Seismic data denoising with a subspace pursuit greedy Radon transform

Juan I. Sabbione*[1], [1] Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata and CONICET

Abstract

The Radon transform is perhaps the most flexible tool in seismic data processing. Applications include velocity analysis, attenuation of multiples, signal-to-noise ratio enhancement, simultaneous source separation, and near-offset reconstruction, to name a few. Traditionally, we compute the Radon transform in the frequency domain after a parabolic approximation, which reduces the computational cost and improves simplicity. However, the parabolic approximation introduces errors in the modeled reflections. On top of this, the Radon transform has other well-known limitations. For instance, it tends to produce low-resolution velocity gathers and can not model AVO variations properly. These limitations motivate us to adopt new strategies for calculating time-variant hyperbolic Radon transforms by inversion.

Seismic data is known to be sparse in a velocity gather transformed domain. When posing the Radon transform as an inverse problem, there are two major approaches for sparsity promotion. The most common approach is L1-minimization by adding a regularization term with an L1-norm or another appropriate norm that promotes sparsity in the cost function. The second one is to use iterative methods known as matching pursuits. Among these methods, the orthogonal matching pursuit (OMP) algorithm has popularity because it guarantees convergence. In the last two decades, other OMP-like algorithms gained a lot of attention due to the rise of the so-called greedy algorithms for compressive sensing. The list of greedy algorithms is long, and includes stage-wise orthogonal matching pursuit (StOMP), regularized orthogonal matching pursuit (ROMP), compressive sampling matching pursuit (CoSaMP), and subspace pursuit (SP). The main idea is to find the model support of the input data iteratively but rapidly using as few coefficients as possible.

We propose a new subspace pursuit Radon transform for seismic data modeling and denoising. The focus is on the efficient computation of the Radon coefficients. A fast iterative shrinkage-thresholding algorithm (FISTA) for L1-minimization allows comparing the performance and analyzing the sparsity promotion of the subspace pursuit Radon transform. Synthetic experiments with different noise levels demonstrate the signal-to-noise ratio enhancement in each experiment. The synthetic tests show that the greedy algorithm permits to define a small subspace support for the Radon model with densely discretized Radon coordinates, thus overcoming the most common Radon transform limitations, including AVO modeling. Finally, field seismic data of the public domain illustrate the new method behavior in data applications.