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Limited-Aperture Migration by Sterotomography Output

M. Alerini* (Sintef Petroleum Research), M. Riede (Now at RWE) & B. Ursin (NTNU)

SUMMARY

In Kirchhoff based migration, the relevant information is located at the specular reflection point along the migration operator. Limiting the migration operator around this specular point not only increases the speed of the process but also improves greatly the quality of the migration results by suppressing important aliasing artifacts. The determination of the specular point is not trivial without any a priori knowledge of the geological structure. We propose here an approach that makes efficient use of the results from a prior reference velocity model estimation method, stereotomography. Indeed, stereotomography provides pieces of local reflectors. This information is used to limit the migration operator and thus to improve significantly the migration results.

Introduction

The limitation of the migration operator aperture around the specular point is highly desirable: it can help to reduce the computation time and to reduce some aliasing artifacts. This is a well-known problem and different attempts have been proposed to solve it. There are numerous publications on this topic nowadays and we can cite among other Sun (1998), Sun (2000), Hua and McMechan (2001), Baina et al. (2003), Brandbergs-Dahl et al. (2003), Lüth et al. (2005) or Buske et al. (2006).

Two points are important: the location of the specular reflection point along the migration operator and the size of the aperture of this operator. Most of the methods assume the specular point is known and focus on the aperture determination. Indeed, the specular point can be determined by the local geological dip. In simple geological areas it is possible to assume only horizontal flat layers. The velocity gradient can also be introduced, while neglecting e.g. the unconformities. More costly, an interpretation on the migrated stack image can as well be used. This latter method is probably the most accurate, but presents some problems: First, a migration is required before hand, secondly a time consuming human interaction is involved. To bypass these problems, we investigate the possibility to use the pieces of reflectors output from stereotomography (Billette and Lambaré, 1998). Those local reflectors are often refered to as dipbars. This approach is similar to the one proposed by Baina et al. (2003) but is performed in the image domain instead of the data domain. This presents several advantages:

- easier interpolation of the sparse information
- use of a priori knowledge on the geology
- allows a posterior selection on the dips

However, the main drawback is a higher inaccuracy of the used slopes. Indeed, Baina et al. (2003) use slopes picked in the data and the only uncertainty lies in this estimation. Our approach is sensitive in the same way to the estimation of the slopes, but in addition affected by the accuracy of the velocity model.

Nevertheless, we show that interpolating stereotomographic dipbars can be used to limit the migration operator aperture, at least when the geological dips are smooth enough. After a short review of our methodology, we apply our approach on a difficult synthetic example and demonstrate the potential of the method and some of its present limitations.

Methodology

Stereotomography is a slope tomography which has been proposed by Billette and Lambaré (1998). It works on the concept of locally coherent events (Lambaré, 2002) and has the particularity of estimating a model containing not only the velocity field but as well pairs of ray segments. Each single picked locally coherent event will provide an estimated pair of ray segments described by: the reflection point position, the shooting angles toward the surface and two one-way travel times. From those parameters it is possible to compute a local geological piece of reflector and thus the geological dip.

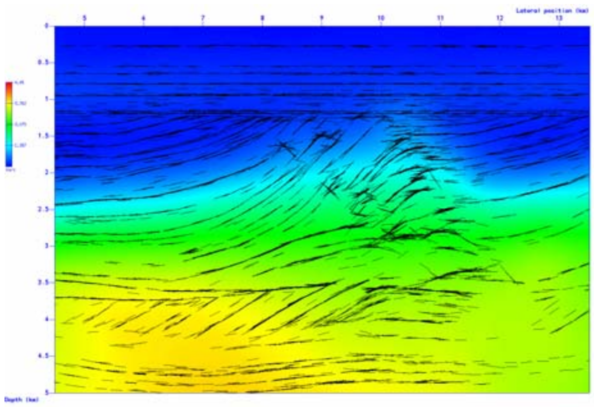

Figure 1: Stereotomographic model: Velocity model and dipbars.

