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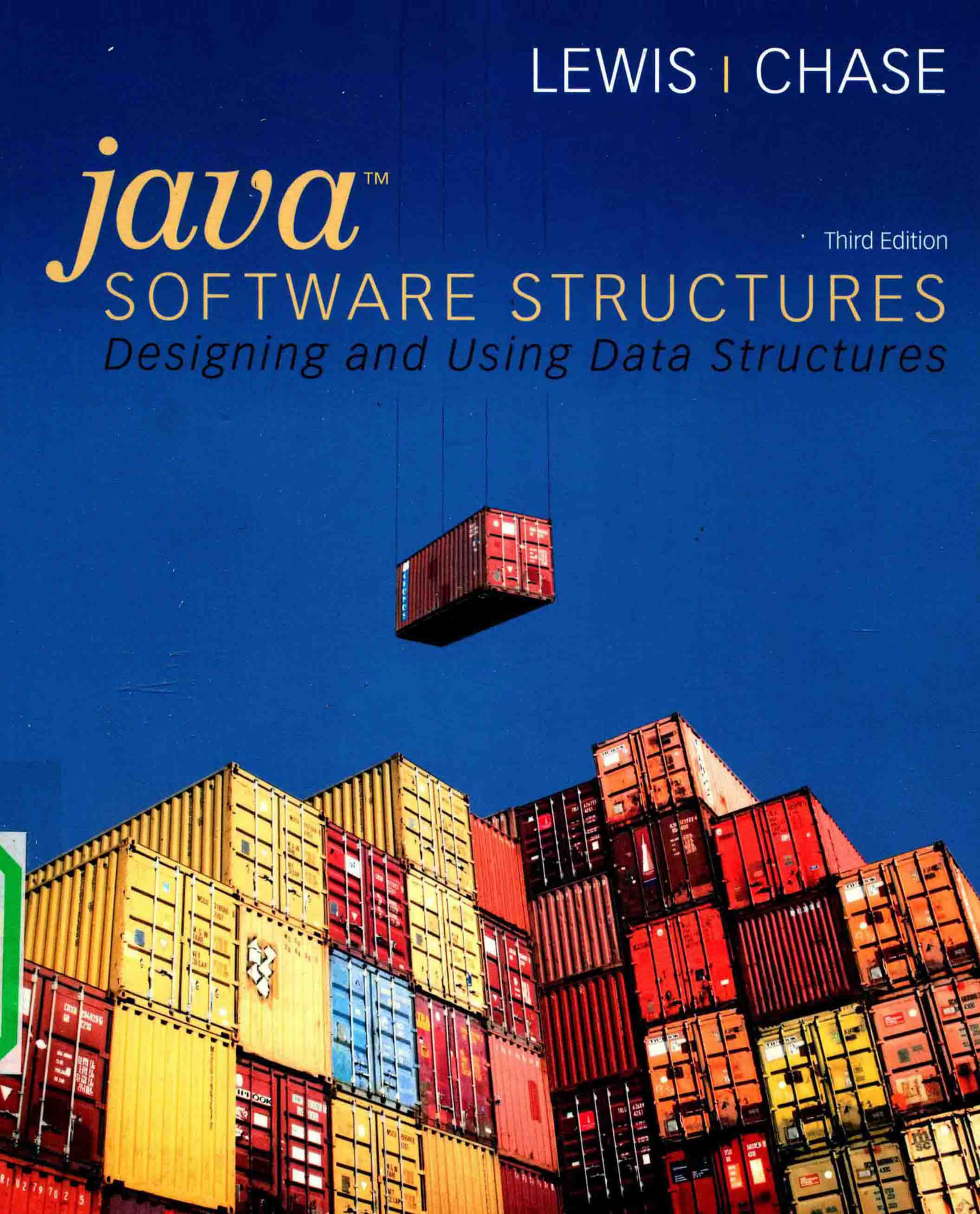
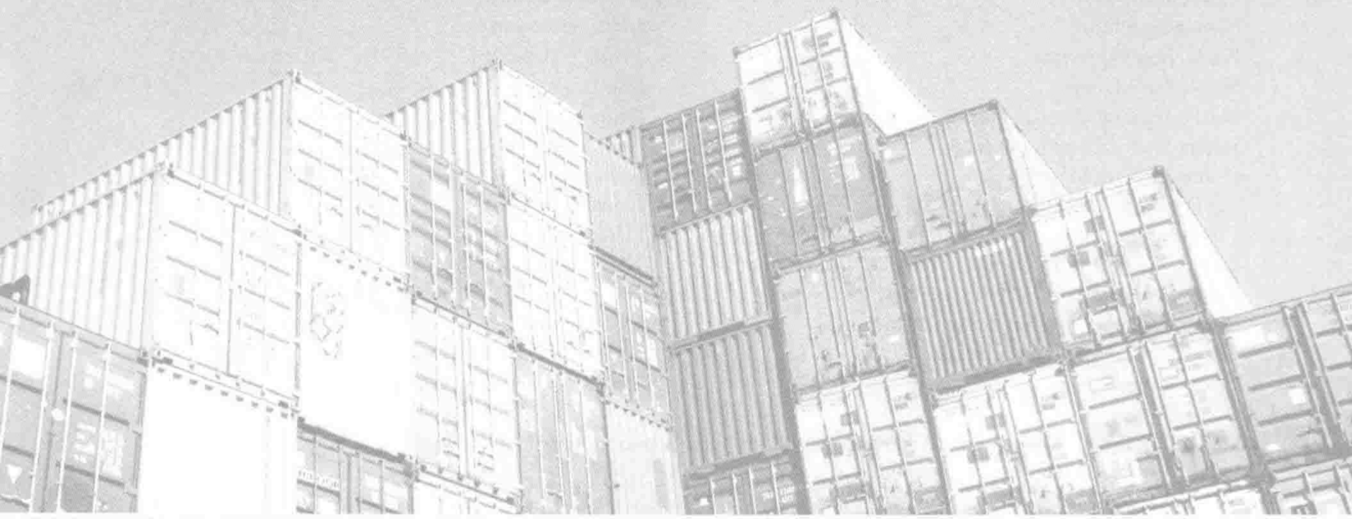
java™ SOFTWARE STRUCTURES

