

Contents

1 Introduction

- 1.1** A brief history of computing 2
- 1.2** What is computer science? 4
- 1.3** A brief tour of computer hardware 6
 - The CPU 7, Memory 7, Secondary storage 8, I/O devices 8
- 1.4** Algorithms 9
- 1.5** Programming languages and compilation 10
- 1.6** Programming errors and debugging 12
- 1.7** Software maintenance 13
- 1.8** The importance of software engineering 14
- 1.9** Some thoughts on the C programming language 15
 - Summary 16
 - REVIEW QUESTIONS 17

1

PART ONE

The Basics of C Programming 19

2 Learning by Example

21

- 2.1** The “Hello world” program 22
 - Comments 22, Library inclusions 23, The main program 24
 - 2.2** A program to add two numbers 26
 - The input phase 28, The computation phase 30, The output phase 30
 - 2.3** Perspectives on the programming process 32
 - 2.4** Data types 33
 - Floating-point data 34, String data 34
 - 2.5** Expressions 37
 - Constants 38, Variables 39, Assignment statements 41, Operators and operands 43, Combining integers and floating-point numbers 44, Integer division and the remainder operator 45, Precedence 45, Applying precedence rules 48, Type conversion 48
- Summary 51
REVIEW QUESTIONS 52
PROGRAMMING EXERCISES 55

3 Problem Solving

59

- 3.1 Programming idioms and paradigms** 60
 - Shorthand assignment idioms 61, Increment and decrement operators 62
 - 3.2 Solving problems on a larger scale** 63
 - 3.3 Control statements** 65
 - The repeat-N-times idiom 65, Iteration and loops 67, Index variables 67, The importance of initialization 69, The read-until-sentinel idiom 69, Building a more practical application 71, Conditional execution and the if statement 74
 - 3.4 An exercise in debugging** 76
 - 3.5 Formatted output** 80
 - Format codes for printf 82, Controlling spacing, alignment, and precision 83
 - 3.6 Crafting a program** 86
 - Programming style 86, Designing for change 88, The #define mechanism 89
- Summary 89
REVIEW QUESTIONS 91
PROGRAMMING EXERCISES 93

4 Statement Forms

99

- 4.1 Simple statements** 100
 - Embedded assignments 102, Multiple assignments 102, Blocks 103
- 4.2 Control statements** 104
- 4.3 Boolean data** 105
 - Relational operators 106, Logical operators 107, Short-circuit evaluation 109, Flags 110, Avoiding redundancy in Boolean expressions 110, An example of Boolean calculation 111
- 4.4 The if statement** 112
 - Single-line if statements 114, Multiline if statements 114, The if-else statement 114, Cascading if statements 115, The ?: operator 115
- 4.5 The switch statement** 117
- 4.6 The while statement** 119
 - Using the while loop 120, Infinite loops 122, Solving the loop-and-a-half problem 123

4.7	The for statement	125
	Nested for loops	126, The relationship between for and while
		129, Using for with floating-point data
	Summary	131
	REVIEW QUESTIONS	132
	PROGRAMMING EXERCISES	133

5 Functions

137

5.1	Using library functions	138
5.2	Function declarations	140
5.3	Writing your own functions	141
	The return statement	142, Putting functions together with main programs
		143, Functions involving internal control structures
		145, Functions that return nonnumeric values
		146, Predicate functions
		148, A predicate function to test for string equality
5.4	Mechanics of the function-calling process	150
	Parameter passing	151, Calling functions from within other functions
5.5	Procedures	163
5.6	Stepwise refinement	165
	Starting at the top	166, Implementing PrintCalendar
		167, Implementing PrintCalendarMonth
		167, Completing the final pieces
	Summary	176
	REVIEW QUESTIONS	177
	PROGRAMMING EXERCISES	178

6 Algorithms

185

6.1	Testing for primality	186
	A simple version of IsPrime	187, Verifying that a strategy represents an algorithm
		187, Demonstrating the correctness of the IsPrime algorithm
		188, Improving algorithmic efficiency
		189, Choosing between alternative implementations
6.2	Computing the greatest common divisor	193
	Brute-force algorithms	194, Euclid's algorithm
		195, Defending the correctness of Euclid's algorithm
		195, Comparing the efficiency of the GCD algorithms
6.3	Numerical algorithms	197
	Successive approximation	198, Reporting errors
6.4	Series expansion	201
	Zeno's paradox	201, Using a series expansion for the square root function
		203, The Taylor series expansion for approximating a square root
		204, Implementing the Taylor series approximation
		205, Staying within the radius of convergence
	207	

6.5	Specifying the size of numeric types	210		
	Integer types	210, Unsigned types	211, Floating-point types	212
	Summary	212		
	REVIEW QUESTIONS	213		
	PROGRAMMING EXERCISES	214		

