

## *Purpose/Goals*

This new Java edition describes *data structures*, methods of organizing large amounts of data, and *algorithm analysis*, the estimation of the running time of algorithms. As computers become faster and faster, the need for programs that can handle large amounts of input becomes more acute. Paradoxically, this requires more careful attention to efficiency, since inefficiencies in programs become most obvious when input sizes are large. By analyzing an algorithm before it is actually coded, students can decide if a particular solution will be feasible. For example, in this text students look at specific problems and see how careful implementations can reduce the time constraint for large amounts of data from centuries to less than a second. Therefore, no algorithm or data structure is presented without an explanation of its running time. In some cases, minute details that affect the running time of the implementation are explored.

Once a solution method is determined, a program must still be written. As computers have become more powerful, the problems they must solve have become larger and more complex, requiring development of more intricate programs. The goal of this text is to teach students good programming and algorithm analysis skills simultaneously so that they can develop such programs with the maximum amount of efficiency.

This book is suitable for either an advanced data structures (CS7) course or a first-year graduate course in algorithm analysis. Students should have some knowledge of intermediate programming, including such topics as object-based programming and recursion, and some background in discrete math.

## *Summary of the Most Significant Changes in the Third Edition*

The third edition incorporates numerous bug fixes, and many parts of the book have undergone revision to increase the clarity of presentation. In addition,

- Chapter 4 includes implementation of the AVL tree deletion algorithm—a topic often requested by readers.
- Chapter 5 has been extensively revised and enlarged and now contains material on two newer algorithms: cuckoo hashing and hopscotch hashing. Additionally, a new section on universal hashing has been added.
- Chapter 7 now contains material on radix sort, and a new section on lower bound proofs has been added.

- Chapter 8 uses the new union/find analysis by Seidel and Sharir, and shows the  $O(M\alpha(M, N))$  bound instead of the weaker  $O(M \log^* N)$  bound in prior editions.
- Chapter 12 adds material on suffix trees and suffix arrays, including the linear-time suffix array construction algorithm by Karkkainen and Sanders (with implementation). The sections covering deterministic skip lists and AA-trees have been removed.
- Throughout the text, the code has been updated to use the diamond operator from Java 7.

## Approach

Although the material in this text is largely language independent, programming requires the use of a specific language. As the title implies, we have chosen Java for this book.

Java is often examined in comparison with C++. Java offers many benefits, and programmers often view Java as a safer, more portable, and easier-to-use language than C++. As such, it makes a fine core language for discussing and implementing fundamental data structures. Other important parts of Java, such as threads and its GUI, although important, are not needed in this text and thus are not discussed.

Complete versions of the data structures, in both Java and C++, are available on the Internet. We use similar coding conventions to make the parallels between the two languages more evident.

## Overview

Chapter 1 contains review material on discrete math and recursion. I believe the only way to be comfortable with recursion is to see good uses over and over. Therefore, recursion is prevalent in this text, with examples in every chapter except Chapter 5. Chapter 1 also presents material that serves as a review of inheritance in Java. Included is a discussion of Java generics.

Chapter 2 deals with algorithm analysis. This chapter explains asymptotic analysis and its major weaknesses. Many examples are provided, including an in-depth explanation of logarithmic running time. Simple recursive programs are analyzed by intuitively converting them into iterative programs. More complicated divide-and-conquer programs are introduced, but some of the analysis (solving recurrence relations) is implicitly delayed until Chapter 7, where it is performed in detail.

Chapter 3 covers lists, stacks, and queues. This chapter has been significantly revised from prior editions. It now includes a discussion of the Collections API `ArrayList` and `LinkedList` classes, and it provides implementations of a significant subset of the collections API `ArrayList` and `LinkedList` classes.

Chapter 4 covers trees, with an emphasis on search trees, including external search trees (B-trees). The UNIX file system and expression trees are used as examples. AVL trees and splay trees are introduced. More careful treatment of search tree implementation details is found in Chapter 12. Additional coverage of trees, such as file compression and game trees, is deferred until Chapter 10. Data structures for an external medium are considered as the final topic in several chapters. New to this edition is a discussion of the Collections API `TreeSet` and `TreeMap` classes, including a significant example that illustrates the use of three separate maps to efficiently solve a problem.

Chapter 5 discusses hash tables, including the classic algorithms such as separate chaining and linear and quadratic probing, as well as several newer algorithms, namely cuckoo hashing and hopscotch hashing. Universal hashing is also discussed, and extendible hashing is covered at the end of the chapter.

Chapter 6 is about priority queues. Binary heaps are covered, and there is additional material on some of the theoretically interesting implementations of priority queues. The Fibonacci heap is discussed in Chapter 11, and the pairing heap is discussed in Chapter 12.

Chapter 7 covers sorting. It is very specific with respect to coding details and analysis. All the important general-purpose sorting algorithms are covered and compared. Four algorithms are analyzed in detail: insertion sort, Shellsort, heapsort, and quicksort. New to this edition is radix sort and lower bound proofs for selection-related problems. External sorting is covered at the end of the chapter.

Chapter 8 discusses the disjoint set algorithm with proof of the running time. The analysis is new. This is a short and specific chapter that can be skipped if Kruskal's algorithm is not discussed.

Chapter 9 covers graph algorithms. Algorithms on graphs are interesting, not only because they frequently occur in practice, but also because their running time is so heavily dependent on the proper use of data structures. Virtually all the standard algorithms are presented along with appropriate data structures, pseudocode, and analysis of running time. To place these problems in a proper context, a short discussion on complexity theory (including *NP*-completeness and undecidability) is provided.

Chapter 10 covers algorithm design by examining common problem-solving techniques. This chapter is heavily fortified with examples. Pseudocode is used in these later chapters so that the student's appreciation of an example algorithm is not obscured by implementation details.

Chapter 11 deals with amortized analysis. Three data structures from Chapters 4 and 6 and the Fibonacci heap, introduced in this chapter, are analyzed.

Chapter 12 covers search tree algorithms, the suffix tree and array, the *k*-d tree, and the pairing heap. This chapter departs from the rest of the text by providing complete and careful implementations for the search trees and pairing heap. The material is structured so that the instructor can integrate sections into discussions from other chapters. For example, the top-down red-black tree in Chapter 12 can be discussed along with AVL trees (in Chapter 4).

Chapters 1–9 provide enough material for most one-semester data structures courses. If time permits, then Chapter 10 can be covered. A graduate course on algorithm analysis could cover Chapters 7–11. The advanced data structures analyzed in Chapter 11 can easily be referred to in the earlier chapters. The discussion of *NP*-completeness in Chapter 9 is far too brief to be used in such a course. You might find it useful to use an additional work on *NP*-completeness to augment this text.

## Exercises

Exercises, provided at the end of each chapter, match the order in which material is presented. The last exercises may address the chapter as a whole rather than a specific section. Difficult exercises are marked with an asterisk, and more challenging exercises have two asterisks.

### ***References***

References are placed at the end of each chapter. Generally the references either are historical, representing the original source of the material, or they represent extensions and improvements to the results given in the text. Some references represent solutions to exercises.

### ***Supplements***

The following supplements are available to all readers at [www.pearsonhighered.com/cssupport](http://www.pearsonhighered.com/cssupport):

- Source code for example programs

In addition, the following material is available only to qualified instructors at Pearson's Instructor Resource Center ([www.pearsonhighered.com/irc](http://www.pearsonhighered.com/irc)). Visit the IRC or contact your campus Pearson representative for access.

- Solutions to selected exercises
- Figures from the book

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