Optimum stacking from optimal velocities

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Introduction

Over the past few years, efficient methods have been developed to estimate densely sampled stacking velocity fields with the aim to improve the S/N ratio, the spatial resolution, and the frequency content of the stack. As a by-product, this densely sampled attribute cube can also be directly interpreted. However, the raw estimates of the automatically derived velocities are often too noisy for immediate use. Fortunately, due to their dense nature we can make use of efficient geostatistical techniques to perform quality control and to remove noise. We will show on a real data example that these techniques can have a clear impact on the NMO stack result.

Automated velocity picking

Manual picking of stacking velocities is one of the most time consuming steps in the processing flow. Hand-picked velocities are therefore usually sparsely sampled both spatially and in time. These velocity functions then have to be interpolated at every bin location in order to produce a stacked data volume. Due to the coarse spatial sampling of the picking, short wavelength variations in the stacking velocity field cannot be recovered. This leads to sub-optimal stacking in areas where an accurate handling of the lateral variation in velocity is needed to properly focus the seismic energy. In order to improve the stack power, those lateral variations in stacking velocity need to be honoured. This can only be achieved by a dense velocity picking.

Dense velocity picking can be efficiently achieved by making use of automated residual velocity analysis as proposed by Doicin et al., 1995 and Adler and Brandwood, 1999. Automated residual velocity analysis is based on the detection of residual normal moveout (RNMO) on CMP gathers that are NMO corrected with a reference velocity function. The method used here is based on the assumption that a parabola can approximate the residual curvature. Velocities are thus derived from the residual parabola that best fits the NMO-corrected reflections along the set of offsets. In general the picks from automated picking will be corrupted by noise. The mispicks may be due to the presence of interfering coherent noise in the data, the non-hyperbolicity of the events, poor signal-to-noise ratio, wavelet stretch, or the effect of the acquisition geometry. This latter feature is well illustrated on a time slice (Fig 1a), extracted from the raw dense velocity cube. The presence of horizontal and vertical stripes strongly correlate with the acquisition geometry displayed in Fig 1b. The spatial variations of the fold, offset, and azimuth distribution caused by the acquisition geometry significantly imprint on the automatically estimated velocity field. This imprint appears even stronger than the one visible on the time slice extracted from the stack volume (Fig 1c).

Both random and spatially high frequency organized noise contaminate the raw velocity cube in a geologically inconsistent manner. The noise components damage the amplitude and phase continuity of the signal along the reflections. This feature is well illustrated when we compare the stack section computed with the sparse hand picked velocity field (Fig 2a) with the one obtained with the dense raw automated velocity field (Fig 2b). The full benefit of an automatic velocity picking is revealed (higher S/N ratio, higher bandwidth, etc.) only when the raw velocity field has been filtered (Fig 2c).

Geostatistical conditioning of the velocities

Filtering, and spatial and temporal regularization of the velocity field are the important processing steps with a direct impact on the quality of the stack, as well as on the interpretation of the velocity attribute.

The filtering step aims at removing undesired, non-geological features that corrupt the raw dense velocity cube. These features can be localized outliers, regular patterns induced by the acquisition geometry and/or inconsistent spatial variability along the inline and crossline directions. The significant advantage of densely sampled stacking velocity cubes is the possibility to estimate the dominant statistical behaviors needed to detect and filter the noise. A simple median filter can effectively remove the high frequency noise in the data, without generating artifacts. However, depending on the size of the filter, some of the true small-scale variations may also be filtered out. Short filters will more effectively preserve the small-scale geological features, but their isotropic characteristics will prevent them to remove undesired non-geological velocity components that are oriented along particular directions (defined by the acquisition imprint for instance). This is illustrated when comparing a time slice of a raw dense picked velocity cube (Fig 3a) with one filtered with a median filter (Fig 3b). More advanced technique such as geostatistical filtering (Le Meur & Magneron, 2000) and factorial kriging (Matheron, 1971) have proven to be the most appropriate for this problem. Such an approach allows the filtering of outliers and acquisition patterns (Fig 3c), without harming the small-scale velocity variations. As a result the S/N ratio as well as the spatial resolution of the stack section are considerably improved. This feature is illustrated on a time slice extracted from a stacked volume using the raw (Fig 4a), the median filtered (Fig 4b) and the geostatistically filtered velocity cube (Fig 4c).

