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# Algorithms in C++ Part 5: Graph Algorithms (3rd Edition) (Pt.5)

By Robert Sedgewick



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Providing exercises to help students learn the properties of algorithms, this text places a greater emphasis on abstract data types, modular programming, object-oriented programming and C++ classes.

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#### **Editorial Review**

#### Amazon.com Review

Robert Sedgewick's **Algorithms** series has earned a place among the classics of computer books. **Algorithms in C++** provides a comprehensive collection of classic algorithms for sorting, searching, parsing, geometrical manipulation, and more. The book includes not just C++ code but detailed--yet readable--explanations of how it works and what each algorithm's advantages and disadvantages are in terms of execution time and memory demands. An invaluable and timeless resource.

#### From the Inside Flap

This book is intended to survey the most important computeralgorithms in use today and to teach fundamental techniques to the growing number of people in need of knowing them. It can beused as a textbook for a second, third, or fourth course incomputer science, after students have acquired some programmingskills and familiarity with computer systems, but before theyhave taken specialized courses in advanced areas of computerscience or computer applications.

Additionally, the book may be useful for self-study or as areference for those engaged in the development of computersystems or applications programs, since it contains a number of implementations of useful algorithms and detailed information on their performance characteristics. The broad perspective taken in the book makes it an appropriate introduction to the field.

The algorithms are expressed in the C++ programming language(versions of the book in Pascal and C are also available). Nospecific knowledge about the language is assumed--the treatmenthere is self-contained (though fast-paced). Readers who havesome familiarity with C++ will find the language a useful vehicle for learning a variety of methods of practical interest. Readerswho have some familiarity with basic algorithms will find thetreatment here a useful vehicle for learning a variety offeatures of the C++ language, while at the same time learningsome new algorithms.

#### SCOPE

The book contains forty-five chapters grouped into eight majorparts: fundamentals, sorting, searching, string processing,geometric algorithms, graph algorithms, mathematical algorithms and advanced topics. A major goal in developing this book hasbeen to bring together the fundamental methods from these diverseareas, in order to provide access to the best methods known forsolving problems by computer. Some of the chapters give introductory treatments of advanced material. It is hoped thatthe descriptions here can give readers some understanding of thebasic properties of fundamental algorithms ranging from priority queues and hashing to simplex and the fast Fourier transform.

One or two previous courses in computer science or equivalentprogramming experience are recommended for a reader to be able toappreciate the material in this book: one course in programming high-level languages such as C++, C or Pascal, and perhapsanother course which teaches fundamental concepts of programmingsystems. This book is thus intended for anyone conversant with amodern programming language and with the basic features of moderncomputer systems. References that might help fill in gaps inone's background are suggested in the text.

Most of the mathematical material supporting the analytic resultsis self-contained (or labeled as "beyond the

scope" of thisbook), so little specific preparation in mathematics is required for the bulk of the book, though a certain amount deal with algorithms related to more advanced mathematical material--these intended to place the algorithms in context with other methods throughout the book, not to teach the mathematical material. Thus the discussion of advanced mathematical concepts brief, general, and descriptive.

#### USE IN THE CURRICULUM

There is a great deal of flexibility in how the material here canbe taught. To a large extent, the individual chapters in thebook can be read independently of the others, though in somecases algorithms in one chapter make use of methods from aprevious chapter. The material can be adapted for use forvarious courses by selecting perhaps 25 or 30 of the 45 chapters, according to the taste of the instructor and the preparation of the students.

The book begins with an introductory section on data structures and the design and analysis of algorithms. This sets the tone for the rest of the book and provides a framework within which more advanced algorithms are treated. Some readers may skip orskim this section; others may learn the basics there.

An elementary course on "data structures and algorithms" mightomit some of the mathematical algorithms and some of the advancedtopics, then emphasize how various data structures are used in the implementations. An intermediate course on "design and analysis of algorithms" might omit some of the more practically oriented sections, then emphasize the identification and study of the ways in which algorithms achieve good asymptotic performance. A course on "software tools" might omit the mathematical and advanced algorithmic material, then emphasize how to integrate the implementations given here into large programs or systems. Acourse on "algorithms" might take a survey approach and introduce concepts from all these areas.

Some instructors may wish to add supplementary material to thecourses described above to reflect their particular orientation. For "data structures and algorithms," more mathematical analysiscould be added; and for "software tools", software engineeringtechniques could be covered in more depth. In this book, attention is paid to all these areas, but the emphasis is on the algorithms themselves.

