

---

# Fundamentals of Digital Image Processing

---

ANIL K. JAIN

*University of California, Davis*



PRENTICE HALL, Englewood Cliffs, NJ 07632

---

# Contents

---

<b>PREFACE</b>	<b>xix</b>
<b>ACKNOWLEDGMENTS</b>	<b>xxi</b>
<b>1 INTRODUCTION</b>	<b>1</b>
1.1 Digital Image Processing: Problems and Applications	1
1.2 Image Representation and Modeling	4
1.3 Image Enhancement	6
1.4 Image Restoration	7
1.5 Image Analysis	7
1.6 Image Reconstruction from Projections	8
1.7 Image Data Compression	9
Bibliography	10
<b>2 TWO-DIMENSIONAL SYSTEMS AND MATHEMATICAL PRELIMINARIES</b>	<b>11</b>
2.1 Introduction	11
2.2 Notation and Definitions	11
2.3 Linear Systems and Shift Invariance	13
2.4 The Fourier Transform	15
Properties of the Fourier Transform,	16
Fourier Transform of Sequences (Fourier Series),	18

2.5	The Z-Transform or Laurent Series	20
	<i>Causality and Stability,</i>	21
2.6	Optical and Modulation Transfer Functions	21
2.7	Matrix Theory Results	22
	<i>Vectors and Matrices,</i>	22
	<i>Row and Column Ordering,</i>	23
	<i>Transposition and Conjugation Rules,</i>	25
	<i>Toeplitz and Circulant Matrices,</i>	25
	<i>Orthogonal and Unitary Matrices,</i>	26
	<i>Positive Definiteness and Quadratic Forms,</i>	27
	<i>Diagonal Forms,</i>	27
2.8	Block Matrices and Kronecker Products	28
	<i>Block Matrices,</i>	28
	<i>Kronecker Products,</i>	30
	<i>Separable Operations,</i>	31
2.9	Random Signals	31
	<i>Definitions,</i>	31
	<i>Gaussian or Normal Distribution,</i>	32
	<i>Gaussian Random Processes,</i>	32
	<i>Stationary Processes,</i>	32
	<i>Markov Processes,</i>	33
	<i>Orthogonality and Independence,</i>	34
	<i>The Karhunen Loève (KL) Transform,</i>	34
2.10	Discrete Random Fields	35
	<i>Definitions,</i>	35
	<i>Separable and Isotropic Covariance</i>	
	<i>Functions,</i>	36
2.11	The Spectral Density Function	37
	<i>Properties of the SDF,</i>	38
2.12	Some Results from Estimation Theory	39
	<i>Mean Square Estimates,</i>	40
	<i>The Orthogonality Principle,</i>	40
2.13	Some Results from Information Theory	41
	<i>Information,</i>	42
	<i>Entropy,</i>	42
	<i>The Rate Distortion Function,</i>	43
	Problems	44
	Bibliography	47

### **3 IMAGE PERCEPTION**

**49**

3.1	Introduction	49
3.2	Light, Luminance, Brightness, and Contrast	49
	<i>Simultaneous Contrast,</i>	51
	<i>Mach Bands,</i>	53

3.3	MTF of the Visual System	54
3.4	The Visibility Function	55
3.5	Monochrome Vision Models	56
3.6	Image Fidelity Criteria	57
3.7	Color Representation	60
3.8	Color Matching and Reproduction	62
	<i>Laws of Color Matching,</i>	63
	<i>Chromaticity Diagram ,</i>	65
3.9	Color Coordinate Systems	66
3.10	Color Difference Measures	71
3.11	Color Vision Model	73
3.12	Temporal Properties of Vision	75
	<i>Bloch's Law,</i>	75
	<i>Critical Fusion Frequency (CFF),</i>	75
	<i>Spatial versus Temporal Effects,</i>	75
	Problems	76
	Bibliography	78