Although the automated velocity picking is performed at regularly sampled bin locations, the picks themselves are only produced at times where a coherent reflection exists. The irregularly sampled raw velocity cube therefore needs to be interpolated. The interpolation scheme must be carefully designed to avoid any imprint of the distribution of the initial scatter onto the final velocity cube. A basic linear interpolation between neighboring picks cannot be used for the following reason: the volume of influence of a given velocity pick would depend on its distance to its neighbors, which is not related to its intrinsic spatial behavior. The interpolation/regularization of an irregularly sampled field can only be properly achieved by knowing the expected spatial behavior of the attribute to be regularized. This spatial behavior can be known through an analysis of the velocity attribute variograms, from which, then, any interpolation using kriging methods can be performed. Once again, using the right interpolation/regularization tools for the velocity field has a direct impact on the resolution of the stack section.

Conclusion

Automatic algorithms used to perform dense stacking-velocity analysis deliver measurements blurred with noise that prevent their direct application. However, the finer sampling of this attribute allows the use of efficient geostatistical filtering and interpolating methods to resolve this problem. These methods have a clear impact not only on the resolution of the velocity field, but also on its effectiveness in delivering the final stack. The pre-conditioning of this attribute must therefore be handled with the same care as the one used for pre-conditioning the seismic data.

References

Adler, F., and Brandwood, S., 1999, *Robust estimation of dense 3D stacking velocities from automated picking*: **69th** Ann. Internat. Mtg., SEG Expanded Abstracts.

Doicin, D., Johnson, C., Hargreaves, N. and Perkins, C., 1995, *Machine-guided velocity interpretation:* **65th** Annual Internat. Mtg., SEG Expanded Abstracts.

Le Meur D. and Magneron C., 2000, *Quality check of automatic velocity picking*. **62nd** EAGE Annual Meeting.

Matheron G., 1971, *The theory of regionalised variables and its applications.* (Ecole des Mines de Fontainebleau, France).

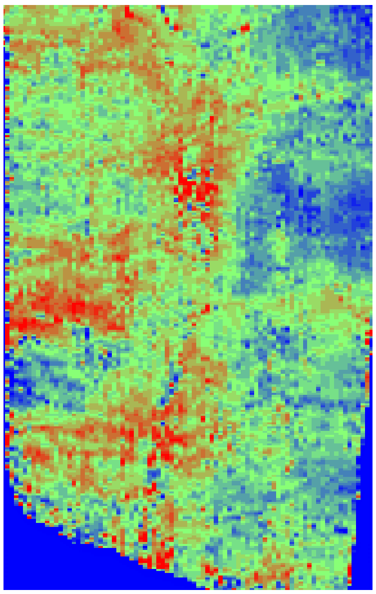

Figure1a: time slice on the raw automated velocity field.

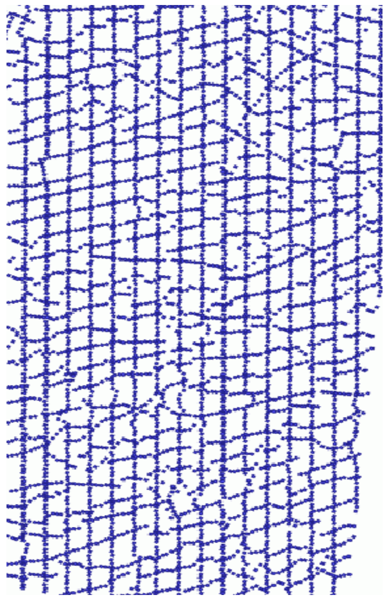

Figure1b: the acquisition geometry.

