Progress and Challenges in the Processing and Use of Land Seismic Data Acquired via Compressive Sensing

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Abstract

Compressive sensing (CS) acquisition schemes promise cost-optimization without compromising final image quality. However, irregular spatial data sampling is a challenge for existing processing and imaging toolboxes as they mainly rely on the assumption of pseudo-regular spatially sampled data. Recent publications, highlighting seismic data from the Sultanate of Oman, have confirmed the capability of processing CS land data by adopting shot reconstruction early in the workflow (Blymyer et al., 2021; Al-Harthi et al., 2022). However, it remains to be proven that CS-acquired land data is suitable for use in advanced demultiple and velocity model building techniques such as Multi-Wave Inversion (MWI) and Full-Waveform Inversion (FWI).

A 170 km^2 subset of a conventionally acquired dataset from the North of the Sultanate of Oman was chosen for this study. Compressive sensing acquisition was simulated by randomly dropping shot points using standard field decimation practices. Similar processing flows were applied to both the conventional and the CS proxy datasets. The processing sequence includes major signal processing steps such as linear and random noise attenuation, deconvolution, final pre-migration reconstruction by 5D regularization, and demultiple methods such as Land Surface Related Multiple Elimination (LSRME). Comparable imaging results and satisfactory quality indicators were obtained for CS simulations. We then explore MWI applications using both active and virtual data to ensure that irregular trace distributions do not compromise virtual shot reconstructions, first-break picking or surface waves velocity picking which are the main inputs needed to derive an accurate shallow sub-surface model. Our study also includes analysis of FWI input gathers to ensure consistency of the inversion process between CS and conventional datasets. We conclude with a comparison of Pre-Stack Depth Migration (PSDM) results based on Amplitude Versus Offset (AVO) analysis.

A rigorous comparison of co-located regular and CS field datasets is important in confirming that seismic data processing technology can overcome the challenges imposed by CS acquisition on land data. This analysis allows the many questions related to the processing integrity and the final use of CS data to be answered.