## **4 IMAGE SAMPLING AND QUANTIZATION**

**80**

4.1	Introduction	80
	<i>Image Scanning,</i>	80
	<i>Television Standards,</i>	81
	<i>Image Display and Recording,</i>	83
4.2	Two-Dimensional Sampling Theory	84
	<i>Bandlimited Images,</i>	84
	<i>Sampling Versus Replication,</i>	85
	<i>Reconstruction of the Image from Its</i>	
	<i>Samples,</i>	85
	<i>Nyquist Rate, Aliasing, and Foldover</i>	
	<i>Frequencies,</i>	87
	<i>Sampling Theorem,</i>	88
	<i>Remarks,</i>	89
4.3	Extensions of Sampling Theory	89
	<i>Sampling Random Fields,</i>	90
	<i>Sampling Theorem for Random Fields,</i>	90
	<i>Remarks,</i>	90
	<i>Nonrectangular Grid Sampling and</i>	
	<i>Interlacing,</i>	91
	<i>Hexagonal Sampling,</i>	92
	<i>Optimal Sampling,</i>	92

4.4	Practical Limitations in Sampling and Reconstruction	93
	<i>Sampling Aperture</i> ,	93
	<i>Display Aperture/Interpolation Function</i> ,	94
	<i>Lagrange Interpolation</i> ,	98
	<i>Moire Effect and Flat Field Response</i> ,	99
4.5	Image Quantization	99
4.6	The Optimum Mean Square or Lloyd-Max Quantizer	101
	<i>The Uniform Optimal Quantizer</i> ,	103
	<i>Properties of the Optimum Mean Square Quantizer</i> ,	103
	<i>Proofs</i> ,	112
4.7	A Compandor Design	113
	<i>Remarks</i> ,	114
4.8	The Optimum Mean Square Uniform Quantizer for Nonuniform Densities	115
4.9	Examples, Comparison, and Practical Limitations	115
4.10	Analytic Models for Practical Quantizers	118
4.11	Quantization of Complex Gaussian Random Variables	119
4.12	Visual Quantization	119
	<i>Contrast Quantization</i> ,	120
	<i>Pseudorandom Noise Quantization</i> ,	120
	<i>Halftone Image Generation</i> ,	121
	<i>Color Quantization</i> ,	122
	Problems	124
	Bibliography	128

## 5 IMAGE TRANSFORMS

132

5.1	Introduction	132
5.2	Two-Dimensional Orthogonal and Unitary Transforms	134
	<i>Separable Unitary Transforms</i> ,	134
	<i>Basis Images</i> ,	135
	<i>Kronecker Products and Dimensionality</i> ,	137
	<i>Dimensionality of Image Transforms</i> ,	138
	<i>Transform Frequency</i> ,	138
	<i>Optimum Transform</i> ,	138
5.3	Properties of Unitary Transforms	138
	<i>Energy Conservation and Rotation</i> ,	138
	<i>Energy Compaction and Variances of Transform Coefficients</i> ,	139
	<i>Decorrelation</i> ,	140
	<i>Other Properties</i> ,	140

5.4	The One-Dimensional Discrete Fourier Transform (DFT)	141
	<i>Properties of the DFT/Unitary DFT, 141</i>	
5.5	The Two-Dimensional DFT	145
	<i>Properties of the Two-Dimensional DFT, 147</i>	
5.6	The Cosine Transform	150
	<i>Properties of the Cosine Transform, 151</i>	
5.7	The Sine Transform	154
	<i>Properties of the Sine Transform, 154</i>	
5.8	The Hadamard Transform	155
	<i>Properties of the Hadamard Transform, 157</i>	
5.9	The Haar Transform	159
	<i>Properties of the Haar Transform, 161</i>	
5.10	The Slant Transform	161
	<i>Properties of the Slant Transform, 162</i>	
5.11	The KL Transform	163
	<i>KL Transform of Images, 164</i>	
	<i>Properties of the KL Transform, 165</i>	
5.12	A Sinusoidal Family of Unitary Transforms	175
	<i>Approximation to the KL Transform, 176</i>	
5.13	Outer Product Expansion and Singular Value Decomposition	176
	<i>Properties of the SVD Transform, 177</i>	
5.14	Summary	180
	Problems	180
	Bibliography	185

## **6 IMAGE REPRESENTATION BY STOCHASTIC MODELS**

**189**

6.1	Introduction	189
	<i>Covariance Models, 189</i>	
	<i>Linear System Models, 189</i>	
6.2	One-Dimensional Causal Models	190
	<i>Autoregressive (AR) Models, 190</i>	
	<i>Properties of AR Models, 191</i>	
	<i>Application of AR Models in Image Processing,</i>	
	<i>193</i>	
	<i>Moving Average (MA) Representations, 194</i>	
	<i>Autoregressive Moving Average (ARMA)</i>	
	<i>Representations, 195</i>	
	<i>State Variable Models, 195</i>	
	<i>Image Scanning Models, 196</i>	

