Seismic Data Reconstruction Using the Nonlinear Beamforming Framework

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Abstract

Objective

We introduce a novel seismic data reconstruction method using the nonlinear beamforming (NLBF) framework. NLBF operators describe kinematic wavefronts via a second-order mathematical expression, and we carry out data reconstruction directly on wavefronts. Since wavefields are represented more coherently in the wavefield domain than in alternative data domains such as shot-gather or receiver-gather domain, this new method can yield robust reconstruction results for challenging seismic data.

Methods

It is a highly nonlinear problem to estimate NLBF operators from an input dataset, and we use the efficiency-improved Genetic Algorithm as its solver. Once all NLBF operators are available, we use them to dissect the input data to wavefronts and carry out data reconstruction on each of them. Every missing data point in the spatial dimension on a wavefront is reconstructed via a weighted summation of a linear interpolation and a bilinear interpolation using its surrounding existent data points. After all missing data points in the spatial dimension on all wavefronts are reconstructed, we go back to the time domain and use a cubic spline interpolation to reconstruct wavefields at predefined time-sample locations of each trace.

Results

We use two datasets to demonstrate our method. The first one is a shot gather from the SEAM Arid model. The inline/crossline spacing between receivers is 12.5 m/37.5 m. Our method achieves a successful reconstruction in the crossline direction, with the result very close to the ground truth and way better than a control result reconstructed by a POCS method. The second example is a field dataset organized in the cross-spread domain. The nominal inline and crossline spacing are both 60 m, but there exist big gaps, up to 240 m in the crossline direction, in this dataset. We use our method to successfully reconstruct this dataset to a 30 m by 30 m grid, and the reconstructed wavefield looks very impressive. Compared to control results generated by both a POCS method and a straightforward combination of linear and bilinear methods on time sections, the uplift brought by our method is clearly visible.

Conclusions

We propose a novel and effective method to reconstruct seismic data on wavefronts using the NLBF framework, and impressive and robust reconstruction results have been observed on both a SEAM Arid dataset and a challenging 3D field dataset. This method is a valuable contribution to the toolbox of seismic data processing.