microearthquake monitoring with sparsely-sampled data

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conventional imaging
notation

x: receiver coordinates
y: image coordinates
t: time
conventional imaging

\[ V(x, y, t) = D(x, t) \ast_t G(x, y, t) \]
conventional imaging

\[ V(x, y, t) = D(x, t) \ast_t G(x, y, t) \]

\[ U(y, t) = \int dx \ V(x, y, t) \]
conventional imaging

\[ V(x, y, t) = D(x, t) \ast_t G(x, y, t) \]

\[ U(y, t) = \int d\mathbf{x} \, V(x, y, t) \]

\[ R(y) = U(y, t = 0) \]
plane-wave superposition
plane-wave superposition

limited aperture
plane-wave superposition

incorrect velocity
plane-wave superposition

sparse acquisition
data without acquisition noise
data with acquisition noise
automatic location challenges

- clean-up the reconstructed wavefield
- identify wavefield focusing, i.e. the sources
Wigner distribution functions

Definition

Time-frequency transformations of complex signals

\[ U(x, t) \leftrightarrow W(x, t, k, \omega) \]

- **Wigner (1932):** Quantum physics
- **Ville (1958):** Signal processing
- **Cohen (1995):** Image processing
\[ W(x, t, k, \omega) = \int d\xi \int d\tau \ U \left( x - \frac{\xi}{2}, t - \frac{\tau}{2} \right) U \left( x + \frac{\xi}{2}, t + \frac{\tau}{2} \right) e^{-i(k \cdot \xi + \omega \tau)} \]

- \( U(x, t) \): wavefield
- \( W(x, t, k, \omega) \): WDF
\[ W(x, t) = \int \int d\xi d\tau U \left( x - \frac{\xi}{2}, t - \frac{\tau}{2} \right) U \left( x + \frac{\xi}{2}, t + \frac{\tau}{2} \right) \]

- \( U(x, t) \): wavefield
- \( W(x, t) \): pseudo-WDF
wavefield
wavefield
conventional imaging

\[ V(x, y, t) = D(x, t) \ast_t G(x, y, t) \]

\[ U(y, t) = \int dx \ V(x, y, t) \]

\[ R(y) = U(y, t = 0) \]
WDF imaging

\[ V(\mathbf{x}, \mathbf{y}, t) = D(\mathbf{x}, t) *_t G(\mathbf{x}, \mathbf{y}, t) \]

\[ U(\mathbf{y}, t) = \int d\mathbf{x} \; V(\mathbf{x}, \mathbf{y}, t) \]

\[ W_y(\mathbf{y}, t) = \int d\tau \int d\eta \; U \left( \mathbf{y} - \frac{\eta}{2}, t - \frac{\tau}{2} \right) U \left( \mathbf{y} + \frac{\eta}{2}, t + \frac{\tau}{2} \right) \]

\[ R_y(\mathbf{y}) = W_y(\mathbf{y}, t = 0) \]
WDF imaging

conventional imaging
automatic location challenges

- clean-up the reconstructed wavefield
- identify wavefield focusing, i.e. the sources
conventional imaging

slope decomposition
WDF imaging

slope decomposition
WDF imaging

slope decomposition
conclusions

WDFs attenuate random wavefield fluctuations
  ▶ unknown velocity
  ▶ sparse data sampling
  ▶ acquisition noise

clean wavefields facilitate automatic event picking
acknowledgment

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