Homogeneous Green's function retrieval using the Marchenko method

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Summary

In wave theory, a Green's function is defined as the response of a medium to an impulsive point source. The homogeneous Green's function is the combination of the Green's function and its time-reversal. Homogeneous Green's functions can be retrieved if the medium is enclosed by a boundary where the full wavefield is recorded. In recent years, the Marchenko method has gained popularity, because unlike many conventional methods it does not require an enclosing boundary. Instead a single-sided boundary is all that is required. The method is sensitive to attenuation, which makes it difficult to apply to field data. We will show that by using corrections on the attenuated data, we can retrieve the Green's functions in the subsurface. These results can be visualized in order to see how the wavefield propagates through the subsurface.

Theory

A Green's function describes the response of a medium due to a impulsive unit source, which can both be located at any point in this medium, and is purely causal. The homogeneous Green's function is defined as the Green's function superposed with its time-reversal. This avoids singularity at the source location. The homogeneous Green's function can be used in a variety of schemes, such as seismic interferometry and holographic imaging, or to visualize the wavefield travelling through the subsurface. In wave theory the Homogeneous Green's function can be retrieved at any location in the medium, if the medium of interest is enclosed by a boundary. As this is often not the case the retrieved function shows artifacts.

In recent years the Marchenko equation has been applied in wave theory in order to improve the previous schemes (Wapenaar et al., 2014). The method does not require an enclosing boundary, but rather a single-sided boundary. The method is capable of retrieving the Green's function at any virtual receiver location in the medium, as well as a focusing function, which focuses from the surface to a focal location in the medium (van der Neut et al., 2015). The only requirments are that the reflection response of the medium is recorded on the boundary and that an estimation of the first arrival of the desired location is available. The first arrival is often estimated from a smooth velocity model. An important feature of the method is that the overburden above the desired location does not need to be resolved (Broggini et al., 2012).

Wapenaar et al. (2016a,b) showed that by convolving the focusing function and the Green's function, one can retrieve the homogeneous Green's function in the subsurface. The focal location will function as a virtual source location, with its response measured at the virtual receiver location. While this approach works very well on synthetic data, it is problematic to apply it to field data. This is due to problems caused by attenuation, which causes energy loss in the medium and therefore dampens the amplitude of the wavefield (Draganov et al., 2010). An assumption of the Marchenko method is that there is no attenuation in the medium (Wapenaar et al., 2014). By applying correction for the loss of energy, we have been able to retrieve the homogeneous Green's function on a real data set in the Vøring Basin in the North Sea. This data was provided to us by SAGA Petroleum A.S. (currently part of Statoil ASA). Using this retrieval we have been able to visualize the wavefield in the subsurface, which is shown in Fig. 1. It shows the first arrival that originates at the virtual source location and travels through the medium, causing reflections at the boundaries between geological layers. This homogeneous Green's function can be used in other schemes and can help to illuminate the subsurface further.

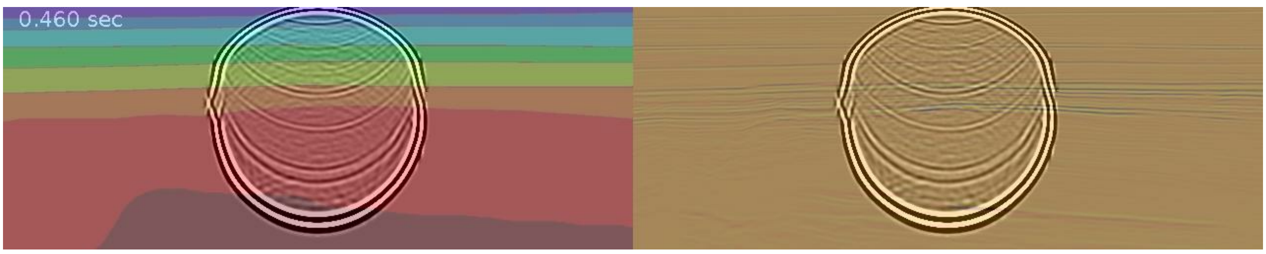

Figure 1: *The homogeneous Green's function in the subsurface of the Vøring Basin with an interpretation of the subsurface on the left and a migration result on the right as an overlay. Both the virtual source in the center and all the virtual receivers have been redatumed from the surface.*

References

Broggini, F., Snieder, R., and Wapenaar, K. (2012). Focusing the wavefield inside an unknown 1d medium: Beyond seismic interferometry. *Geophysics*, 77(5):A25–A28.

Draganov, D., Ghose, R., Ruigrok, E., Thorbecke, J., and Wapenaar, K. (2010). Seismic interferometry, intrinsic losses and q-estimation. *Geophysical Prospecting*, 58(3):361–373.

van der Neut, J., Vasconcelos, I., and Wapenaar, K. (2015). On green's function retrieval by iterative substitution of the coupled marchenko equations. *Geophysical Journal International*, 203(2):792–813.

Wapenaar, K., Thorbecke, J., and van der Neut, J. (2016a). A single-sided homogeneous green's function representation for holographic imaging, inverse scattering, time-reversal acoustics and interferometric green's function retrieval. *Geophysical Supplements to the Monthly Notices of the Royal Astronomical Society*, 205(1):531–535.

Wapenaar, K., Thorbecke, J., Van Der Neut, J., Broggini, F., Slob, E., and Snieder, R. (2014). Marchenko imaging. *Geophysics*, 79(3):WA39–WA57.

Wapenaar, K., van der Neut, J., and Slob, E. (2016b). Unified double-and single-sided homogeneous green's function representations. In *Proc. R. Soc. A*, volume 472, page 20160162. The Royal Society.