

Table of Contents

Preface v

Contributors xv

Ch. 1. Signal Processing for Linear Instrumental Systems with Noise: A General Theory with Illustrations from Optical Imaging and Light Scattering Problems 1

M. Bertero and E. R. Pike

1. Introduction 1
 2. Compact operators and singular systems 4
 3. Linear filtering and regularization 9
 4. Diffraction-limited imaging 16
 5. Recovery of exponential relaxation rates and Laplace transform inversion 25
 6. Sampling theorem and resolution limits 31
 7. Concluding remarks 43
- References 43

Ch. 2. Boundary Implication Results in Parameter Space 47

N. K. Bose

1. Introduction 47
 2. Interval polynomials and stability 47
 3. Interval rational functions and PR, PC properties 50
 4. Transcendental functions characterizing interval delay-differential systems 51
 5. Robust frequency response 54
 6. Interval multivariate polynomial positivity 54
 7. Conclusions 54
- References 56

Ch. 3. Sampling of Bandlimited Signals: Fundamental Results and Some Extensions 59

J. L. Brown, Jr.

- Introduction 59
1. Notation and general considerations 61

- 2. Multi-channel sampling 74
- 3. Prediction from past samples 86
- 4. Nonuniform sampling 89
- References 99

Ch. 4. Localization of Sources in a Sector: Algorithms and Statistical Analysis 103

K. Buckley and X.-L. Xu

- 1. Source localization in a sector 103
- 2. The array observation 106
- 3. Eigenspace spatial-spectrum estimators 107
- 4. Statistical analysis of eigenspace based location estimators 111
- 5. Comparison and study of location estimators 115
- 6. Summary 123
- References 123

Ch. 5. The Signal Subspace Direction-of-Arrival Algorithm 127

J. A. Cadzow

- 1. Introduction 127
- 2. Snapshot vector model: One incident wavefield 128
- 3. General snapshot vector model for multiple incident wavefields 132
- 4. Covariance domain modeling 133
- 5. Signal subspace DOA estimation 135
- 6. Parameter reduction by a decoupling operation 137
- 7. Nonlinear programming solution 140
- 8. Jacobian matrix determination 142
- 9. Estimate of the number of incident wavefields 144
- 10. Initial composite source DOA selection 145
- 11. Linear arrays with equispaced sensors 148
- 12. Numerical examples 149
- 13. Conclusions 156
- Acknowledgment 156
- References 156

Ch. 6. Digital Differentiators 159

S. C. Dutta Roy and B. Kumar

List of abbreviations and symbols 159

- 1. Introduction 161
- 2. IIR digital differentiators 163
- 3. Differentiators for stochastic processes 166
- 4. Earlier work on design of FIR differentiators 168
- 5. FIR digital differentiators 171

- 6. Differentiators for low frequencies: $H_\ell(\omega)$ 172
- 7. Differentiators for midband frequencies 175
- 8. Differentiators for high frequencies: $H_h(\omega)$ 179
- 9. Variable frequency range differentiators: $H_m(\omega)$, $H_\ell(m)$ 182
- 10. DDs which are maximally linear at spot frequency $\omega = \pi/p$, p integer: $H_p(\omega)$ 184
- 11. Relationships between digital differentiators and other filters 187
- 12. Second and higher degree differentiators 193
- 13. Concluding comments 199
 - Acknowledgment 201
 - References 201

Ch. 7. Orthogonal Decompositions of 2D Random Fields and their Applications for 2D Spectral Estimation 207

J. M. Francos

- 1. Introduction 207
- 2. Definitions and fundamental properties 208
- 3. Homogeneous fields 213
- 4. The concept of multiple total order definitions 216
- 5. Approximations and applications 220
- 6. Summary and discussion 226
 - Acknowledgments 227
 - References 227

Ch. 8. VLSI in Signal Processing 229

A. Ghouse

Introduction 229

PART 1. DEVELOPMENT OF SPECIAL-PURPOSE PROCESSORS FOR SIGNAL PROCESSING 230

Introduction 230

- 1.1. Considerations in the design of special-purpose processors 230
- 1.2. Emergence of the TMS320 family of DSP processors 231
- 1.3. Advanced special-purpose processors for signal processing 242
- 1.4. Conclusion 249
 - References to Part 1 249

PART 2. HARDWARE DESIGN METHODOLOGIES FOR SIGNAL PROCESSING 249

Introduction 249

- 2.1. Considerations in the hardware realization of a task 249
- 2.2. Derivation of dedicated hardware structures 251
- 2.3. Hardware realization of existing signal processing algorithms 251
- 2.4. Hardware realization of signal processing operations 258
- 2.5. Conclusion 267
 - References to Part 2 267

Ch. 9. Constrained Beamforming and Adaptive Algorithms 269

L. C. Godara

List of symbols and acronyms 269

1. Introduction 272

PART 1. CONSTRAINED BEAMFORMING 273

1. Array signal model 273
2. Steering vector representation 275
3. Narrowband beamformer structure 275
4. Conventional processor 276
5. Optimal processor 280
6. Effect of correlation 282
7. Effect of errors 288
8. PIC processor 300
9. Comparison of two processors 318
10. Effect of look direction errors 320

