A Simple Algorithm for the Restoration of clipped GPR amplitudes.

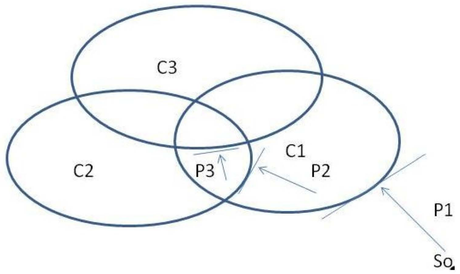
Akshay Gulati[1] and Robert J. Ferguson[1]

1. Consortium for Research in Elastic Wave Exploration Seismology (CREWES), University of Calgary

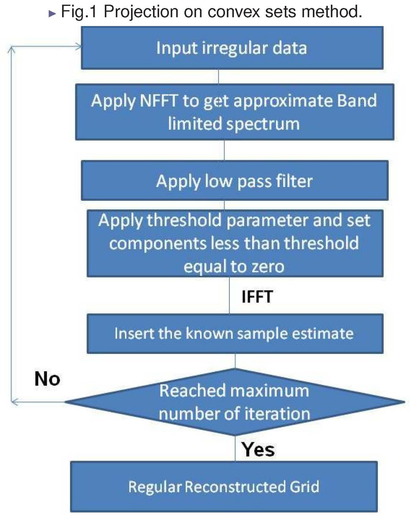
Summary

- In this paper, an algorithm for clipped amplitude restoration using hybrid POCS is presented and tested. It is able to completely restore the clipped amplitude of GPR data.
- Two different methods for estimating the clipping are tested. The first one is the conventional method of spline interpolation, which is widely used in the GPR industry.
- The second is hybrid POCS, which uses *a priori* information from the signal to recover clipped amplitudes.
- A comparative study show that hybrid POCS is better than conventional spline interpolation. Hybrid POCS results in improved lateral continuity of the energy across the horizons in reconstructed data.

Methodology



▸ Fig.1 Projection on convex sets method.



▸ Fig.2: Flow chart representation for Proposed Methodology.

- POCS is iterative and typically projects consecutive solutions onto consecutive properties sets.
- Each iteration is followed by the NFFT kernel, which is the FFT when sampling is regular enough.
- A threshold is applied to the Fourier domain leaving components greater than the threshold as zero.

- During the first few iterations, sample points with high energy are restored.
- In each iterations, higher frequencies are made zero in the frequency domain.
- The threshold parameter enforces a cut off in amplitude which gives some amplitude to unknown values.
- After this, the value of known components are restored by replacing them with their true values. This will reconstruct the high frequency values.

The whole process can be written in form of Equation 1.

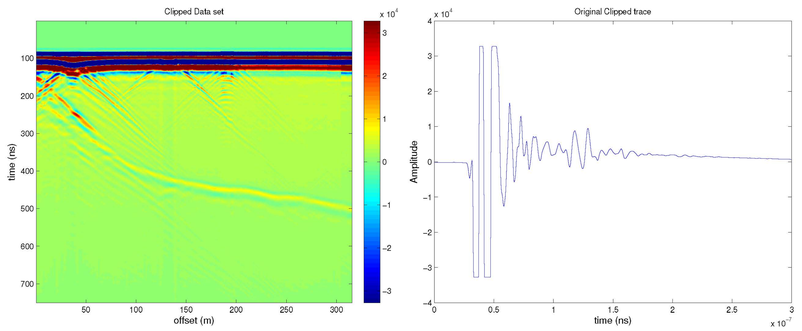
$$S_k = S_{obs} + (I - S)F^{-1}T^k B(NFFT)S^{k-1}, \tag{1}$$

where, S_{obs} is a original data at kth iteration. S_{obs} will keep getting updated until it finally converges to a solution. NFFT and F^{-1} represents non uniform fast Fourier transform and inverse fast Fourier transform which operates on t. S is a sampling operator that identifies known and unknown values. T^k is threshold operator with elements.

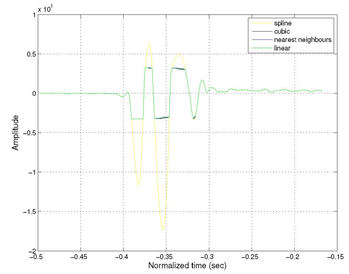
$$T^k = \begin{cases} 0, & F_{k-1} \geq I_k \\ 1, & F_{k-1} < I_k \end{cases}, \tag{2}$$

where, F_{k-1} denotes the Fourier domain representation of the reconstructed signal after the $(k-1)$th iteration. I represents the N dimensional threshold set $I = I_1, I_2, \cdots I_N$ where $I_1 > I_2 > I_N$ and N denotes the maximum number of iterations.

