Problems with imaging regularly-sampled seismic data

Peter W. Cary and Xinxiang Li, Sensor Geophysical Ltd.*

Summary

Processing noise caused by improper cancellation of prestack migration wavefronts can produce unreliable amplitudes and distorted waveforms on imaged events. This "migration noise" is a type of acquisition footprint that is often attributed to the inherent irregularity of the spatial sampling of 3-D seismic surveys (Ronen and Liner, 2000). However, irregular sampling is not necessarily a cause of this problem. Comparable problems can exist even with **regularly**-sampled 2-D and 3-D data. Being able to recognize and resolve these problems with regularly sampling data can shed light on the irregular sampling problems as well.

Prestack sampling problems can come about with regularly sampled data because of the method that we use to choose the CMP bin size during survey design. At least in theory, we choose the CMP interval to be small enough to ensure that spatial aliasing of the signal does not occur on a hypothetical zero-offset section (Liner and Underwood, 1999). This insures that the zero-offset section can be correctly migrated. However, it can be shown that this condition implies that there will be, or at least could be, data aliasing problems in the prestack domain, even on shot gathers. This obviously should be a concern with methods that assume that individual prestack gathers can be individually imaged. This potential aliasing problem has not caused great difficulties up to now possibly because the highest frequencies in the data are not crucial to interpretation, or because the high frequencies do not exist in the data to begin with. Another possible explanation is that the problem of imaging individual aliased gathers is at least partly overcome by the combination of more than one prestack gather, either before or after migration.

The oldest and least expensive solution to this problem for 2-D data is partial stacking into common-offset sections. This technique, which has been in standard use for decades, probably has not received as much respect as it deserves for being a legitimate least-squares solution to the problem. The built-in assumption of this method is that events are in their correct temporal and spatial positions after partial NMO is applied to the offset-bin centre. Although this assumption is obviously wrong, it is an obvious improvement over the much worse assumption that we use in NMO stack (that full NMO to zero offset puts events in their correct position). Perhaps the best thing of all for Canadian plains data (which is dominated by flat events) is the fact that flat events remain flat throughout the partial stacking process. So at least prestack migration of flat events after partial stacking into common-offset sections will give the correct answer, which is certainly better than the standard method of prestack migration, which can distort waveforms on flat events.

The error incurred by partial stacking of offsets increases with the width of the offset bin, which is determined, in turn, by the size of the source interval. Therefore, decreasing the source interval not only improves the attenuation of random noise due to the fact that the CMP fold is increased, but it also decreases the error in imaging the signal.

The comparable solution for 3-D land data is partial stacking into common-offset-vector (COV) volumes (Cary, 1999). For 3-D data, the source line spacing and the receiver line spacing determine the minimum widths of the offset bins in the inline and crossline directions. COV volumes are exactly analogous to common-offset sections in 2-D in terms of their imaging properties. The spacing of traces is given by the CMP bin widths, which allows operator aliasing to be controlled properly, and the edges of the survey are also known, so edge-effects for each COV volume can be controlled.

More sophisticated and expensive solutions with least-squares DMO and least-squares migration have received attention along with related techniques (offset continuation, shot continuation and azimuth moveout) for their ability to overcome sparse prestack sampling problems when sampling is irregular (Ronen and Liner, 2000). However, these methods should properly be recognized as being just as applicable to regularly-sampled data as to irregularly-sampled data. The need to use these more accurate types of solutions for the 2-D problem (compared to a simpler partial stack solution) increases as the shot interval increases. For 3-D data, the need to use them increases as the shot line spacing and receiver line spacing increase.

References

Cary, P.W., 1999, Common-offset-vector gathers: an alternative to cross-spreads for wide-azimuth 3-D surveys, 69th Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1496-1499.

Liner, C.L. and Underwood, W.D., 1999, 3-D seismic survey design for linear v(z) media: Geophysics, **64**, 486-493.

Ronen, S. and Liner, C.L., 2000, Least-squares DMO and migration: Geophysics, **65**, 1364-1371.