

Table of Contents

Preface	1
Goals of this Book	1
Structure of the Book	1
For whom is this Book?	1
Using the Boost Libraries	2
Practical Hints and Guidelines	2
What's Next?	2
1 The Boost C++ Libraries Overview.....	5
1.1 Library Classification	5
1.2 Essential Libraries	6
1.3 Supporting Libraries	7
2 Math Toolkit: Special Functions	10
2.1 Introduction and Objectives.....	10
2.2 An Overview of the Math Toolkit Special Functions	10
2.3 Gamma Functions.....	11
2.3.1 Gamma Function.....	11
2.3.2 Incomplete Gamma Functions and their Inverses	12
2.4 Beta and Error Functions	14
2.5 Incomplete Beta Functions and their Inverses	15
2.6 Factorials and Binomial Coefficients	15
2.7 The Error Function and its Inverse	17
2.8 Bessel Functions.....	18
2.9 Elliptic Integral Functions	20
2.9.1 Elliptic Integrals of the First, Second and Third Kinds.....	20
2.9.2 Complete Elliptic Integrals	20
2.10 Other Functions	22
2.10.1 Zeta Function	22
2.10.2 Exponential Integrals	22
2.10.3 Inverse Hyperbolic Functions	22
2.11 Sinus Cardinal and Hyperbolic Sinus Cardinal Functions.....	23
2.12 Rounding, Truncation and Integer Conversions	24
2.13 Applications and Relationships with STL and Boost	28
2.14 Summary and Conclusions	28
3 Math Toolkit: Orthogonal Functions	29
3.1 Introduction and Objectives.....	29
3.2 An Introduction to Orthogonal Polynomials	29
3.3 Common Properties	29
3.4 Laguerre and Hermite Polynomials	33
3.5 Spherical Harmonics	35
3.6 Chebychev Polynomials	36
3.7 Computing the Roots of Bessel Functions.....	37
3.8 Statistics Distributions	39
3.9 Summary and Conclusions	42
4 Date and Time	43
4.1 Introduction and Objectives.....	43
4.2 Overview of Concepts and Functionality	43
4.3 Gregorian Time	44
4.3.1 Date	44

4.3.2	Date Duration.....	47
4.3.3	Date Period	49
4.3.4	Date Iterators.....	52
4.4	Creating User-defined Utilities.....	53
4.4.1	A generic Date Iterator using Boost Variant.....	53
4.4.2	General Schedules of Date Period.....	55
4.4.3	International Money Market (IMM) Dates in Trading Systems	56
4.5	Posix Time System	57
4.6	Local Time	59
4.7	Date Generators and Algorithms	60
4.8	Date/Time I/O and Serialisation	61
4.9	Set-Like Operations.....	63
4.10	Application Areas	64
4.11	Summary and Conclusions	64
5	Some Building Block Data Structures and Libraries	66
5.1	Introduction and Objectives.....	66
5.2	Timer Library	66
5.3	Uuid (Universally Unique Identifiers).....	68
5.3.1	Creating Uuids	68
5.3.2	Other Functionality	69
5.4	Dynamic Bitset and STL Bitsets	70
5.4.1	Boolean Operations.....	72
5.4.2	Type Conversions	73
5.4.3	dynamic_bitset	73
5.4.4	Applications of Dynamic Bitsets	73
5.5	Circular Buffer.....	74
5.5.1	The Boost Circular Buffer Class	75
5.5.2	Using Circular Buffer: Producer-Consumer Pattern	77
5.6	Summary and Conclusions	80
6	Matrix Algebra in Boost Part I: uBLAS Data Structures	81
6.1	Introduction and Objectives.....	81
6.2	BLAS (Basic Linear Algebra Subprograms)	81
6.2.1	BLAS Level 1	82
6.2.2	BLAS Level 2	82
6.2.3	BLAS Level 3	82
6.3	Dense Vectors.....	83
6.3.1	Creating and Accessing Dense Vectors	84
6.3.2	Special Dense Vectors	85
6.4	Sparse Vectors.....	86
6.4.1	Mapped Vector.....	86
6.4.2	Compressed Vector.....	88
6.4.3	Coordinate Vector.....	89
6.5	Dense Matrices	89
6.5.1	Creating and Accessing Dense Matrices	90
6.5.2	Special Dense Matrices	91
6.6	Other Kinds of Matrices	92
6.6.1	Sparse Matrices	92
6.6.2	Triangular Matrices.....	94
6.6.3	Triangular Adaptor.....	94
6.7	Summary and Conclusions	95