Designing and Using Data Structures

Third Edition





java™ SOFTWARE STRUCTURES

Third Edition

Designing and Using Data Structures

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To my wife Sharon and my kids:
Justin, Kayla, Nathan, and Samantha

–J. L.

To my loving wife Melissa for her support and encouragement
and to our families, friends, colleagues, and students who have provided
so much support and inspiration through the years.

–J. C.

Preface

This book is designed to serve as a text for a course on data structures and algorithms. This course is typically referred to as the CS2 course because it is often taken as the second course in a computing curriculum. We have designed this book to embrace the tenets of Computing Curricula 2001 (CC2001).

Pedagogically, this book follows the style and approach of the leading CS1 book *Java Software Solutions: Foundations of Program Design*, by John Lewis and William Loftus. Our book uses many of the highly regarded features of that book, such as the Key Concept boxes and complete code examples. Together, these two books support a solid and consistent approach to either a two-course or three-course introductory sequence for computing students. That said, this book does not assume that students have used *Java Software Solutions* in a previous course.

Material that might be presented in either course (such as recursion or sorting) is presented in this book as well. We also include strong reference material providing an overview of object-oriented concepts and how they are realized in Java.

We understand the crucial role that the data structures and algorithms course plays in a curriculum and we think this book serves the needs of that course well.

The Third Edition

We have made some key modifications in this third edition to enhance its pedagogy. The most important change is a fundamental reorganization of material that is designed to create a cleaner flow of topics. Instead of having an early, large chapter to review object-oriented concepts, we've included that material as an appendix for reference. Then we review concepts as needed and appropriate in the context of the implementation strategies discussed throughout the book and cite the appropriate reference material. This not only links the topics in a timely fashion but also demonstrates the usefulness of particular language constructs.

