Adaptive Eigenstructure Classification and Stochastic Decorrelation Filters for Coherent Interference Suppression in the Acoustic Zoom Method*

J. Guigné¹, S. Azad¹, C. Clements¹, A. Gogacz¹, W. Hunt¹, A. Pant¹, and J. Stacey¹

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¹Geoscience, Acoustic Zoom Inc, Paradise, NF, Canada (sazad@acousticzoom.ca)

Abstract

The Acoustic Zoom® (AZ) Method is an unconventional oil and gas exploration technology for 3D/4D seismic imaging that offers unique resolution and direct focusing of non-specular backscatter energy returns in land and marine environments. The receiver array has sixteen spokes (eight lines through a hub) at ∼22.5° increments. This array was deployed to intersect GGS's Wrangler 3D survey in Wilson County, Texas, over the prolific Eagle Ford, Austin Chalk, and Buda (limestone) formations. The AZ purpose-designed array, covering 12.5 km², encompassing over 4,000 receivers and with recorded frequencies up to 170 Hz, acquired over two terabytes of data. Five vibroseis locations were established in a cross configuration at a quarter of wavelength separation. At each of the five vibroseis locations, 512 sweeps were generated and vertically stacked for 2,560 sweeps. By design, AZ accentuates the rich content of non-specular backscatter energy by directly probing underlying geophysical properties of the earth where conventional migration accentuates specular reflections from ambiguous impedance changes in the subsurface. The totality of energy backscattered in the direction and range of a corresponding beam forms each AZ image. AZ adds value to existing 3D surveys by reconstructing complementary components of recorded energy that 3D seismic rejects as incoherent noise. Imaging of non-specular returns requires significant attenuation of coherent background interference (e.g. ground roll, specular reverberation) achieved by combining the narrow beam-width of the receiver array with adaptive classification and filtering of specular energy using Singular Value Decomposition, Stochastic Spectral Decorrelation, and advanced Eigen-structure methods. This approach replaces conventional filters that could introduce artifacts greater than the non-specular signals being sought.
Objectives

The Acoustic Zoom (AZ) seismic processing technology is an unconventional oil and gas exploration technology. All the data to existing 3D imagery by reconstructing complementary non-specular components of the recorded energy that 3D seismic processing projects as coherent noise. AoD analysis of non-specular energy requires significant alteration of coherent background interference (e.g., ground roll). Stochastic decorrelation is achieved by minimizing the variance components of the source side, with adaptive classification and filtering of specular and non-specular energy using simple wave decomposition (SWD), a propulsive nonlinear spectral decomposition (NSD) algorithm, and an advanced eigenspace classification (ESC) method. The resulting algorithm is analogous to the Bechhoff transform (in image processing) intended to separate point sources and diffractions. This approach replaces conventional filters that could introduce artifacts greater than the non-specular signals sought.

Introduction

The AZ method adopts an eigenspace-based classification and filtering algorithms to extract individual output images, thereby extracting the imaging problem into a non-linear convolutional filter. Adaptive processing allows the AZ method to include more realistic models of propagating wavefield, including frequency attenuation of the source function, for example. Conventional seismic processing only the imaging problem into convolutional forms to allow efficient processing using Fourier transfer functions. The family of beamforming methods includes spectral deconvolution (SBP beamforming), delay-filter-sum (Capon, Frost beamformers), and adaptive delay-filter-sum (AZ method). The current method is described here can incorporate repeated application of forward and inverse flattenings of an arbitrary dataset into a flattened dataset. The defining property of the projection functional is the projection of an arbitrary radiation pattern as an analyzing image into a flat image. The AZ method provides a systematic method by which an arbitrary radiation pattern may be embodied as an analyzing image. Image templates can be developed to image particular geophysical properties of commercial value.

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Stochastic Spectral Decorrelation Filter

The projection-based approach suggests a dataset that encompasses additional filtering during flattenings and imaging. The objective is to define a set of weights that shapes the purpose of all non-specular-image point contributions that have the same travel times (i.e., same phase) and to enhance the frequency spectrum so that all phases are suitably distributed. It all the in-phase amplitudes of wavelets are the same and the phase amplitudes are suitably distributed, then the contributions due to reverberation will cancel and approximately zero are (or preferably suppressed). The stochastic spectral decorrelation (NSD) algorithm aims at enhancing both the frequency and in-phase amplitudes of wavelets. To this end, the NSD algo- rithm is a deterministic and scalable array of arbitrary size and geometry. Although the NSD filter is not optimal in the Wiener filter sense given in single assumptions and the consideration of the reverberating wavefield, its robust and efficient performance allows the NSD filter be adapted to each image point.

Figure 1: A subset of the full array is used to identify potential non-specular candidates while rejecting sources of specular return.

Non-Specular Candidate

Adversional Non-Specular Candidates (as indicated by Arrow)

Figure 3: The original gather of data is exactly decomposed into (a) signal and (b) residual (adaptively smoothed).

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Figure 4: When the spatial and temporal frequencies of the wavelet amplitudes at an "allocated", these wavefields "mixed out" when the final beam forming image is calculated.

Conclusion

The AZ method provides a systematic method by which an arbitrary radiation pattern may be embodied as an analyzing image template. The method projects the observed data onto a component image template to determine the agreement between the observed data and the component data model. This projection operation is dependent on defining a scalar product (or projection) operator for images. Prior to beamforming, the flattened gather of data is first exactly classified as either consistent with the template for the signal or not consistent with the same template. The output is a measure that is proportional to the agreement between the data and the template image. This is analogous to the output of the Bechhoff transform (in image processing) intended to preserve efficient analysis and diffraction. Image template can be developed to image particular geophysical properties of commercial value.

Figure 2: (a) Eigen-structure classification is applied to a sliding time window of a flattened gather of data. The spatial vector component of each window is written into the corresponding gather of processed data. The residual vector of data may be similarly saved for later use. The analysis window is then advanced by one unit of time and processing proceeds until the entire data gather is analyzed.