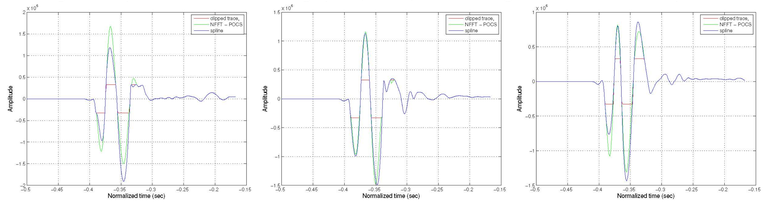
Examples



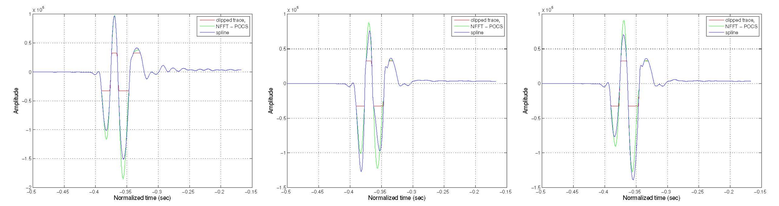
▸ Fig.3: Original GPR data and randomly extracted trace from the dataset .



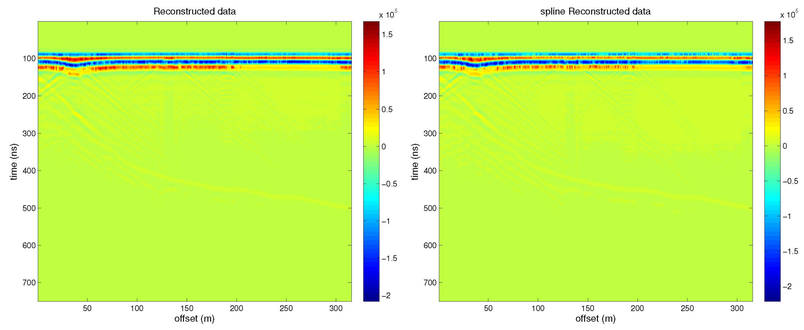
▸ Fig.4: Interpolated GPR trace using spline, cubic, nearest neighbour and linear interpolation.



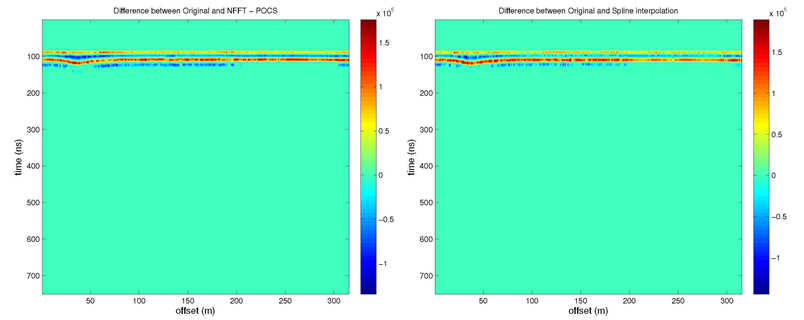
▸ Fig.5: Reconstructed clipped GPR traces.



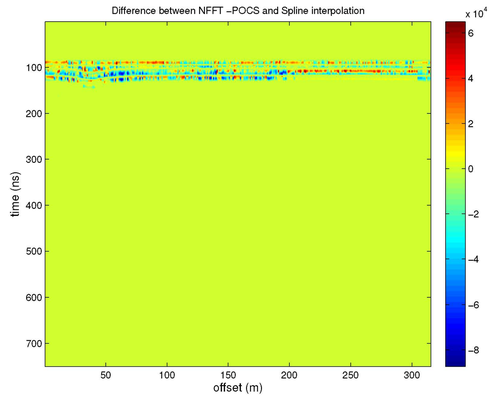
▸ Fig.6: Reconstructed clipped GPR trace.



▸ Fig.7: Reconstructed GPR data using Hybrid POCS and spline.



▸ Fig.8: Residuals between original GPR and reconstructed GPR Data.



▸ Fig.9: Difference between proposed methodology and spline reconstructed data.

Acknowledgement

- We wish to thank the sponsors, staff and faculty of the Consortium for Research in Elastic Waves Exploration Seismology (CREWES) for their support of this research.