Cross Correlation for Noisy Signal Extraction

Richard Williams

December 1, 2015

1 Introduction

A synthetic seismogram $s(t)$ can be created by convolving a minimum phase wavelet $w(t)$ with a reflectivity profile $r(t)$. The effects of noise can be included by adding a noise term $n(t)$.

$$s(t) = w(t) * r(t) + n(t) \tag{1}$$

If the noise is too large, it can dominate the synthetic seismogram. In this lab, the effect of cross correlating the wavelet with the noisy seismogram in order to extract information about the reflectivity was investigated.

2 Methods

A time vector from 0 to 1.5 seconds with a time interval of 0.002s was created. A simple, idealized reflectivity section was created with three spikes at 0.2s, 0.75s and 1s, and the section was plotted. A minimum phase wavelet with a dominant frequency of 15Hz was created using the *wavemin* function. A convolutional synthetic seismogram (Equation 1) was created using the *convm* function. Noise was added to the convolutional seismograms using the *rnoise* function. Signal to noise ratios of 1, 1/2 and 1/4 were used.

The cross correlation of the wavelet with the seismogram was calculated using the *xcorr* function. The cross correlation was plotted as a function of its time lag, and compared to the reflectivity sections.

A more realistic reflectivity section was created using the *reflec* function. A convolutional synthetic seismogram was created, and noise was added with a S/N ratio of 1/4. The reflectivity, synthetic seismogram and noisy synthetic seismograms were plotted. The cross correlation was computed and plotted as a function of its time lag, and compared to its reflectivity section.

3 Results/Discussion

The simple reflectivity profile is shown in Figure 1. The results of correlating the wavelet with the noiseless seismogram is shown in Figure 2. The wavelet and the seismogram are most correlated at time lags that correspond to the time of the spikes in the reflectivity section. The correlation looks similar to a zero phase wavelet convolved with the reflectivity section. These results are interesting but of little use in the noiseless case because the reflectors can easily be identified in the synthetic seismogram (Fig 3).

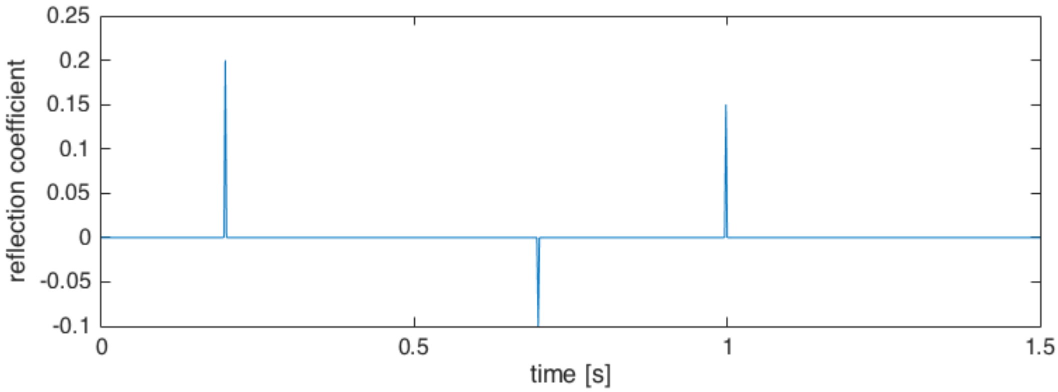

Figure 1: Simple reflectivity profile

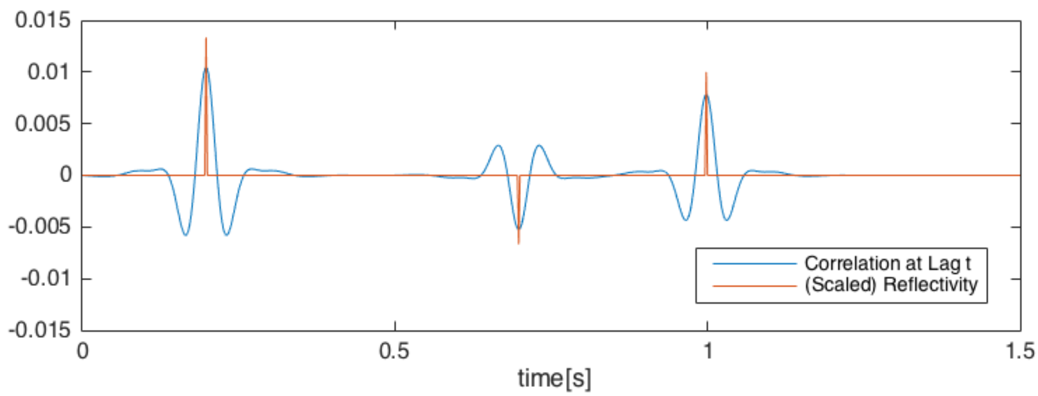

Figure 2: Reflectivity and correlation of wavelet and noiseless seismogram at lag t.