PART TWO

Libraries and Modular Development **219**

7 Libraries and Interfaces: A Simple Graphics Library **221**

7.1	The concept of an interface	222					
	Interfaces and header files	224					
7.2	An introduction to the graphics library	225					
	The underlying model for graphics.h	225, The functions in the graphics.h interface	227, Initializing the package	231, Drawing straight lines	231, Drawing circles and arcs	233, Obtaining information about the graphics window	235
7.3	Building your own tools	235					
	Defining DrawBox	236, Defining DrawCenteredCircle	237, Switching between absolute and relative coordinates	239, The advantages of defining procedures	240		
7.4	Solving a larger problem	240					
	Using stepwise refinement	241, Implementing the DrawHouse procedure	242, looking for common patterns	243, Finishing the decomposition	245		
	Summary	250					
	REVIEW QUESTIONS	251					
	PROGRAMMING EXERCISES	252					

8 Designing Interfaces: A Random Number Library **259**

8.1	Interface design	260				
	The importance of a unifying theme	261, Simplicity and the principle of information hiding	261, Meeting the needs of your clients	263, The advantages of general tools	263, The value of stability	264
8.2	Generating random numbers by computer	265				
	Deterministic versus nondeterministic behavior	265, Random versus pseudo-random numbers	265, Generating pseudo-random numbers in ANSI C	266, Changing the range of random numbers	267, Generalizing the problem	272
8.3	Saving tools in libraries	274				
	The contents of an interface	275, Writing the random.h interface	276, The random.c implementation	277, Constructing a client program	278, Initializing the random number generator	280

8.4	Evaluating the design of the <code>random.h</code> interface 283	283
	Generating random real numbers 284, Simulating a probabilistic event 285, Including header files in an interface 286, Completing the implementation of the random-number package 286	
8.5	Using the random-number package 286	286
	Summary 290	
	REVIEW QUESTIONS 291	
	PROGRAMMING EXERCISES 292	
9	Strings and Characters	301
9.1	The principle of enumeration 302	302
	Representing enumeration types inside the machine 303, Representing enumeration types as integers 304, Defining new enumeration types 304, Operations on enumeration types 307, Scalar types 307	
9.2	Characters 308	308
	The data type <code>char</code> 308, The ASCII code 308, Character constants 310, Important properties of the ASCII coding scheme 310, Special characters 311, Character arithmetic 312, The <code>ctype.h</code> interface 314, Control statements involving characters 315, Character input and output 316	
9.3	Strings as abstract data 316	316
	Layered abstractions 317, The concept of an abstract type 319	
9.4	The <code>strlib.h</code> interface 319	319
	Determining the length of a string 320, Selecting characters from a string 321, Concatenation 321, Converting characters to strings 322, Extracting parts of a string 323, Comparing one string with another 324, Searching within a string 325, Case conversion 327, Numeric conversion 329, Efficiency and the <code>strlib.h</code> library 330	
	Summary 331	
	REVIEW QUESTIONS 332	
	PROGRAMMING EXERCISES 334	
10	Modular Development	339
10.1	Pig Latin—a case study in modular development 342	342
	Applying top-down design 342, Using pseudocode 343, Implementing <code>TranslateLine</code> 344, Taking spaces and punctuation into account 345, Refining the definition of a word 347, Designing the token scanner 348, Completing the <code>TranslateLine</code> implementation 349, Specifying the scanner module interface 352	
10.2	Maintaining internal state within a module 352	352
	Global variables 355, The dangers of using global variables 356, Keeping variables private to a module 356, Initializing global variables 357, Private functions 359	
10.3	Implementing the scanner abstraction 359	359
	Summary 366	
	REVIEW QUESTIONS 366	
	PROGRAMMING EXERCISES 367	

PART THREE**Compound Data Types 373****11 Arrays 375****11.1 Introduction to arrays 376**

Array declaration 377, Array selection 378, Example of a simple array 379, Changing the index range 381

11.2 Internal representation of data 382

Bits, bytes, and words 382, Memory addresses 383, The sizeof operator 385, Allocation of memory to variables 385, References to elements outside the array bound 386

11.3 Passing arrays as parameters 388

Generalizing the number of elements 390, The mechanics of array parameter transmission 392, Implementing PrintIntegerArray and GetIntegerArray 394, Implementing ReverseIntegerArray 396, Implementing SwapIntegerElements 397

11.4 Using arrays for tabulation 398**11.5 Static initialization of arrays 404**

Automatic determination of array size 408, Determining the size of an initialized array 409, Initialized arrays and scalar types 409

11.6 Multidimensional arrays 410

Passing multidimensional arrays to functions 411, Initializing multidimensional arrays 412

Summary 413

REVIEW QUESTIONS 414

PROGRAMMING EXERCISES 416

12 Searching and Sorting 425**12.1 Searching 426**

Searching in an integer array 426, A more sophisticated example of searching 429, Linear search 431, Binary search 433, Relative efficiency of the search algorithms 435

