Working Classes

DATA STRUCTURES AND ALGORITHMS USING C++

工作类型:数据结构与算法的 C++实现

Rick Decker
Stuart Hirshfield

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Data Structures and Algorithms Using C++

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PREFACE

The overwhelming majority of authors have very little to say. If we suppose, rather charitably, that in a typical book of fifteen chapters there are only eight passages worthy of quotation, then simple mathematics will convince us that in short order there will be no original quotations left for chapter headings. The implication is obvious...

Armand Blague
How To Write

Over the years, we've had a number of students who have said, in one form or another, "I want to be a computer scientist because I really like programming and am very good at it." Of course computer scientists, both novices and seasoned veterans, are often called upon to write programs, but to equate computer science with programming is to confuse the product with the process. Being an excellent draftsman who can faithfully represent a scene on paper is no guarantee that your works will eventually hang in the Metropolitan Museum. It's a step in the right direction, but an artist must also have an intimate familiarity with the more general principles of composition, perspective, color and so on.

In essence, programming is little more than the efficient management of a particular kind of large intellectual process, and the guidelines for good programming are nothing but the application of common-sense principles that apply to any complex creative task. It goes without saying, though, that before you can think efficiently you have to have something to think *about*, which for our purposes means that in order to write good programs, you must have an idea about how information may be represented in a program.

Computer science is a young discipline, but has developed enough over the past few decades to gain a consensus about what should constitute the core data structures. In this book, we have tried to capture this core by providing what might be called the "classic" data structures—the most commonly applied methods for representing information in a computer program—along with the algorithms for manipulating this information. In terms of things to think about for programming, this book offers a collection of tools that should be part of the working knowledge of any programmer.

This book is not about programming, however. Computer science is a science, and as such mainly seeks a theoretical framework that can be used to describe the behavior of the objects under study, which in our case are computers and their programs. One of the objectives that have determined the form of the book is to provide a broad view of what a data structure really is. In our approach, data structures are not just a collection of ad hoc type declarations and function definitions, but rather any data structure is a particular instance of an abstract data type, which consists of (1) a set of positions and a set of elements associated with the positions; (2) a logical structure defined on the positions; and (3) a collection of structure-preserving operations on the positions and the elements they "contain."

We have chosen to define the structure of an abstract data type by specifying a structural relation on each set of positions. Doing so provides a natural progression of the chapters, where each new abstract data type is introduced by removing some of the structural restrictions from a prior type. Thus we begin with lists, whose structure is defined by a linear order, and progress to trees by removing the requirement that each position have a unique successor, then to directed graphs by removing the requirement of a unique predecessor, and finally to sets, where there is no structure at all on the positions. Throughout this process, we see that each new abstract data type still can be described by the threefold view of a collection of positions with a structural relation and a collection of structure-preserving operations.

Some History

After using Pascal in this course for five years, it was clear to us that, for all its strengths as a teaching language, Pascal is not the most felicitous choice as a vehicle for a course in data structures. An abstract data type is nothing more than a collection of data and operations on that data, and that, of course, is the definition of a class. When preparing to write the book you have before you, we considered several object-oriented languages and finally settled on C++, largely because of its popularity. We'd be the first to admit that C++ has its warts and blemishes, but in our opinion it is the appropriate choice at present.

The Audience

Though we did not set out to tailor this book to any preexisting curriculum, it turned out that it covers essentially all of CS2 and part of CS7, as described in the ACM Curriculum '78, and a subset of the union of CS2 and CO2, set forth in Norman Gibbs and Alan Tucker's 1985 Model Curriculum for a Liberal Arts Degree in Computer Science. The material contained here should be covered early in any computer science curriculum, and we have written this book for an audience of first and second year students in computer science

who are familiar with C or (preferably) C++. For those readers whose background is Pascal, we provide a Pascal–C++ "dictionary" in Appendix A. A course in discrete mathematics is desirable as a pre- or corequisite for this material, but the relevant mathematical background is summarized in Appendices B and C for those who need it.

The Contents

Our intent has been to write a book that could be used as the basis for a semester-length course in data structures or advanced programming. Realizing that the subject matter of this book comes at an early stage in the education of a computer scientist, we included a number of mentions, necessarily brief, of some of the topics awaiting the student down the road. Most of the canonical sorting and searching algorithms are covered, along with mentions of computational complexity, compiler design, unsolvable problems, NP-completeness, and fundamental paradigms for algorithms. We believe that one can never have enough exercises—this book has 359, by actual count, and each chapter concludes with an optional Explorations section, where we treat interesting topics that extend the material of the chapter.

