

Distributed Source Coding

*Theory, Algorithms, and
Applications*

**Pier Luigi Dragotti and
Michael Gastpar**



Contents

List of Contributors	xiii
Introduction	xix

PART I THEORY

CHAPTER 1	Foundations of Distributed Source Coding	3
1.1	Introduction	4
1.2	Centralized Source Coding	4
1.2.1	Lossless Source Coding	4
1.2.2	Lossy Source Coding	5
1.2.3	Lossy Source Coding for Sources with Memory	8
1.2.4	Some Notes on Practical Considerations	9
1.3	Distributed Source Coding	9
1.3.1	Lossless Source Coding	10
1.3.2	Lossy Source Coding	11
1.3.3	Interaction	15
1.4	Remote Source Coding	16
1.4.1	Centralized	16
1.4.2	Distributed: The CEO Problem	19
1.5	Joint Source-channel Coding	22
	Acknowledgments	23
	Appendix A: Formal Definitions and Notations	23
A.1	Notation	23
A.1.1	Centralized Source Coding	25
A.1.2	Distributed Source Coding	26
A.1.3	Remote Source Coding	27
	References	28
CHAPTER 2	Distributed Transform Coding	33
2.1	Introduction	33
2.2	Foundations of Centralized Transform Coding	35
2.2.1	Transform Coding Overview	35
2.2.2	Lossless Compression	36

2.2.3	Quantizers	37
2.2.4	Bit Allocation	38
2.2.5	Transforms	39
2.2.6	Linear Approximation	41
2.3	The Distributed Karhunen-Loève Transform	42
2.3.1	Problem Statement and Notation	43
2.3.2	The Two-terminal Scenario	44
2.3.3	The Multiterminal Scenario and the Distributed KLT Algorithm	49
2.4	Alternative Transforms	49
2.4.1	Practical Distributed Transform Coding with Side Information	50
2.4.2	High-rate Analysis of Source Coding with Side Information at Decoder	50
2.5	New Approaches to Distributed Compression with FRI	51
2.5.1	Background on Sampling of 2D FRI Signals	52
2.5.2	Detailed Example: Coding Scheme for Translating a Bi-level Polygon	53
2.6	Conclusions	58
	References	58

CHAPTER 3	Quantization for Distributed Source Coding.....	61
3.1	Introduction	62
3.2	Formulation of the Problem	64
3.2.1	Conventions	64
3.2.2	Network Distributed Source Coding	65
3.2.3	Cost, Distortion, and Rate Measures	66
3.2.4	Optimal Quantizers and Reconstruction Functions	67
3.2.5	Example: Quantization of Side Information	67
3.3	Optimal Quantizer Design	68
3.3.1	Optimality Conditions	68
3.3.2	Lloyd Algorithm for Distributed Quantization	69
3.4	Experimental Results	70
3.5	High-rate Distributed Quantization	73
3.5.1	High-rate WZ Quantization of Clean Sources	74
3.5.2	High-rate WZ Quantization of Noisy Sources	76
3.5.3	High-rate Network Distributed Quantization	80
3.6	Experimental Results Revisited	84
3.7	Conclusions	85
	References	86

CHAPTER 4	Zero-error Distributed Source Coding	89
4.1	Introduction	89
4.2	Graph Theoretic Connections	92
4.2.1	VLZE Coding and Graphs	92
4.2.2	Basic Definitions and Notation	95
4.2.3	Graph Entropies	96
4.2.4	Graph Capacity	98
4.3	Complementary Graph Entropy and VLZE Coding	98
4.4	Network Extensions	100
4.4.1	Extension 1: VLZE Coding When Side Information May Be Absent	100
4.4.2	Extension 2: VLZE Coding with Compound Side Information	102
4.5	VLZE Code Design	104
4.5.1	Hardness of Optimal Code Design	104
4.5.2	Hardness of Coding with Length Constraints	107
4.5.3	An Exponential-time Optimal VLZE Code Design Algorithm	108
4.6	Conclusions	109
	References	110
CHAPTER 5	Distributed Coding of Sparse Signals	111
5.1	Introduction	111
5.1.1	Sparse Signals	112
5.1.2	Signal Recovery with Compressive Sampling	113
5.2	Compressive Sampling as Distributed Source Coding	114
5.2.1	Modeling Assumptions	116
5.2.2	Analyses	117
5.2.3	Numerical Simulation	121
5.3	Information Theory to the Rescue?	123
5.4	Conclusions—Whither Compressive Sampling?	125
5.5	Appendix: Quantizer Performance and Quantization Error	125
	Acknowledgments	126
	References	126

PART II ALGORITHMS AND APPLICATIONS

CHAPTER 6	Toward Constructive Slepian–Wolf Coding Schemes ..	131
6.1	Introduction	131
6.2	Asymmetric SW Coding	132
6.2.1	Principle of Asymmetric SW Coding	132

