Using common information in compressive time-lapse full-waveform inversion

Time-lapse seismic inversion

Aim
Obtain time-lapse velocity models and differences

Challenges
Nonrepeatability in acquisition geometry
Weak 4D signal below noise level
Expensive baseline/monitor acquisitions

Approach
Use random subsets of data
Inversion with modified Gauss-Newton
Joint inversion with the joint recovery model (JRM)

Inversion with JRM

Sparsity-promoting Gauss-Newton

\[
\min_{\delta m} \frac{1}{2} \| D_0 - \mathcal{F}(m_0^0 + \delta m) \|_2^2 + \lambda \| \delta m \|_1
\]

\(D_0\): observed data
\(\mathcal{F}\): forward modelling kernel
\(m_0\): model parameters
\(\delta m\): model update

Goal: Compute baseline, monitor, and difference from common component and innovations w.r.t. the common component

\[
\hat{z} = \arg \min_{z} \frac{1}{2} \| b - A z \|_2^2 \quad \text{s.t.} \quad \| z \| \leq \tau
\]

\(A\): Jacobian
\(b\): source function

Zoom of time-lapse

Figure 2: Time-lapse inversion results obtained by subtracting monitor from baseline

(a) Independent inversion
SNR = 4.5dB
(b) Joint inversion
SNR = 1.4dB

Figure 3: Zoom of time-lapse inversion result in Figure 2

(a) Independent inversion
SNR = 0.7dB
(b) Joint inversion
SNR = 3.6dB

Conclusions

- With random subsampled time-lapse data, we can perform 4D FWI using a modified Gauss-Newton inversion
- Significant attenuation of artifacts in the time-lapse difference model obtained from joint inversion with JRM, giving improved signal to noise
- We propose using the models from JRM for subsequent migration
- The key is in exploiting the shared information during inversion of time-lapse data