Distributed Source Coding

Theory, Algorithms, and Applications

Pier Luigi Dragotti and
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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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