	6.2.2	Practical Code Design Based on Channel Codes	136
	6.2.3	Rate Adaptation	139
6.3		Nonasymmetric SW Coding	143
	6.3.1	Time Sharing	143
	6.3.2	The Parity Approach	143
	6.3.3	The Syndrome Approach	144
	6.3.4	Source Splitting	148
	6.3.5	Rate Adaptation	149
6.4		Advanced Topics	151
	6.4.1	Practical Code Design Based on Source Codes	151
	6.4.2	Generalization to Nonbinary Sources	153
	6.4.3	Generalization to M Sources	153
6.5		Conclusions	153
		References	154
CHAPTER 7		Distributed Compression in Microphone Arrays	157
	7.1	Introduction	158
	7.2	Spatiotemporal Evolution of the Sound Field	159
	7.2.1	Recording Setups	159
	7.2.2	Spectral Characteristics	163
	7.2.3	Spatiotemporal Sampling and Reconstruction	164
	7.3	Huygens's Configuration	169
	7.3.1	Setup	169
	7.3.2	Coding Strategies	170
	7.3.3	Rate-distortion Trade-offs	171
	7.4	Binaural Hearing Aid Configuration	177
	7.4.1	Setup	177
	7.4.2	Coding Strategies	179
	7.4.3	Rate-distortion Trade-offs	180
	7.5	Conclusions	185
		Acknowledgment	186
		References	186
CHAPTER 8		Distributed Video Coding: Basics, Codecs, and Performance	189
	8.1	Introduction	190
	8.2	Basics on Distributed Video Coding	192
	8.3	The Early Wyner-Ziv Video Coding Architectures	195
	8.3.1	The Stanford WZ Video Codec	195
	8.3.2	The Berkeley WZ Video Codec	198
	8.3.3	Comparing the Early WZ Video Codecs	200

8.4	Further Developments on Wyner–Ziv Video Coding	201
8.4.1	Improving RD Performance	201
8.4.2	Removing the Feedback Channel	204
8.4.3	Improving Error Resilience	205
8.4.4	Providing Scalability	206
8.5	The DISCOVER Wyner–Ziv Video Codec	207
8.5.1	Transform and Quantization	210
8.5.2	Slepian–Wolf Coding	211
8.5.3	Side Information Creation	213
8.5.4	Correlation Noise Modeling	214
8.5.5	Reconstruction	215
8.6	The DISCOVER Codec Performance	216
8.6.1	Performance Evaluation Conditions	216
8.6.2	RD Performance Evaluation	219
8.6.3	Complexity Performance Evaluation	232
8.7	Final Remarks	241
	Acknowledgments	242
	References	242

CHAPTER 9	Model-based Multiview Video Compression Using Distributed Source Coding Principles	247
9.1	Introduction	247
9.2	Model Tracking	249
9.2.1	Image Appearance Model of a Rigid Object	250
9.2.2	Inverse Compositional Estimation of 3D Motion and Illumination	251
9.3	Distributed Compression Schemes	254
9.3.1	Feature Extraction and Coding	255
9.3.2	Types of Frames	256
9.3.3	Types of Side Information	257
9.4	Experimental Results	258
9.5	Conclusions	263
	References	266

CHAPTER 10	Distributed Compression of Hyperspectral Imagery ...	269
10.1	Introduction	269
10.1.1	Hyperspectral Imagery Compression: State of the Art ..	271
10.1.2	Outline of This Chapter	273
10.2	Hyperspectral Image Compression	273
10.2.1	Dataset Characteristics	273

10.2.2	Intraband Redundancy and Cross-band Correlation	274
10.2.3	Limitations of Existing Hyperspectral Compression Techniques	275
10.3	DSC-based Hyperspectral Image Compression	277
10.3.1	Potential Advantages of DSC-based Hyperspectral Compression	278
10.3.2	Challenges in Applying DSC for Hyperspectral Imaging	279
10.4	Example Designs	280
10.4.1	DSC Techniques for Lossless Compression of Hyperspectral Images	280
10.4.2	Wavelet-based Slepian-Wolf Coding for Lossy-to- lossless Compression of Hyperspectral Images	283
10.4.3	Distributed Compression of Multispectral Images Using a Set Theoretic Approach	288
10.5	Conclusions	289
	References	289
 CHAPTER 11 Securing Biometric Data		293
11.1	Introduction	294
11.1.1	Motivation and Objectives	294
11.1.2	Architectures and System Security	295
11.1.3	Chapter Organization	296
11.2	Related Work	296
11.3	Overview of Secure Biometrics Using Syndromes	299
11.3.1	Notation	299
11.3.2	Enrollment and Authentication	299
11.3.3	Performance Measures: Security and Robustness	300
11.3.4	Quantifying Security	302
11.3.5	Implementation Using Syndrome Coding	305
11.4	Iris System	306
11.4.1	Enrollment and Authentication	306
11.4.2	Experimental Results	307
11.5	Fingerprint System: Modeling Approach	309
11.5.1	Minutiae Representation of Fingerprints	309
11.5.2	Modeling the Movement of Fingerprint Minutiae	310
11.5.3	Experimental Evaluation of Security and Robustness	313
11.5.4	Remarks on the Modeling Approach	315

11.6	Fingerprint System: The Transformation Approach	315
11.6.1	Desired Statistical Properties of Feature Vectors	316
11.6.2	Feature Transformation Algorithm	317
11.6.3	Experimental Evaluation of Security and Robustness ..	318
11.7	Summary	322
	References	323
Index	325