Dipbars exhibit a skeleton of the geological structure (Figure 1) and this information should be used *a posteriori*. In particular, migration can benefit from the use of it to localize the specular point along the migration operator and thus to limit its aperture. We propose to extrapolate/interpolate the dipbar information and to extend the anti-aliasing filter proposed by Baina et al. (2003) in the depth domain. This extension is straightforward considering the normal vector to the local reflector instead of the horizontal component of the slowness vector. We limit the migration operator according to

$$\left\|\left(\nu^m - \nu^g\right)\cdot\hat{x}\right\| < \frac{V}{I_z F_{\max}} \quad \text{and} \quad \left\|\left(\nu^m - \nu^g\right)\cdot\hat{z}\right\| < \frac{V}{I_z F_{\max}},$$

Where ν^m and ν^g are the normal vectors to the migrated dip and to the geological dip, respectively. $\hat{x}$ and $\hat{z}$ are the unit vectors of the Cartesian frame. V is the local velocity, F_{max}, the maximum frequency in the data and I_z controls the aperture of the migration operator. Baina et al. (2003) chose I_z=2, meaning that contributions up to half the period are considered. We prefer keeping it as a tuning parameter to compensate some possible problems in the dipbars interpolation. The interpolation/extrapolation of the dip field is not an easy task. A linear interpolation will perform well in smooth regions, but not in parts with conflicting dips. In addition, the dipbars field might not be dense enough. We thus extrapolate first the dipbars before linear interpolation

Examples

We consider the synthetic dataset used by Alerini (2006). The modeling is done through an acoustic 2.5D ray+Born algorithm, considering a smooth velocity background and some perturbations. For acquisition, we have 25m between sources as well as between receivers and the maximum offset is 4475m. The source is a filtered Dirac delta function. For our test, we used the stereotomography results of Alerini (2006): smooth velocity model and dipbars. Several values of I_z have been tested, and we kept I_z=0.5 which is the one leading to the wider migration operator before artifacts appears on the common image gathers.

We present on Figure 2 the migrated stacks without (left) and with (right) the limitation aperture of the migration operator. The acquisition being dense enough and horizontal layers existing in the upper part of the model, aliasing is not obvious even without limiting the migration operator. On the other hand, in the central part of the migrated image, where the geology structure presents conflicting dips, the image quality of the dip limited migration is attenuated (image partially destroyed and reflectors partially disappearing). This is due to the smoothing inherent to the interpolation of our dip field. However, in regions presenting some gentle dip variations, amplitude along reflectors is nicely preserved and artifacts are eliminated, even for non flat reflectors.

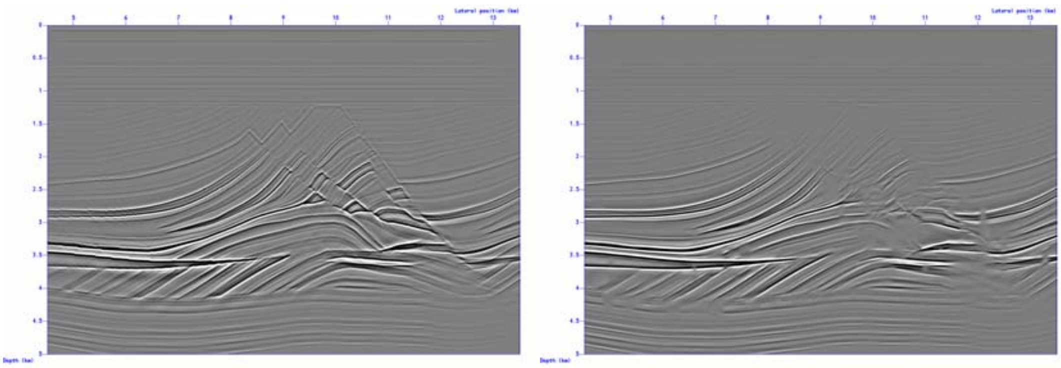

Figure 2: Migrated stack without (left) and with (right) limited aperture of the migration operator. In the regions with smooth dips, the interpolation works well and attenuates the kinematic artifacts. In the regions with strong geological dip contrasts, the interpolation of the dips destroys the image.

Comparing common image gathers (CIGs) in angle domain (Figure 3) shows better the advantage of limiting the migration aperture. Our dip field extrapolation associated to our migration aperture scheme allows to clean up the CIGs from aliasing artifacts. Such gathers can then be used to improve the velocity model by differential semblance optimization or for AVA studies.

Conclusion

Our approach has been tested in very difficult situation for the method: horizontal layers at the surface decreasing the aliasing and conflicting dips in the central region. The horizontal layers decreased the aliasing artifacts in the stack section, even without limiting the migration operator. The conflicting dips are smoothed by the interpolation leading to very bad approximation of the geological structure. Although those difficulties, we could show some very good results on CIGs. The clean CIGs can be used for posterior processing. We emphasize that those results have been obtained in a nearly automatic way with very limited human interaction. The main limitation of our approach is the smoothing introduced by the interpolation of the dip field and in no way the strength of the dip of the reflectors. More clever interpolation schemes than a simple linear one would certainly improve greatly our results. Nevertheless, the previous results show the potential of using the stereotomographic dipbars to limit the migration operator.

