

PARALLEL SUPERCOMPUTING: METHODS, ALGORITHMS and APPLICATIONS

EDITED BY

Graham F. Carey



WILEY SERIES IN PARALLEL COMPUTING

Contents

1	Performance Limits for Parallel Processors	1
1.1	Introduction	1
1.2	Parallel Speedup	2
1.3	The Sandia Experiments	4
1.4	Sullivan's Theorems	9
1.5	Worley's Limit	13
1.6	Conclusion	15
2	Overview of Current Developments in Parallel Architectures	17
2.1	Introduction	17
2.2	Overview of Parallel Systems	20
2.3	Some Representative Parallel Systems	25
3	Machine Independent Parallel Numerical Algorithms	33
3.1	Introduction	33
3.2	Parallel Communication Primitives	34
3.3	Reduction to Upper Hessenberg Form	36
3.4	Other Applications	38
3.5	Limitations and Extensions	41
3.6	Conclusion	43
4	A Linear Algebra Library for High-Performance Computers	45
4.1	Introduction and Objectives	45
4.2	Use of the BLAS	46
4.3	Block Algorithms	47
4.4	Target Machines	50
4.5	Programming Language and Style	51
4.6	User Interface and Documentation	52

5	Parallel Sub-Domain and Element-by-Element Techniques	57
5.1	Scientific Computing	57
5.2	Methods and Algorithms	58
5.3	Domain Decomposition Concepts	60
5.4	Iteration and Block Methods	63
5.5	Adaptive Grid Refinement	68
5.6	Sample Results	69
6	Pseudo-Boundary Conditions to Accelerate Parallel Schwarz Methods	77
6.1	Domain Decomposition Methods	77
6.2	Convergence Analysis	79
6.3	Computational Experiment	83
6.4	Three-Subdomains	84
6.5	Conclusions	86
7	The Search for "High-Level" Parallelism for Iterative Sparse Linear System Solvers	89
7.1	Introduction	89
7.2	Parallel Iteration	91
7.3	Residual Decomposition	92
7.4	Minimization Procedures	95
7.5	Related Linear Systems	97
7.6	Time Dependent Problems	99
7.7	Rational Iteration	100
8	Pipelined Successive Overrelaxation	107
8.1	Introduction	107
8.2	The SOR Method	107
8.3	Previous Work	108
8.4	The Pipeline SOR Method	109
8.5	Experimental Results	112
8.6	Conclusion	115
9	Some Parallel Algorithms on the Four Processor Cray X-MP4 Supercomputer	121
9.1	Introduction	121
9.2	Microtasked ITPACK	121
9.3	Parallel Line Jacobi PCG	124
9.4	Parallel <i>LU</i>	128
9.5	Conclusions	131

10 A SLAP for the Masses	135
10.1 Introduction	135
10.2 Data Structures	136
10.3 Preconditioners	138
10.4 Iterative Methods	140
10.5 Utility Routines	144
10.6 Results	144
10.7 Future Parallel Extensions	149
10.8 Conclusions	154
11 Parallel Direct Solution of Sparse Linear Systems	157
11.1 Introduction	157
11.2 Sequential Algorithms	158
11.3 Parallel Sparse Matrix	161
11.4 Identifying Parallelism	163
11.5 Concluding Remarks	170
12 Node Orderings and Concurrency in Structurally-Symmetric Sparse Problems	177
12.1 Introduction	177
12.2 Measures of Achievable Parallelism	179
12.3 Orderings	182
12.4 Results	184
12.5 Conclusions	187
13 A Multilevel Solution Method for Nine-Point Difference Approximations	191
13.1 Introduction	191
13.2 Two-Level Hierarchical Basis and Matrices	195
13.3 Preconditioner	199
13.4 Relative Condition Number	201
13.5 Concluding Remarks	204
14 A Structural Analysis Algorithm for Massively Parallel Computers	207
14.1 Introduction	207
14.2 Performance Models	208
14.3 The NCUBE Parallel Computer	211
14.4 Structural Analysis Methods	212
14.5 Summary	220

15	Parallel Spectral Element Methods for Viscous Flow	223
15.1	Introduction	223
15.2	Spectral Element Discretizations	223
15.3	Iterative Solution Procedures	227
15.4	Parallelism	228
15.5	Navier-Stokes Calculations	232
16	A Multiplier/Element by Element Method for a Class of Non-linear Boundary Value Problems	239
16.1	Introduction	239
16.2	Formulation of the Problems	239
16.3	Variational Formulation	241
16.4	A Decomposition Principle	242
16.5	Algorithms	243
16.6	Time Relaxation Interpretation	244
16.7	Application to Example 1	245
16.8	Finite Element Implementation	246
16.9	Application to Visco-Plastic Flow	248
16.10	Yang-Mills Equations	250
16.11	Conclusion	253
17	Exploring Parallel Algorithms Having No Serial Analogues	255
17.1	Introduction	255
17.2	Description	257
17.3	Results and Analysis	261
17.4	TPCS as a Serial Analogue	264
17.5	Concluding Remarks	265
18	Application of Vectorization and Microtasking for Reservoir Simulation	267
18.1	Introduction	267
18.2	Chemical Flooding Simulator	268
18.3	Vectorization of UTCHEM	270
18.4	Microtasking Results	275
18.5	Conclusions	280