6.3	One-Dimensional Spectral Factorization	196
	<i>Rational SDFs</i> ,	197
	<i>Remarks</i> ,	198
6.4	AR Models, Spectral Factorization, and Levinson Algorithm	198
	<i>The Levinson-Durbin Algorithm</i> ,	198
6.5	Noncausal Representations	200
	<i>Remarks</i> ,	201
	<i>Noncausal MVRs for Autoregressive Sequences</i> ,	201
	<i>A Fast KL Transform</i> ,	202
	<i>Optimum Interpolation of Images</i> ,	204
6.6	Linear Prediction in Two Dimensions	204
	<i>Causal Prediction</i> ,	205
	<i>Semicausal Prediction</i> ,	206
	<i>Noncausal Prediction</i> ,	206
	<i>Minimum Variance Prediction</i> ,	206
	<i>Stochastic Representation of Random Fields</i> ,	207
	<i>Finite-Order MVRs</i> ,	208
	<i>Remarks</i> ,	209
	<i>Stability of Two-Dimensional Systems</i> ,	212
6.7	Two-Dimensional Spectral Factorization and Spectral Estimation Via Prediction Models	213
	<i>Separable Models</i> ,	214
	<i>Realization of Noncausal MVRs</i> ,	215
	<i>Realization of Causal and Semicausal MVRs</i> ,	216
	<i>Realization via Orthogonality Condition</i> ,	216
6.8	Spectral Factorization via the Wiener-Doob Homomorphic Transformation	219
	<i>Causal MVRs</i> ,	220
	<i>Semicausal WNDs</i> ,	220
	<i>Semicausal MVRs</i> ,	222
	<i>Remarks and Examples</i> ,	222
6.9	Image Decomposition, Fast KL Transforms, and Stochastic Decoupling	223
	<i>Periodic Random Fields</i> ,	223
	<i>Noncausal Models and Fast KL Transforms</i> ,	224
	<i>Semicausal Models and Stochastic Decoupling</i> ,	225
6.10	Summary	226
	Problems	227
	Bibliography	230

7.1	Introduction	233
7.2	Point Operations	235
	<i>Contrast Stretching</i> ,	235
	<i>Clipping and Thresholding</i> ,	235
	<i>Digital Negative</i> ,	238
	<i>Intensity Level Slicing</i> ,	238
	<i>Bit Extraction</i> ,	239
	<i>Range Compression</i> ,	240
	<i>Image Subtraction and Change Detection</i> ,	240
7.3	Histogram Modeling	241
	<i>Histogram Equalization</i> ,	241
	<i>Histogram Modification</i> ,	242
	<i>Histogram Specification</i> ,	243
7.4	Spatial Operations	244
	<i>Spatial Averaging and Spatial Low-pass Filtering</i> ,	244
	<i>Directional Smoothing</i> ,	245
	<i>Median Filtering</i> ,	246
	<i>Other Smoothing Techniques</i> ,	249
	<i>Unsharp Masking and Crispening</i> ,	249
	<i>Spatial Low-pass, High-pass and Band-pass Filtering</i> ,	250
	<i>Inverse Contrast Ratio Mapping and Statistical Scaling</i> ,	252
	<i>Magnification and Interpolation (Zooming)</i> ,	253
	<i>Replication</i> ,	253
	<i>Linear Interpolation</i> ,	253
7.5	Transform Operations	256
	<i>Generalized Linear Filtering</i> ,	256
	<i>Root Filtering</i> ,	258
	<i>Generalized Cepstrum and Homomorphic Filtering</i> ,	259
7.6	Multispectral Image Enhancement	260
	<i>Intensity Ratios</i> ,	260
	<i>Log-Ratios</i> ,	261
	<i>Principal Components</i> ,	261
7.7	False Color and Pseudocolor	262
7.8	Color Image Enhancement	262
7.9	Summary	263
	Problems	263
	Bibliography	265