Earlier versions of this book have been used in recent years atscores of colleges and universities around the country as a textfor the second or third course in computer science and assupplemental reading for other courses. At Princeton, ourexperience has been that the breadth of coverage of material inthis book provides our majors with an introduction to computerscience that can be expanded upon in later courses on analysis of algorithms, systems programming and theoretical computer science, while at the same time providing all the students with a largeset of techniques that they can immediately put to good use.

There are 450 exercises ten following each chapter, that generally divide into one of two types. Most are intended totest students' understanding of material in the next and askstudents to work through an example or apply concepts described in the text. A few of them, however, involve implementing and putting together some of the algorithms, perhaps running empirical studies to compare algorithms and to learn their properties.

#### ALGORITHMS OF PRACTICAL USE

The orientation of the book is toward algorithms likely to be of practical use. The emphasis is on teaching students the tools of their trade to the point that they can confidently implement, runand debug useful algorithms. Full implementations of the methods discussed are included in the text, along with descriptions of the operations of these programs on a consistent set of examples. Indeed, as discussed in the epilog, hundreds of figures are included in the book that have been created by the algorithms themselves. Many

algorithms are brought to light on an intuitivelevel through the visual dimension provided by these figures.

Characteristics of the algorithms and situations in which they might be useful are discussed in detail. Though not emphasized, connections to the analysis of algorithms and theoretical computer science are not ignored. When appropriate, empirical and analytic results are discussed to illustrate why certain algorithms are preferred. When interesting, the relationship of the practical algorithms being discussed to purely theoretical results is described. Specific information performance characteristics of algorithms is encapsulated throughout in "properties," important facts about the algorithms that deserve further study.

Some algorithms are used in relatively small programs to solvespecific problems. Others play an integral part in relativelylarge systems. Many fundamental algorithms find application inboth domains. We indicate as appropriate how algorithms might bespecialized for use as problem-solving tools or generalized for integration into much bigger programs. Such considerations areof particular interest for algorithms expressed in anobject-oriented language such as C++. In this book we provide relevant information that can be used to make intelligenttradeoffs between utility and performance in implementing widelyapplicable algorithms.

While there is little direct treatment of specific uses of the algorithms in science and engineering applications, the potential for such use is mentioned when appropriate. Our experience hasbeen that when students learn good algorithms in a computerscience context early in their education, they are able to apply them to solve problems when warranted later on.

#### PROGRAMMING LANGUAGE

The programming language used throughout the book is C++ (Pascaland C versions of the book are also available). Any particularlanguage has advantages and disadvantages--our intention here isto provide access to the fundamental algorithms that have beendeveloped over the years to the growing number of people who aremoving to C++ as a primary language and using it forapplications. The programs can easily be translated to othermodern programming languages, since they are written in astylized form that are relatively language-independent. Indeed,many of the programs have been translated from Pascal, C, andother languages, though we try to use standard C++ idioms whenappropriate. On the other hand, C++ is particularly well-suited to our task, because its basic support for data abstraction andmodular programming allows us to clearly express relationshipsamong algorithms and data structures.

Some of the programs can simplified by using more advancedlanguage feature, but this is true less often than one might think. Although language features are discussed when appropriate, thisbook is not intended to be reference work on C++ or onobject-oriented programming. While we use C++ classes heavily,we do not use templates, inheritance or virtual functions. Butthe algorithms are coded so as to ease the process of embeddingthem in large systems where such features can be used toadvantage in an object-oriented programming approach. Whenforced to make a choice, we concentrate on the algorithms, notlanguage feature or implementations details.

A goal of this book is to present the algorithms in as simple anddirect a form as possible. The programs are intended to be readnot by themselves, but as part of the surrounding text. Thisstyle was chosen as an alternative, for example, to having inlinecomments. The style is consistent whenever possible, so that programs that are similar look similar.

#### ACKNOWLEDGMENTS

Many people gave me helpful feedback on earlier versions of thisbook. In particular, students at Princeton and Brown suffered through preliminary versions of the material in this book in the 1980's. Special thanks are

due to Trina Avery, Tom Freeman andJanet Incerpi for their help in producing the first edition. Iwould particularly like to thank Janet for converting the bookinto TeX format, adding the thousands of changes I made after the "last draft" of the first edition, guiding the files throughvarious systems to produce printed pages and even writing thescan-conversion routine for TeX used to produce draftmanuscripts, among many other things. Only after performing manyof these tasks myself for later versions do I truly appreciateJanet's contribution. I would also like to thank the manyreaders who provided me with detailed comments about the secondedition, including Guy Almes, Jay Gischer, Kennedy Lemke, UdiManber, Dana Richards, John Reif, M. Rosenfield, Stephen Seidman, Michael Quinn.

