Sparse Image and Signal Processing: Wavelets, Curvelets, Morphological Diversity

Jean-Luc Starck, Fionn Murtagh, and Jalal M. Fadili, 336 pp., ISBN 978-0-521-11913-9, Cambridge University Press (2010), $70.00 hardcover.

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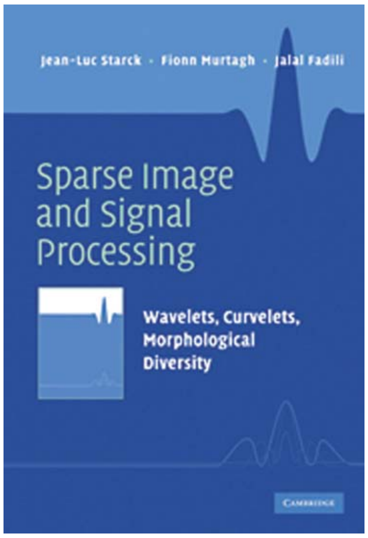

There has been a great deal of research conducted in the areas of sparse and multiscale data representation, and as a result, numerous approaches and algorithms have been proposed in these areas. Sparse and multiscale representation find their applications in many image and signal processing areas including remote sensing, digital camera applications, biomedical imaging, and data compression. This book presents a summary of recent state-of-the-art work in sparse and multiscale image and signal processing and addresses many of the key perspectives of these areas: analysis and synthesis frameworks for various multiscale approaches (e.g., wavelet, ridgelet, curvelet, etc.), a concise comparison of these multiscale approaches, theoretical insight necessary to understand sparse representation, and the role of sparse and multiscale representation to solve various problems such as denoising, inverse problem regularization, morphological decomposition, and blind source separation.

This book provides an excellent landscape of the cutting-edge research in multiscale representation but offers a narrow view of the sparse representation. Several important aspects related to sparse analysis, such as geometric interpretation, dictionary design and selection, and video and computer vision applications, are missing.

The book has total of 11 chapters. Chapter 1 introduces the essential terminology widely used in the research community to discuss sparsity, compressed sensing, and multiscale analysis. This chapter also provides a very high-level description of wavelet and overcomplete representations and their applications to visualization, filtering, feature detections, and image grading.

Chapters 2 to 5 discuss various multiscale transforms ranging from the continuous-wavelet transform to the ridgelet and curvelet transforms. Chapter 2 discusses continuous- and discrete-wavelet transform. An excellent treatment of the 2-D decimated wavelet transform and the Feauveau multiresolution algorithm is also presented in this chapter.

In many applications, such as restoration and detection, a translation-invariance property is highly desirable, and in such cases redundant-wavelet transform is preferred as compared to the discrete-wavelet transform. Chapter 3 addresses discrete-redundant wavelet transform and looks into its various aspects, such as nonorthogonal filter bank design, to perform the redundant wavelet transform, computational and storage efficiency, etc.

Chapter 4 covers several approaches for nonlinear multiscale transforms, which are used for handling outliers in the data, or performing an integer wavelet transform or a wavelet transform on an irregularly sampled grid. The main focus of this chapter is on the multiscale median transform.

The ridgelet and curvelet transforms outperform wavelets in terms of characterizing anisotropic elements such as lines and edges present in the object of interest. Chapter 5 addresses the ridgelet and curvelet transforms and a number of algorithms to implement them. This chapter also contains a section on contrast enhancement of images using the curvelet transform.

Chapter 6 presents an extensive coverage of multiscale-based signal and image denoising. The breadth and depth of the denoising models and algorithms covered in this chapter is quite impressive. Various noise cases ranging from the classical additive white Gaussian, additive colored Gaussian, multiplicative, to Poisson noise have been considered in detail in this chapter. Furthermore, issues related to the estimation of noise-level and algorithm-related parameters such as threshold have been addressed systematically. However, the treatment of color images is very basic and does not provide any insight as to how cross-channel correlation can be exploited to improve the denoising performance for color images. Overall, this chapter is a treat for researchers who have a practical interest in denoising.

Chapter 7 provides a comprehensive overview of the role of sparsity for solving linear inverse problems. This chapter first presents the key concepts from convex analysis required to understand the design principle of the numerical solvers, discussed subsequently in this chapter, to solve the linear inverse problems using sparsity.

Chapters 8 and 9 are related to the applications of sparse representation. Chapter 8 addresses the application of sparse representation for decomposing images and signals into morphologically diverse components. In particular, the morphological component analysis framework for morphological diversity is discussed in great detail. The morphological diversity–based edge detection and inpainting results presented at the end of the chapter look very impressive.

Chapter 9 addresses the role of sparsity and morphological diversity to solve the blind source separation problem. Before discussing the sparsity- and morphological diversity–based framework, authors provide a concise description of the prior art in this area, which makes this chapter a nice reference for researchers interested in the blind-source separation problem.

Chapter 10 discusses design of multiscale transforms for spherical data and demonstrates their applications to denoising, image decomposition, and inpainting on the sphere.

Chapter 11 provides a high-level overview of compressed sensing. A major drawback of this chapter is that its presentation relies heavily on the references to published literature in this area, which impedes the readability.

There are several unique features about this book that make it useful for the intended readers. Each chapter has an introduction and a summary section, which makes it easier to understand the big picture conveyed in each chapter. Furthermore, each chapter begins with a meaningful motivation for the concepts discussed in that chapter. Guided numerical experiments containing visual results for each chapter illustrate the feasibility of the algorithms in a lucid manner. MATLAB and IDL code required to reproduce the results presented in this book are available for free. Some of the ideas, especially those related to sparsity and compressed sensing, are not discussed in detail; however, references provided in the book are excellent and can be used for further research.

One criticism, in my opinion, is that this book intertwines sparsity and multiscale representation, which makes it less obvious that sparse representation is a separate research area in itself, and multiscale-based sparsity is just a special case of the overall sparse analysis. This could be confusing for the beginners. Treating multiscale and sparse representation separately and relating them as needed will make this book appealing to an even wider range of readers.

On the whole, this book is well written with several numerical examples, MATLAB and IDL code, and a very nice set of references. The authors of this book are well-known experts in image and signal processing. I recommend it as an excellent resource for researchers, graduate students, and practitioners interested in sparse and multiscale image and signal processing.

Mrityunjay Kumar is a research scientist with the Kodak Research Labs in Rochester, New York. He received his BTech degree in electronics and communication engineering from the Indian Institute of Technology, Guwahati, India, in 2000, and his MS and PhD in electrical engineering from Michigan State University in 2007 and 2008, respectively. His research interests include digital image and video processing, computer vision, multisensor image fusion, multimedia understanding, and compressed sensing. He is the author of 14 patent-pending inventions in the areas of image and video processing, and has published over 20 journal articles, conference papers, and book chapters in these areas. He has received several technical awards including the best paper award of IEEE EIT 2005. He is a member of IEEE and SPIE.