque

The ADT Priority Queue

A Problem Solved: Tracking Your Assignments

Java Class Library: The Class PriorityQueue



Chapter 11: Queue, Deque, and Priority Queue Implementations

A Linked Implementation of a Queue

An Array-Based Implementation of a Queue

A Circular Array

A Circular Array with One Unused Location

Circular Linked Implementations of a Queue

A Two-Part Circular Linked Chain

Java Class Library: The Class AbstractQueue

A Doubly Linked Implementation of a Deque

Possible Implementations of a Priority Queue

Chapter 12: Lists

Specifications for the ADT List

Using the ADT List

Java Class Library: The Interface List

Java Class Library: The Class ArrayList

Chapter 13: A List Implementation That Uses an Array

Using an Array to Implement the ADT List

An Analogy

The Java Implementation

The Efficiency of Using an Array to Implement the ADT List

Chapter 14: A List Implementation That Links Data

Operations on a Chain of Linked Nodes

Adding a Node at Various Positions

Removing a Node from Various Positions

The Private Method getNodeAt

Beginning the Implementation

The Data Fields and Constructor

Adding to the End of the List

Adding at a Given Position Within the List

The Methods is Empty and to Array

Testing the Core Methods

Continuing the Implementation

A Refined Implementation

The Tail Reference

The Efficiency of Using a Chain to Implement the ADT List



Java Class Library: The Class LinkedList

Java Interlude 5: Iterators

What Is an Iterator?

The Interface Iterator

The Interface Iterable

Using the Interface Iterator

Iterable and for-each Loops

The Interface ListIterator

The Interface List Revisited

Using the Interface ListIterator

Chapter 15: Iterators for the ADT List

Ways to Implement an Iterator

A Separate Class Iterator

An Inner Class Iterator

A Linked Implementation

An Array-Based Implementation

Why Are Iterator Methods in Their Own Class?

An Array-Based Implementation of the Interface ListIterator

The Inner Class

Java Interlude 6: Mutable and Immutable Objects

Mutable Objects

Immutable Objects

Creating a Read-Only Class

Companion Classes

Chapter 16: Sorted Lists

Specifications for the ADT Sorted List

Using the ADT Sorted List

A Linked Implementation

The Method add

The Efficiency of the Linked Implementation

An Implementation That Uses the ADT List

Efficiency Issues

Java Interlude 7: Inheritance and Polymorphism



Further Aspects of Inheritance

When to Use Inheritance

Protected Access

Abstract Classes and Methods

Interfaces Versus Abstract Classes

Polymorphism

Chapter 17: Inheritance and Lists

Using Inheritance to Implement a Sorted List

Designing a Base Class

Creating an Abstract Base Class

An Efficient Implementation of a Sorted List

The Method add

Chapter 18: Searching

The Problem

Searching an Unsorted Array

An Iterative Sequential Search of an Unsorted Array

A Recursive Sequential Search of an Unsorted Array

The Efficiency of a Sequential Search of an Array

Searching a Sorted Array

A Sequential Search of a Sorted Array

A Binary Search of a Sorted Array

Java Class Library: The Method binarySearch

The Efficiency of a Binary Search of an Array

Searching an Unsorted Chain

An Iterative Sequential Search of an Unsorted Chain

A Recursive Sequential Search of an Unsorted Chain

The Efficiency of a Sequential Search of a Chain

Searching a Sorted Chain

A Sequential Search of a Sorted Chain

A Binary Search of a Sorted Chain

Choosing a Search Method

Java Interlude 8: Generics Once Again

More Than One Generic Type

Chapter 19: Dictionaries



Specifications for the ADT Dictionary

A Java Interface

Iterators

Using the ADT Dictionary

A Problem Solved: A Directory of Telephone Numbers

A Problem Solved: The Frequency of Words A Problem Solved: A Concordance of Words

Java Class Library: The Interface Map

Chapter 20: Dictionary Implementations

Array-Based Implementations

An Unsorted Array-Based Dictionary

A Sorted Array-Based Dictionary

Linked Implementations

An Unsorted Linked Dictionary

A Sorted Linked Dictionary

Chapter 21: Introducing Hashing

What Is Hashing?

