Processing of the Field Data using Predictive Deconvolution

Aydar Zaripov, Dias Urozayev, Yuqing Chen[1]
[1]King Abdullah University of Science and Technology (KAUST)

ABSTRACT

The seismic data we collected near the Golf club has many harmonic noise. In this paper, we try to use predictive deconvolution method to predict the predictable noise and then cancel them out from the original data to increase the S/N ration of the data.

EXPERIMENT DESCRIPTION

The goal of the field experiment was to collect data and detect Qademah fault and subsurface geology. But collected data was too noisy and picking first arrivals was really challenging, that is why we did not get reliable tomograms and results. Then our next step was to apply different processing technics to enhance signal to noise ratio of the field data. Our group used predictive deconvolution method. Predictive deconvolution is a special case of Wiener deconvolution. We seek a causal filter that predicts future values of the input (our obtained seismogram) from current and past values of the input. Predictive deconvolution filters can be used to eliminate predictable noise such as multiples, wavelets, or harmonic noise.

Seismic profile was in KAUST campus near golf course along the road, between the stadium and construction side. Figure 1 shows seismic profile AB on Google Earth map. Seismic refraction method was used to acquire the data. Experiment parameters were:

Profile length $-1200m\,(E-W direction)$;
Number of receivers and shots -240;
Receiver and shot spacing $-5m$;
Number of stack -20 shots;
Source $-$ weight drop.

THEORY

For prediction deconvolution problem we have system of equations:

Figure 1: Seismic profile AB on Google Earth map

GIVEN: $x\,(t){*}f\,(t) = x\,(t + alpha)$, where$x$is input,$x\,(t+\alpha)$ is desired output andα is prediction distance $(\alpha > 0)$
FIND: $f\,(t)$
SOLUTION: Solve $\mathbf{X}^T\mathbf{X}\mathbf{f} = \mathbf{X}^T\mathbf{x}\,(t+\alpha)$
$\rightarrow \mathbf{f} = \left(\mathbf{X}^T\mathbf{X}\right)^{-1}\mathbf{T}\mathbf{x}\,(t+\alpha)$

where$[\mathbf{X}^T\mathbf{X}]_i j = \phi_{xx}\,(i-j)$are the elements of the autocorrelation matrix.

fs assumed to be a causal or one-sided filter. Crosscorrelation between the input vector and the desired output is given by $\mathbf{X}^T\mathbf{x}\,(t+\alpha)\,i = \phi_{xx}\,(i+\alpha)$,which is the autocorrelation function lagged by the prediction time α

Commonly used strategy for choosing prediction distance α is the 2nd-zero-crossing of the autocorrelation function. Prediction filter should be at least as long as the second zero crossing of the autocorrelation wavelet, but at the same time filter should be no longer than 1/6 the total length of the seismogram. Another common procedure is adding damping to the diagonal of the autocorrelation matrix to be able to suppress the high frequency noise.

Assumptions for the validity of the predictive deconvolution are following:

1· White noise reflectivity satisfies stationarity.

2· Autocorrelation can be computed by finite summations of data, so that ergodicity and stationarity are assumed. Wavelet or reflectivity sequence does not change

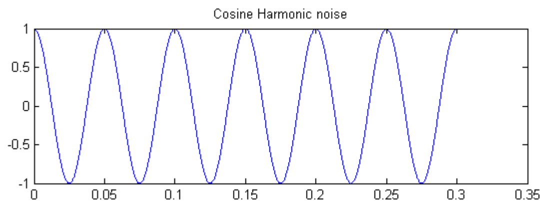

Figure 2: Cosine Harmonic noise

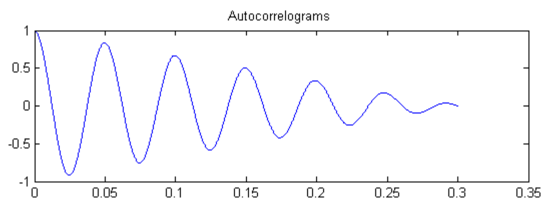

Figure 3: Corresponding autocorrelogram

shape/character with increasing time.

3· Periodic multiple generator, otherwise multiple signature will not appear at far lags in autocorrelation.

4· No additive noise.

