Summary

The focusing process for time imaging is improved drastically when high-density parameter fields are used. Large offsets, steep dips and finally the anisotropy of the subsurface revise the bases of time processing. Today, two parameters are required: velocity \( V \) and anellipticity \( \eta \). Picking \( V \) and \( \eta \) using two-pass techniques cannot be a long-term solution. The estimation of both parameters is very sensitive to the mute function separating near to far offsets. Picking both parameters simultaneously using dense bispectral analysis overcomes this situation.

We are proposing in this paper an original parameterization of the non-hyperbolic moveout, which increases the sensitivity of the analysis and allows static moveout corrections, necessary for automatic dense pickings.

An intelligent QC sorting of the raw \( V \) and \( \eta \) fields, based on lateral coherency of the semblance and the Dix-inversion ability of local \( V \) and \( \eta \) functions, prepares skeleton fields for simultaneous geostatistical filtering of both parameters.

Introduction

The automatic picking of moveout velocity, as done in the past, has shown the benefits of using a high-density velocity field (Adler and Brandwood, 1999). However, the focusing of the far-offset data, especially dipping events, through an anisotropic subsurface, using only the moveout velocity field, cannot be achieved.

The non-hyperbolic behavior of reflection curves is generally due to ray bending through an isotropic-layered medium as well as to the propagation in an anisotropic-homogeneous medium. Alkhalifah and Tsvankin (1995) demonstrated that the anellipticity \( h \) which encompasses both effects is the required second moveout parameter.

Siliqi and Bousquié (2000) showed that the behavior of the vertical inhomogeneous media containing anisotropic layers remains of the ray bending type, but the magnitude of the far offset effects is mainly due to anisotropy. Updating the moveout equation for the layered media (Castle, 1994), by introducing VTI layers inside the model, they proposed the \( V, \eta \) parameterization of the shifted hyperbola equation (e.1). This approach seems to be very accurate in the most realistic cases and can be used successfully for bispectral velocity analysis (Siliqi, 2001).

\[
\frac{x}{V_{true}} - \frac{(1+8\eta_{true})}{V^2} t0 + \frac{1}{V^2} t0^2 + \frac{1}{V^2} x^2 = \frac{1+8\eta_{true}}{8V_{true}^2} \tag{e.1}
\]

where: \( x \) is the offset and \( t_0 \) the zero-offset traveltime.

The residual moveout due to the anellipticity alone is the kernel of the automatic dense \( \eta \) picking proposed by Le Meur et al (2001). However, this technique requires prior dense picking of the moveout velocity. The values of \( V \) and \( \eta \) are very sensitive to the mute function used for the first velocity picking. In the case of deep offshore data, it is usual to observe small errors in velocity causing erroneous \( \eta \) values.

Unlike these techniques based on residual moveout approaches, de Bazelaire and Viallix, (1994) proposed an original dense velocity analysis based on the full moveout equation. They demonstrated that the moveout correction using the shifted hyperbola could be transformed to an equation independent of \( t_0 \) (zero-offset traveltime), which is fundamental for any automatic dense picking.

Moveout parameters affecting all offsets

The effects of \( V \) and \( \eta \) on the moveout are not uniformly distributed along the offsets. If the velocity affects all the offsets, the effect of the \( \eta \) is concentrated on far offsets only. The Taylor series development of the residuals from the non-hyperbolic moveout correction (e.1) attests that:

\[
t_{res} = \frac{1}{2t_0-V_{true}} - \frac{1}{V^2} + \frac{1+8\eta_{true}}{V^2} + \frac{1+8\eta}{V^2} t_0 + \ldots \tag{e.2}
\]

where: \( V_{true} \) and \( \eta_{true} \) are the true moveout parameters of the reflection curve.

Let us describe the shifted hyperbola moveout on the local coordinates, where the reflection curve appears to be a hyperbola. Two features can constrain the hyperbolic shape of the reflection curve for these coordinates: the residual moveout at the largest offset (\( dtn \)) and the zero-offset traveltime (\( \tau_0 \)).
If $dtn$ is independent of the fact that the moveout is hyperbolic or not, $\tau_0$ differs from $t_0$ only when the reflection curve has a non-hyperbolic shape. Figure 1 shows the double scan of moveout corrections parameterized with $dtn$ and $\tau_0$.

