## **CONTENTS**

Preface Acknowledgments List of Acronyms Notation	ix xi xiii xvii
Chapter 1 Discrete Cosine Transform	1
1.1 Introduction	1
1.2 Organization of the Book	4
1.3 Appendices	5
1.4 References	6
Chapter 2 Definitions and General Properties	7
2.1 Introduction	7
2.2 The Fourier Cosine Transform	7
2.3 Definitions	10
2.4 The Unitarity of DCTs	12
2.5 Scaling in Time	16
2.6 Shift in Time	17
2.7 The Difference Property	21
2.8 The Convolution Property	22
2.9 Summary	25
Problems	25
Chapter 3 DCT and Its Relations to the Karhunen-Loeve Transform	27
3.1 Introduction	27
3.2 The Karhunen-Loeve Transform	28

vi Contents

3.3	The DCT-I and DCT-II	32
3.4	Asymptotic Equivalence and the Generation of Discrete	
	Unitary Transforms	38
3.5	Summary	47
	Problems	47
Chapter 4	Fast Algorithms for DCT-II	48
4.1	Introduction	48
4.2	DCT via FFT	49
4.3	Direct Computation by Sparse Matrix Factorizations	53
4.4	Decimation-in-Time (DIT) and Decimation-in-Frequency	
	(DIF) Algorithms	56
4.5	DCT via Other Discrete Transforms	62
4.6	Other Algorithms	65
4.7	Summary	81
	Problems	82
Chapter 5	Two-Dimensional DCT Algorithms	88
5.1	Introduction	88
5.2	Two-Dimensional DCT by Reduction to One-	-
3.2	Dimensional DCT	90
5.3	Block Matrix Decomposed Algorithm	96
5.4	Computation via Two-Dimensional DFT	102
5.5	Two-Dimensional DCT via WHT	104
5.6	Hardware Implementation of DCT Processor	106
5.7	Summary	119
<b>5.</b> ,	Problems	120
Chapter 6	Performance of the DCT	122
-		
6.1	Introduction	122
6.2	Variance Distribution	122
6.3	Energy Packing Efficiency (EPE)	123
6.4	Residual Correlation	128
6.5	Rate Distortion and Maximum Reducible Bits	128
6.6	Generalized Wiener Filtering	132
6.7	Summary	134
	Problems	135

CONTENTS	vii

Chapter 7	Applications of the DCT	136
7.1	Introduction	136
7.2	Filtering	140
7.3	Decimation and Interpolation	141
7.4	LMS Filtering	144
7.5	Transmultiplexers	145
7.6	Speech Coding	
7.7	Cepstral Analysis	162
7.8	Image Coding	163
7.9	DCT/VQ	207
7.10	Low Bit-Rate Coding	240
7.11	HDTV Image Coding	273
7.12	Block Structure/Distortion in Transform Image Coding	286
7.13	Activity Classification in Adaptive Transform Coding	292
7.14	HVS in Transform Coding	303
7.15	Data Compression	305
7.16	Classification	307
7.17	Surface Texture Analysis	308
7.18	Topographic Classification	308
7.19	Photovideotex	309
7.20	Pattern Recognition	312
7.21	Progressive Image Transmission	312
7.22	Printed Image Coding	334
7.23	Packet Video	335
7.24	BTC/Transform Coding	344
7.25	Summary	344
	Problems	344
Appendice	S	
<b>A</b> .1	Computer Programs for DCT-II and IDCT-II, $N=8$ and	
	16 [FRA-3, FRA-4]	349
<b>A.2</b>	Computer Programs for DCT-II and IDCT-II, $N = 8$ and	
	16 [FD-1, FRA-12]	370
<b>A</b> .3	Computer Program for 2D 16×16 DCT and IDCT	394
<b>A.4</b>	Computer Program for Generating Lloyd-Max	
	Quantizer	400
<b>A</b> .5	Computer Program for Block Quantization	413
<b>A.</b> 6	Computer Program for DHT	417
<b>A</b> .7	Computer Program for DCT via DHT	422
<b>A.8</b>	Computer Program for DCT-IV	425
<b>A.9</b>	Computer Program for DST	428

viii		CONTENTS
<b>A</b> .10	Computer Program for DST-IV	431
A.11	- A TOT	434
<b>B</b> .1	DCT VLSI Chip Manufacturers	439
B.2	Image Compression Boards	443
B.3	Motion Estimation VLSI Chip Manufacturers	447
Reference	es	450
Index		484