Common-Reflection-Surface Stack and Wavefield Attributes

Jürgen Mann, Rainer Jäger, German Höcht, and Peter Hubral

Overview

- Comparison of different stacking operators
- Eigenwave based CRS stacking operator
- Synthetic example vs. forward modeled attributes
- Real data example: imaging a salt dome
- Conclusions and outlook
Summary

The common reflection surface (CRS) stack is a macro velocity model independent method to simulate zero-offset (ZO) sections from multi-coverage seismic reflection data for 2-D media.

The CRS stacking operator depends on attributes of hypothetical wavefronts observed at the surface that allow to perform a subsequent inversion.

The CRS stacking operators fitting best to actual reflection events in the data set have to be determined by coherency analysis. The main task is the determination of these operators by variation of the attributes in a reasonable computation time preserving a sufficient accuracy.
Stacking operators of NMO/DMO/stack and pre-stack depth migration
CRS stacking operator

Eigenwave experiments

- CRS stacking surface
- Distance [km]
- Depth [km]
- Depth [m]
- Time [s]
- Half-offset [m]
- Midpoint [m]
Common-reflection-surface stacking operator

\[ t^2 (\Delta x, h) = \left( t_0 + \frac{2 \sin \alpha \Delta x}{v_0} \right)^2 + \frac{2 t_0 \cos^2 \alpha}{v_0} \left( \frac{\Delta x^2}{R_N} + \frac{h^2}{R_{NIP}} \right) \]

- \( h \): half offset between shot and receiver
- \( \Delta x \): midpoint distance
- \( \alpha \): emergence angle of the normal ray
- \( R_{NIP} \): radius of curvature of the NIP wave
- \( R_N \): radius of curvature of the normal wave

In the CMP gather in terms of the stacking velocity \( v_{NMO} \):

\[ t^2 (h) = t_0^2 + \frac{4 h^2}{v_{NMO}^2} \quad \text{with} \quad v_{NMO}^2 = 2 v_0 R_{NIP} / (t_0 \cos^2 \alpha) \]
Synthetic example: model and ZO section of multi-coverage data set
Coherence in the wavefield attribute domain
Synthetic example: result of the optimized CRS stack

simulated ZO section

coherency section
Synthetic example: attribute sections

emergence angle [$^\circ$]

radius of curvature $R_{NIP}$ [m]
Synthetic example: attribute sections

radius of curvature $R_N$ [m]

model-derived vs. data-derived $R_N$
Synthetic example: attribute sections

model-derived vs. data-derived emergence angle

model-derived vs. data-derived $R_{NIP}$
Real data example: NMO/DMO/stack vs. CRS stack

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Real data example: conventional NMO/DMO/stack

CMP location
approx. 13km

Time [s]

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Real data example: optimized CRS stack

CMP location approx. 13km

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Real data example: post-stack depth migrated sections

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Real data example: post-stack depth migrated NMO/DMO/stack

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Real data example: post-stack depth migrated CRS stack

Data courtesy of BEB Erdgas und Erdöl GmbH and Preussag Energie GmbH.
Conclusions

The CRS stack is a model independent seismic imaging method and thereby can be performed without any ray tracing and macro velocity model estimation. Only the knowledge of the near surface velocity is required. As a result of a CRS stack one obtains in addition to each simulated ZO reflection time important wave-field attributes: the angle of emergence and the radii of curvature of the NIP and the normal wave. The application to real and synthetic datasets showed noteworthy results with respect to the stack section and the determined attributes. In view of the authors, the proposed strategies offer an exciting approach to improve the stack section and to allow for a subsequent inversion.
References


Acknowledgements

This work was kindly supported by the sponsors of the Wave Inversion Technology Consortium, Karlsruhe, Germany and Elf Exploration Production, Pau, France.