7	Matrix Algebra in Boost Part II: Advanced Features and Applications.....	96
7.1	Introduction and Objectives.....	96
7.2	Patterned Matrices	96
7.2.1	Symmetric Matrices	96
7.2.2	Hermitian Matrices	99
7.2.3	Banded Matrices	100
7.3	Vector and Matrix Proxies.....	101
7.3.1	Vector Range	101
7.3.2	Vector Slice.....	102
7.3.3	Matrix Proxies: Rows and Columns	102
7.3.4	Matrix Views: What are Options?.....	103
7.4	Vector Expressions	105
7.5	Matrix Expressions	108
7.6	Applying uBLAS: Solving Linear Systems of Equations.....	110
7.6.1	Conjugate Gradient Method (CGM)	110
7.6.2	LU Decomposition.....	112
7.6.3	Cholesky Decomposition	114
7.7	Applications of uBLAS	117
7.8	Summary and Conclusions	117
8	An Introduction to Network Programming Concepts and Protocols.....	118
8.1	Introduction and Objectives.....	118
8.2	Overview of OSI and TCP/IP Protocols and Services	118
8.3	Internet Addresses	120
8.3.1	Some Special IP Addresses	121
8.4	Internet Addresses in Boost.....	121
8.4.1	Implementing Endpoints	123
8.5	Domain Name System (DNS)	124
8.6	Client-Server Model of Interaction.....	125
8.6.1	Connectionless and Connection-Oriented Servers	126
8.7	The Socket Interface	126
8.8	Protocol for Acknowledgement and Retransmission.....	127
8.9	Summary and Conclusions	128
9	Boost ASIO: Synchronous Operations.....	129
9.1	Introduction	129
9.1.1	Testing Network Applications and Troubleshooting	130
9.2	DNS	131
9.2.1	Reverse DNS.....	133
9.3	Buffers	133
9.4	UDP	135
9.4.1	Example: UDP Echo Server.....	136
9.4.2	Example: UDP Echo Client	137
9.5	TCP	138
9.5.1	Example: TCP Echo Server	138
9.5.2	Example: TCP Echo Client	141
9.5.3	Using Socket IOStreams to improve Ease of Use	142
9.6	Summary and Conclusions	144
10	Boost ASIO: Asynchronous Operations.....	145
10.1	Introduction	145
10.2	Timers.....	146
10.2.1	Synchronous Deadline Timer.....	146

10.2.2	Asynchronous Deadline Timer	146
10.2.3	Binding Arguments	147
10.2.4	Binding to Member Functions	148
10.2.5	Thread Pooling and Synchronising Threads	149
10.3	Asynchronous UDP Server.....	151
10.4	Asynchronous TCP Server	153
10.4.1	The ASyncEchoServer Class	154
10.4.2	The ASyncConnection Class	155
10.5	Thread-Pooled Asynchronous TCP Server.....	157
10.6	CRC Checksums and Time-outs.....	159
10.6.1	Message and CRC	159
10.6.2	Heartbeats and Time-outs	162
10.6.3	Sending messages	163
10.6.4	Echo Client Implementation	163
10.7	Summary and Conclusions	173
11	Boost Interprocess: IPC Mechanisms	174
11.1	Introduction and Objectives.....	174
11.2	Persistence of IPC Mechanisms	174
11.3	Shared Memory	175
11.4	Memory Mapped File	178
11.5	Advanced Mapped Regions.....	179
11.5.1	Pointers in Mapped Regions	179
11.5.2	Static Members in Mapped Regions	182
11.6	Managed Memory Segments	183
11.6.1	Managed Shared Memory	183
11.6.2	Managed Memory Mapped File	184
11.6.3	Allocating Memory Fragments in Managed Memory.....	185
11.6.4	Allocating Objects in Managed Memory	185
11.6.5	Synchronisation of Object Construction and Retrieving.....	187
11.6.6	Composite Objects	187
11.6.7	Synchronising Composite Object Creation	190
11.6.8	Using Allocators	191
11.6.9	Other Allocators.....	195
11.6.10	STL Compatible Containers.....	195
11.6.11	Managed External Buffer and Managed Heap Memory	198
11.6.12	Other Managed Segment Functionality	201
11.7	Summary and Conclusions	201
12	Boost Interprocess II: Process Synchronisation	202
12.1	Introduction and Objectives.....	202
12.2	Mutexes	202
12.2.1	Mutex Operations.....	203
12.2.2	Named Mutex.....	203
12.2.3	Anonymous Mutex.....	204
12.2.4	Scoped Lock.....	206
12.3	Condition Variables.....	208
12.4	Message Queue.....	212
12.5	Semaphores	213
12.6	Upgradable Mutexes.....	217
12.6.1	Introduction to Upgradable Mutexes	217
12.6.2	Upgradable Mutexes in Boost Interprocess	218

