

Contents

Preface

xxii

Before You Begin

I

1 Introduction to Computers, the Internet and the World Wide Web

I

1.1	Introduction	2
1.2	What Is a Computer?	4
1.3	Computer Organization	4
1.4	Early Operating Systems	5
1.5	Personal, Distributed and Client/Server Computing	6
1.6	The Internet and the World Wide Web	6
1.7	Web 2.0	7
1.8	Machine Languages, Assembly Languages and High-Level Languages	8
1.9	History of C and C++	9
1.10	C++ Standard Library	10
1.11	History of Java	11
1.12	Fortran, COBOL, Pascal and Ada	11
1.13	BASIC, Visual Basic, Visual C++, C# and .NET	12
1.14	Key Software Trend: Object Technology	13
1.15	Typical C++ Development Environment	14
1.16	Notes About C++ and <i>C++ How to Program, 6/e</i>	16
1.17	Test-Driving a C++ Application	17
1.18	Software Technologies	23
1.19	Game Programming with the Ogre Libraries	24
1.20	Future of C++: Open Source Boost Libraries, TR1 and C++0x	25
1.21	Software Engineering Case Study: Introduction to Object Technology and the UML	25
1.22	Wrap-Up	30
1.23	Web Resources	31

2 Introduction to C++ Programming

43

2.1	Introduction	44
2.2	First Program in C++: Printing a Line of Text	44
2.3	Modifying Our First C++ Program	48
2.4	Another C++ Program: Adding Integers	49

x Contents

2.5	Memory Concepts	53
2.6	Arithmetic	55
2.7	Decision Making: Equality and Relational Operators	58
2.8	(Optional) Software Engineering Case Study: Examining the ATM Requirements Specification	63
2.9	Wrap-Up	72

3 Introduction to Classes and Objects 81

3.1	Introduction	82
3.2	Classes, Objects, Member Functions and Data Members	82
3.3	Overview of the Chapter Examples	84
3.4	Defining a Class with a Member Function	84
3.5	Defining a Member Function with a Parameter	88
3.6	Data Members, <i>set</i> Functions and <i>get</i> Functions	91
3.7	Initializing Objects with Constructors	98
3.8	Placing a Class in a Separate File for Reusability	102
3.9	Separating Interface from Implementation	106
3.10	Validating Data with <i>set</i> Functions	112
3.11	(Optional) Software Engineering Case Study: Identifying the Classes in the ATM Requirements Specification	117
3.12	Wrap-Up	125

4 Control Statements: Part I 131

4.1	Introduction	132
4.2	Algorithms	132
4.3	Pseudocode	133
4.4	Control Structures	134
4.5	<i>if</i> Selection Statement	138
4.6	<i>if...else</i> Double-Selection Statement	139
4.7	<i>while</i> Repetition Statement	144
4.8	Formulating Algorithms: Counter-Controlled Repetition	146
4.9	Formulating Algorithms: Sentinel-Controlled Repetition	152
4.10	Formulating Algorithms: Nested Control Statements	163
4.11	Assignment Operators	169
4.12	Increment and Decrement Operators	169
4.13	(Optional) Software Engineering Case Study: Identifying Class Attributes in the ATM System	173
4.14	Wrap-Up	177

5 Control Statements: Part 2 192

5.1	Introduction	193
5.2	Essentials of Counter-Controlled Repetition	193
5.3	<i>for</i> Repetition Statement	195
5.4	Examples Using the <i>for</i> Statement	200

5.5	do...while Repetition Statement	204
5.6	switch Multiple-Selection Statement	206
5.7	break and continue Statements	216
5.8	Logical Operators	218
5.9	Confusing the Equality (==) and Assignment (=) Operators	222
5.10	Structured Programming Summary	223
5.11	(Optional) Software Engineering Case Study: Identifying Objects' States and Activities in the ATM System	228
5.12	Wrap-Up	233