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This C++ version owes its existence to the persistence of KeithWollman who convinced me to proceed, and the patience of PeterGordon, who was confident that I would get around to doing so. Dave Hanson's willingness to answer questions about C and C++ wasinvaluable. I also would like to thank Darcy Cotten and SkipPlank for their help in producing the book.

Much of what I've written here I've learned from the teachings and writings of Don Knuth, my advisor at Stanford. Though Donhad no direct influence on this work, his presence may be felt in the book, for it was he who put the study of algorithms on ascientific footing that makes a work such as this possible.

I am very thankful for the support of Brown University and INRIAwhere I did most of the work on the book, and the Institute forDefense Analyses and the Xerox Palo Alto Research Center, where Idid some work on the book while visiting. Many parts of the bookare dependent on research that has been generously supported by the National Science Foundation and the Office of Naval Research. Finally, I would like to thank Bill Bowen, Aaron Lemonick, andNeil Rudenstine at Princeton University for their support inbuilding an academic environment in which I was able to prepare book, despite numerous other responsibilities. 0201510596P04062001

From the Back Cover

Once again, Robert Sedgewick provides a current and comprehensive introduction to important algorithms. The focus this time is on graph algorithms, which are increasingly critical for a wide range of applications, such as network connectivity, circuit design, scheduling, transaction processing, and resource allocation. In this book, Sedgewick offers the same successful blend of theory and practice that has made his work popular with programmers for many years. Christopher van Wyk and Sedgewick have developed concise new C++ implementations that both express the methods in a natural and direct manner and also can be used in real applications.

*Algorithms in C++, Third Edition, Part 5: Graph Algorithms* is the second book in Sedgewick's thoroughly revised and rewritten series. The first book, Parts 1-4, addresses fundamental algorithms, data structures, sorting, and searching. A forthcoming third book will focus on strings, geometry, and a range of advanced algorithms. Each book's expanded coverage features new algorithms and implementations, enhanced descriptions and diagrams, and a wealth of new exercises for polishing skills. A focus on abstract data types makes the programs more broadly useful and relevant for the modern object-oriented programming environment.

Coverage includes:

- A complete overview of graph properties and types
  - Diagraphs and DAGs
  - Minimum spanning trees
  - Shortest paths
  - Network flows
  - Diagrams, sample C++ code, and detailed algorithm descriptions

The Web site for this book (http://www.cs.princeton.edu/~rs/) provides additional source code for programmers along with a wide range of academic support materials for educators.

A landmark revision, *Algorithms in C++, Third Edition, Part 5* provides a complete tool set for programmers to implement, debug, and use graph algorithms across a wide range of computer applications.

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#### **Users Review**

#### From reader reviews:

#### **Michael Stein:**

Information is provisions for folks to get better life, information today can get by anyone at everywhere. The information can be a know-how or any news even a huge concern. What people must be consider any time those information which is inside former life are challenging be find than now's taking seriously which one is suitable to believe or which one typically the resource are convinced. If you obtain the unstable resource then you buy it as your main information you will see huge disadvantage for you. All of those possibilities will not happen with you if you take Algorithms in C++ Part 5: Graph Algorithms (3rd Edition) (Pt.5) as the daily resource information.

#### **Robert Eslinger:**

Reading a book tends to be new life style with this era globalization. With reading you can get a lot of information that can give you benefit in your life. Using book everyone in this world can share their idea. Books can also inspire a lot of people. Lots of author can inspire their very own reader with their story or their experience. Not only the storyplot that share in the guides. But also they write about the ability about something that you need example of this. How to get the good score toefl, or how to teach your sons or daughters, there are many kinds of book that exist now. The authors these days always try to improve their ability in writing, they also doing some investigation before they write to the book. One of them is this Algorithms in C++ Part 5: Graph Algorithms (3rd Edition) (Pt.5).

#### **Patricia Stroud:**

The e-book with title Algorithms in C++ Part 5: Graph Algorithms (3rd Edition) (Pt.5) includes a lot of information that you can study it. You can get a lot of profit after read this book. This book exist new expertise the information that exist in this publication represented the condition of the world today. That is important to yo7u to be aware of how the improvement of the world. This book will bring you in new era of the the positive effect. You can read the e-book in your smart phone, so you can read it anywhere you want.

#### Wendy Fuller:

The book untitled Algorithms in C++ Part 5: Graph Algorithms (3rd Edition) (Pt.5) contain a lot of information on this. The writer explains the girl idea with easy approach. The language is very simple to implement all the people, so do not really worry, you can easy to read it. The book was compiled by famous author. The author provides you in the new period of time of literary works. You can read this book because you can please read on your smart phone, or device, so you can read the book inside anywhere and anytime. In a situation you wish to purchase the e-book, you can open up their official web-site as well as order it. Have a nice learn.

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