- 8.1 Introduction 267
- 8.2 Image Observation Models 268
  - Image Formation Models, 269*
  - Detector and Recorder Models, 273*
  - Noise Models, 273*
  - Sampled Image Observation Models, 275*
- 8.3 Inverse and Wiener Filtering 275
  - Inverse Filter, 275*
  - Pseudoinverse Filter, 276*
  - The Wiener Filter, 276*
  - Remarks, 279*
- 8.4 Finite Impulse Response (FIR) Wiener Filters 284
  - Filter Design, 284*
  - Remarks, 285*
  - Spatially Varying FIR Filters, 287*
- 8.5 Other Fourier Domain Filters 290
  - Geometric Mean Filter, 291*
  - Nonlinear Filters, 291*
- 8.6 Filtering Using Image Transforms 292
  - Wiener Filtering, 292*
  - Remarks, 293*
  - Generalized Wiener Filtering, 293*
  - Filtering by Fast Decompositions, 295*
- 8.7 Smoothing Splines and Interpolation 295
  - Remarks, 297*
- 8.8 Least Squares Filters 297
  - Constrained Least Squares Restoration, 297*
  - Remarks, 298*
- 8.9 Generalized Inverse, SVD, and Iterative Methods 299
  - The Pseudoinverse, 299*
  - Minimum Norm Least Squares (MNLS)*
    - Solution and the Generalized Inverse, 300*
  - One-step Gradient Methods, 301*
  - Van Cittert Filter, 301*
  - The Conjugate Gradient Method, 302*
  - Separable Point Spread Functions, 303*
- 8.10 Recursive Filtering For State Variable Systems 304
  - Kalman Filtering, 304*
  - Remarks, 307*

8.11	Causal Models and Recursive Filtering	307
	<i>A Vector Recursive Filter</i> ,	308
	<i>Stationary Models</i> ,	310
	<i>Steady-State Filter</i> ,	310
	<i>A Two-Stage Recursive Filter</i> ,	310
	<i>A Reduced Update Filter</i> ,	310
	<i>Remarks</i> ,	311
8.12	Semicausal Models and Semirecursive Filtering	311
	<i>Filter Formulation</i> ,	312
8.13	Digital Processing of Speckle Images	313
	<i>Speckle Representation</i> ,	313
	<i>Speckle Reduction: N-Look Method</i> ,	315
	<i>Spatial Averaging of Speckle</i> ,	315
	<i>Homomorphic Filtering</i> ,	315
8.14	Maximum Entropy Restoration	316
	<i>Distribution-Entropy Restoration</i> ,	317
	<i>Log-Entropy Restoration</i> ,	318
8.15	Bayesian Methods	319
	<i>Remarks</i> ,	320
8.16	Coordinate Transformation and Geometric Correction	320
8.17	Blind Deconvolution	322
8.18	Extrapolation of Bandlimited Signals	323
	<i>Analytic Continuation</i> ,	323
	<i>Super-resolution</i> ,	323
	<i>Extrapolation Via Prolate Spheroidal Wave</i>	
	<i>Functions (PSWFs)</i> ,	324
	<i>Extrapolation by Error Energy Reduction</i> ,	324
	<i>Extrapolation of Sampled Signals</i> ,	326
	<i>Minimum Norm Least Squares (MNLS)</i>	
	<i>Extrapolation</i> ,	326
	<i>Iterative Algorithms</i> ,	327
	<i>Discrete Prolate Spheroidal Sequences (DPSS)</i> ,	327
	<i>Mean Square Extrapolation</i> ,	328
	<i>Generalization to Two Dimensions</i> ,	328
8.19	Summary	330
	Problems	331
	Bibliography	335

## **9 IMAGE ANALYSIS AND COMPUTER VISION**

**342**

9.1	Introduction	342
9.2	Spatial Feature Extraction	344
	<i>Amplitude Features</i> ,	344
	<i>Histogram Features</i> ,	344

