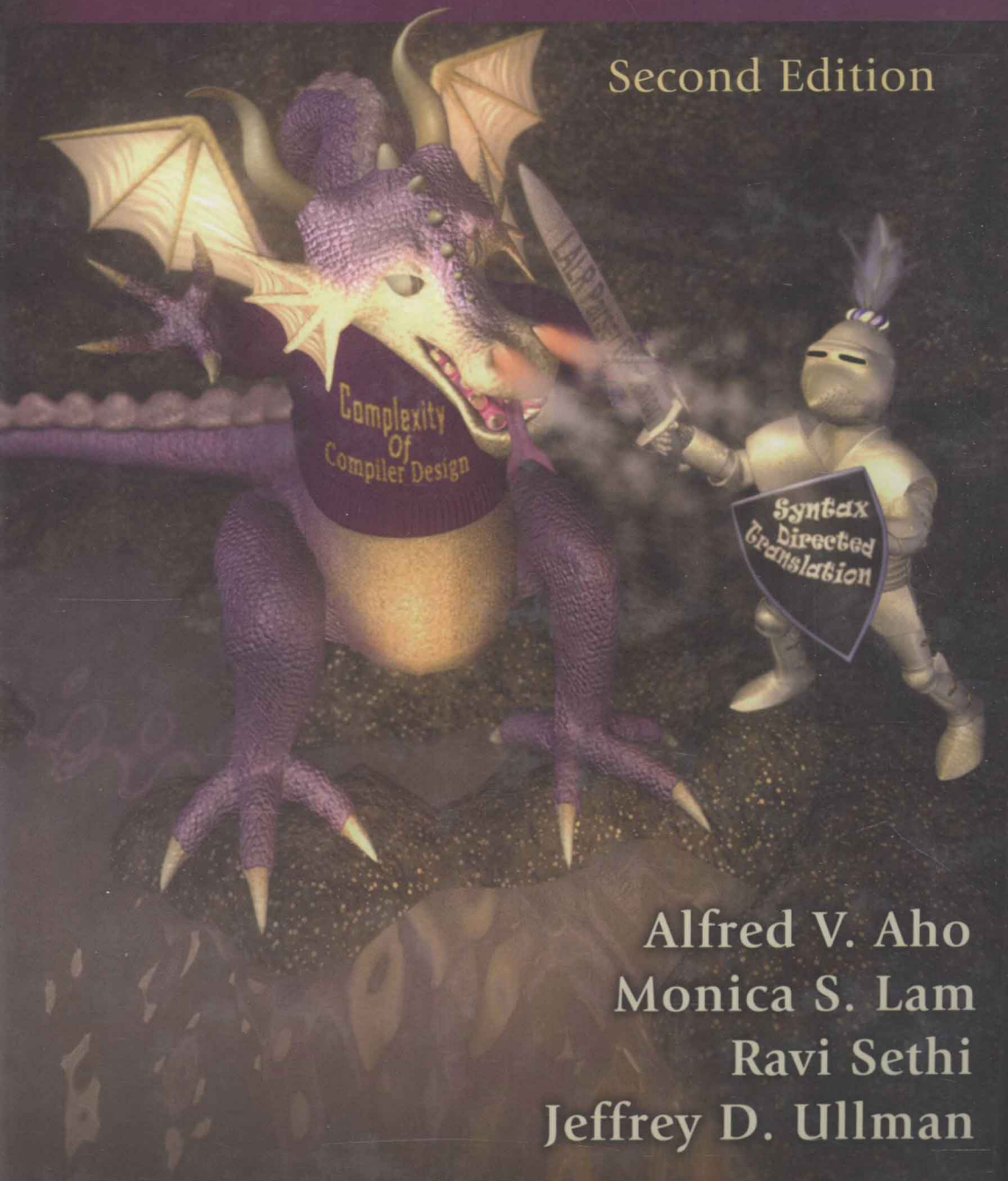
Compilers

Principles, Techniques, & Tools

Second Edition



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Preface

In the time since the 1986 edition of this book, the world of compiler design has changed significantly. Programming languages have evolved to present new compilation problems. Computer architectures offer a variety of resources of which the compiler designer must take advantage. Perhaps most interestingly, the venerable technology of code optimization has found use outside compilers. It is now used in tools that find bugs in software, and most importantly, find security holes in existing code. And much of the "front-end" technology — grammars, regular expressions, parsers, and syntax-directed translators — are still in wide use.