The reflectors were less visible in the synthetic seismograms as the signal to noise ratio was decreased (Fig 3). With an S/N ratio of 1/4, the signal was almost completely masked by noise. The cross correlation of the wavelet with the seismograms (Fig 4) revealed the location of the reflectors from the noise. The lags with the highest correlations corresponded to the location of the reflectors. As S/N decreased, the correlations became less pronounced, but still more visible than in the seismograms. These results suggest that cross correlation can be used as a form of noise suppression if the source waveform is known.

A more complicated reflectivity and its synthetics seismograms are shown in Figure 5. The profile was more comparable to a reflectivity profile of the earth. The cross correlation of the wavelet and the noisy seismogram were related to the reflectivity in a way that was similar to the simpler case. The method did not pick out all of the pronounced spikes properly. When the reflectivity spikes were close together (indicated with an arrow), the cross correlation was only able to pick out one of the reflectors.

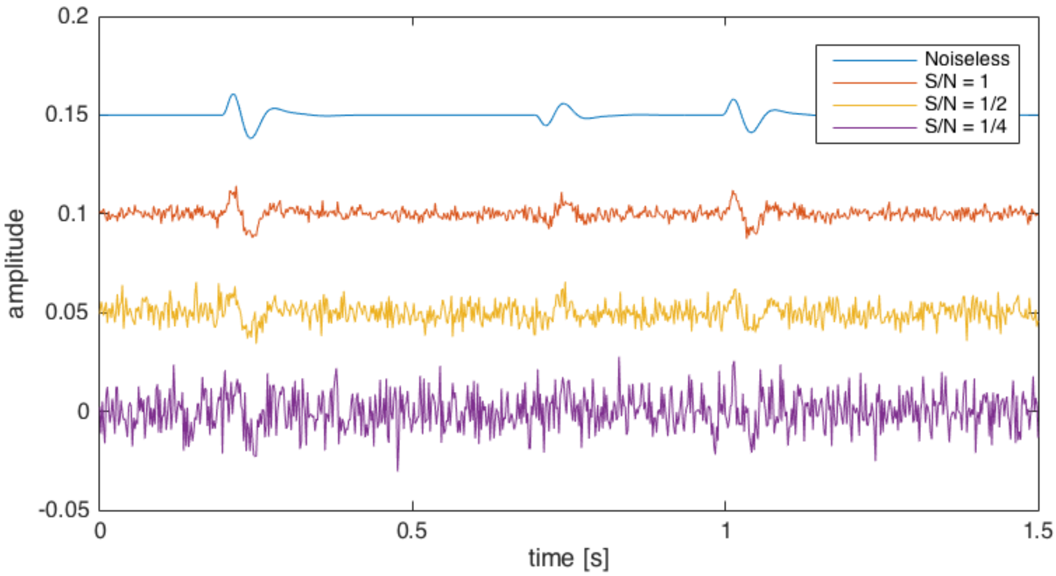

Figure 3: Synthetic seismograms for simple reflectivity profile with varying signal to noise ratios (S/N).

The results suggest that cross-correlation of a noisy seismogram with a known wavelet is an effective method of extracting a reflectivity signal from noise.

