

Contents

List of Figures	xiii
Preface	xix
Part I Basics	
1. PRINCIPLES AND ISSUES	3
1.1 Illustrative Examples	4
1.2 The R-Mesh at a Glance	9
1.3 Important Issues	11
Problems	13
Bibliographic Notes	14
2. THE RECONFIGURABLE MESH: A PRIMER	17
2.1 The Reconfigurable Mesh	17
2.1.1 The (Two-Dimensional) R-Mesh	18
2.2 Expressing R-Mesh Algorithms	22
2.3 Fundamental Algorithmic Techniques	23
2.3.1 Data Movement	24
2.3.2 Efficiency Acceleration—Adding Bits	27
2.3.3 Neighbor Localization—Chain Sorting	33
2.3.4 Sub-R-Mesh Generation—Maximum Finding	40
2.3.5 Distance Embedding—List Ranking	43
2.3.6 Connectivity Embedding— s - t Connectivity	46
2.3.7 Function Decomposition—Adding N Numbers	49
2.4 Why an R-Mesh?	58
Problems	58
Bibliographic Notes	68

3. MODELS OF RECONFIGURATION	71
3.1 The Reconfigurable Mesh—A Second Coat	71
3.1.1 Restricted Bus Structure	72
3.1.2 Word Size	75
3.1.3 Accessing Buses	77
3.1.4 Higher Dimensions	79
3.1.5 One-Way Streets	86
3.2 More Ways to Reconfigure	90
3.2.1 Reconfigurable Network	91
3.2.2 Reconfigurable Multiple Bus Machine	91
3.2.3 Optical Models	92
3.2.4 Reconfiguration in FPGAs	96
3.3 How Powerful Is Reconfiguration?	98
Problems	100
Bibliographic Notes	109
 Part II Algorithms	
4. ARITHMETIC ON THE R-MESH	117
4.1 Starter Set	117
4.1.1 Conversion among Number Formats	118
4.1.2 Floating Point Numbers	119
4.1.3 Maximum/Minimum	120
4.2 The Foundation	122
4.2.1 Addition	123
4.2.2 Multiplication	134
4.2.3 Division	139
4.3 Multiplying Matrices	139
4.3.1 Matrix-Vector Multiplication	140
4.3.2 Matrix Multiplication	142
4.3.3 Sparse Matrix Multiplication	143
Problems	146
Bibliographic Notes	149
5. SORTING AND SELECTION	153
5.1 Sorting on an R-Mesh	154
5.2 A Sub-Optimal Sorting Algorithm	155
5.3 An Optimal Sorting Algorithm	156

<i>Contents</i>	ix
5.3.1 Constant Time Sorting	156
5.3.2 Area-Time Tradeoffs	158
5.3.3 Sorting on Three-Dimensional R-Meshes	159
5.4 Selection on an R-Mesh	162
5.4.1 Indexing Schemes	162
5.4.2 An Outline of the Selection Algorithm	163
5.4.3 The Selection Algorithm	165
5.4.4 The Sorted Sample Algorithm	167
5.4.5 Complexity Analysis	171
Problems	173
Bibliographic Notes	176
6. GRAPH ALGORITHMS	179
6.1 Graph Representations	180
6.2 Algorithms for Trees	180
6.2.1 Euler Tour	181
6.2.2 Euler Tour Applications	182
6.2.3 Tree Reconstruction	186
6.3 Algorithms for Graphs	192
6.3.1 Minimum Spanning Tree	192
6.3.2 Connectivity Related Problems	193
6.4 Algorithms for Directed Graphs	198
6.4.1 The Algebraic Path Problem Approach	198
6.4.2 Directed Acyclic Graphs	202
6.5 Efficient List Ranking	206
6.5.1 The Deterministic Method	207
6.5.2 The Randomized Approach	212
Problems	218
Bibliographic Notes	229
7. COMPUTATIONAL GEOMETRY & IMAGE PROCESSING	231
7.1 Computational Geometry	232
7.1.1 Convex Hull	232
7.1.2 Convex Polygon Problems	244
7.1.3 Nearest Neighbors	249
7.1.4 Voronoi Diagrams	250
7.1.5 Euclidean Minimum Spanning Tree	253
7.1.6 Triangulation	254

