Z-99 Novel statistical approach to Blind Recovery of Earth Signals and Source Wavelet

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Summary

The main goal of seismic signal processing is to separate the observed signal as far as possible into its constituent components of wavelet, earth response, and noise. A lack of *a priori* information about these components results in the current seismic signal processing sequence that is complicated and may rely on inappropriate assumptions about the input wavelet.

This paper presents a new, fast and simple, blind method for recovering the earth response, wavelet and noise from the observed signal. The main advantage of this new methodology is that it is a blind process.

Introduction

Seismic signals are a convolution of a source wavelet and the response at each earth layer boundary. Despite attempts to record the outgoing source wavelet at the surface, often little is known of the source wavelet at depth, and there is no *a priori* knowledge of the earth response or the noise. Current practice makes the basic assumptions that the source wavelet is known, and the noise can be neglected.

In this abstract, we propose a new blind technique for recovering both the earth signals and wavelet from the seismic data. The term ‘blind’ refers to the fact that the technique does not require any information except for the seismic signal. The proposed technique is culminated from previous works carried out in [1-3]. Our algorithm is a statistical technique that involves matching two sets of probability density function (PDF). It is therefore a technique that is robust against noise and with a fast convergence to the solution.

Methodology

Simulation of the convolution process of synthetic earth signals and Ricker wavelet demonstrates the transformation of an earth signal with an impulsive PDF into a seismic signal with a PDF that tends towards Gaussian. This is confirmed by the kurtosis a measure of the peakedness of a PDF where a positive kurtosis indicates an impulsive PDF and a Gaussian PDF would return zero kurtosis. The simulated earth signals used in this study have kurtosis values of ~6.0 whereas the simulated seismic signals have kurtosis values of ~1.5 indicating a shift towards a more Gaussian PDF.

The statistical properties of the seismic signal rendered by the convolution process can be exploited in the process of recovering the earth signal. Our novel algorithm aims to perform a 'degaussianising' process that will produce the desired earth signal by matching the PDF of the output to a nongaussian PDF. This is performed by the optimisation of a function that describes the PDF of the signal.

An approximate formula to parameterise the PDF of the output of the algorithm in terms of higher order moments can be obtained from the Edgeworth series defined as below:

$$p(y) = \alpha(y)\left(1 + \frac{\kappa_3}{3!}H_3(y) + \frac{\kappa_4}{4!}H_4(y) + \frac{10(\kappa_3)^2}{6!}H_6(y) + \dots\right)$$

where $\alpha(y)$, κ_i and H_i represent the standardized gaussian density, i^{th} order cumulant of the random variable y and the i^{th} order Hermite polynomial respectively. The nongaussian properties of the PDF are measured by the third and fourth order cumulant that measures the skewness and kurtosis of the PDF. The coefficients of this expansion series decrease in a uniform manner and therefore can be truncated without losing any important terms. Through simple derivations we obtain an approximation of negentropy; this measures the nongaussianity of the PDF. The algorithm optimises the negentropy based objective function to obtain a set of filters that will recover the earth signals.

A wavelet denoising procedure is performed on the output of the filter to denoise the result of the filter process. This procedure consists of three simple steps, a wavelet transform of the filter output, thresholding of the wavelet coefficients and finally an inverse wavelet transform. The threshold value in the second step is determined from the universal threshold [4] that will remove the contribution from the lower coefficients that represents noise. The recovery of the wavelet was also implemented in a 'blind' manner; this was based only on the estimated filter and without making any prior assumption on the wavelet.

Results

Figure 1 presents the synthetically generated earth signal and observed seismic signal with additional noise respectively. The generated noisy seismic signal is used to test the proposed algorithm in terms of accuracy of the recovered earth signal and wavelet. Based on just the seismic signal as input, the algorithm was able to successfully recover both the earth signal and wavelet. Figure 2(a) presents the recovered earth signal and Figure 2(b) presents the comparison of the recovered wavelet with the original source wavelet. The enhanced resolution of the earth signal recovered by the proposed algorithm is clearly seen by comparison of Figures 1(b) and 2(a). This ability of the technique for recovering the seismic wavelet is confirmed by comparing the recovered wavelet with the original source wavelet in Figure 2(b) where the original source wavelet is represented by the red line marked with circles.