6 Functions and an Introduction to Recursion **244**

6.1	Introduction	245
6.2	Program Components in C++	246
6.3	Math Library Functions	247
6.4	Function Definitions with Multiple Parameters	249
6.5	Function Prototypes and Argument Coercion	254
6.6	C++ Standard Library Header Files	256
6.7	Case Study: Random Number Generation	258
6.8	Case Study: Game of Chance; Introducing enum	264
6.9	Storage Classes	268
6.10	Scope Rules	271
6.11	Function Call Stack and Activation Records	274
6.12	Functions with Empty Parameter Lists	278
6.13	Inline Functions	279
6.14	References and Reference Parameters	281
6.15	Default Arguments	286
6.16	Unary Scope Resolution Operator	288
6.17	Function Overloading	289
6.18	Function Templates	292
6.19	Recursion	294
6.20	Example Using Recursion: Fibonacci Series	298
6.21	Recursion vs. Iteration	301
6.22	(Optional) Software Engineering Case Study: Identifying Class Operations in the ATM System	304
6.23	Wrap-Up	311

7 Arrays and Vectors **333**

7.1	Introduction	334
7.2	Arrays	335
7.3	Declaring Arrays	337
7.4	Examples Using Arrays	337
7.4.1	Declaring an Array and Using a Loop to Initialize the Array's Elements	337
7.4.2	Initializing an Array in a Declaration with an Initializer List	338

7.4.3	Specifying an Array's Size with a Constant Variable and Setting Array Elements with Calculations	340
7.4.4	Summing the Elements of an Array	342
7.4.5	Using Bar Charts to Display Array Data Graphically	343
7.4.6	Using the Elements of an Array as Counters	345
7.4.7	Using Arrays to Summarize Survey Results	346
7.4.8	Using Character Arrays to Store and Manipulate Strings	349
7.4.9	Static Local Arrays and Automatic Local Arrays	351
7.5	Passing Arrays to Functions	354
7.6	Case Study: Class GradeBook Using an Array to Store Grades	358
7.7	Searching Arrays with Linear Search	365
7.8	Sorting Arrays with Insertion Sort	366
7.9	Multidimensional Arrays	369
7.10	Case Study: Class GradeBook Using a Two-Dimensional Array	372
7.11	Introduction to C++ Standard Library Class Template vector	379
7.12	(Optional) Software Engineering Case Study: Collaboration Among Objects in the ATM System	384
7.13	Wrap-Up	391

8 Pointers and Pointer-Based Strings **408**

8.1	Introduction	409
8.2	Pointer Variable Declarations and Initialization	410
8.3	Pointer Operators	411
8.4	Passing Arguments to Functions by Reference with Pointers	414
8.5	Using const with Pointers	418
8.6	Selection Sort Using Pass-by-Reference	425
8.7	sizeof Operator	428
8.8	Pointer Expressions and Pointer Arithmetic	431
8.9	Relationship Between Pointers and Arrays	434
8.10	Arrays of Pointers	438
8.11	Case Study: Card Shuffling and Dealing Simulation	439
8.12	Function Pointers	445
8.13	Introduction to Pointer-Based String Processing	450
8.13.1	Fundamentals of Characters and Pointer-Based Strings	451
8.13.2	String-Manipulation Functions of the String-Handling Library	453
8.14	Wrap-Up	461

9 Classes: A Deeper Look, Part I **487**

9.1	Introduction	488
9.2	Time Class Case Study	489
9.3	Class Scope and Accessing Class Members	494
9.4	Separating Interface from Implementation	496
9.5	Access Functions and Utility Functions	498
9.6	Time Class Case Study: Constructors with Default Arguments	500
9.7	Destructors	506

9.8	When Constructors and Destructors Are Called	507
9.9	Time Class Case Study: A Subtle Trap—Returning a Reference to a <code>private</code> Data Member	510
9.10	Default Memberwise Assignment	513
9.11	(Optional) Software Engineering Case Study: Starting to Program the Classes of the ATM System	515
9.12	Wrap-Up	523

10 Classes: A Deeper Look, Part 2 **530**

10.1	Introduction	531
10.2	<code>const</code> (Constant) Objects and <code>const</code> Member Functions	531
10.3	Composition: Objects as Members of Classes	541
10.4	<code>friend</code> Functions and <code>friend</code> Classes	548
10.5	Using the <code>this</code> Pointer	552
10.6	Dynamic Memory Management with Operators <code>new</code> and <code>delete</code>	557
10.7	<code>static</code> Class Members	559
10.8	Data Abstraction and Information Hiding	565
	10.8.1 Example: Array Abstract Data Type	566
	10.8.2 Example: String Abstract Data Type	567
	10.8.3 Example: Queue Abstract Data Type	567
10.9	Container Classes and Iterators	568
10.10	Proxy Classes	568
10.11	Wrap-Up	572