7.2	Image Processing	254
7.2.1	Basics	255
7.2.2	Histogram	257
7.2.3	Quadtree	259
7.2.4	Moments	265
7.2.5	Image Transforms	267
	Problems	268
	Bibliographic Notes	271
Part III Simulations and Complexity		
8.	MODEL AND ALGORITHMIC SCALABILITY	277
8.1	Scaling Simulation on a Smaller Model Instance	278
8.1.1	Scaling the HVR-Mesh	281
8.1.2	Scaling the LR-Mesh	283
8.1.3	Scaling the FR-Mesh	289
8.1.4	Scaling the R-Mesh	294
8.2	Self-Simulation on a Larger Model Instance	298
8.3	Scaling Algorithms	299
8.3.1	Degree of Scalability	300
8.3.2	Matrix Multiplication	301
8.3.3	Matrix-Vector Multiplication	302
	Problems	307
	Bibliographic Notes	310
9.	COMPUTATIONAL COMPLEXITY OF RECONFIGURATION	313
9.1	Mapping Higher Dimensions to Two Dimensions	314
9.1.1	Lower Bound on Mapping	315
9.1.2	Mapping d Dimensions to Two Dimensions	315
9.1.3	Separation of the One-Dimensional R-Mesh from Higher Dimensional R-Meshes	320
9.2	Simulations between Bit and Word Models	320
9.3	Relations to the PRAM	322
9.4	Loosen Up—Polynomially Bounded Models	326
9.5	Segmenting and Fusing Buses	326
9.5.1	The Reconfigurable Multiple Bus Machine	327
9.5.2	Relative Power of Polynomially Bounded Models	329

<i>Contents</i>	xi
9.5.3 Relating the B-RMBM and the PRAM	332
9.5.4 Relating the S-RMBM, HVR-Mesh, and PRAM	333
9.5.5 Relating the F-RMBM, E-RMBM, and R-Mesh	336
9.6 Relations to Turing Machines and Circuits: Hierarchy	340
9.6.1 Turing Machine Definitions	340
9.6.2 Circuit Definitions	340
9.6.3 Complexity Classes	341
9.6.4 Relations to Turing Machines	342
9.6.5 Relations to Circuits	346
Problems	348
Bibliographic Notes	351
 Part IV Other Reconfigurable Architectures	
10. OPTICAL RECONFIGURABLE MODELS	357
10.1 Models, Models Everywhere	358
10.1.1 The LARPBS Model	360
10.1.2 Other Models	364
10.2 Basic Algorithmic Techniques	368
10.2.1 Permutation Routing	369
10.2.2 Binary Prefix Sums	369
10.3 Algorithms for Optical Models	374
10.3.1 Basic Results	374
10.3.2 Sorting and Selection	377
10.3.3 Multiple Addition	383
10.3.4 Matrix Multiplication	383
10.3.5 h -Relations	387
10.4 Complexity of Optical Models	394
10.4.1 Simulating PRAMs	395
10.4.2 Equivalence of One-Dimensional Models	396
10.4.3 Relating the PR-Mesh and the LR-Mesh	399
10.4.4 Relating Two-Dimensional Optical Models	403
Problems	408
Bibliographic Notes	412
11. RUN-TIME RECONFIGURATION	417
11.1 FPGA Background	419
11.1.1 FPGA Structure	419

11.1.2	FPGA System Model	422
11.2	Run-Time Reconfiguration Concepts and Examples	424
11.2.1	Basic Concepts	424
11.2.2	Examples: Specific Problems	428
11.2.3	Examples: Generic Problems	434
11.3	Hardware Operating System	438
11.3.1	Dynamic Instruction Set Computer	439
11.3.2	RAGE	440
11.3.3	Configuration Controllers	441
11.3.4	Task Compaction	442
11.4	Alternative Implementations	445
11.4.1	Early Configurable Computing Machines	446
11.4.2	Other Directions in RTR	447
11.5	Designing Implementable R-Mesh Algorithms	450
11.5.1	Bus Delay	451
11.5.2	An LR-Mesh Implementation	455
11.5.3	Retooling Algorithms for the Bends-Cost Measure	458
	Problems	461
	References	471
	Index	499