The corrections seem to be very well constrained by $dtn$, nevertheless $\tau_0$ controls the fine-tuning of the flattening process. It is important to note that the scan of $\tau_0$ affects all offsets and the maximum of the magnitude is located somewhere at the middle. Because moveout effects and $(dtn, \tau_0)$ are both time quantities, the quality of the flatness can be as high as the user requires it.

The second benefit of this new parameterization of the shifted hyperbola is the capability to perform static moveout corrections, which are necessary for automatic bispectral picking. The substitution of dynamic moveout correction by static moveout correction drastically reduces the time taken for velocity analysis and improves the quality of the spectra by avoiding the stretch at far offsets.

**Automatic dense bispectral picking**

Thanks to this parameterization, the conventional velocity spectra are extended to a 3D analysis volume $(t_0, dtn, \tau_0)$. Figure 2 illustrates the 3D spectrum of semblance estimated through a bin gather of deep offshore data.
The search for the maximum semblance per $t_0$ allows continuous $(dtm, \tau_0)$ bispectral picking. Any pair can be transformed to $V$ and $\eta$. The estimated time-variant moveout parameters are shown in figure 3. The density and the quality of parameters are remarkable.

A threshold of the semblance can still reduce the number of pairs, but that remains a very local control. Before undertaking any sorting of the picking, it is necessary to check for the lateral coherence of these values.

In spite of the non-dependency of each picking, figure 4 shows the lateral coherency of final raw fields. The velocity field as well as $\eta$ field is laterally coherent from a statistical point of view. Moreover, on a wider scale, the semblance field looks like zero-offset seismic data (figure 5a), which is encouraging.

### Intelligent sorting of $V, \eta$ pairs

The output from the automatic picking contains more information than is required for the moveout process. $V$ and $\eta$ are locally estimated, and there is more than one pair per wavelet (see figure 4). In order to reduce this redundancy, an intelligent sorting of the pickings is necessary.

The reliability of any $(V, \eta)$ pair is certified by a series of tests. The Dix-type inversions of velocity and/or anellipticity between all pairs of the bin location have to provide plausible interval parameters.

The sorting of the pairs is weighted using the semblance values corresponding to the current level and their lateral neighbors. If a vertical minimum distance between picks is maintained, the output of this process looks like a skeleton, and the result seems to be similar to the products of horizon picking algorithms (figure 5).
The raw $V$ and $\eta$ fields contain different information at different scales but at the same time they are contaminated by wrong values due to interference, multiples and artifacts. The filtering of these dense fields is necessary. However, the filtering route is dependent on the final use of $V$ and $\eta$ fields.

In the second part of this paper (Le Meur et al, 2003), the authors propose an appropriate route for the simultaneous filtering of $V$ and $\eta$, specially designed for moveout correction purposes. The QC sorting of the fields prepares the input of the filtering route. As shown in figure 6, $V$ and $\eta$ functions remain dense, and their reliability is increased.

![Figure 6. The intelligent sorting (QC) of raw $V$ and $\eta$ functions.](image)

This paper maps out the route for obtaining reliable high-density $V$ and $\eta$ fields for moveout purposes. The search for lateral coherency in the pickings, combined with Dix-inversion capabilities, allows significant $V$ and $\eta$ skeletons, close to horizon-consistent pickings. The simultaneous geostatistical interpolation and filtering of these dense fields achieve the exposed objective: performing the most accurate moveout through the use of meaningful parameters.

**Conclusions**

Performing the focusing process using two dense moveout parameter fields is the new challenge of time processing. The successful achievement of this objective requires tools, which are able to pick simultaneously both parameters $V$ and $\eta$. We propose in this paper an original automatic bispectral picking, using the full moveout equation, valid for an offset/depth ratio of up to 2. Two internal moveout parameters, which seem to be uncorrelated, are sensitive to the full offset distribution. The presented automatic picking provides $V$ and $\eta$ fields as dense as the seismic. The raw local pickings, which seem to be naturally coherent with their neighbors, contain useful information for various concerns.

**References**


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