11 Operator Overloading; String and Array Objects **578**

11.1	Introduction	579
11.2	Fundamentals of Operator Overloading	580
11.3	Restrictions on Operator Overloading	581
11.4	Operator Functions as Class Members vs. Global Functions	583
11.5	Overloading Stream Insertion and Stream Extraction Operators	584
11.6	Overloading Unary Operators	588
11.7	Overloading Binary Operators	588
11.8	Case Study: Array Class	589
11.9	Converting between Types	601
11.10	Case Study: String Class	602
11.11	Overloading <code>++</code> and <code>--</code>	614
11.12	Case Study: A Date Class	616
11.13	Standard Library Class <code>string</code>	620
11.14	<code>explicit</code> Constructors	624
11.15	Wrap-Up	628

12 Object-Oriented Programming: Inheritance **640**

12.1	Introduction	641
------	--------------	-----

12.2	Base Classes and Derived Classes	642
12.3	protected Members	645
12.4	Relationship between Base Classes and Derived Classes	645
12.4.1	Creating and Using a CommissionEmployee Class	646
12.4.2	Creating a BasePlusCommissionEmployee Class Without Using Inheritance	651
12.4.3	Creating a CommissionEmployee–BasePlusCommissionEmployee Inheritance Hierarchy	657
12.4.4	CommissionEmployee–BasePlusCommissionEmployee Inheritance Hierarchy Using protected Data	662
12.4.5	CommissionEmployee–BasePlusCommissionEmployee Inheritance Hierarchy Using private Data	669
12.5	Constructors and Destructors in Derived Classes	677
12.6	public, protected and private Inheritance	685
12.7	Software Engineering with Inheritance	685
12.8	Wrap-Up	687

13 Object-Oriented Programming: Polymorphism **693**

13.1	Introduction	694
13.2	Polymorphism Examples	696
13.3	Relationships Among Objects in an Inheritance Hierarchy	697
13.3.1	Invoking Base-Class Functions from Derived-Class Objects	697
13.3.2	Aiming Derived-Class Pointers at Base-Class Objects	705
13.3.3	Derived-Class Member-Function Calls via Base-Class Pointers	706
13.3.4	Virtual Functions	708
13.3.5	Summary of the Allowed Assignments Between Base-Class and Derived-Class Objects and Pointers	714
13.4	Type Fields and switch Statements	715
13.5	Abstract Classes and Pure virtual Functions	715
13.6	Case Study: Payroll System Using Polymorphism	717
13.6.1	Creating Abstract Base Class Employee	719
13.6.2	Creating Concrete Derived Class SalariedEmployee	722
13.6.3	Creating Concrete Derived Class HourlyEmployee	724
13.6.4	Creating Concrete Derived Class CommissionEmployee	727
13.6.5	Creating Indirect Concrete Derived Class BasePlusCommissionEmployee	729
13.6.6	Demonstrating Polymorphic Processing	731
13.7	(Optional) Polymorphism, Virtual Functions and Dynamic Binding “Under the Hood”	735
13.8	Case Study: Payroll System Using Polymorphism and Runtime Type Information with Downcasting, dynamic_cast, typeid and type_info	739
13.9	Virtual Destructors	742
13.10	(Optional) Software Engineering Case Study: Incorporating Inheritance into the ATM System	743
13.11	Wrap-Up	751