We've expanded the discussion of Analysis of Algorithms, and given it its own chapter. The discussion, however, stays at an appropriately moderate level. Our strategy is to motivate the concepts involved in the analysis of algorithms, laying a solid foundation, rather than get embroiled in too much formality.

Another key organizational change is that the introduction to collections uses a stack as the primary example. In previous editions of this book we went out of our way to introduce collections in an abstract way that separated it from the core data structures, using examples such as a bag or set collection. This new approach capitalizes on the fact that a stack is conceptually about as straightforward as it gets. Using it as a first example enhances the understanding of collections as a whole.

The previous edition of the book had several chapters that focused on larger case studies that made use of collections to solve non-trivial problems. While many instructors found these useful, they also seemed to interrupt the flow of coverage of core topics. Therefore we have taken the case study chapters out of the book and put them on the web as supplementary resources. We encourage all instructors to download and use these resources as they see fit.

Finally, for this edition we've reviewed and improved the discussions throughout the book. We've expanded the discussion of graphs and reversed the order of the graphs and hashing chapters to make a cleaner flow. And we've added a chapter that specifically covers sets and maps.

We think these modifications build upon the strong pedagogy established by previous editions and give instructors more opportunity and flexibility to cover topics as they choose.

Our Approach

Books of this type vary greatly in their overall approach. Our approach is founded on a few important principles that we fervently embraced. First, we present the various collections explored in the book in a consistent manner. Second, we emphasize the importance of sound software design techniques. Third, we organized the book to support and reinforce the big picture: the study of data structures and algorithms. Let's examine these principles further.

Consistent Presentation

When exploring a particular type of collection, we carefully address each of the following issues in order:

1. **Concept:** We discuss the collection conceptually, establishing the services it provides (its interface).
2. **Use:** We explore examples that illustrate how the particular nature of the collection, no matter how it's implemented, can be useful when solving problems.
3. **Implementation:** We explore various implementation options for the collection.
4. **Analysis:** We compare and contrast the implementations.

The Java Collections API is included in the discussion as appropriate. If there is support for a particular collection type in the API, we discuss it and its implementation. Thus we embrace the API, but are not completely tied to it. And we are not hesitant to point out its shortcomings.

The analysis is kept at a high level. We establish the concept of Big-Oh notation in Chapter 2 and use it throughout the book, but the analysis is more intuitive than it is mathematical.

Sound Program Design

Throughout the book, we keep sound software engineering practices a high priority. Our design of collection implementations and the programs that use them follow consistent and appropriate standards.

Of primary importance is the separation of a collection's interface from its underlying implementation. The services that a collection provides are always formally defined in a Java interface. The interface name is used as the type designation of the collection whenever appropriate to reinforce the collection as an abstraction.

In addition to practicing solid design principles, we stress them in the discussion throughout the text. We attempt to teach both by example and by continual reinforcement.

Clean Organization

The contents of the book have been carefully organized to minimize distracting tangents and to reinforce the overall purpose of the book. The organization supports the book in its role as a pedagogical exploration of data structures and algorithms as well as its role as a valuable reference.

The book can be divided into numerous parts: Part I consists of the first two chapters and provides an introduction to the concept of a collection and analysis of algorithms. Part II includes the next four chapters, which cover introductory and underlying issues that affect all aspects of data structures and algorithms as well as linear collections (stacks, queues, and lists). Part III covers the concepts of recursion, sorting, and searching. Part IV covers the nonlinear collections (trees, heaps, hashing, and graphs). Each type of collection, with the exception of trees, is covered in its own chapter. Trees are covered in a series of chapters that explore their various aspects and purposes.

Chapter Breakdown

Chapter 1 (Introduction) discusses various aspects of software quality and provides an overview of software development issues. It is designed to establish the appropriate mindset before embarking on the details of data structure and algorithm design.

