## **Table of Contents**

Preface	ix
Chapter 1 Overview of Compilers and Language Translation	1
1.1 The Role of Programming Languages	1
1.2 Translators and Compilers	
1.3 Tombstone Diagrams	4
1.4 Bootstrapping a Compiler	8
1.5 Interpreters	
1.6 The Compiler Project	11
1.7 Essential Terms and Concepts	14
1.8 Exercises	14
Chapter 2 Structure of a Compiler	17
2.1 Scanner	
2.2 Parser	18
2.3 Constraint Analyzer	19
2.4 Code Generator	19
2.5 Optimizer	20
2.6 Final Code Generator	21
2.7 Tables and Maps	21
2.8 Error Handler	22
2.9 Passes	23
2.10 Compiler Design Goals	23
2.11 Essential Terms and Concepts	24
2.12 Exercises	25
Chapter 3 Context-Free Grammars	27
3.1 Specifying a Programming Language	27
3.2 Context-Free Grammars	28
3.3 Alternate Rule Notations	35
3.4 Grammar Transformations	38
3.5 Derivations and Parse Trees	39
3.6 Abstract Syntax Trees	43
3.7 A Context-Free Grammar for Context-Free Grammars	44
3.8 Essential Terms and Concepts	45
3.9 Exercises	46

Chapter 4 The Programming Language CPRL	49
4.1 General Lexical Considerations	49
4.2 Declarations, Statements, and Expressions	50
4.3 Types	51
4.4 Statements	54
4.5 Programs	56
4.6 Subprograms	57
4.7 Essential Terms and Concepts	59
4.8 Exercises	60
Chapter 5 Lexical Analysis (a.k.a. Scanning)	63
5.1 Class Position	63
5.2 Class Source	63
5.3 Class Symbol	65
5.4 Class Token	66
5.5 Class CharUtil	67
5.6 Class ErrorHandler	67
5.7 Class BoundedBuffer	68
5.8 Class Scanner	69
5.9 Handling Lexical Errors	76
5.10 Testing Class Scanner	78
5.11 Essential Terms and Concepts	80
5.12 Exercises	80
Chapter 6 Syntax Analysis (a.k.a. Parsing)	83
6.1 Example: Implementing Method parseLoopStmt()	
6.2 Recursive Descent Parsing	
6.3 First and Follow Sets	
6.4 LL(k) Grammars and Recursive Descent Parsing	100
6.5 Variables versus Variable Expressions	102
6.6 Handling Grammar Limitations	102
6.7 Scope and Visibility	105
6.8 Class IdTable	108
6.9 Parsing Variables and Variable Expressions	114
6.10 Class Parser	115
6.11 Essential Terms and Concepts	116
6.12 Exercises	117

Chapter 7 Error Handling/Recovery	119
7.1 Types of Compilation Errors	119
7.2 Handling Errors	121
7.3 Error Recovery	122
7.4 Additional Error Recovery Strategies	128
7.5 Essential Terms and Concepts	129
7.6 Exercises	129
Chapter 8 Abstract Syntax Trees	131
8.1 Overview of Abstract Syntax Trees	131
8.2 Structure of Abstract Syntax Trees	135
8.3 Extending Scopes with References to Declarations	137
8.4 Types and Declarations	
8.5 Structural References versus Nonstructural References	145
8.6 Determining Types of Variables and Expressions	148
8.7 Maintaining Context During Parsing	150
8.8 Essential Terms and Concepts	152
8.9 Exercises	153
Chapter 9 Constraint Analysis	155
9.1 Overview of Constraint Analysis	155
9.2 Constraint Rules for CPRL/0	159
9.3 Examples of Constraint Analysis	161
9.4 Essential Terms and Concepts	165
9.5 Exercises	165
Chapter 10 The CPRL Virtual Machine	167
10.1 Overview of the CVM	
10.2 Brief Comparison with the JVM	169
10.3 CVM Uses Relative Addressing	170
10.4 Loading a Program into Memory	170
10.5 Using the Stack to Hold Temporary Values	173
10.6 Essential Terms and Concepts	
10.7 Exercises	180
Chapter 11 Code Generation	181
11.1 Overview of Code Generation	181
11.2 Labels and Branching	
11.3 Load and Store Instructions	
11.4 Computing Relative Addresses for Variables	

11.5 Expressions	189
11.6 Statements	193
11.7 Initial Declarations	197
11.8 Disassembler	
11.9 Essential Terms and Concepts	200
11.10 Exercises	200
Chapter 12 Code Optimization	203
12.1 Overview of Code Optimization	203
12.2 Common Optimizations	206
12.3 Optimization in CPRL	211
12.4 Essential Terms and Concepts	213
12.5 Exercises	213
Chapter 13 Subprograms	215
13.1 Review of Subprograms, Scope, and Parameters	215
13.2 Run-time Organization for Subprograms	219
13.3 Activation Record	221
13.4 Parameters	228
13.5 Subprogram Calls and Returns	230
13.6 Calling Conventions for CPRL on the CVM	231
13.7 Computing Relative Addresses	232
13.8 Example of Program Execution	
13.9 Essential Terms and Concepts	248
13.10 Exercises	248
Chapter 14 Arrays	251
14.1 Using CPRL Arrays	251
14.2 Implementing CPRL Arrays	253
14.3 Essential Terms and Concepts	259
14.4 Exercises	259
Chapter 15 Strings	261
15.1 Using CPRL Strings	261
15.2 Implementing CPRL Strings	
15.3 Essential Terms and Concepts	272
15 / Evereises	272

Chapter 16 Records	275
16.1 Using CPRL Records	275
16.2 Implementing CPRL Records	279
16.3 Essential Terms and Concepts	283
16.4 Exercises	284
Appendix A The Compiler Project	287
Appendix B Additional Project Exercises	297
Appendix C Definition of the Programming Language CPRL	301
C.1 Lexical Considerations	301
C.2 Types	303
C.3 Constants and Variables	305
C.4 Operators and Expressions	307
C.5 Statements	308
C.6 Programs	311
C.7 Subprograms	311
Appendix D The CPRL Grammar	315
Appendix E Definition of the CPRL Virtual Machine	319
E.1 Specification.	
E.2 Implementation	320
E.3 CVM Instruction Set Architecture	323
Appendix F Searching for Reserved Words	333
F.1 Benchmarking the Search Algorithms	334
F.2 Sequential Search 1	
F.3 Sequential Search 2	
F.4 Sequential Search 3	337
F.5 Binary Search	338
F.6 Search by Length	339
F.7 Search by First Character	341
F.8 Gperf Hash Search	342
F.9 Search Using Switch Expression	345
F.10 Search Using HashMap	346
Appendix G JIT Compilation versus AOT Compilation	347
Annotated Compiler References and Websites	351
Index	355