Thus, our philosophy from previous versions of the book has not changed. We recognize that few readers will build, or even maintain, a compiler for a major programming language. Yet the models, theory, and algorithms associated with a compiler can be applied to a wide range of problems in software design and software development. We therefore emphasize problems that are most commonly encountered in designing a language processor, regardless of the source language or target machine.

Use of the Book

It takes at least two quarters or even two semesters to cover all or most of the material in this book. It is common to cover the first half in an undergraduate course and the second half of the book — stressing code optimization — in a second course at the graduate or mezzanine level. Here is an outline of the chapters:

Chapter 1 contains motivational material and also presents some background issues in computer architecture and programming-language principles.

Chapter 2 develops a miniature compiler and introduces many of the important concepts, which are then developed in later chapters. The compiler itself appears in the appendix.

Chapter 3 covers lexical analysis, regular expressions, finite-state machines, and scanner-generator tools. This material is fundamental to text-processing of all sorts.

Chapter 4 covers the major parsing methods, top-down (recursive-descent, LL) and bottom-up (LR and its variants).

Chapter 5 introduces the principal ideas in syntax-directed definitions and syntax-directed translations.

Chapter 6 takes the theory of Chapter 5 and shows how to use it to generate intermediate code for a typical programming language.

Chapter 7 covers run-time environments, especially management of the run-time stack and garbage collection.

Chapter 8 is on object-code generation. It covers construction of basic blocks, generation of code from expressions and basic blocks, and register-allocation techniques.

Chapter 9 introduces the technology of code optimization, including flow graphs, data-flow frameworks, and iterative algorithms for solving these frameworks.

Chapter 10 covers instruction-level optimization. The emphasis is on the extraction of parallelism from small sequences of instructions and scheduling them on single processors that can do more than one thing at once.

Chapter 11 talks about larger-scale parallelism detection and exploitation. Here, the emphasis is on numeric codes that have many tight loops that range over multidimensional arrays.

Chapter 12 is on interprocedural analysis. It covers pointer analysis, aliasing, and data-flow analysis that takes into account the sequence of procedure calls that reach a given point in the code.

Courses from material in this book have been taught at Columbia, Harvard, and Stanford. At Columbia, a senior/first-year graduate course on programming languages and translators has been regularly offered using material from the first eight chapters. A highlight of this course is a semester-long project in which students work in small teams to create and implement a little language of their own design. The student-created languages have covered diverse application domains including quantum computation, music synthesis, computer graphics, gaming, matrix operations and many other areas. Students use compiler-component generators such as ANTLR, Lex, and Yacc and the syntax-directed translation techniques discussed in chapters two and five to build their compilers. A follow-on graduate course has focused on material in Chapters 9 through 12, emphasizing code generation and optimization for contemporary machines including network processors and multiprocessor architectures.

At Stanford, a one-quarter introductory course covers roughly the material in Chapters 1 through 8, although there is an introduction to global code optimization from Chapter 9. The second compiler course covers Chapters 9 through 12, plus the more advanced material on garbage collection from Chapter 7. Students use a locally developed, Java-based system called `Joeq` for implementing data-flow analysis algorithms.

Prerequisites

The reader should possess some "computer-science sophistication," including at least a second course on programming, and courses in data structures and discrete mathematics. Knowledge of several different programming languages is useful.

Exercises

The book contains extensive exercises, with some for almost every section. We indicate harder exercises or parts of exercises with an exclamation point. The hardest exercises have a double exclamation point.

Gradiance On-Line Homeworks

A feature of the new edition is that there is an accompanying set of on-line homeworks using a technology developed by Gradiance Corp. Instructors may assign these homeworks to their class, or students not enrolled in a class may enroll in an "omnibus class" that allows them to do the homeworks as a tutorial (without an instructor-created class). Gradiance questions look like ordinary questions, but your solutions are sampled. If you make an incorrect choice you are given specific advice or feedback to help you correct your solution. If your instructor permits, you are allowed to try again, until you get a perfect score.

A subscription to the Gradiance service is offered with all new copies of this text sold in North America. For more information, visit the Addison-Wesley web site `www.aw.com/gradiance` or send email to `computing@aw.com`.

Support on the World Wide Web

The book's home page is

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dragonbook.stanford.edu
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Here, you will find errata as we learn of them, and backup materials. We hope to make available the notes for each offering of compiler-related courses as we teach them, including homeworks, solutions, and exams. We also plan to post descriptions of important compilers written by their implementers.

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