14	Templates	756
14.1	Introduction	757
14.2	Function Templates	758
14.3	Overloading Function Templates	761
14.4	Class Templates	761
14.5	Nontype Parameters and Default Types for Class Templates	768
14.6	Notes on Templates and Inheritance	769
14.7	Notes on Templates and Friends	769
14.8	Notes on Templates and <code>static</code> Members	770
14.9	Wrap-Up	771
15	Stream Input/Output	776
15.1	Introduction	777
15.2	Streams	778
15.2.1	Classic Streams vs. Standard Streams	779
15.2.2	<code>iostream</code> Library Header Files	779
15.2.3	Stream Input/Output Classes and Objects	779
15.3	Stream Output	782
15.3.1	Output of <code>char *</code> Variables	782
15.3.2	Character Output Using Member Function <code>put</code>	782
15.4	Stream Input	783
15.4.1	<code>get</code> and <code>getline</code> Member Functions	784
15.4.2	<code>istream</code> Member Functions <code>peek</code> , <code>putback</code> and <code>ignore</code>	787
15.4.3	Type-Safe I/O	787
15.5	Unformatted I/O Using <code>read</code> , <code>write</code> and <code>gcount</code>	787
15.6	Introduction to Stream Manipulators	788
15.6.1	Integral Stream Base: <code>dec</code> , <code>oct</code> , <code>hex</code> and <code>setbase</code>	789
15.6.2	Floating-Point Precision (<code>precision</code> , <code>setprecision</code>)	790
15.6.3	Field Width (<code>width</code> , <code>setw</code>)	791
15.6.4	User-Defined Output Stream Manipulators	793
15.7	Stream Format States and Stream Manipulators	794
15.7.1	Trailing Zeros and Decimal Points (<code>showpoint</code>)	795
15.7.2	Justification (<code>left</code> , <code>right</code> and <code>internal</code>)	796
15.7.3	Padding (<code>fill</code> , <code>setfill</code>)	798
15.7.4	Integral Stream Base (<code>dec</code> , <code>oct</code> , <code>hex</code> , <code>showbase</code>)	799
15.7.5	Floating-Point Numbers; Scientific and Fixed Notation (<code>scientific</code> , <code>fixed</code>)	800
15.7.6	Uppercase/Lowercase Control (<code>uppercase</code>)	800
15.7.7	Specifying Boolean Format (<code>boolalpha</code>)	802
15.7.8	Setting and Resetting the Format State via Member Function <code>flags</code>	803
15.8	Stream Error States	804
15.9	Tying an Output Stream to an Input Stream	807
15.10	Wrap-Up	807

16	Exception Handling	817
16.1	Introduction	818
16.2	Exception-Handling Overview	819
16.3	Example: Handling an Attempt to Divide by Zero	819
16.4	When to Use Exception Handling	825
16.5	Rethrowing an Exception	826
16.6	Exception Specifications	828
16.7	Processing Unexpected Exceptions	829
16.8	Stack Unwinding	829
16.9	Constructors, Destructors and Exception Handling	831
16.10	Exceptions and Inheritance	832
16.11	Processing new Failures	832
16.12	Class <code>auto_ptr</code> and Dynamic Memory Allocation	836
16.13	Standard Library Exception Hierarchy	839
16.14	Other Error-Handling Techniques	840
16.15	Wrap-Up	841
17	File Processing	848
17.1	Introduction	849
17.2	Data Hierarchy	849
17.3	Files and Streams	851
17.4	Creating a Sequential File	852
17.5	Reading Data from a Sequential File	856
17.6	Updating Sequential Files	863
17.7	Random-Access Files	863
17.8	Creating a Random-Access File	864
17.9	Writing Data Randomly to a Random-Access File	869
17.10	Reading from a Random-Access File Sequentially	871
17.11	Case Study: A Transaction-Processing Program	874
17.12	Overview of Object Serialization	881
17.13	Wrap-Up	881
18	Class <code>string</code> and String Stream Processing	893
18.1	Introduction	894
18.2	<code>string</code> Assignment and Concatenation	895
18.3	Comparing strings	897
18.4	Substrings	900
18.5	Swapping strings	901
18.6	<code>string</code> Characteristics	902
18.7	Finding Substrings and Characters in a <code>string</code>	904
18.8	Replacing Characters in a <code>string</code>	906
18.9	Inserting Characters into a <code>string</code>	908
18.10	Conversion to C-Style Pointer-Based <code>char *</code> Strings	909
18.11	Iterators	911

18.12	String Stream Processing	912
18.13	Wrap-Up	915

19 Searching and Sorting **922**

19.1	Introduction	923
19.2	Searching Algorithms	923
19.2.1	Efficiency of Linear Search	923
19.2.2	Binary Search	925
19.3	Sorting Algorithms	931
19.3.1	Efficiency of Selection Sort	931
19.3.2	Efficiency of Insertion Sort	931
19.3.3	Merge Sort (A Recursive Implementation)	932
19.4	Wrap-Up	939

