

Contents

1. Introduction	1
-----------------------	---

Part 1 Fundamentals of the Theory of Digital Signal Processing

2. Elements of Signal Theory	8
2.1 Signals as Mathematical Functions	8
2.2 Signal Space	10
2.3 The Most Common Systems of Basis Functions	16
2.3.1 Impulse Basis Functions	16
2.3.2 Harmonic Functions	17
2.3.3 Walsh Functions	18
2.3.4 Haar Functions	20
2.3.5 Sampling Functions	22
2.4 Continuous Representations of Signals	22
2.5 Description of Signal Transformations	25
2.5.1 Linear Transformations	30
2.5.2 Nonlinear Element-by-Element Transforms	31
2.6 Representation of Linear Transformations with Respect to Discrete Bases	31
2.6.1 Representation Using Vector Responses	32
2.6.2 Matrix Representations	32
2.6.3 Representation of Operators by Means of Their Eigenfunctions and Eigenvalues	33
2.7 Representing Operator with Respect to Continuous Bases	34
2.7.1 Operator Kernel	34
2.7.2 Description in Terms of Impulse Responses	34
2.7.3 Description Using Frequency Transfer Functions	35
2.7.4 Description with Input and Output Signals Referred to Different Bases	35
2.7.5 Description Using Eigenfunctions	36
2.8 Examples of Linear Operators	36
2.8.1 Shift-Invariant Filters	36
2.8.2 The Identity Operator	38
2.8.3 Shift Operator	38
2.8.4 Sampling Operator	38
2.8.5 Gating Operator (Multiplier)	39
3. Discretization and Quantization of Signals	40
3.1 Generalized Quantization	40
3.2 Concepts of Discretization and Element-by-Element Quantization	42

3.2.1	Discretization	43
3.2.2	Element-by-Element Quantization	43
3.3	The Sampling Theorem	44
3.4	Sampling Theory for Two-Dimensional Signals	45
3.5	Errors of Discretization and Restoration of Signals in Sampling Theory	51
3.6	Other Approaches to Discretization	55
3.7	Optimal Discrete Representation and Dimensionality of Signals	56
3.8	Element-by-Element Quantization	59
3.9	Examples of Optimum Quantization	65
3.9.1	Example: The Threshold Metric	65
3.9.2	Example: Power Criteria for the Absolute Value of the Quantization Error	67
3.9.3	Example: Power Criteria for the Relative Quantization Error	68
3.10	Quantization in the Presence of Noise. Quantization and Representation of Numbers in Digital Processors	70
3.11	Review of Picture-Coding Methods	72
4.	Discrete Representations of Linear Transforms	75
4.1	Problem Formulation and General Approach	75
4.2	Discrete Representation of Shift-Invariant Filters for Band-Limited Signals	76
4.3	Digital Filters	78
4.4	Transfer Functions and Impulse Responses of Digital Filters	82
4.5	Boundary Effects in Digital Filtering	88
4.6	The Discrete Fourier Transform (DFT)	92
4.7	Shifted, Odd and Even DFTs	99
4.8	Using Discrete Fourier Transforms	110
4.8.1	Calculating Convolutions	110
4.8.2	Signal Interpolation	113
4.9	Walsh and Similar Transforms	114
4.10	The Haar Transform. Addition Elements of Matrix Calculus	119
4.11	Other Orthogonal Transforms. General Representations. Review of Applications	121
5.	Linear Transform Algorithms	128
5.1	Fast Algorithms of Discrete Orthogonal Transforms	128
5.2	Fast Haar Transform (FHT) Algorithms	133
5.3	Fast Walsh Transform (FWT) Algorithms	135
5.4	Fast Discrete Fourier Transform (FFT) Algorithms	141
5.5	Review of Other Fast Algorithms. Features of Two-Dimensional Transforms	147
5.5.1	Truncated FFT and FWT Algorithms	149
5.5.2	Transition Matrices Between Various Transforms	152
5.5.3	Calculation of Two-Dimensional Transforms	155
5.6	Combined DFT Algorithms	156
5.6.1	Combined DFT Algorithms of Real Sequences	156
5.6.2	Combined SDFT (1/2, 0) Algorithms of Even and Real Even Sequences	159
5.7	Recursive DFT Algorithms	161
5.8	Fast Algorithms for Calculating the DFT and Signal Convolution with Decreased Multiplication	163
6.	Digital Statistical Methods	166
6.1	Principles of the Statistical Description of Pictures	166
6.2	Measuring the Grey-Level Distribution	167

6.2.1	Step Smoothing	170
6.2.2	Smoothing by Sliding Summation	170
6.2.3	Smoothing with Orthogonal Transforms	170
6.3	The Estimation of Correlation Functions and Spectra	171
6.3.1	Averaging Local Spectra	173
6.3.2	Masking (Windowing) the Process by Smooth Functions ..	174
6.3.3	Direct Smoothing of Spectra	174
6.4	Generating Pseudorandom Numbers	174
6.5	Measuring Picture Noise	177
6.5.1	The Prediction Method	179
6.5.2	The Voting Method	179
6.5.3	Measuring the Variance and the Auto-Correlation Function of Additive Wideband Noise	179
6.5.4	Evaluation of the Intensity and Frequency of the Harmonic Components of Periodic Interference and Other Types of Interference with Narrow Spectra	182
6.5.5	Evaluation of the Parameters of Pulse Noise, Quantization Noise and Strip-Like Noise	183

Part 2 Picture Processing

7.	Correcting Imaging Systems	186
7.1	Problem Formulation	186
7.2	Suppression of Additive Noise by Linear Filtering	188
7.3	Filtering of Pulse Interference	196
7.4	Correction of Linear Distortion	199
7.5	Correction of Amplitude Characteristics	205
8.	Picture Enhancement and Preparation	211
8.1	Preparation Problems and Visual Analysis of Pictures	211
8.1.1	Feature Processing	213
8.1.2	Geometric Transformations	213
8.2	Adaptive Quantization of Modes	214
8.3	Preparation by Nonlinear Transformation of the Video Signal Scale	222
8.4	Linear Preparation Methods	228
8.5	Methods of Constructing Graphical Representation: Computer Graphics	232
8.6	Geometric Picture Transformation	236
8.6.1	Bilinear Interpolation	238
8.6.2	Interpolation Using DFT and SDFT	238
9.	Measuring the Coordinates of Objects in Pictures	241
9.1	Problem Formulation	241
9.2	Localizing a Precisely Known Object in a Spatially Homogeneous Picture	245
9.3	Uncertainty in the Object and Picture Inhomogeneity. Localization in "Blurred" Pictures	251
9.3.1	"Exhaustive" Estimator	251
9.3.2	Estimator Seeking an Averaged Object	252
9.3.3	Adjustable Estimator with Fragment-by Fragment Optimal Filtering	253
9.3.4	Non-Adjustable Estimator	254
9.3.5	Localization in Blurred and Noisy Pictures	254

9.4 Optimal Localization and Picture Contours. Choice of Reference Objects	256
9.5 Algorithm for the Automatic Detection and Extraction of Bench-Marks in Aerial and Space Photographs	260
10. Conclusion	263
References	267
Subject Index	275