Full Waveform Inversion of Seismic Data using Scattering Integral (SI) Method

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Summary

Two different formulations of structural inversion have been studied in recent years. One of them is the Adjoint-Wavefield (AW) method and the other one is Scattering Integral (SI) method. Both AW and SI methods are closely related, but the SI method is computationally more efficient than the AW method for a large set of source-receiver combinations. In this paper, we have investigated the SI method for a two-dimensional acoustic case as proof of the concept, but the approach can easily be extended to the elastic case. In the SI method, data functionals are linearly related to the model perturbations using source-receiver specific sensitivity kernel. Sensitivity kernels can be defined as a linear, integral relationship between differential variations of the model parameters and the functionals of that model. Amplitude difference between the starting and target displacement seismograms is used as data functional in this paper. The Green's function for each source-receiver pair and source wavefield needed to calculate sensitivity kernels was computed using a two-dimensional time-domain staggered-grid finite-difference method. Preliminary results showed the SI method can be implemented for structural inversion even with a starting model that is far off from the true model. Artifacts, resolution, and overall inversion accuracy can be improved by increasing the number of source and receiver in the acquisition, applying normalization to wavefields before inversion, and using better suited a priori information and regularization techniques.

In this study, we have implemented Scattering Integral (SI) formulation of the structural inversion, based on the Fréchet differential kernel discussed by Zhao *et. al*., 2000. In this method, the inverse problem is setup by calculating and storing each source-receiver specific Fréchet kernel in the reference model space for the specified type of data functional. Amplitude difference, cross-correlation, traveltime shift, and relative amplitude anomaly between the starting and target seismograms are the four common types of data functional used in many inversion methods.

Quality of inversion result in the Scattering Integral (SI) method depends mostly on the data sensitivity matrix, also known as Fréchet kernels. Sensitivity kernels are generated by convolving spatial derivatives of receiver wavefield with the source wavefield, and then integrating against the seismogram perturbation kernel (Chen *et. al.*, 2007). For the amplitude difference data functional, the seismogram perturbation kernel is the time shifted delta function. So the integration operation is just the time shifting of the convolved wavefield at each node in the model space.

References

Chen, P., Jordan, T. H., and Zhao L., 2007. Full three-dimensional tomography: a comparison between the scattering-integral and adjoint-wavefield, Geophysical Journal International: 170, 175-181.

Zhao, L., Jordan, T. H., and Chapman, C. H., 2000. Three dimensional Fréchet differential kernels for seismic delay times, , Geophysical Journal International: 141, 558-576.