20 Data Structures **945**

20.1	Introduction	946
20.2	Self-Referential Classes	947
20.3	Dynamic Memory Allocation and Data Structures	948
20.4	Linked Lists	948
20.5	Stacks	963
20.6	Queues	968
20.7	Trees	972
20.8	Wrap-Up	980

21 Bits, Characters, C Strings and structs **1004**

21.1	Introduction	1005
21.2	Structure Definitions	1005
21.3	Initializing Structures	1008
21.4	Using Structures with Functions	1008
21.5	typedef	1008
21.6	Example: High-Performance Card Shuffling and Dealing Simulation	1009
21.7	Bitwise Operators	1012
21.8	Bit Fields	1021
21.9	Character-Handling Library	1025
21.10	Pointer-Based String-Conversion Functions	1031
21.11	Search Functions of the Pointer-Based String-Handling Library	1036
21.12	Memory Functions of the Pointer-Based String-Handling Library	1041
21.13	Wrap-Up	1046

22 Standard Template Library (STL) **1057**

22.1	Introduction to the Standard Template Library (STL)	1059
22.1.1	Introduction to Containers	1060
22.1.2	Introduction to Iterators	1064

22.1.3	Introduction to Algorithms	1069
22.2	Sequence Containers	1071
22.2.1	vector Sequence Container	1072
22.2.2	list Sequence Container	1080
22.2.3	deque Sequence Container	1083
22.3	Associative Containers	1085
22.3.1	multiset Associative Container	1086
22.3.2	set Associative Container	1089
22.3.3	multimap Associative Container	1090
22.3.4	map Associative Container	1092
22.4	Container Adapters	1094
22.4.1	stack Adapter	1094
22.4.2	queue Adapter	1096
22.4.3	priority_queue Adapter	1098
22.5	Algorithms	1099
22.5.1	fill, fill_n, generate and generate_n	1100
22.5.2	equal, mismatch and lexicographical_compare	1101
22.5.3	remove, remove_if, remove_copy and remove_copy_if	1104
22.5.4	replace, replace_if, replace_copy and replace_copy_if	1106
22.5.5	Mathematical Algorithms	1109
22.5.6	Basic Searching and Sorting Algorithms	1112
22.5.7	swap, iter_swap and swap_ranges	1114
22.5.8	copy_backward, merge, unique and reverse	1116
22.5.9	inplace_merge, unique_copy and reverse_copy	1118
22.5.10	Set Operations	1120
22.5.11	lower_bound, upper_bound and equal_range	1123
22.5.12	Heapsort	1125
22.5.13	min and max	1128
22.5.14	STL Algorithms Not Covered in This Chapter	1128
22.6	Class bitset	1130
22.7	Function Objects	1134
22.8	Wrap-Up	1137
22.9	STL Web Resources	1138

23 Game Programming with Ogre

1148

23.1	Introduction	1149
23.2	Installing Ogre, OgreAL and OpenAL	1149
23.3	Basics of Game Programming	1149
23.4	The Game of Pong: Code Walkthrough	1152
23.4.1	Ogre Initialization	1153
23.4.2	Creating a Scene	1162
23.4.3	Adding to the Scene	1164
23.4.4	Animation and Timers	1175
23.4.5	User Input	1176
23.4.6	Collision Detection	1178

23.4.7	Sound	1184
23.4.8	Resources	1185
23.4.9	Pong Driver	1185
23.5	Wrap-Up	1186
23.6	Ogre Web Resources	1187

24 Boost Libraries, Technical Report 1 and C++0x **1197**

24.1	Introduction	1198
24.2	Deitel Online C++ and Related Resource Centers	1198
24.3	Boost Libraries	1199
24.4	Adding a New Library to Boost	1199
24.5	Installing the Boost Libraries	1200
24.6	Boost Libraries in Technical Report 1 (TR1)	1200
24.7	Regular Expressions with the <code>Boost.Regex</code> Library	1203
24.7.1	Regular Expression Example	1204
24.7.2	Validating User Input with Regular Expressions	1206
24.7.3	Replacing and Splitting Strings	1209
24.8	Smart Pointers with <code>Boost.Smart_ptr</code>	1212
24.8.1	Reference Counted <code>shared_ptr</code>	1212
24.8.2	<code>weak_ptr</code> : <code>shared_ptr</code> Observer	1217
24.9	Technical Report 1	1223
24.10	C++0x	1224
24.11	Core Language Changes	1224
24.12	Wrap-Up	1229

