Data-driven internal multiple reflection manipulation

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Summary

We present schemes based on the Marchenko method, one that retrieves primary reflections in the two-way travel time domain by filtering the data and a second that redatums the sources and receivers from the reflection data to inside the medium, while taking into account all multiples. In the first application, the data is its own filter that removes internal multiple reflections. Application of the filter does not require any model information. It consists of convolutions and correlations of the data with itself. A truncation in the time domain is applied after each convolution or correlation. The retrieved dataset can be used as input to construct a better velocity model than the one that would be obtained by working directly with the original data and to construct an enhanced subsurface image. A field data example shows the effectiveness of the method for both point-source and plane-wave datasets. The second method uses the non-filtered reflection data, but employs a similar technique of applying convolutions and correlations and a truncation in time. Aside from redatuming the sources from the reflection data, we also demonstrate how to use the redatumed receivers to monitor an actual response from the subsurface. This is demonstrated using a field dataset.

Introduction

Recently, Marchenko imaging has been introduced to deal with internal multiple reflections (Slob et al., 2014; Wapenaar et al., 2014). For this scheme, an image of the subsurface without artefacts due to internal multiple reflections can be retrieved. Based on the Marchenko imaging scheme, we proposed a data-driven scheme to account for internal multiple reflections without model information or adaptive subtraction (Zhang and Staring, 2018). The application of this scheme on field dataset is presented in the following section. Furthermore, the Marchenko method also allows for the redatuming of both sources and receivers into the subsurface from a single-sided boundary, while taking all internal multiples properly into account (Wapenaar et al., 2017). Through this approach, wavefields in the subsurface of the Earth can be monitored, as if a source was present in the subsurface. An example of this application on field data is presented in the final section.

Marchenko Multiple Elimination

We apply the MME scheme to a 2D field dataset provided by Equinor, which was measured in the Norwegian Sea in 1994. There are 399 shot gathers and 399 traces per gather in the data. The spatial sampling of the sources and receivers is 25m. For this field dataset, the direct wave has been muted, near-offset traces have been interpolated and 3D effects have been compensated. The source signature has been deconvolved and free-surface related multiple reflections have been attenuated by SRME.

We use the MME scheme to remove internal multiple reflections in the field dataset and use a one-way equation migration scheme to migrate both datasets before and after internal multiple reflection elimination. The resulting images are given in Figures 1a and 1c. No model information or adaptive subtraction is used in the implementation of the MME scheme. The detailed theory of the MME scheme can be found in Zhang and Staring (2018). The work discussed in Zhang and Staring (2018) has been extended to provide retrieval of primary plane-wave responses (Meles et al., 2019). Imaging results, involving one primary synthesis step and a single migration, are shown in Figures 1b and 1d.

Homogeneous Green's function retrieval

Using the Marchenko method, the sources and receivers at the surface of the Earth can be redatumed to any position inside the medium from an open single-sided boundary, while taking into account both primary and multiple reflections correctly. This approach is called homogeneous Green's function retrieval and creates virtual sources and receivers. A Green's function is the solution to the wave equation using a Dirac function as a source and a homogeneous Green's function is the superposition of a Green's function and its time-reversal. The equation for homogeneous Green's function retrieval can be found in Wapenaar et al. (2017). It makes use of a Green's function and a focusing function, the latter of which describes a wavefield that focuses to a focal location inside the medium of interest from the single-sided boundary. Using the Marchenko method, as described in Wapenaar et al. (2014), the required Green's function and focusing functions can be obtained. An example of this approach on the same field data that was used in the previous section is shown in figure 2. In this approach, the source signature of the virtual source has been changed to a double-couple signature. The result shows that scattering of the wavefield takes place at the locations of major reflectors and that the full wavefield contains the double-couple signature. A more detailed consideration of the versatility of this approach can be found in Brackenhoff et al. (2019).

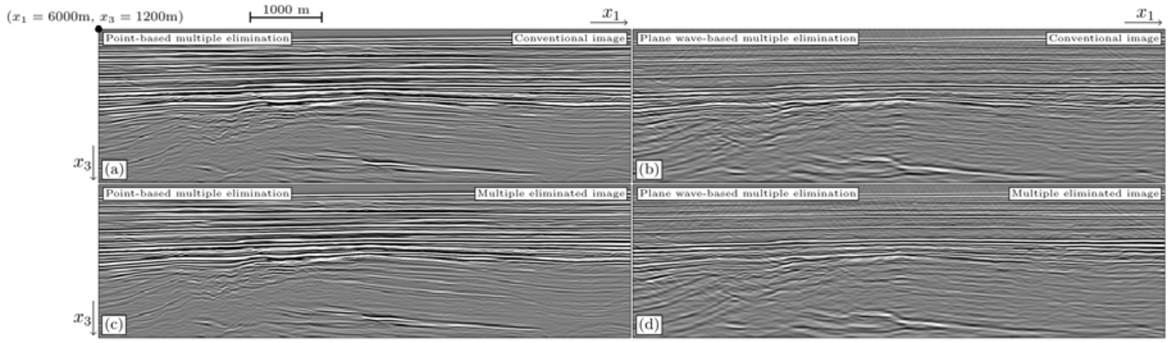

Figure 1. ***(a)*** *the image from point source original dataset and* ***(c)*** *the image from point source multiple-eliminated dataset,* ***(b)*** *the image from plane wave original dataset and* ***(d)*** *the image from plane wave multiple-eliminated dataset.*

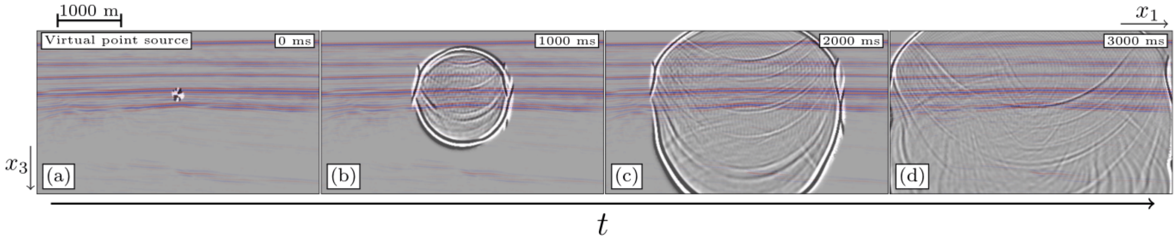

Figure 2*. Snapshots of the homogeneous Green's function in the subsurface.* ***(a-d)*** *Homogeneous wave field retrieved for virtual receivers and a virtual double-couple source inclined at -20 degrees. All wavefields have their wavelets reshaped to a 30 Hz Ricker wavelet and are overlain with the subsurface image from figure 1-****(c)****.*

Conclusions

We have shown that the Marchenko method can be used in variety of applications, such as for the removal of internal multiples and the redatuming of sources and receivers. The Marchenko method is robust and functions even when the source signature is changed to plane-waves or double-couple sources.

References

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