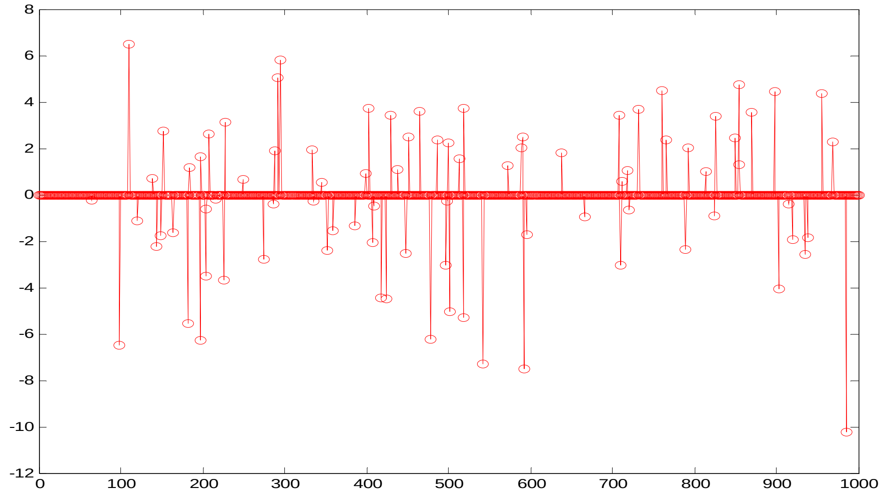

Figure 1(a): Synthetic Earth Signal

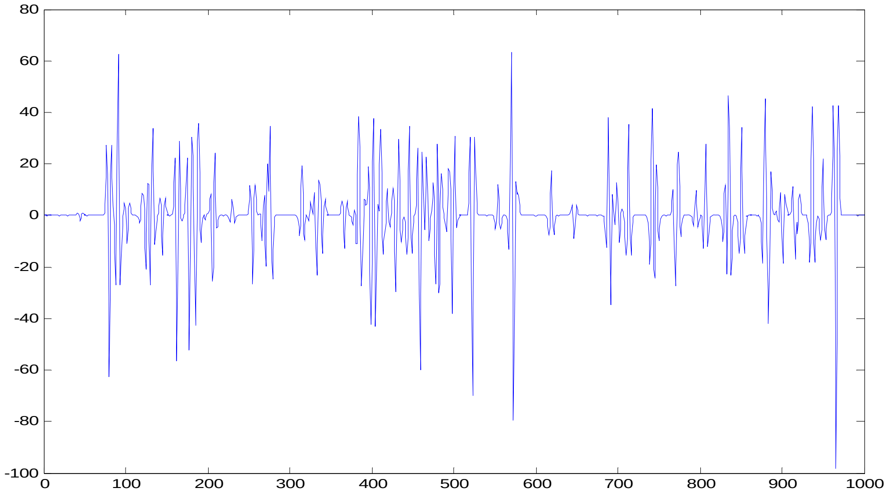

Figure 1(b): Simulated Seismic Signal

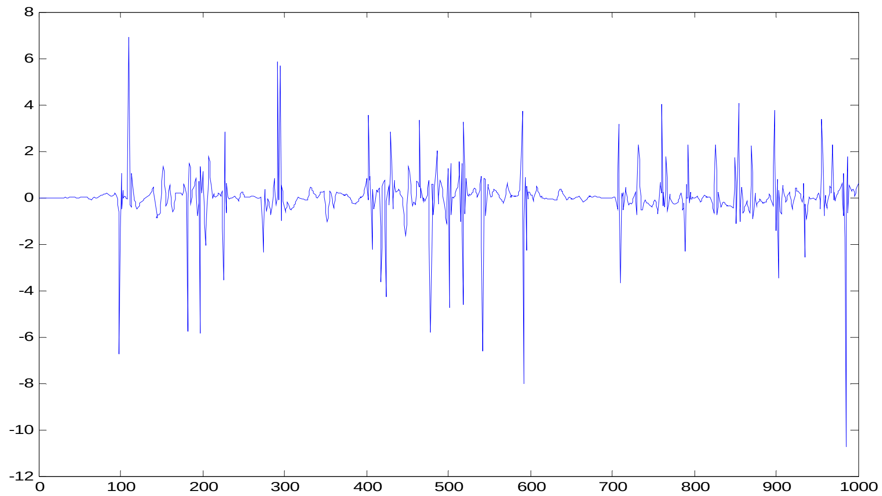

Figure 2 (a): Recovered Earth Signal

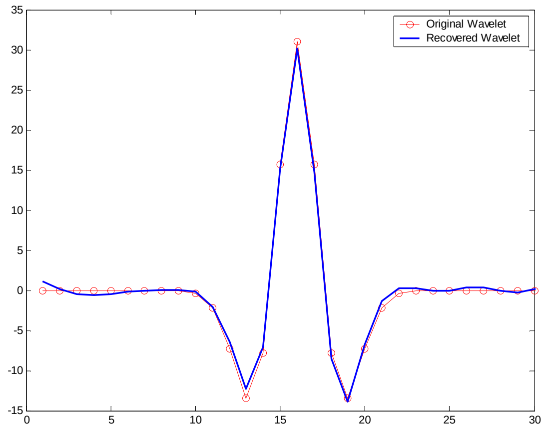

Figure 2 (b): Original and Recovered Wavelet

Conclusions

Simulations of the blind recovery of the earth signal and source wavelet with only the seismic signal as input has demonstrated the efficacy of the new algorithm. The process differs from many deconvolution techniques in that it simultaneously addresses both the problem of wavelet removal and de-noising. Although the technique is computationally intensive it can be applied once the data volume has been reduced through the stacking process. The technique therefore has the potential to be used as a post stack enhancement process to provide datasets for use in conjunction with the conventionally processed reflectivity data. The evaluation of the technique on a range of post stack seismic reflectivity datasets is underway and the initial results of this evaluation will be presented.

References

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