Noise suppression, prestack imaging and freedom of choice

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> *"Land exploration today is in a transitional phase similar in scale to that of the 1980s and 1990s when recording methodologies migrated from 2D to 3D. In fact, the industry is undergoing a profound shift from orthogonal line and swath surveys to free-form nodal surveys, replete with the myriad challenges that accompany advances in technology. Present-day acquisition methodology dictates that surveys be designed, systems engineered, and software developed to accommodate grid geometries—parallel lines of equally spaced receivers deployed in geometric arrays alongside another geometric array of parallel lines of equally spaced sources. This approach works well in theory, but eventually the real world meets the artificial Euclidian geometry of our surveys."* (Freed, 2008).

Freedom of choice?

From time to time it is argued that cable-free systems would bring freedom in the choice of receiver station locations. The quote above is a case in point. This freedom has been there all along for source station locations, but if applied it is no good for final data quality. In this note I want to argue against freedom of choice for source and receiver locations and in favour of better insight into what is needed for optimal quality of the final processed data.

Noise suppression

Modern land seismic data acquisition parameters are designed on basis of (regular) nominal geometries, in particular orthogonal geometry. Orthogonal geometry data can be split into cross-spreads, which are eminently suited for various prestack processing steps, in particular for random noise, ambient noise and for ground-roll suppression (Vermeer, 2005).

Random noise can be suppressed in cross-spreads because the seismic wavefield itself is continuous in a well-sampled cross-spread. Random-noise does not satisfy this behaviour and can be simply suppressed by various processes available in the industry for this type of noise.

Ambient noise may be continuous in common shot gathers, but behaves like random noise in common receiver gathers; hence, ambient noise can be removed using the same processes as available for random noise, provided the receiver gathers are well-sampled.

Ground-roll can be drastically suppressed in cross-spreads by 3D filters. These filters may be velocity filters in the (f, k_x, k_y)-domain or slowness filters in the (τ, p_x, p_y)-domain; alternatively, time-space domain filters may be used as well. A prerequisite is again that the cross-spreads are well-sampled. Basically, this means that the intersecting shot line and receiver line corresponding to each cross-spread should be smooth and well-sampled. The finer the sampling the more successful ground-roll suppression will be. Aliased noise that would fold back onto the signal domain should be suppressed by the use of field arrays with length equal to the station intervals.

In Vermeer (2005) it is argued that, for optimal results, orthogonal geometry requires special software that exploits the properties of the geometry. This may be seen as a disadvantage of that geometry. However, once that software is available, it makes processing of the acquired data so much easier and that more successful that the extra effort pays for itself many times over. This in contrast with data acquired in an unorganized way; such data is much more difficult to process, and a much higher fold will be required to stack out noise that cannot be suppressed successfully prestack.

Prestack imaging

It is widely accepted in the industry that prestack imaging should provide images that are better focused in the correct location. Of course, the result also depends on the quality of the technique used (depth imaging is better than time imaging) and on the type of algorithm (varying from Kirchhoff to reverse time migration). It is not yet widely understood what should be done ideally in acquisition for optimal imaging results.

There is no problem in imaging data that have been acquired with so-called full-fold geometry, i.e., a geometry with dense sampling in *x* and in *y* of sources as well as receivers. However, full-fold geometry is beyond reach, not only because of hardware limitations, but also because of time limitations: it would take too much time to plant all the geophones and to shoot all the shots. Instead, sparse acquisition geometries are used. In 3D symmetric sampling, two of the four spatial coordinates are properly sampled, whereas the other two are coarsely sampled. That type of acquisition is affordable.

In orthogonal geometry this recipe means that the *y*-coordinate of the shots and the *x*-coordinate of the receivers are properly sampled. The shot-line interval (*SLI*) represents the coarsely sampled *x*-coordinate of the shots and the receiver line interval (*RLI*) represents the coarsely sampled *y*-coordinate of the receivers. *SLI* and *RLI* form the sides of the rectangular area called unit cell; it is the area between two adjacent receiver lines and two adjacent shot lines.

Ideally, the data of a seismic survey can be split into *M* single-fold subsets that are suitable for imaging (*M* is total fold of geometry). The only survey-wide single-fold data sets suitable for imaging are COV gathers (common offset-vector gathers; i.e., gathers with constant offset and constant azimuth). Similar to the zero-offset gather or cube, each COV gather can be used to create an image of that part of the subsurface that it has illuminated. If the gather is well-sampled the images made with this gather are clean and free of artefacts. Hence, with *M* such gathers, one should be able to generate *M* different images of the subsurface (barring illumination problems due to complex geology).

However, such COV gathers are only available in the full-fold geometry. The nearest one can get to COV gathers with orthogonal geometry are OVT (offset-vector tile) gathers that are made up from unit-cell sized tiles with the least possible variation in offset and azimuth, or, least possible variation in inline offset and crossline offset (Vermeer, 2002, 2005). The images created with OVT gathers are relatively clean and have limited artefacts (Gesbert, 2002; Vermeer, 2002). The magnitude of the artefacts depends on the size of the unit cell; the smaller *RLI* and *SLI* the cleaner the images created with OVT gathers. Only in case sampling of shots and receivers is equally dense in *x* and in *y*, then the OVT gathers are virtually equal to COV gathers and will there be no imaging artefacts.

The significance of this approach is that creation of artefacts in imaging is restricted as much as possible, thus limiting the need for high fold-of-coverage to suppress such artefacts. Only in regular one-line roll orthogonal geometry continuous OVT gathers will be generated. This sets the standard to be aimed for in seismic data acquisition: regular geometry capable of generating continuous single-fold OVT gathers. In practice, there will always be deviations from the ideal; however, knowing what should be aimed for provides the impetus for better practices and solutions in the field, so that any deviations from the ideal can be tackled with better chances for success.

Conclusion

On basis of above reasoning, what should definitely not be done is to exploit the freedom of cable-free systems to go for acquisition without rules. Regular orthogonal geometry is the standard to be aimed for in land data acquisition. Fortunately for the cable-free system manufacturers, there are plenty of other good reasons to use cable-free systems (Heath, 2008; Freed, 2008).

References

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