5· Minimum phase wavelet. Any violation of above assumptions can degrade results in unpredictable ways.

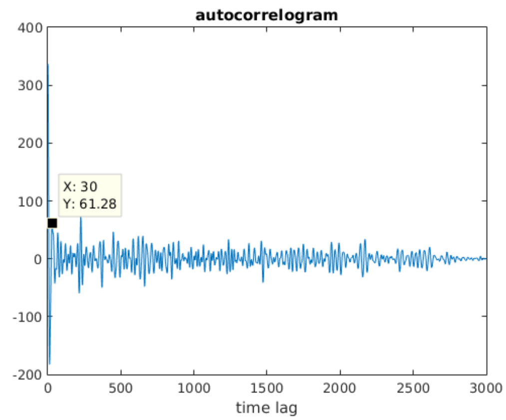

Figure 4: Autocorrelogram of one of the traces

RESULTS AND IMPLEMENTATION

3 critical parameters are to be set to start implementation:

•Prediction length

•Filter length

•Prewhitening

Prediction length

To estimate this parameter the following autocorrelogram is computed as shown in the following example (Figure 2 Figure 3):

For ideal harmonic function, the maximas at the autocorrelogram map will be distributed with uniform spacing, which defines the periodicity (period) of the harmonic function. Analogically , the corresponding autocorrelogram of the trace in the seismogram should give an estimate of our prediction lag(Figure 4).

The second maxima is appeared around 30 ms time lag, which should be a good estimate for our prediction lag.

As we can see in the Figure , the second maxima has appeared around the same time lag for many of the traces, therefore we expect this estimate to be valid in our implementation.

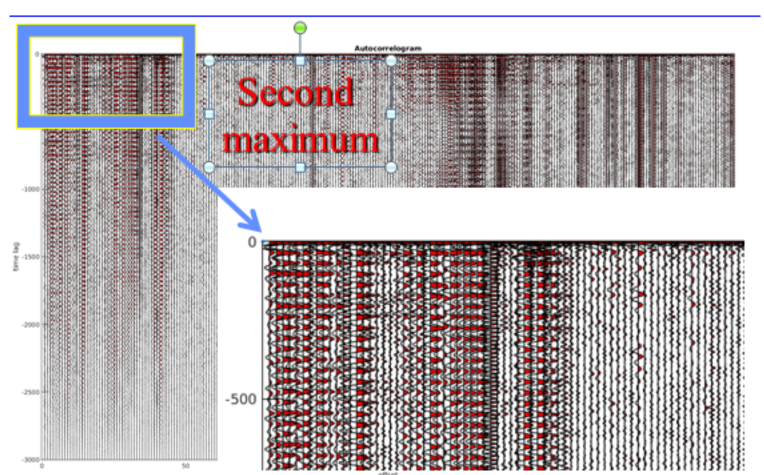

Figure 5: The autocorrelograms of each trace of CSG

filter length

•The filter length should at least longer than the predict length

•We chose the filter length also from the spectrum.

