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Seismic interferometric reverse time migration to passive seismic data for subsurface structural survey

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In this study, I propose an imaging method, SI-RTM, for a direct subsurface imaging from passive seismic data by implementing the reverse time migration (RTM) with a concept of the seismic interferometry (SI). The RTM based on a two-way wave equation is a powerful imaging technique in reflection seismic survey for complex subsurface structures, while it takes higher computational cost than conventional migration methods. The RTM principle is represented an imaging condition that the reflected or scattered waves are focused on the imaging points by time integrating the product of two extrapolated wavefields at same recording time; the forward extrapolated wavefield of source wavelet from a source point and the backward extrapolated wavefield of the recorded seismic data from receiver points. The SI is generally used for a redatuming or a signal extraction by crosscorrelating the different seismic traces in a data domain, then the synthesized waveforms are analyzed for wavefield characterization or processed for the subsurface imaging.

The SI-RTM could be recognized as a wavefield interference in an image domain. Instead of the wavefield extrapolation in the conventional RTM, arbitrary time-windowed seismic record is propagated forwards from a receiver point which become a virtual source and is propagated backwards from other receiver points. If any multiple reflecting waves between the surface and the reflection boundaries satisfy the imaging condition, the reflected energy will be focused on subsurface reflection points. The imaging process corresponds to the wavefield extrapolation with a velocity model and interference in the image domain simultaneously. In this study, I evaluated the SI-RTM algorithm by a two-dimensional numerical simulation. Two kinds of synthetic passive seismic data were generated by a finite difference elastic wave modeling; (a) local earthquakes data, and (b) ambient seismic noise data which contain body waves randomly generated. The SI-RTM was implemented under acoustic wavefield condition. Both the test results show validity of the imaging algorithm of SI-RTM.

The SI-RTM needs a velocity model for wavefield extrapolation and takes high computational cost which is dependent on the data volume and the size of a target area. However, it enables us to achieve the direct seismic imaging without source information, and it improves analysis method of the passive seismic data by not only the SI record synthesized in the data domain but also the SI profiles in the image domain when it is difficult to recognize the significant phase on the SI virtual source record. In the engineering aspect, this method will contributes to beneficial use of the passive seismic data in any monitoring projects. In the future work, realistic problems will be overcome by continuing field data study, including further applications such as the imaging of multi-component passive seismic data.

Keywords: reverse time migration, seismic interferometry, passive seismic, reflection seismic survey, numerical simulatioin