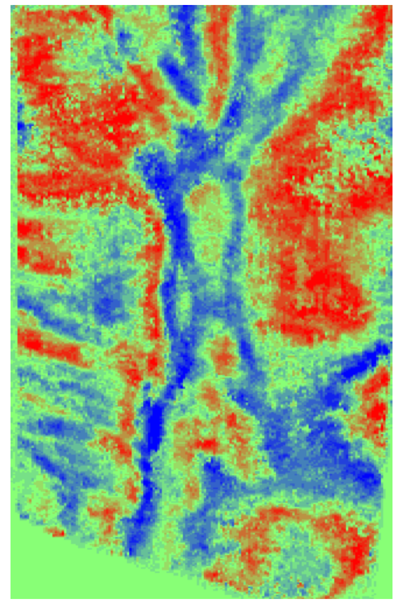

Figure1c: time slice on stack section obtained with the raw automated velocity field.

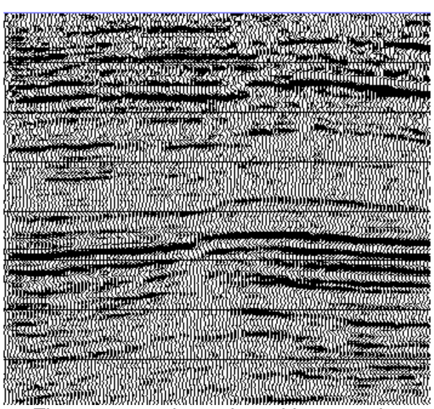

Figure2a: stack section with manual velocity field.

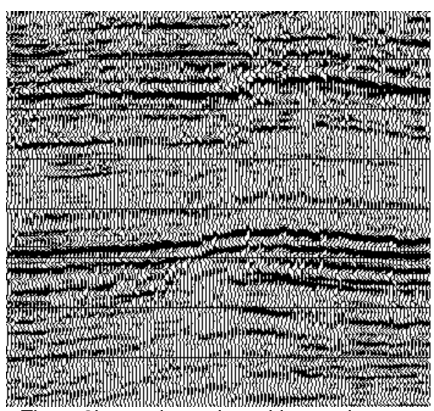

Figure2b: stack section with raw dense automatic velocity field.

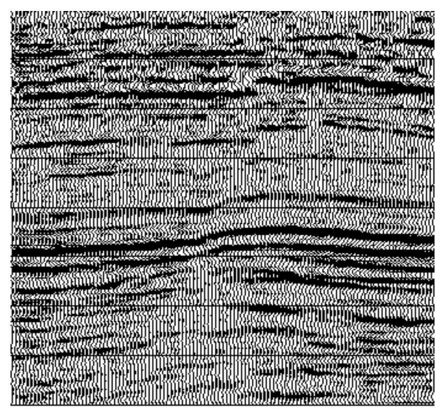

Figure2c: stack section with filtered dense automatic velocity field.