12.6.3	Lock Transfer	221
12.7	Summary and Conclusions	222
13	Interval Arithmetic	223
13.1	Introduction and Objectives.....	223
13.2	What is Interval Analysis, Interval Arithmetic, Interval Mathematics?	223
13.3	Interval Arithmetic: Mathematical Foundations	226
13.4	Boost Interval Library: Functionality and Initial Examples	227
13.5	Application: Matrix Computations with Intervals	230
13.6	Function Evaluation in Interval	232
13.7	Advanced Functions and Related Data Structures.....	234
13.8	Solution of Nonlinear Equations	236
13.9	Summary and Conclusions	238
14	User-defined Memory Allocation: Boost Pool	239
14.1	Introduction and Objectives.....	239
14.2	Dynamic Memory Allocation in C++ and STL Allocator Requirements	239
14.3	Pool Concepts	240
14.3.1	Simple Segregated Storage Concept	241
14.4	Pool.....	242
14.5	Singleton Pool	244
14.6	Object Pool	246
14.7	Pool Allocator and Fast Pool Allocator	247
14.8	Summary and Conclusions	248
15	An Introduction to Graph Theory and Graph Algorithms	249
15.1	Introduction and Objectives.....	249
15.2	Directed and Undirected Graphs; Terms and Definitions	249
15.2.1	Further Properties of Graphs and Digraphs.....	250
15.2.2	Paths and Connectivity	251
15.2.3	Special Types of Graphs	252
15.3	Graph Data Structures	253
15.4	Operations on Graphs	256
15.5	Minimum Spanning Tree (MST) Problems	256
15.6	Depth-First and Breadth-First Searches in Graphs	258
15.7	Shortest Path Problems	259
15.8	Connected Components	261
15.9	Applications of Graph Theory	262
15.9.1	Project Planning	262
15.9.2	Some Specific Graphs	265
15.9.3	Eulerian, de Bruijn and Hamiltonian Digraphs	266
15.9.4	Random Graphs	267
15.10	Flow Networks	268
15.11	Summary and Conclusions	270
16	The Boost Graph Library Data Structures and Fundamental Algorithms	271
16.1	Introduction and Objectives.....	271
16.2	An Overview of the Functionality in BGL	271
16.3	Boost Property Map Library	271
16.3.1	Boost Property Map Category Tags and Traits	272
16.3.2	Property Map Types.....	273
16.4	An Introduction to Data Structures in BGL.....	274
16.5	Auxiliary Classes.....	278

16.6	Minimum Spanning Tree (MST) Algorithms	281
16.6.1	Kruskal Algorithm	281
16.6.2	Prim Algorithm	282
16.7	Shortest Path Algorithms	283
16.7.1	Dijkstra's Algorithm	283
16.7.2	Bellman-Ford Algorithm.....	285
16.8	Summary and Conclusions	287
17	The Boost Graph Library (BGL) Advanced Algorithms	288
17.1	Introduction and Objectives.....	288
17.2	More Shortest-Path Algorithms.....	288
17.2.1	Floyd-Warshall Algorithm	288
17.2.2	Johnson Algorithm.....	289
17.2.3	Transitive Closure	291
17.3	Connected Component Algorithms	292
17.3.1	Connected Components	292
17.3.2	Biconnected Components and Articulation Points.....	296
17.3.3	Incremental Connected Components	297
17.3.4	Strong Components.....	300
17.4	Graph Structure Comparison	301
17.4.1	Isomorphic Graphs	301
17.5	Extending Algorithms with Visitor	304
17.6	Basic Graph Algorithms	305
17.7	Other Graph Algorithms in BGL	306
17.7.1	Sparse Matrix Ordering Algorithms.....	307
17.7.2	Random Graphs	309
17.8	Summary and Conclusions	310
18	Interval Container Library	311
18.1	Introduction and Objectives.....	311
18.2	Overview of the ICL.....	311
18.3	What Kinds of Intervals?	311
18.3.1	Statically Bound Interval Types.....	313
18.3.2	Modelling Intervals by Parameter Variation	314
18.3.3	Intervals and Temporal Types.....	315
18.4	Interval Sets and Interval Maps	316
18.5	Interval Combining Styles	318
18.5.1	Splitting Interval Containers	318
18.5.2	Separating Interval Containers	319
18.5.3	Iterators for Interval Sets and Maps	320
18.6	Some '101' Examples.....	320
18.7	Applying ICL to Managements Information Systems (MIS)	322
18.7.1	Daily Planning	324
18.8	Summary and Conclusions	325
19	Boost Functional Factory	326
19.1	Introduction and Objectives.....	326
19.2	An Overview of GOF Patterns	326
19.2.1	Strengths and Limitations of GOF Patterns	328
19.3	An Example: Traditional Windows Factories	328
19.4	Boost Functional Factory.....	330
19.5	Function Factory with Smart Pointers	331
19.6	R-Value Arguments.....	332

19.7	Allocators	332
19.8	Value Factory	333
19.9	Factory with Algorithms.....	334
19.10	Summary and Conclusions	334
	Bibliography	335
	Index	336
	Book Registration Form – Boost Volume II	343
	User Agreement	345