AIAA Journal
Vol. 49, No. 5, May 2011

Book Review

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

J.-L. Starck, F. Mrtagh, and J. M. Fadili, Cambridge University Press, New York, 2010, 352 pp., $70

DOI: 10.2514/1.J051009

The authors manage to assemble, in about 300 pages, a coherent well-balanced combination of the theory of compressed sensing of sparse signals and images, with the cases of orthonormal and overcomplete representations considered, as well as a wealth of supporting application examples, complete with software codes.

A given signal is expressed as a linear combination of basis functions, which are called "atoms." The set of atoms form a "dictionary." The set of atoms could be redundant (overcomplete) to allow for more economical choices for signal representation, rendering "sparse". A sparse signal is defined as one with a nonzero value in only a small fraction of its support. A signal could have a sparse transform when expressed in terms of atoms of a judicially chosen dictionary. The discussion usually begins with expressing the signal over an orthonormal basis. A good choice for a given class of signals would be a basis in which the signal is well represented by a small number of nonzero coefficients. An overcomplete representation provides a richer variety of atoms that could result in a more sparse signal representation. The increased size of the dictionary could, however. become computationally prohibitive.

The first chapter, entitled "Introduction to the World of Sparsity," is a nice overview, but a figure similar to that on page 279 to accompany Eq. (1.1) would have made good sense. In Chapter 2, the wavelet transform is introduced, beginning with the continuous wavelet transform and followed by the most significant discrete wavelet transform, with applications and software code included. Redundant wavelet transforms are discussed in Chapter 3, beginning with the complex wavelet transform followed by the starlet transform and the pyramidal wavelet transform wavelet filters, and nonorthogonal filter banks used with the preceding transforms are discussed. The best filter banks or multiresolution schemes are highly dependent on the applications, which include compression, denoising, deconvolution, and object finding. Chapters 2 and 3, by themselves, are self-sufficient and supply the reader with the necessary tools for modeling and processing a wide variety of signals.

Nonlinear multiscale transforms are introduced in Chapter 4, motivated by overcoming some of the problems in the wavelet transform. These include the presence of negative values, point artifacts, and the need for integer values in only some applications. The integer wavelet transform, the wavelet transform on irregular grid, and the adaptive wavelet transform are introduced. Multiscale transforms and mathematical morphology follow with the discussion of lifting schemes, the pyramidal transform, and undecimated multiscale morphological transform. Nonlinear median-based transforms including the pyramidal follow, including the pyramidal transform. The chapter is concluded with a discussion of merging wavelets with the median transform.

The ridgelet and curvelet transforms are introduced in Chapter 5. They generalize the wavelet transform by incorporating angular alignment and its length while maintaining multiscale properties. The idea is to build an image from edge-related building blocks that represent a particular dictionary. As in all the presented methods, the choice of which dictionary to use is crucial and highly dependent on the type of signal or image and the application in question.

Sparsity and noise removal are discussed in Chapter 6. By representing the signal via the atoms of a suitable dictionary, the largest set of coefficients could be enough to represent the signal, while the smaller coefficients are sacrificed since their noise content is large. The main discussion is whether to consider each coefficient separately, using one of several types of thresholds, or to use more global decision-making based on blocks of data.

Linear inverse problems are discussed in Chapter 7. A unified framework of monotone operator splitting is introduced to recover a signal subjected to a linear transformation, and corrupted by an additive noise term, using the sparsity properties of the signal.

The important concept of morphological diversity is introduced in Chapter 8. In this chapter, the concept of redundant representation is pushed to an extreme. Multiple dictionaries could be used, and their content could be adaptively changed in a learning process to find the best descriptors for a sparse signal representation.

Sparse blind source separation is discussed in Chapter 9. After reviewing independent component analysis and its limitations, the use of sparsity and morphological diversity is discussed, followed by illustrative examples.

Chapter 10 is dedicated to multiscale geometric analysis on the sphere. Two applications that motivate this development are at the extremes of size scale. One is in fusion physics, and the other is in cosmology. All the concepts and transforms introduced earlier in the book are shown in cited literature to be applicable to different geometries, such as the sphere.

Compressed sensing is discussed in Chapter 11, concluding this excellent exposition of sparse signals and images for the scientist as well as the practicing engineer.

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