Hash Functions

Computing Hash Codes

Compressing a Hash Code into an Index for the Hash Table

Resolving Collisions

Open Addressing with Linear Probing

Open Addressing with Quadratic Probing

Open Addressing with Double Hashing

A Potential Problem with Open Addressing

Separate Chaining

Chapter 22: Hashing as a Dictionary Implementation

The Efficiency of Hashing

The Load Factor

The Cost of Open Addressing

The Cost of Separate Chaining

Rehashing

Comparing Schemes for Collision Resolution

A Dictionary Implementation That Uses Hashing

Entries in the Hash Table

Data Fields and Constructors



The Methods getValue, remove, and add

Iterators

Java Class Library: The Class HashMap

Jave Class Library: The Class HashSet

Chapter 23: Trees

Tree Concepts

Hierarchical Organizations

Tree Terminology

Traversals of a Tree

Traversals of a Binary Tree

Traversals of a General Tree

Java Interfaces for Trees

Interfaces for All Trees

An Interface for Binary Trees

Examples of Binary Trees

Expression Trees

Decision Trees

Binary Search Trees

Heaps

Examples of General Trees

Parse Trees

Game Trees

Chapter 24: Tree Implementations

The Nodes in a Binary Tree

A Class of Binary Nodes

An Implementation of the ADT Binary Tree

Creating a Basic Binary Tree

The Method privateSetTree

Accessor and Mutator Methods

Computing the Height and Counting Nodes

Traversals

An Implementation of an Expression Tree

General Trees

A Node for a General Tree

Using a Binary Tree to Represent a General Tree



Java Interlude 9: Cloning

Cloneable Objects

Cloning an Array

Cloning a Chain

A Sorted List of Clones

Cloning a Binary Node

Chapter 25: A Binary Search Tree Implementation

Getting Started

An Interface for the Binary Search Tree

Duplicate Entries

Beginning the Class Definition

Searching and Retrieving

Traversing

Adding an Entry

A Recursive Implementation

An Iterative Implementation

Removing an Entry

Removing an Entry Whose Node Is a Leaf

Removing an Entry Whose Node Has One Child

Removing an Entry Whose Node Has Two Children

Removing an Entry in the Root

A Recursive Implementation

An Iterative Implementation

The Efficiency of Operations

The Importance of Balance

The Order in Which Nodes Are Added

An Implementation of the ADT Dictionary

Chapter 26: A Heap Implementation

Reprise: The ADT Heap

Using an Array to Represent a Heap

Adding an Entry

Removing the Root

Creating a Heap

Heap Sort



Chapter 27: Balanced Search Trees

AVL Trees

Single Rotations

Double Rotations

Implementation Details

2-3 Trees

Searching a 2-3 Tree

Adding Entries to a 2-3 Tree

Splitting Nodes During Addition

2-4 Trees

Adding Entries to a 2-4 Tree

Comparing AVL, 2-3, and 2-4 Trees

Red-Black Trees

Properties of a Red-Black Tree

Adding Entries to a Red-Black Tree

Java Class Library: The Class TreeMap

B-Trees

Chapter 28: Graphs

Some Examples and Terminology

Road Maps

Airline Routes

Mazes

Course Prerequisites

Trees

Traversals

Breadth-First Traversal

Depth-First Traversal

Topological Order

Paths

Finding a Path

The Shortest Path in an Unweighted Graph

The Shortest Path in a Weighted Graph

Java Interfaces for the ADT Graph

Chapter 29: Graph Implementations

An Overview of Two Implementations



The Adjacency Matrix

The Adjacency List

Vertices and Edges

Specifying the Class Vertex

The Inner Class Edge

Implementing the Class Vertex

An Implementation of the ADT Graph

Basic Operations

Graph Algorithms

Appendix A: Documentation and Programming Style

Naming Variables and Classes

Indenting

Comments

Single-Line Comments

Comment Blocks

When to Write Comments

Java Documentation Comments

Appendix B: Java Basics (online)

Introduction

Applications and Applets

Objects and Classes

A First Java Application Program

Elements of Java

Identifiers

Reserved Words

Variables

Primitive Types

Constants

Assignment Statements

Assignment Compatibilities

Type Casting

Arithmetic Operators and Expressions

Parentheses and Precedence Rules



Increment and Decrement Operators

Special Assignment Operators

Named Constants

The Class Math

Simple Input and Output Using the Keyboard and Screen

Screen Output

Keyboard Input Using the Class Scanner

The if-else Statement

Boolean Expressions

Nested Statements

Multiway if-else Statements

The Conditional Operator (Optional)

The switch Statement

Enumerations

Scope

Loops

The while Statement

The for Statement

The do-while Statement

Additional Loop Information

The Class String

Characters Within Strings

Concatenation of Strings

String Methods

The Class StringBuilder

Using Scanner to Extract Pieces of a String

Arrays

Array Parameters and Returned Values

Initializing Arrays

Array Index Out of Bounds

Use of = and == with Arrays

Arrays and the For-Each Loop



Multidimensional Arrays

Wrapper Classes

Appendix C: Java Classes (online)

Objects and Classes

Using the Methods in a Java Class

References and Aliases

Defining a Java Class

Method Definitions

Arguments and Parameters

Passing Arguments

A Definition of the Class Name

Constructors

The Method toString

Methods That Call Other Methods

Methods That Return an Instance of Their Class

Static Fields and Methods

Overloading Methods

Enumeration as a Class

Packages

The Java Class Library

Appendix D: Creating Classes from Other Classes

Composition

Adapters

Inheritance

Invoking Constructors from Within Constructors

Private Fields and Methods of the Superclass

Overriding and Overloading Methods

Multiple Inheritance

Type Compatibility and Superclasses

The Class Object

Appendix E: File Input and Output (online)



Preliminaries

Why Files?

Streams

The Kinds of Files

File Names

Text Files

Creating a Text File

Reading a Text File

Changing Existing Data in a Text File

Defining a Method to Open a Stream

Binary Files

Creating a Binary File of Primitive Data

Reading a Binary File of Primitive Data

Strings in a Binary File

Object Serialization

Glossary (online)

Index