9.3	Transform Features	346
9.4	Edge Detection	347
	<i>Gradient Operators,</i>	<i>348</i>
	<i>Compass Operators,</i>	<i>350</i>
	<i>Laplace Operators and Zero Crossings,</i>	<i>351</i>
	<i>Stochastic Gradients,</i>	<i>353</i>
	<i>Performance of Edge Detection Operators,</i>	<i>355</i>
	<i>Line and Spot Detection,</i>	<i>356</i>
9.5	Boundary Extraction	357
	<i>Connectivity,</i>	<i>357</i>
	<i>Contour Following,</i>	<i>358</i>
	<i>Edge Linking and Heuristic Graph Searching,</i>	<i>358</i>
	<i>Dynamic Programming,</i>	<i>359</i>
	<i>Hough Transform,</i>	<i>362</i>
9.6	Boundary Representation	362
	<i>Chain Codes,</i>	<i>363</i>
	<i>Fitting Line Segments,</i>	<i>364</i>
	<i>B-Spline Representation,</i>	<i>364</i>
	<i>Fourier Descriptors,</i>	<i>370</i>
	<i>Autoregressive Models,</i>	<i>374</i>
9.7	Region Representation	375
	<i>Run-length Codes,</i>	<i>375</i>
	<i>Quad-Trees,</i>	<i>375</i>
	<i>Projections,</i>	<i>376</i>
9.8	Moment Representation	377
	<i>Definitions,</i>	<i>377</i>
	<i>Moment Representation Theorem,</i>	<i>378</i>
	<i>Moment Matching,</i>	<i>378</i>
	<i>Orthogonal Moments,</i>	<i>379</i>
	<i>Moment Invariants,</i>	<i>380</i>
	<i>Applications of Moment Invariants,</i>	<i>381</i>
9.9	Structure	381
	<i>Medial Axis Transform,</i>	<i>381</i>
	<i>Morphological Processing,</i>	<i>384</i>
	<i>Morphological Transforms,</i>	<i>387</i>
9.10	Shape Features	390
	<i>Geometry Features,</i>	<i>391</i>
	<i>Moment-Based Features,</i>	<i>392</i>
9.11	Texture	394
	<i>Statistical Approaches,</i>	<i>394</i>
	<i>Structural Approaches,</i>	<i>398</i>
	<i>Other Approaches,</i>	<i>399</i>

9.12	Scene Matching and Detection	400
	<i>Image Subtraction</i> ,	400
	<i>Template Matching and Area Correlation</i> ,	400
	<i>Matched Filtering</i> ,	403
	<i>Direct Search Methods</i> ,	404
9.13	Image Segmentation	407
	<i>Amplitude Thresholding or Window Slicing</i> ,	407
	<i>Component Labeling</i> ,	409
	<i>Boundary-based Approaches</i> ,	411
	<i>Region-based Approaches and Clustering</i> ,	412
	<i>Template Matching</i> ,	413
	<i>Texture Segmentation</i> ,	413
9.14	Classification Techniques	414
	<i>Supervised Learning</i> ,	414
	<i>Nonsupervised Learning or Clustering</i> ,	418
9.15	Image Understanding	421
	Problems	422
	Bibliography	425

## **10 IMAGE RECONSTRUCTION FROM PROJECTIONS**

**431**

10.1	Introduction	431
	<i>Transmission Tomography</i> ,	431
	<i>Reflection Tomography</i> ,	432
	<i>Emission Tomography</i> ,	433
	<i>Magnetic Resonance Imaging</i> ,	434
	<i>Projection-based Image Processing</i> ,	434
10.2	The Radon Transform	434
	<i>Definition</i> ,	434
	<i>Notation</i> ,	436
	<i>Properties of the Radon Transform</i> ,	437
10.3	The Back-projection Operator	439
	<i>Definition</i> ,	439
	<i>Remarks</i> ,	440
10.4	The Projection Theorem	442
	<i>Remarks</i> ,	443
10.5	The Inverse Radon Transform	444
	<i>Remarks</i> ,	445
	<i>Convolution Back-projection Method</i> ,	446
	<i>Filter Back-projection Method</i> ,	446
	<i>Two-Dimensional Filtering via the Radon Transform</i> ,	447

10.6	Convolution/Filter Back-projection Algorithms: Digital Implementation 448
	<i>Sampling Considerations, 448</i>
	<i>Choice of Filters, 448</i>
	<i>Convolution Back-projection Algorithm, 450</i>
	<i>Filter Back-projection Algorithm, 451</i>
	<i>Reconstruction Using a Parallel Pipeline Processor, 452</i>
10.7	Radon Transform of Random Fields 452
	<i>A Unitary Transform <math>\tilde{R}</math>, 452</i>
	<i>Radon Transform Properties for Random Fields, 456</i>
	<i>Projection Theorem for Random Fields, 457</i>
10.8	Reconstruction from Blurred Noisy Projections 458
	<i>Measurement Model, 458</i>
	<i>The Optimum Mean Square Filter, 458</i>
	<i>Remarks, 458</i>
10.9	Fourier Reconstruction 462
	<i>Algorithm, 462</i>
	<i>Reconstruction of Magnetic Resonance Images, 463</i>
10.10	Fan-Beam Reconstruction 464
10.11	Algebraic Methods 465
	<i>The Reconstruction Problem as a Set of Linear Equations, 465</i>
	<i>Algebraic Reconstruction Techniques, 466</i>
10.12	Three-Dimensional Tomography 468
	<i>Three-Dimensional Reconstruction Algorithms, 469</i>
10.13	Summary 470
	Problems 470
	Bibliography 473