12.2 Sorting 437

Sorting an integer array 437, The selection sort algorithm 438, Evaluating the efficiency of selection sort 442, Measuring the running time of a program 442, Analyzing the selection sort algorithm 445

Summary 446

REVIEW QUESTIONS 446

PROGRAMMING EXERCISES 447

13 Pointers 453**13.1 Using addresses as data values 455****13.2 Pointer manipulation in C 457**

Declaring pointer variables in C 457, The fundamental pointer operations 458, The special pointer NULL 461

13.3	Passing parameters by reference 461
	Designing a SwapInteger function 465, Using call by reference to return multiple results 466, The danger of overusing call by reference 467
13.4	Pointers and arrays 468
	Pointer arithmetic 469, New capabilities of the <code>++</code> and <code>--</code> operators 473, Incrementing and decrementing pointers 475, The relationship between pointers and arrays 476
13.5	Dynamic allocation 478
	The type <code>void *</code> 478, Dynamic arrays 480, Detecting errors in <code>malloc</code> 481, Freeing memory 481
	Summary 482
	REVIEW QUESTIONS 483
	PROGRAMMING EXERCISES 486

14 Strings Revisited 491

14.1	Conceptual representations of the type <code>string</code> 492
	Strings as arrays 491, Strings as pointers 495, Strings as an abstract type 496, String parameters 497, String variables 497, Differences between pointer and array variables 499, Deciding on a strategy for string representation 502
14.2	The ANSI string library 502
	The <code>strcpy</code> function 504, The <code>strncpy</code> function 507, The <code>strcat</code> and <code>strncat</code> functions 508, The <code>strlen</code> , <code>strcmp</code> , and <code>strncmp</code> functions 509, The <code>strchr</code> , <code> strrchr</code> , and <code>strrstr</code> functions 510, An application of the ANSI string functions 510
14.3	Implementing the <code>strlib</code> library 511
	Implementing the pass-through functions 511, Implementing the <code>strlib</code> allocation functions 514
	Summary 516
	REVIEW QUESTIONS 517
	PROGRAMMING EXERCISES 517

15 Files 523

15.1	Text files 524
15.2	Using files in C 525
	Declaring a <code>FILE *</code> variable 526, Opening a file 526, Performing I/O operations 527, Closing files 528, Standard files 528
15.3	Character I/O 529
	Updating a file 531, Rereading characters in the input file 533
15.4	Line-oriented I/O 536

15.5	Formatted I/O	539
The three forms of printf 539, The scanf functions 539, Reading strings with scanf 541, An example of formatted I/O 543, Limitations on the use of scanf 546		
Summary 547		
REVIEW QUESTIONS	548	
PROGRAMMING EXERCISES	549	

16 Records

557

16.1	The concept of the data record	558
16.2	Using records in C	559
Defining a new structure type 560, Declaring structure variables 560, Record selection 561, Initializing records 561, Simple records 562		
16.3	Combining records and arrays	563
16.4	Pointers to records	566
Defining a pointer-to-record type 566, Allocating storage for record data 568, Manipulating pointers to records 569		
16.5	Building a database of records	570
Creating the employee database 570, Using the database 573		
16.6	Designing a record-based application	574
The importance of using a database 575, Framing the problem 575, Designing the internal representation 576, Designing the external structure 580, Coding the program 581, The value of a data-driven design 588		
Summary 589		
REVIEW QUESTIONS	592	
PROGRAMMING EXERCISES	593	

17 Looking Ahead

601

17.1	Recursion	602
A simple illustration of recursion 603, The Factorial function 604, The recursive leap of faith 609, The recursive paradigm 610, Generating permutations 611, Thinking recursively 614		
17.2	Abstract data types	614
The queue abstraction 615, Representing types in the queue abstraction 616, The queue.h interface 618, Implementing the queue abstraction 620, Alternative implementation of the queue abstraction 622		

17.3 Analysis of algorithms	628
Evaluating algorithmic efficiency	628
Big-O notation	629
Selection sort revisited	630
Divide-and-conquer strategies	631
Merging two arrays	632
The merge sort algorithm	633
The computational complexity of merge sort	635
Comparing quadratic and $N \log N$ performance	636
Summary	637
REVIEW QUESTIONS	638
PROGRAMMING EXERCISES	639

Appendix A. Summary of C Syntax and Structure **647**

A.1	An overview of the compilation process	648
A.2	The C preprocessor	648
A.3	The lexical structure of C programs	650
A.4	Expressions	652
A.5	Statements	653
A.6	Functions	657
A.7	Declarations	658
A.8	Data types	659
A.9	ANSI libraries	662

Appendix B. Library Sources **669**

Index **696**