

Distributed Source Coding

*Theory, Algorithms, and
Applications*

Pier Luigi Dragotti and
Michael Gastpar



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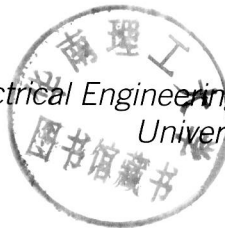
Theory, Algorithms, and Applications

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Distributed Source Coding

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Introduction

In conventional source coding, a single encoder exploits the redundancy of the source in order to perform compression. Applications such as wireless sensor and camera networks, however, involve multiple sources often separated in space that need to be compressed independently. In such applications, it is not usually feasible to first transport all the data to a central location and compress (or further process) it there. The resulting source coding problem is often referred to as distributed source coding (DSC). Its foundations were laid in the 1970s, but it is only in the current decade that practical techniques have been developed, along with advances in the theoretical underpinnings. The practical advances were, in part, due to the rediscovery of the close connection between distributed source codes and (standard) error-correction codes for noisy channels. The latter area underwent a dramatic shift in the 1990s, following the discovery of turbo and low-density parity-check (LDPC) codes. Both constructions have been used to obtain good distributed source codes.

In a related effort, ideas from distributed coding have also had considerable impact on video compression, which is basically a centralized compression problem. In this scenario, one can consider a compression technique under which each video frame must be compressed separately, thus mimicking a distributed coding problem. The resulting algorithms are among the best-performing and have many additional features, including, for example, a shift of complexity from the encoder to the decoder.

This book summarizes the main contributions of the current decade. The chapters are subdivided into two parts. The first part is devoted to the theoretical foundations, and the second part to algorithms and applications.

Chapter 1, by Eswaran and Gastpar, summarizes the state of the art of the theory of distributed source coding, starting with classical results. It emphasizes an important distinction between direct source coding and indirect (or noisy) source coding: In the distributed setting, these two are fundamentally different. This difference is best appreciated by considering the scaling laws in the number of encoders: In the indirect case, those scaling laws are dramatically different. Historically, compression is tightly linked to transforms and thus to transform coding. It is therefore natural to investigate extensions of the traditional centralized transform coding paradigm to the distributed case. This is done by Chaisinthop and Dragotti in Chapter 2, which presents an overview of existing distributed transform coders. Rebollo-Monedero and Girod, in Chapter 3, address the important question of quantization in a distributed setting. A new set of tools is necessary to optimize quantizers, and the chapter gives a partial account of the results available to date. In the standard perspective, efficient distributed source coding always involves an error probability, even though it vanishes as the coding block length is increased. In Chapter 4, Tuncel, Nayak, Koulgi, and Rose take a more restrictive view: The error probability must be exactly zero. This is shown to lead to a strict rate penalty for many instances. Chapter 5, by Goyal, Fletcher, and Rangan, connects ideas from distributed source coding with the sparse signal models

that have recently received considerable attention under the heading of compressed (or compressive) sensing.

The second part of the book focuses on algorithms and applications, where the developments of the past decades have been even more pronounced than in the theoretical foundations. The first chapter, by Guillemot and Roumy, presents an overview of practical DSC techniques based on turbo and LDPC codes, along with ample experimental illustration. Chapter 7, by Roy, Ajdler, Konsbruck, and Vetterli, specializes and applies DSC techniques to a system of multiple microphones, using an explicit spatial model to derive sampling conditions and source correlation structures. Chapter 8, by Pereira, Brites, and Ascenso, overviews the application of ideas from DSC to video coding: A single video stream is encoded, frame by frame, and the encoder treats past and future frames as side information when encoding the current frame. The chapter starts with an overview of the original distributed video coders from Berkeley (PRISM) and Stanford, and provides a detailed description of an enhanced video coder developed by the authors (and referred to as DISCOVER). The case of the multiple multiview video stream is considered by Nayak, Song, Tuncel, and Roy-Chowdhury in Chapter 9, where they show how DSC techniques can be applied to the problem of multiview video compression. Chapter 10, by Cheung and Ortega, applies DSC techniques to the problem of distributed compression of hyperspectral imagery. Finally, Chapter 11, by Vetro, Draper, Rane, and Yedidia, is an innovative application of DSC techniques to securing biometric data. The problem is that if a fingerprint, iris scan, or genetic code is used as a user password, then the password cannot be changed since users are stuck with their fingers (or irises, or genes). Therefore, biometric information should not be stored in the clear anywhere. This chapter discusses one approach to this problematic issue, using ideas from DSC.

One of the main objectives of this book is to provide a comprehensive reference for engineers, researchers, and students interested in distributed source coding. Results on this topic have so far appeared in different journals and conferences. We hope that the book will finally provide an integrated view of this active and ever evolving research area.

Edited books would not exist without the enthusiasm and hard work of the contributors. It has been a great pleasure for us to interact with some of the very best researchers in this area who have enthusiastically embarked in this project and have contributed these wonderful chapters. We have learned a lot from them. We would also like to thank the reviewers of the chapters for their time and for their constructive comments. Finally we would like to thank the staff at Academic Press—in particular Tim Pitts, Senior Commissioning Editor, and Melanie Benson—for their continuous help.

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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