## **11 IMAGE DATA COMPRESSION**

**476**

11.1	Introduction 476
	<i>Image Raw Data Rates, 476</i>
	<i>Data Compression versus Bandwidth Compression, 477</i>
	<i>Information Rates, 477</i>
	<i>Subsampling, Coarse Quantization, Frame Repetition, and Interlacing, 479</i>

11.2	Pixel Coding 479
	<i>PCM, 480</i>
	<i>Entropy Coding, 480</i>
	<i>Run-Length Coding, 481</i>
	<i>Bit-Plane Encoding, 483</i>
11.3	Predictive Techniques 483
	<i>Basic Principle, 483</i>
	<i>Feedback versus Feedforward Prediction, 484</i>
	<i>Distortionless Predictive Coding, 485</i>
	<i>Performance Analysis of DPCM, 486</i>
	<i>Delta Modulation, 488</i>
	<i>Line-by-Line DPCM, 490</i>
	<i>Two-Dimensional DPCM, 491</i>
	<i>Performance Comparisons, 493</i>
	<i>Remarks, 494</i>
	<i>Adaptive Techniques, 495</i>
	<i>Other Methods, 497</i>
11.4	Transform Coding Theory 498
	<i>The Optimum Transform Coder, 498</i>
	<i>Proofs, 499</i>
	<i>Remarks, 501</i>
	<i>Bit Allocation and Rate-Distortion Characteristics, 501</i>
11.5	Transform Coding of Images 504
	<i>Two-Dimensional Coding Algorithm, 504</i>
	<i>Transform Coding Performances Trade-offs and Examples, 507</i>
	<i>Zonal versus Threshold Coding, 508</i>
	<i>Fast KL Transform Coding, 510</i>
	<i>Remarks, 512</i>
	<i>Two-Source Coding, 513</i>
	<i>Transform Coding under Visual Criterion, 515</i>
	<i>Adaptive Transform Coding, 515</i>
	<i>Summary of Transform Coding, 516</i>
11.6	Hybrid Coding and Vector DPCM 518
	<i>Basic Idea, 518</i>
	<i>Adaptive Hybrid Coding, 520</i>
	<i>Hybrid Coding Conclusions, 521</i>
11.7	Interframe Coding 521
	<i>Frame Repetition, 521</i>
	<i>Resolution Exchange, 521</i>
	<i>Conditional Replenishment, 522</i>
	<i>Adaptive Predictive Coding, 522</i>
	<i>Predictive Coding with Motion Compensation, 524</i>
	<i>Interframe Hybrid Coding, 527</i>
	<i>Three-Dimensional Transform Coding, 529</i>

11.8	Image Coding in the Presence of Channel Errors	532
	<i>The Optimum Mean Square Decoder</i> ,	532
	<i>The Optimum Encoding Rule</i> ,	533
	<i>Optimization of PCM Transmission</i> ,	534
	<i>Channel Error Effects in DPCM</i> ,	536
	<i>Optimization of Transform Coding</i> ,	537
11.9	Coding of Two Tone Images	540
	<i>Run-length Coding</i> ,	540
	<i>White Block Skipping</i> ,	546
	<i>Prediction Differential Quantization</i> ,	547
	<i>Relative Address Coding</i> ,	547
	<i>CCITT Modified Relative Element Address</i>	
	<i>Designate Coding</i> ,	548
	<i>Predictive Coding</i> ,	551
	<i>Adaptive Predictors</i> ,	552
	<i>Comparison of Algorithms</i> ,	553
	<i>Other Methods</i> ,	553
11.10	Color and Multispectral Image Coding	553
11.11	Summary	557
	Problems	557
	Bibliography	561

## **INDEX**

**566**