PART 2. CONSTRAINED LMS ALGORITHM 325

11. Standard LMS algorithm 326
12. Perturbation algorithms 332
13. Structured gradient algorithm 341
14. Recursive LMS algorithm 348
15. Improved LMS algorithm 349
- References 353

Ch. 10. Bispectral Speckle Interferometry to Reconstruct Extended Objects from Turbulence-Degraded Telescope Images 355

*D. M. Goodman, T. W. Lawrence, E. M. Johansson
and J. P. Fitch*

1. Introduction 355
2. Statistical characterization of the effect of turbulence on astronomical imaging 356
3. Signal processing issues 375
4. Experimental results 383
5. Improved algorithms 394
- References 395

Ch. 11. Multi-Dimensional Signal Processing 399

K. Hirano and T. Nomura

1. Introduction 399
2. 2D digital signals and systems 399
3. Analysis of 2D digital systems 422
4. Design of 2D digital systems 437

- 5. Application areas 465
- 6. Conclusion and further reading 477
- References 478

Ch. 12. On the Assessment of Visual Communication 479
*F. O. Huck, C. L. Fales, R. Alter-Gartenberg and
Z. Rahman*

- 1. Introduction 479
- 2. Image gathering and display 482
- 3. Image gathering and restoration 489
- 4. Image gathering and coding 509
- 5. Optical design 517
- 6. Summary 527
- Acknowledgement 529
- References 529

Ch. 13. VLSI Implementations of Number Theoretic Concepts with
Applications in Signal Processing 535
G. A. Jullien, N. M. Wigley and J. Reilly

- 1. Introduction 535
- 2. Basic number theory and signal processing 537
- 3. Inner products and finite rings 539
- 4. Multivariate polynomial representations and general theory 543
- 5. Implementation examples 553
- 6. VLSI implementation of pipelined residue computations 560
- 7. Conclusions 574
- Acknowledgment 575
- References 575

Ch. 14. Decision-level Neural Net Sensor Fusion 577
R. Y. Levine and T. S. Khuon

- 1. Introduction 577
- 2. SXOR benchmark for neural net data fusion 581
- 3. Firefly sensor fusion experiment 594
- 4. Conclusion 606
- Appendix A 607
- Appendix B 617
- Acknowledgment 618
- References 618

Ch. 15. Statistical Algorithms for Noncausal Gauss–Markov Fields 623*J. M. F. Moura and N. Balram*

1. Introduction 623
2. Motivation 625
3. Statistical approach: Markov random fields 632
4. Smoothing of 2D fields 654
5. Applications 677
6. Summary 688
- References 689

Ch. 16. Subspace Methods for Directions-of-Arrival Estimation 693*A. Paulraj, B. Ottersten, R. Roy, A. Swindlehurst,
G. Xu and T. Kailath*

1. Introduction 693
2. The subspace-based data model and applications 694
3. Subspace methods for parameter estimation 702
4. Asymptotic properties 708
5. A performance analysis for model errors 716
6. Fast subspace decomposition (FSD) 723
7. Concluding remarks 735
- References 736

**Ch. 17. Closed Form Solution to the Estimates of Directions of Arrival
Using Data from an Array of Sensors 741***C. R. Rao and B. Zhou*

1. Introduction 741
2. Signal model and basic assumptions 742
3. An eigenstructure-based approach 743
4. A spatial smoothing approach 746
5. A direct approach 747
6. A modified approach 748
7. Conclusions 752
- References 752

Ch. 18. High-Resolution Direction Finding 755*S. V. Schell and W. A. Gardner*

1. Introduction 755
2. Possible approaches 757
3. Narrowband sensor arrays 759
4. A high-resolution array-based approach 766

- 5. Super-resolution array-based approaches 771
- 6. Performance limits 798
- 7. Departures from ideality 803
- 8. Summary 813
- References 813

Ch. 19. Multiscale Signal Processing Techniques: A Review 819

A. H. Tewfik, M. Kim and M. Deriche

- 1. Introduction 819
- 2. Filtered fractal models 820
- 3. Wavelet transforms 845
- 4. Conclusion 878
- References 878

Ch. 20. Sampling Theorems and Wavelets 883

G. G. Walter

- 1. Introduction 883
- 2. A general RKHS setting for sampling theorems 886
- 3. A little wavelet theory 888
- 4. Sampling in wavelet subspaces 893
- 5. Examples 898
- References 902

Ch. 21. Image and Video Coding Research 905

J. W. Woods

- 1. Introduction 905
- 2. Intra-frame coding 906
- 3. Pyramid coding 914
- 4. Color image coding 915
- 5. Interframe coding 916
- 6. Three-dimensional subband coding 920
- 7. Advanced television 921
- 8. Advanced television broadcast systems 924
- 9. Conclusions 929
- References 929

Ch. 22. Fast Algorithms for Structured Matrices in Signal Processing 933

A. E. Yagle

- 1. Introduction 933
- 2. Toeplitz matrices 934

3. Block-Toeplitz matrices 944
4. Split algorithms 948
5. Toeplitz-plus-Hankel matrices 956
6. Close-to-Toeplitz matrices 964
- References 971

Subject Index 973

Contents of Previous Volumes 983