Smoothing and automated picking of kinematic wavefield attributes

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Overview

Introduction

3D Common-Reflection-Surface (CRS) stack

Velocity determination with 3D CRS attributes

CRS-based workflow

Event-consistent smoothing

Automated picking

Data example

Conclusions

Acknowledgments
Introduction

- The Common-Reflection-Surface (CRS) stack provides
  - high S/N stacked ZO volume
  - coherence value for each sample
  - kinematic wavefield attributes for each sample
  - generalised, high density stacking velocity analysis

- The CRS attributes can further be used for many applications, e.g.:
  - calculation of projected Fresnel zone and geometrical spreading factor
  - improved AVO-analysis
  - tomographic determination of macro-velocity models
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  - improved AVO-analysis
  - tomographic determination of macro-velocity models
Introduction

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  - outliers
  - non-physical fluctuations

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CRS tomography

- Advantages:
  - picking in simulated ZO volume of high S/N ratio (output of CRS)
  - pick locations independent of each other
  - very few picks required

- Quality of result depends on quality of input CRS attributes
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▶ Quality of result depends on quality of input CRS attributes
3D CRS attributes

Traveltime depends on eight attributes:

\[ t^2 (\Delta \xi, h) = \left( t_0 + 2 p_\xi \cdot \Delta \xi \right)^2 + 2 t_0 \left( \Delta \xi^T M_\xi \Delta \xi + h^T M_h h \right) \]

\[ p_\xi = \frac{1}{v_0} (\sin \alpha \cos \psi, \sin \alpha \sin \psi)^T \]

\[ M_h = \frac{1}{v_0} \mathbf{D} \mathbf{K}_{\text{NIP}} \mathbf{D}^T \]

\[ M_\xi = \frac{1}{v_0} \mathbf{D} \mathbf{K}_\mathbf{N} \mathbf{D}^T \]

NIP: normal incidence point
3D CRS attributes

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NIP waves and velocities

CRS attributes $M_h$ and $p_\xi$ at $(t_0, \xi)$ describe second-order traveltime approximation of emerging NIP wave.
NIP waves and velocities

(T, M_h, p_ξ, ξ)

In consistent velocity models, NIP waves focus at zero traveltime.
Tomography with CRS attributes

Find a velocity model in which all considered NIP waves, described by kinematic wavefield attributes, are correctly modelled.
CRS-based workflow

- CRS – stack
- NIP-wave tomography
- Migration
fluctuations in CRS attributes, which are not consistent with theory, influence the inversion result

- manual picking is very time consuming, especially in 3D
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- manual picking is very time consuming, especially in 3D
CRS-based workflow

- How to remove outliers and fluctuations in the attributes?
- Where to pick the limited number of locally coherent reflection events needed in NIP-wave tomography?
- How to do this automatically?

CRS – stack

NIP-wave tomography

Migration
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**CRS-based workflow**

- **Strategy**
  - smoothing and picking in volumes aligned with reflection events:
    - volume size defines locality
    - usage of locally valid statistics
  - to remove outliers and fluctuations
  - to identify valid pick locations

- **Smoothing**
- **optional restacking**
- **automated picking**
- **NIP-wave tomography**
- **Migration**

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3D CRS stack
Velocity determination
NIP waves
CRS tomography

**Workflow**

Smoothing
Picking
Data example
Attribute volumes
Picked attributes

**Conclusions**

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**Related talks**
CRS-based workflow

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Event-aligned volume

$\begin{align*}
\text{time} \\
2\vec{p}_0 \\
\text{seismic event} \\
\text{midpoint } y \\
\text{midpoint } x \\
\text{midpoint } y_0 \\
\text{midpoint } x_0 \\
\end{align*}$
Event-aligned volume

smoothing box

midpoint x

midpoint y

seismic event

2p₀

t₀

x₀

y₀

0

time
Event-consistent smoothing

For each zero-offset sample and CRS-parameter:

- align smoothing volume with reflection event using first traveltime derivatives
- reject samples below user-defined coherence threshold
- reject samples with dip difference beyond user-defined threshold
  - avoid mixing of events
- apply combined filter:
  - median filter  ➩ remove outliers
  - averaging  ➩ remove fluctuations
- assign result to zero-offset sample
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Stack, unsmoothed attributes
Stack, smoothed attributes
Coherence, unsmoothed attributes
Coherence, smoothed attributes
Automated picking

For each selected trace

- search (next) coherence maximum
- get nearest maximum of stack envelope
- align volume with reflection event using first traveltime derivatives
- reject pick if user-defined percentage of all samples inside the volume is below a given coherence threshold or has a dip difference exceeding a given threshold or if amplitude is below a user-defined threshold
- continue on selected trace
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Picks on selected sections
Stacking velocity
“Smoothed” stacking velocity
Normal ray emergence angle
Smoothed normal ray emergence angle
Coherence, unsmoothed attributes
Coherence, smoothed attributes
Stacking velocity
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Conclusions

- fast and efficient smoothing and picking algorithms
- accounts for neighbouring information using windows aligned with reflection events
- no mixing of intersecting events
- no human interaction required
- smoothing can improve the CRS image significantly
- automated smoothing and picking closes the gap between CRS stack and NIP-wave tomography
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Related presentations

Workshop WS-2 “Velocity analysis for depth imaging”, Monday afternoon:

13:30 Common-Reflection-Surface stack – a generalized stacking velocity analysis tool

Session “Seismic Imaging”, Wednesday morning:

09:45 CRS-stack-based seismic imaging for land data and complex near-surface conditions

11:00 True-amplitude CRS-based Kirchhoff time migration for AVO analysis

11:25 Common-Reflection-Surface stack for OBS and VSP geometries and multi-component seismic reflection data
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