Bin-Share Stacking for 3D Converted Wave Processing

Summary

A Bin-Share Stacking method is proposed for maintaining an optimum bin size for 3D converted wave stacking. This Bin-Sharing method for stacking converted waves allows for keeping the same grid and bin sizes as used for stacking P-P data, with the P-S data stacking radius equivalent to a larger bin size. One advantage of this is that the stacked P-S data is output on the same grid as the P-P data. A second advantage is to optimally vary the stacking bin radius with time which is important for shallow depths as the optimum bin size is larger than that of deeper horizons.

Introduction

A conventional flow for 3D converted wave processing begins with processing of the P-P data volume including calculation of an optimum bin size for the P-wave processing, velocity analysis, NMO, stacking, and other steps including migration. P-S data processing requires different binning and a bin size larger than that used for P-P processing, as outlined by Harrison (1989) or Cary (1994). The optimum bin size for P-S processing is determined from the Vp/Vs ratio. This means that for the P-S processing a new binning grid would need to be created with a new optimum bin size.

Correlating events between P-P and P-S can be difficult and is made worse when the P-P and P-S stacks are on two different grids. To simplify this we propose to use a Bin-Sharing method on the P-S data outputting to the P-P binning grid. By picking a varying stacking radius parameter in a Bin-Share method, we can stack to an equivalent of the desired larger bin size than that of the P-P grid. The Bin-Sharing method also helps in varying the stacking bin size with depth. This is necessary since in P-S processing the optimum bin size for the shallow depths is larger than the optimum bin size for the deeper layers.

Theory

From a computational point of view, the main difference between stacking P-P waves in CMP bins and stacking P-S waves is that the locations of the common conversion points (CCP) are not in the middle between source and receivers as for CMP bins, but are moved toward the receiver, vary with depth and depend on the Vp/Vs ratio, where Vp is P-wave velocity and Vs is S-wave velocity. A quartic equation for offset distance between shot converted-wave reflection point coordinates was given by Tessmer and Behle (1988).

For 3D converted wave data and its asymptotic conversion point (ACP), Lawton (1993) determined the optimum bin size to be dR/(1+Vs/Vp). This optimum bin size is calculated as a separation between projections on a horizontal plane of two conversion points for two adjacent receivers and one shot point.

Using this definition of an optimum bin size as a separation of two conversion points for two adjacent receivers for finding optimum bin size for an arbitrary CCP (not necessarily the asymptotic case), we see that the optimum bin size will vary with depth. It will be equal to the receiver interval for shallow depths when conversion points are very close to the receivers and will gradually decrease to the value of dR/(1+Vs/Vp) for the asymptotic case.

Figure 1 shows locations of conversion points for two adjacent receivers R1 and R2 versus depth calculated using Tessmer and Behle's quartic equation. It shows that the separation between CCPs decreases from 60 m (receiver interval) at zero depth to 45 m at 850 m depth, and, respectively, the optimum bin size changes from 60 to 45 m. The asymptotic optimum bin size is less – it is 40 m.

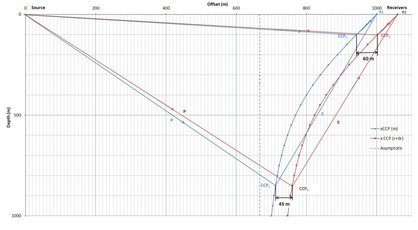
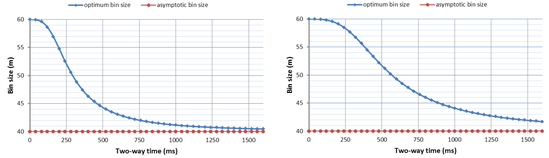


Figure 1: CCP offset (m) vs. depth (m) for two adjacent receivers R1 and R2 at 1000 and 1060 m offsets. Vp/Vs= 2, Vp = 2500 m/s model. The distance between the adjacent receivers CCPs - CCP_1 and CCP_2 which is equal to an optimum bin size decreases with depth.

Figure 2 (a-b) shows more examples of how the optimum bin size varies with time for different model parameters. These examples convince us that it would be desirable, for stacking converted waves, to find some way to vary a bin size to keep it optimum since too small bin size would cause uneven fold distribution and degrade the stacking (Eaton and Lawton, 1992; Lawton 1993) and too large would smear the data.

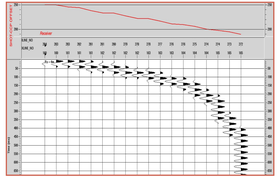


a. Shot-receiver offset 500 m

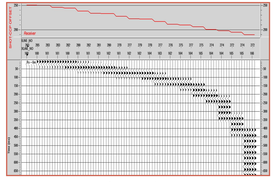
b. Shot-receiver offset 1000 m

Figure 2: Optimum and optimum asymptotic bin sizes (m) versus 2-way time (ms) for Vp=2500 m/s, Vp/Vs =2, receiver offset interval 10 m, and two shot-receiver offset values 500 and 1000 m.