Acknowledgments

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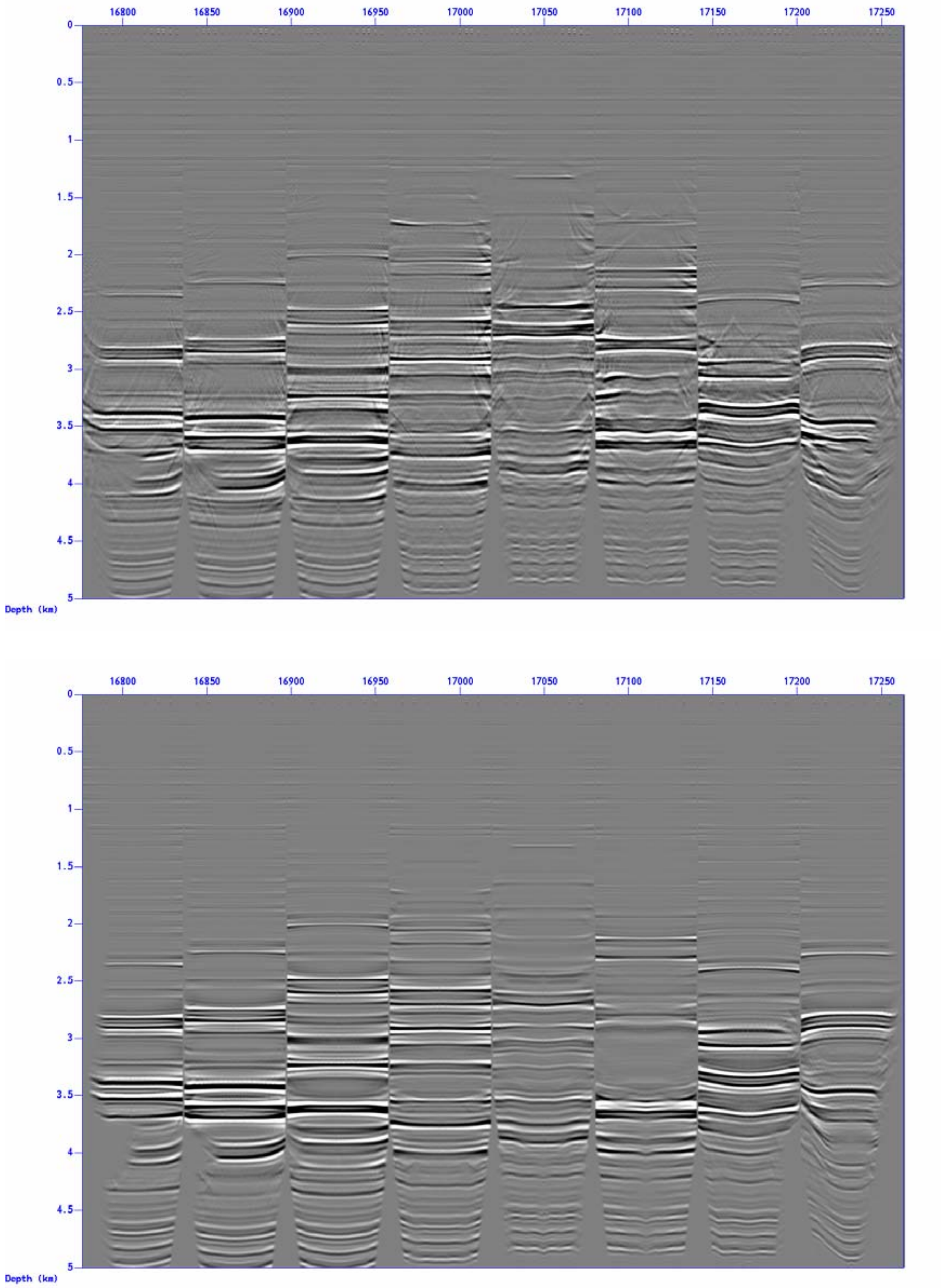

Figure 3: Common image gathers in angle domain [-90;+90] degrees for some selected positions (every kilometer from position 5.5 km). The migration has been performed without (up) and with (down) limitation of the aperture of the migration operator. Aliasing artifacts disappear by limiting the aperture of the migration operator.