Chapter 2 (Analysis of Algorithms) lays the foundation for determining the efficiency of an algorithm and explains the important criteria that allow a developer to compare one algorithm to another in proper ways. Our emphasis in this chapter is understanding the important concepts more than getting mired in heavy math or formality.

Chapter 3 (Collections) establishes the concept of a collection, stressing the need to separate the interface from the implementation. It also conceptually introduces a stack, then explores an array-based implementation of a stack.

Chapter 4 (Linked Structures) discusses the use of references to create linked data structures. It explores the basic issues regarding the management of linked lists, and then defines an alternative implementation of a stack (introduced in Chapter 3) using an underlying linked data structure.

Chapter 5 (Queues) explores the concept and implementation of a first-in, first-out queue. Radix sort is discussed as an example of using queues effectively. The implementation options covered include an underlying linked list as well as both fixed and circular arrays.

Chapter 6 (Lists) covers three types of lists: ordered, unordered, and indexed. These three types of lists are compared and contrasted, with discussion of the operations that they share and those that are unique to each type. Inheritance is used appropriately in the design of the various types of lists, which are implemented using both array-based and linked representations.

Chapter 7 (Recursion) is a general introduction to the concept of recursion and how recursive solutions can be elegant. It explores the implementation details of recursion and discusses the basic idea of analyzing recursive algorithms.

Chapter 8 (Sorting and Searching) discusses the linear and binary search algorithms, as well as the algorithms for several sorts: selection sort, insertion sort, bubble sort, quick sort, and merge sort. Programming issues related to searching and sorting, such as using the Comparable interface as the basis of comparing objects, are stressed in this chapter. Searching and sorting that are based in particular data structures (such as heap sort) are covered in the appropriate chapter later in the book.

Chapter 9 (Trees) provides an overview of trees, establishing key terminology and concepts. It discusses various implementation approaches and uses a binary tree to represent and evaluate an arithmetic expression.

Chapter 10 (Binary Search Trees) builds off of the basic concepts established in Chapter 9 to define a classic binary search tree. A linked implementation of a binary search tree is examined, followed by a discussion of how the balance in the tree nodes is key to its performance. That leads to exploring AVL and red/black implementations of binary search trees.

Chapter 11 (Priority Queues and Heaps) explores the concept, use, and implementations of heaps and specifically their relationship to priority queues. A heap sort is used as an example of its usefulness as well. Both linked and array-based implementations are explored.

Chapter 12 (Multi-way Search Trees) is a natural extension of the discussion of the previous chapters. The concepts of 2-3 trees, 2-4 trees, and general B-trees are examined and implementation options are discussed.

Chapter 13 (Graphs) explores the concept of undirected and directed graphs and establishes important terminology. It examines several common graph algorithms and discusses implementation options, including adjacency matrices.

Chapter 14 (Hashing) covers the concept of hashing and related issues, such as hash functions and collisions. Various Java Collections API options for hashing are discussed.

Chapter 15 (Sets and Maps) explores these two types of collections and their importance to the Java Collections API.

Appendix A (UML) provides an introduction to the Unified Modeling Language as a reference. UML is the de facto standard notation for representing object-oriented systems.

Appendix B (Object-Oriented Design) is a reference for anyone needing a review of fundamental object-oriented concepts and how they are accomplished in Java. Included are the concepts of abstraction, classes, encapsulation, inheritance, and polymorphism, as well as many related Java language constructs such as interfaces.

Supplements

The following supplements are available to all readers of this book at www.aw.com/cssupport.

- **Source Code** for all programs presented in the book
- **Full case studies** of programs that illustrate concepts from the text, including a Black Jack Game, a Calculator, a Family Tree Program, and a Web Crawler

The following instructor supplements are only available to qualified instructors at Pearson Education's Instructor Resource Center, http://www.pearsonhighered.com/irc. Please visit the Web site, contact your local Pearson Education Sales Representative, or send an e-mail to computing@pearson.com, for information about how to access them.

- **Solutions** for selected exercises and programming projects in the book
- **Test Bank,** containing questions that can be used for exams
- **PowerPoint® Slides** for the presentation of the book content

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