25 Other Topics **1238**

25.1	Introduction	1239
25.2	<code>const_cast</code> Operator	1239
25.3	namespaces	1241
25.4	Operator Keywords	1245
25.5	<code>mutable</code> Class Members	1247
25.6	Pointers to Class Members (<code>.*</code> and <code>->*</code>)	1249
25.7	Multiple Inheritance	1251
25.8	Multiple Inheritance and <code>virtual</code> Base Classes	1256
25.9	Wrap-Up	1260

A Operator Precedence and Associativity Chart **1266**

A.1	Operator Precedence	1266
-----	---------------------	------

B ASCII Character Set **1269**

C Fundamental Types **1270**

D	Number Systems	1272
D.1	Introduction	1273
D.2	Abbreviating Binary Numbers as Octal and Hexadecimal Numbers	1276
D.3	Converting Octal and Hexadecimal Numbers to Binary Numbers	1277
D.4	Converting from Binary, Octal or Hexadecimal to Decimal	1277
D.5	Converting from Decimal to Binary, Octal or Hexadecimal	1278
D.6	Negative Binary Numbers: Two's Complement Notation	1280
E	C Legacy Code Topics	1285
E.1	Introduction	1286
E.2	Redirecting Input/Output on UNIX/Linux/Mac OS X and Windows Systems	1286
E.3	Variable-Length Argument Lists	1287
E.4	Using Command-Line Arguments	1290
E.5	Notes on Compiling Multiple-Source-File Programs	1291
E.6	Program Termination with <code>exit</code> and <code>atexit</code>	1293
E.7	Type Qualifier <code>volatile</code>	1295
E.8	Suffixes for Integer and Floating-Point Constants	1295
E.9	Signal Handling	1295
E.10	Dynamic Memory Allocation with <code>calloc</code> and <code>realloc</code>	1298
E.11	Unconditional Branch: <code>goto</code>	1299
E.12	Unions	1300
E.13	Linkage Specifications	1303
E.14	Wrap-Up	1304
F	Preprocessor	1311
F.1	Introduction	1312
F.2	The <code>#include</code> Preprocessor Directive	1312
F.3	The <code>#define</code> Preprocessor Directive: Symbolic Constants	1313
F.4	The <code>#define</code> Preprocessor Directive: Macros	1313
F.5	Conditional Compilation	1315
F.6	The <code>#error</code> and <code>#pragma</code> Preprocessor Directives	1316
F.7	Operators <code>#</code> and <code>##</code>	1317
F.8	Predefined Symbolic Constants	1317
F.9	Assertions	1318
F.10	Wrap-Up	1318
G	ATM Case Study Code	1323
G.1	ATM Case Study Implementation	1323
G.2	Class <code>ATM</code>	1324
G.3	Class <code>Screen</code>	1331
G.4	Class <code>Keypad</code>	1332
G.5	Class <code>CashDispenser</code>	1333

G.6	Class DepositSlot	1335
G.7	Class Account	1336
G.8	Class BankDatabase	1338
G.9	Class Transaction	1342
G.10	Class BalanceInquiry	1344
G.11	Class Withdrawal	1346
G.12	Class Deposit	1351
G.13	Test Program ATMCASEStudy.cpp	1354
G.14	Wrap-Up	1354

H UML 2: Additional Diagram Types **1355**

H.1	Introduction	1355
H.2	Additional Diagram Types	1355

I Using the Visual Studio Debugger **1357**

I.1	Introduction	1358
I.2	Breakpoints and the Continue Command	1358
I.3	Locals and Watch Windows	1363
I.4	Controlling Execution Using the Step Into , Step Over , Step Out and Continue Commands	1366
I.5	Autos Window	1369
I.6	Wrap-Up	1370

J Using the GNU C++ Debugger **1373**

J.1	Introduction	1374
J.2	Breakpoints and the run , stop , continue and print Commands	1374
J.3	print and set Commands	1381
J.4	Controlling Execution Using the step , finish and next Commands	1383
J.5	watch Command	1385
J.6	Wrap-Up	1387

Bibliography **1390**

Index **1396**