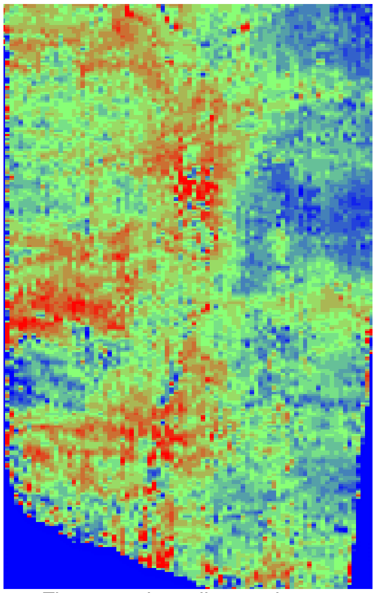

Figure3a: time slice on the raw automated velocity field

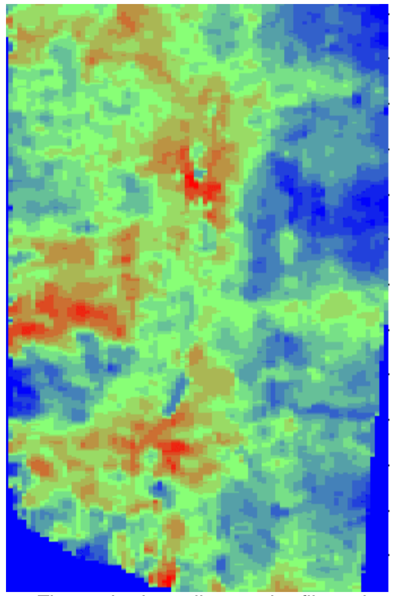

Figure3b: time slice on the filtered velocity field using a median filter

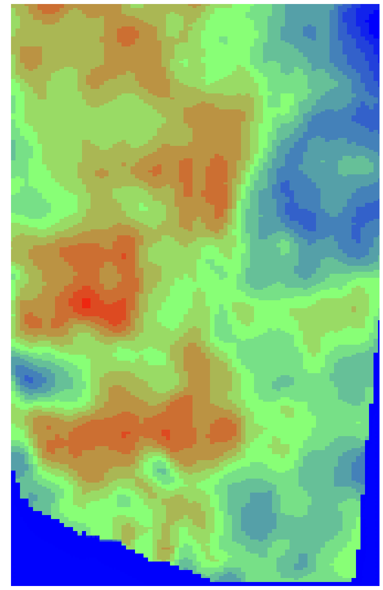

Figure3c: time slice on the filtered velocity field using Geostatistical filtering.

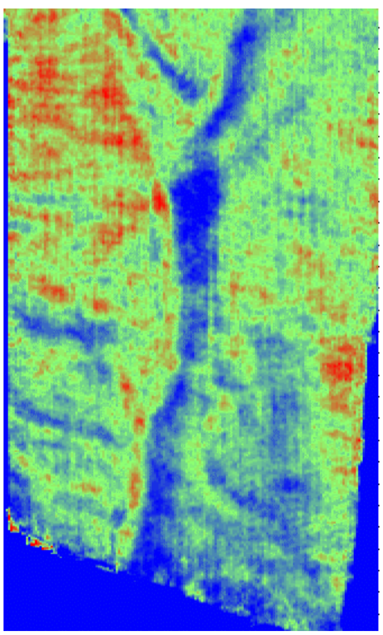

Figure4a: time slice on the rms amplitude stack with the manual velocity picking.

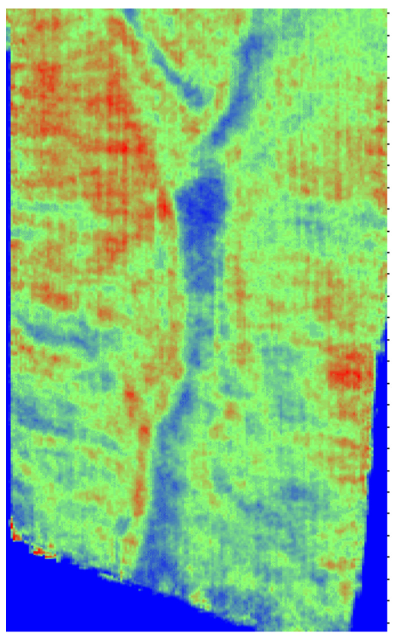

Figure4b: time slice on the rms amplitude stack with the filtered velocity field using a median filter.

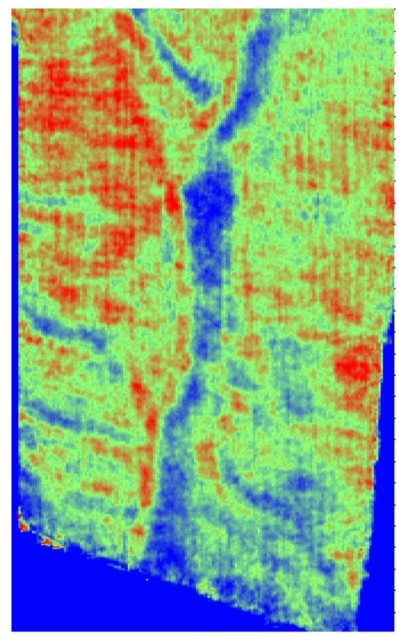

Figure4c: time slice on the rms amplitude stack with the filtered velocity field using geostatistical filtering.