Seismic data filtering with lapped transforms and hidden Markov models

A. Laurent Duval*, B. Caroline Chaux+

*Institut Français du Pétrole, Technology Department
+Institut Français du Pétrole, Technology Department

Abstract

The discrete wavelet transform (DWT) provides sparse bases for natural signal and image processing. DWT is particularly successful for noise removal [1]. Recently, algorithms based on wavelet-domain hidden Markov models (HMMs) have demonstrated excellent performance for image filtering, segmentation and detection [2, 3].

HMM-based algorithms seem to take more advantage of the "clustering" and "persistence" properties of wavelet coefficients around image features, such as edges. They enable statistical dependencies modeling and coefficients' non Gaussian behaviour assessment.

Wavelets also have recently re-emerged as well as efficient compression and noise filtering tools [4] in seismics (originally the field "wavelets" came from). Some authors have remarked that, although seismic traces usually appear as naturally made of physical wavelets, seismic images are more efficiently represented by short local bases such as the Local Cosine Transform [5]. These short local bases are believed to be more efficient at capturing seismic oscillary patterns (similar to textures for natural images).

The superiority of lapped transform (LT) over wavelets may come from additional design degrees of freedom and sharper frequency attenuation properties of the M filters (potentially reducing aliasing throughout the subbands). One other interesting feature is based on [6]: the dyadic remapping property. When the number of channels M is a power of 2, the transformed coefficients may be rearranged into an octave-like representation. Experiments demonstrate that the resulting "scales" still bear interesting clustering and persistance properties, while keeping superior oscillatory pattern preservation.

As a consequence, we propose here to use hidden Markov models with lapped transforms, relying on [2, 3]. Special care is taken in the design of the LT used, to assess the anisotropic shape of some seismic surveys.

Figure 1 demonstrate the potential improvement of LT based HMMs: seismic data (Fig. 1-left) is corrupted with random noise with known statistics (25 dB). It is filtered with a 8-channel 16-tap biorthogonal lapped transform (GLBT) [7] and a 16-tap 3-level Daubechies wavelet. The residual noise after filtering is displayed (on the same magnitude scale) on Fig. 1 (center and right). Although the objective SNRs are quite similar after filtering (31.8 and 31.0 dB resp.), the center panel (LT) exhibits a more random residual noise than the right panel (wavelet), where ripples (*i. e.* lost information) show up clearly, as a result of poorer oscillatory pattern preservation.

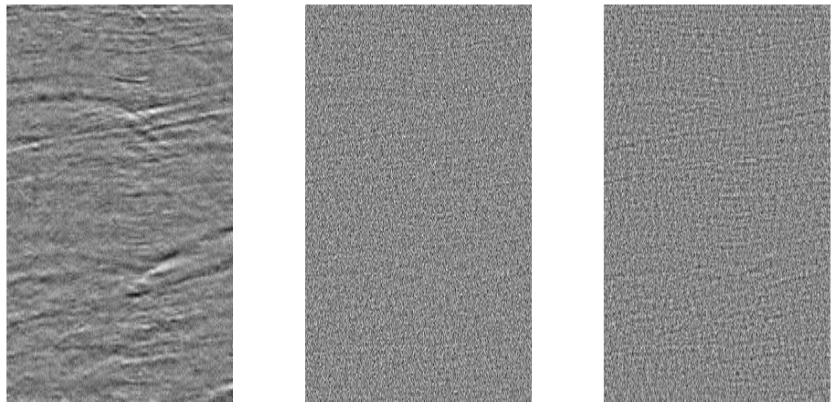

Figure 1: Original data (left) and remaining noise after filtering (center: 8×2 GLBT; right: db8 wavelet).

References

[1] D. L. Donoho. De-noising by soft-thresholding. *IEEE Trans. on Inform. Theory*, 41(3):613–627, May 1995.

[2] M. Crouse, R. Nowak, and R. Baraniuk. Wavelet-based signal processing using hidden Markov models. *IEEE Trans. on Signal Proc.*, 46(4):886–902, April 1998.

[3] J. Romberg, H. Choi, and R. Baraniuk. Bayesian tree-structured image modeling using wavelet-domain hidden markov models. In *Proc. SPIE Technical Conference on Mathematical Modeling, Bayesian Estimation, and Inverse Problems*, pages 31–44, 1999.

[4] P. L. Donoho, R. A. Ergas, R. S. Polzer, and J. D. Villasenor. Compression optimization by multidimensional wavelet transforms and data dependent quantization. In *Annual International Meeting*, volume 2, page 2042. Soc. of Expl. Geophysicists, 1996. Exp. abstracts.

[5] A. Averbuch, R. Coifman, F. Meyer, J.-O. Stromberg, and A. Vassiliou. Low bit-rate efficient compression for seismic data. *IEEE Trans. on Image Proc.*, pages 1801–1814, Dec. 2001.

[6] Z. Xiong, O. Guleryuz, and Michael T. Orchard. A DCT-based embedded image coder. *IEEE Signal Processing Letters*, November 1996.

[7] T. D. Tran, R. L. de Queiroz, and T. Q. Nguyen. Linear phase perfect reconstruction filter bank: lattice structure, design, and application in image coding. *IEEE Trans. on Signal Proc.*, 48:133–147, January 2000.