Chapter 1 covers some of the necessary preliminaries, such as program design, the definition of an abstract data type, and assertions and program verification. We begin by specifying an array as an abstract data type, and conclude with the *Number* ADT that represents integers of arbitrary size. Chapter 2 describes the *List* ADT and continues the preliminary material of Chapter 1 by discussing parametrized classes and functions, big-O notation, and timing of algorithms. The chapter concludes with a discussion of memory management. In the Explorations section, we discuss sorted lists and searching, along with self-organizing lists.

In Chapters 3 and 4 we continue the investigation of linear data structures. Chapter 3 covers strings and introduces the Boyer-Moore string search algorithm. Chapter 4 covers the remaining standard linear structures, stacks and queues, motivating these by applications to manipulate postfix expressions. The Explorations cover stack-based maze traversal and a simple operating system simulation. Since a considerable number of queue applications involve simulation, Appendix C (Random Numbers and Simulation) may be useful at this point.

Chapter 5 provides a segue into nonlinear structures by introducing recursion and recursively defined data structures. Timing estimates for recursive algorithms are covered in depth, along with an introduction to LISP. We deal with Quicksort in the Explorations. Appendix B, which covers logarithms and exponentials, induction, and elementary combinations, is helpful supplementary material at this stage.

Chapters 6 and 7 cover trees. Chapter 6 provides the necessary background on binary trees and their implementations, traversal algorithms, and treesort; and the Explorations discuss threaded trees, minimal-length codes,

and tries. Chapter 7, which can be omitted if necessary, covers two extensions of binary search trees, namely AVL trees and B-trees.

Chapter 8 covers graphs and digraphs, along with a representative sample of graph algorithms for traversal, spanning trees, minimal-cost paths, minimal spanning trees, and an introduction to complexity theory through the Traveling Salesperson Problem. In the Explorations, we discuss topological sorting and applications of powers of the adjacency matrix.

Chapter 9, on sets, describes bit vector, list implementations of sets, dictionaries, and associations, and provides a comprehensive introduction to hashing. The chapter concludes with *PriorityQueue* ADT and heapsort. In the Explorations, we continue our discussion of hashing and introduce the *DisjointSet* ADT.

In Chapter 10 we consider the problem of regenerating text from a large sample and trace the development of programs to solve this problem, using a real computer/compiler system to show how practical time and space constraints arise from choices of data structure.

Supplementary Material

In addition to the data disk (IBM PC compatible) included with this book, an *Instructor's Manual* is available from the publisher. A Macintosh version of the data disk is also available from the publisher.

Acknowledgments

A lot of people deserve praise for seeing this book through to completion. Thanks go to Billy Lim, *Illinois State University*, Barbara Boucher Owens, *St. Edward's University*, and Daniel Ling, *Okanagan University College*, for their thoughtful reviews; and to our students and colleagues for suggesting countless changes in earlier versions. Special kudos go to the folks at PWS Publishing, especially Mike Sugarman and Ben Steinberg (the Batman and Robin of publishing), Abby Heim (who held her nervous breakdown at bay throughout an insanely busy production process that included working on two of our books simultaneously), J. P. Lenney (for picking out great wines and picking up the tab), and Nathan Wilbur (for just being Nathan). Writing and producing a book is a task that rates up there on the discomfort scale with cholera, except that writing takes longer. It can never be called pleasurable, but the friendship and warmth of the PWS crew at least has made it bearable.

Rick Decker
Stuart Hirshfield

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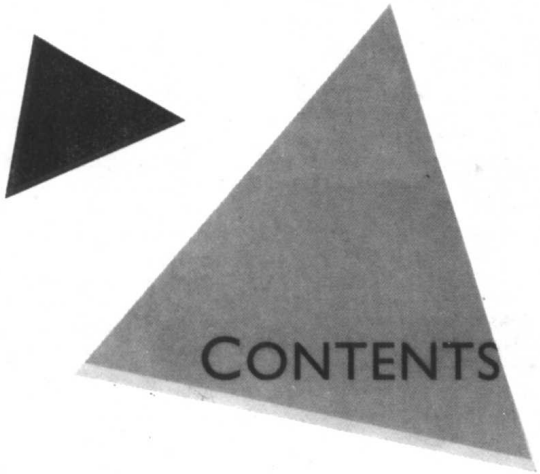
For Natty, Adam, Ben, and Shauna



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