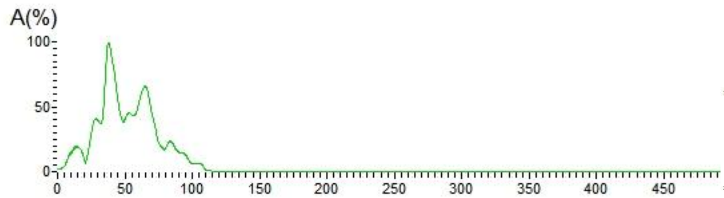

Figure 6: Amplitude spectrum of the trace

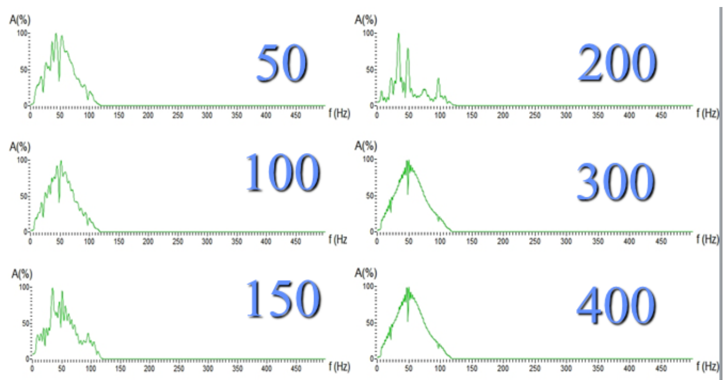

Figure 7: Amplitude spectrum of the trace after applying different filter length

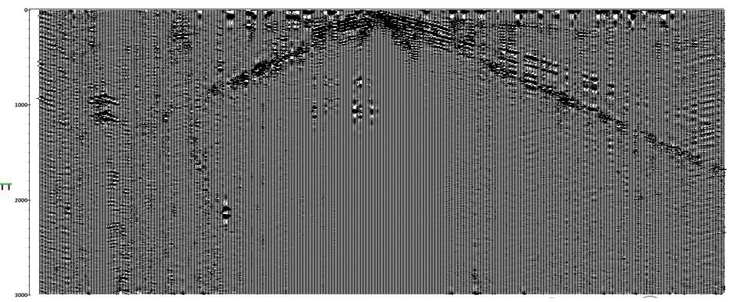

Figure 9: CSG 120 after bandpass filter

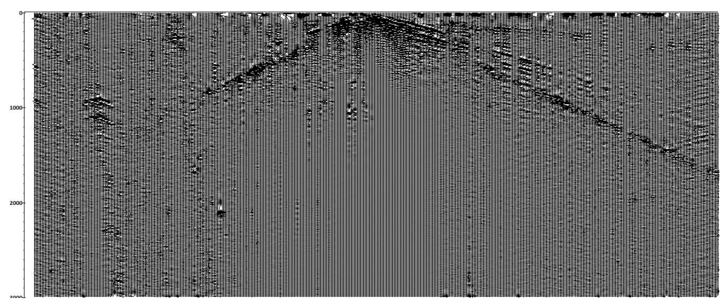

Figure 10: CSG 120 after PEF which pred length is 30 ms

Given the amplitude spectrum of the trace (Figure 6 Figure 7):

By examining the given amplitude spectrums of different filter length, we decide to use 150 ms filter length. And by testing them on raw data we can examine the improvement in the data.

CONCLUSION AND DISCUSSIONS

The implementation of predictive deconvolution has improved our results as we can see from figures 9 and 13. To compare and validate, the raw data with bandpass filter applied, as well as deconvolved data with different prediction lags are given in the previous part. We can observe the temporal resolution improvement due to wavelet suppression and the elimination of harmonic noise using the appropriate parameters (30 ms of prediction lag and 150 ms of filter length) defined at the beginning. We can see from the CSG ♯40 that we have enlarged first arrival visibility in the seismogram after applying PEF.

In the PEF implementation we assume having zero level of the white noise. However, in real data case it is always there. Therefore, we can also observe the improvement of PEF due to prewhitening, which actually works as a regularization term. It will simply add to the diagonal terms of the inverting matrix, therefore the inversion should be improved.

In conclusion, results after applying predictive deconvolution and bandpass filter showed overall improvements. We also see the improvement in resolution of the first arrival refraction events in the data.

Main results of our work are:

1) Predictable harmonic noise has been mitigated;

2) Seismogram resolution has been improved.

To obtain better results we recommend to apply:

1) 2D predictive deconvolution;

2) Compute different parameters of prediction deconvolution for different segments of seismograms.

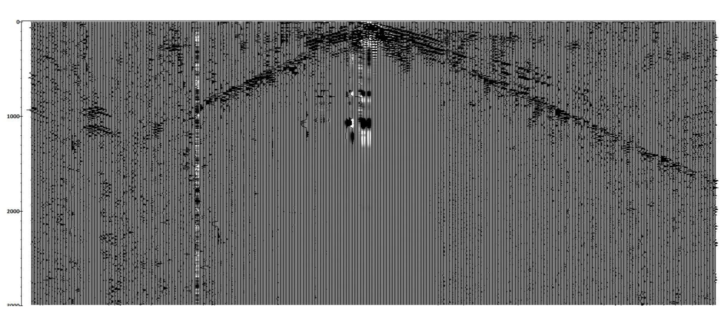

Figure 8: CSG 120 (Raw data)