We propose using a Bin-Sharing method which allows the trace samples at each conversion point to be stacked into those bins whose centers fall in a circle of a given radius with the circle center at the conversion point. The optimum bin-share radius is calculated from using the same area criterion of a round and a square bin. If an optimum bin size is D, and the bin is square, the bin-share radius of the circle covering the same area will be $R = D/\sqrt{\pi}$ or $R \approx 0.56\ D$. By picking such a bin-share radius, the stacking will be equivalent to the desired optimum bin size D. Figure 3 shows on a synthetic example on how the trace parts would be distributed over different bins for two different stacking radius values.



a. R = 4 m



b. R = 6 m

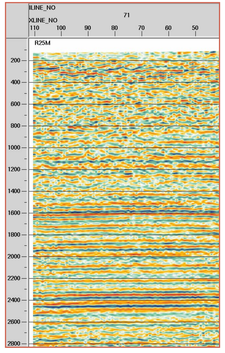
Figure 3: Distribution of trace fragments falling into different CCPs over different bins for two values of stacking radius R. Shot-receiver offset is 250 m.

Real Data Examples

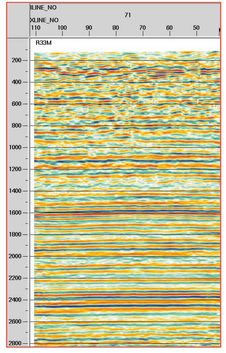
Figure 4 shows two stacks on the CREWES Blackfoot 3D-3C dataset with two different stacking radii: 25.2 m (a) estimated as an optimum for deeper layers (asymptotic case), and 33.6 m (b) as an optimum for the shallow data. The shallow section looks obviously better with a larger stacking radius (as expected). The deeper section also seems to be better with a larger stacking radius. However, the difference in the deeper section is not as big as in the shallow part. It was expected that for deeper layers the larger stacking radius would cause smearing, but apparently the radius was not large enough to make it obvious on this dataset.

Figure 4 (c) shows the result of stacking with a time-variant radius linearly varying from 33.6 m at zero depth to 25.2 m at 1000 m depth. The stack is better at shallow depths (compared to 25.2 m radius stack) and for the deeper layers it looks the same as the 25.2 m radius stack which is an optimum for the deeper horizons.

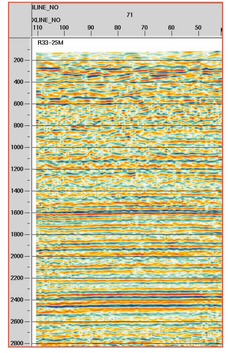
Figure 5 displays the same features on the Clearwater West 3D-3C dataset – stacking with an equivalent bin size optimized for an asymptotic case is not good in shallow section where the optimum bin size should be bigger. If all data were stacked with a bin size optimized for a deeper horizons, it would essentially degrade the quality of stack in the shallow part (Fig. 5, a) with a zone of interest. However, stacking with time-variant stacking radius provides an optimum equivalent bin size for shallow and deeper sections (Fig. 5, c).



a. Stacking radius 25.2 m:
Equivalent to an optimum bin size 45 m

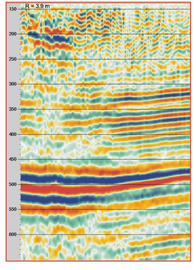


b. Stacking radius 33.6 m:
Equivalent to an optimum bin size 60 m

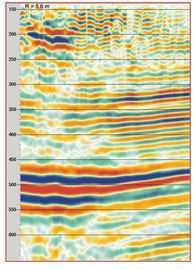


c. Stacking radius varies from 33.6 - 25.2 m:
Equivalent to an optimum bin size variance 60-45 m

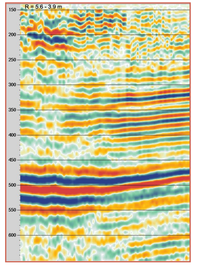
Figure 4: Constant stacking radius and time-variant stacking radius CCP stacks.



a. Stacking radius 3.9 m:
Equivalent to an optimum bin size 6.7 m



b. Stacking radius 5.6 m:
Equivalent to an optimum bin size 10 m



c. Stacking radius varies from 5.6 to 3.9 m:
Equivalent to an optimum bin size variance 10 – 6.7 m

Figure 5: Constant stacking radius and time-variant stacking radius CCP stacks.

Data courtesy of ALBERTA OILSANDS Inc.

Conclusions

When processing P-S data, we have to deal with at least two different binning grids - one smaller bin size used for P-P processing and a larger bin size that is optimal for converted waves. In such a situation, it is natural to try using the original binning from P-P processing for processing P-S waves, and there are examples of such practice. For P-S processing, Eaton and Lawton (1992) mentioned using two adjoining bins for improving the stacked data quality, Cary (1992) also considered using sufficient overlapped CMP sized bins for an intermediate asymptotic CCP stack.

The Bin-Share Stacking method makes it possible to stack data on the P-P binning grid with a correction for any desirable bin size larger than the original size by changing the stacking radius. This approach is more flexible than merging several bins since the optimum bin size does not have to be a multiple of an original size. It is even more important that the Bin-Share Stacking radius be able to vary with depth to keep an optimum bin size for all depths, as it was shown here that the optimum bin size for the shallow depth is quite different from the optimum asymptotic bin size.

References

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Eaton, D.W.S., and Lawton, D.C., 1992, P-SV stacking charts and binning periodicity: Geophysics, 57, 745-748.

Harrison, M.P., 1989, Three-component seismic data processing: Carrot Creek, Alberta: CREWES Research Report: Vol. 1.

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