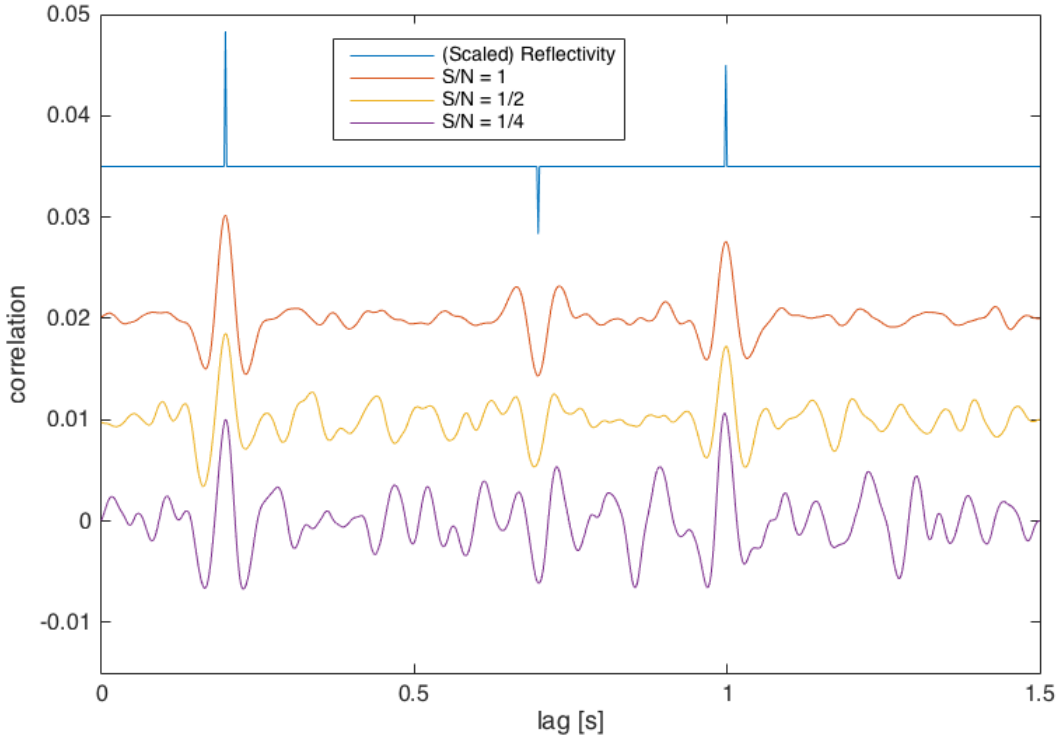

Figure 4: Reflectivity and correlation of wavelet and noisy seismograms.

4 References

Margrave. Gary F. 2014. Methods of Seismic Data Processing. University of Calgary Bookstore Custom Course Materials.

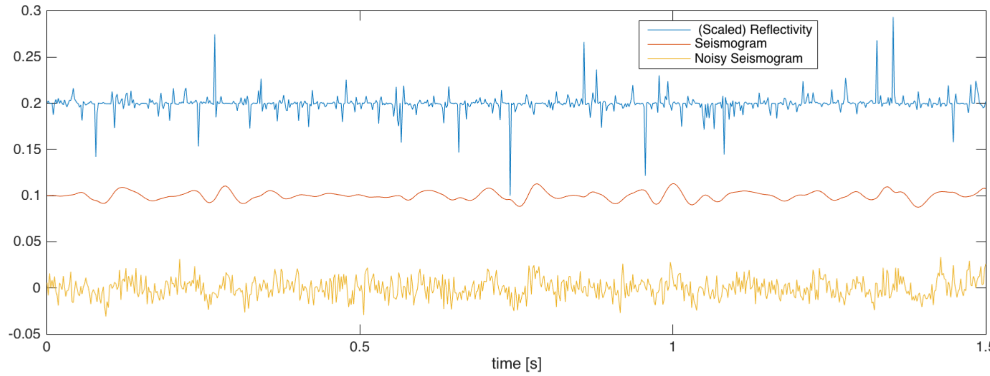

Figure 5: Reflectivity, Synthetic seismograms, and Noisy (S/N=1/4) for more complicated reflectivity.

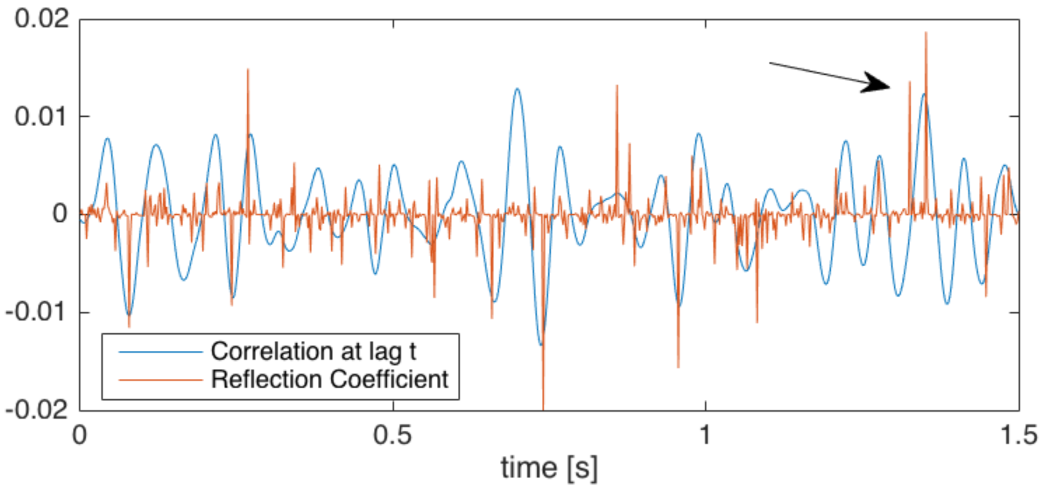

Figure 6: Reflectivity and correlation of wavelet and noisy seismogram.