SUMMARY

From a geophysical point of view, curvelets can be seen as the representation of local plane waves. They can be useful for a series of seismic processing tasks. Here we propose to use the decomposition in the curvelet domain in the context of velocity model scanning for prestack time migration. We start from an initial prestack time migration that we decompose into curvelet components. Each individual component is kinematically demigrated and then remigrated in a new velocity model. The demigration/migration sequence is reduced to a simple mapping of the curvelet coefficients and avoids the classical summations along isochrones. An application on a 2D real data set shows the advantages and the current limitations of the time demigration/migration approach.
Introduction

Curvelets have been initially defined for the processing of conventional images characterised by smooth discontinuities [Candès and Donoho, 2004; Do, 2001]. By construction, 2D curvelets are directional along a line and oscillatory in the perpendicular direction. From the geophysical point of view, curvelets can be seen as the representation of local plane waves. This led to many applications related to seismic processing, e.g. [Herrmann et al., 2007; Douma and de Hoop, 2007]. Chauris and Nguyen (2008) investigated the use of curvelets for a strategy of demigration/migration in depth allowing for a fast and accurate QC of velocity models.

We investigate here how curvelets can be used for effective velocity scanning for prestack time migration (PreSTM). Effective velocity scanning is used for updating locally effective velocity models. In a reference effective velocity model \( v_{ref} \), a first reference PreSTM image is computed. The objective is to predict the migrated image that would be obtained in a set of perturbed velocity models \( v_{pert} \). The conventional approach involves a full remigration using \( v_{pert} \). The alternative strategy consists of three steps. First, the reference migrated section is decomposed in the curvelet domain. Then each curvelet coefficient is kinematically demigrated in the reference velocity model and remigrated in the perturbed model. This operation, referred to demigration/migration, can be simplified when the perturbed velocity model only slightly differs from the reference model [Chauris and Nguyen, 2008]. As a first-order approximation, the transform of a curvelet is restricted to a shift, rotation and dilation of the original curvelet. These are the basic operations in the curvelet domain. The inverse curvelet transform provides then the final section. In this work, we study how different the two models could be and also how the selection of curvelet coefficient affects the final result.

![Figure 1: Time-migrated common offset sections for offset 1550 m and for a velocity model at 98% of the exact velocity model. Left: obtained by full PreSTM, right: after curvelet demigration/migration.](image)

Application

A reference image has been obtained with a 2D PreSTM scheme in the reference velocity model defined by effective velocity and anellipticity. With the same input data, a new 2D PreSTM section is migrated in the perturbed effective velocity model corresponding to 98% of the original model (Figure 1, left). This section is compared to the curvelet section that is obtained from the reference image after demigration/migration in the curvelet domain (Figure 1, right). Despite the global velocity perturbation, the two sections are almost identical. This
proves the validity of the simplified demigration/migration scheme restricted to basic operations in the curvelet domain.

For larger velocity perturbations, the theory does not guaranty that the curvelet demigration/migration is correct. Compared to the configuration in Figure 1, the velocity perturbation equals 90% of the original velocity model. Despite this large velocity perturbation, the two sections are similar (Figure 2). However, as displayed in the upper part of Figure 2, residuals smiles are not correctly predicted.

**Figure 2**: Same as for Figure 1, but for a velocity perturbation of 90% of the reference velocity model

For the 90% velocity perturbation, the same process is repeated for all offsets (Figures 3 and 4). Then Common Image Gathers (CIGs) are extracted at different positions at the surface. The main difference between the Kirchhoff time migrated sections and the curvelet time demigration/migration sections are visible at the larger offsets. Part of the missing information is due to issues with grazing rays.

**Figure 3**: Common Image Gathers obtained by PreSTM and for a velocity model equal to 98% of the exact velocity model.

Finally, we study how a given image is affected when the number of selected curvelet coefficients decreases. Figures 5 and 6 respectively present the result obtained when 100%,
10%, 5% and 2.5% of the total number of coefficients are selected based on the highest amplitudes. From the geophysical point of view, the quality of the image remains correct until the 5% limit.

Figure 4: Common Image Gathers obtained by the time curvelet demigration/migration and for a velocity model equal to 98% of the exact velocity model.

In terms of CPU efficiency for that particular example (image of 512 by 512 points), the classical PreSTM scheme and the curvelet demigration/migration (100% of the coefficient) scheme have the same cost. The cost is directly proportional to the number of selected coefficients. It means that the construction of the image in Figure 6 left is obtained much faster than the PreSTM. But this does not include the time ray tracing nor the curvelet forward and inverse transforms (about ten 2D Fast Fourier Transforms).

Discussion

For small velocity perturbations, the curvelet demigration/migration is an attractive alternative to the classical PreSTM scheme. Beyond the CPU efficiency, it provides new possibilities for filtering the data before picking on the section or interpreting the results. For large velocity perturbation, e.g. a global decrease of 10%, some events are missing but the main features are retrieved. The applicability of the curvelet demigration/migration essentially depends on the use of the results. For example, curvelet demigration/migration could be recommended for velocity analysis, but not for a subtle reservoir characterization where amplitudes have to be correctly predicted.

Compared to depth demigration/migration in the curvelet domain, the ray tracing part in time processing is extremely efficient. For depth processing, the ray tracing part becomes the most prohibitive sequence.

Finally, extensions to 3D require a 3D curvelet transform with a possible large redundancy ratio. However, the sparsity of the main curvelet coefficients is potentially more attractive. The key remaining point is how to efficiently select the curvelet coefficients, probably not only on their amplitudes, for example to facilitate an automatic picking in a later stage.

Conclusions

This simple application on real data has proven the potential of curvelets for time processing in the frame of demigration/migration. More work is needed to know how to correctly select the key coefficients. That selection depends on the processing performed after time migration.
Figure 5: Curvelet demigration/migration with all (left) and 10% (right) of the coefficients.

Figure 6: Curvelet demigration/migration with 5% (left) and 2.5% (right) of the coefficients.

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References


Chauris, H., and Nguyen, T. [2008], Seismic demigration/migration in the curvelet domain, *Geophysics*. 73 (2), S35-S46

