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One-dimensional SURE-LET method using various wavelets for random noise attenuation of seismic data

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Extended Abstract

Summary

In seismic data processing, the processing steps are completely affected by the data quality. Reflection seismic data are often affected by various noises including random and coherent noises. Low signal to noise ratio can produce problems for stacking and migration steps, which ultimately leads to poor interpretation. There are many methods that can be used for noise removal or attenuation of seismic data. The basic assumption of the Fourier transform is that it considers stationary signal, thus, for non-stationary signals, it is not always applicable. Based on this fact that the wavelet transform decomposes a function by translation and stretching, it can provide time-scale representation of a signal. In this paper, we have used SURE-LET method for noise removal in the wavelet transform domain. In the SURE-LET method, any assumptions of noise free signals are avoided.

Introduction

The purpose of seismic data acquisition is to acquire data with the lowest possible noise level. The presence of noise in seismic data is inevitable (Yilmaz, 2001). To improve the signal-to-noise ratio, we can use two approaches: first, changing the seismic energy source or receiver array design and second, processing the seismic data for noise reduction. Considering the source of energy is absorbed by the earth, the increase of seismic energy sources or weighted receiver arrays is limited (Sheriff and Geldart, 1995). Therefore, reduction the noise in order to increase the signal to noise ratio of seismic data is very important.

Morlet (1981) showed that by changing the width of the window, wavelet transform could provide better time-frequency distribution. By wavelet transform, various denoising methods based on thresholding of wavelet coefficients have been proposed. Donoho and Johnstone (1994) presented thresholding theory. Chang et al. (2000) presented Bayes shrink method to remove noise. The sensitivity of the soft thresholding function (to the upper limit of the threshold) for the minimization, does not give suitable results. Luisier et al. (2007), to optimize Stein's Unbiased Risk Estimate (SURE), used another principle, such that the noise attenuation to be expressed as a linear expansion of thresholding (LET) functions. In fact, by combining the SURE and LET and solving a system of linear equations, the noise is attenuated. SURE is an unbiased statistical estimate of the mean squared error (MSE) between an original unknown signal and a processed version of its noisy observation. This estimate depends only on the observed data and does not require any prior assumption on the noise-free signal (Luisier et al., 2010). Blu and Luisier (2007) presented SURE-LET method based on pointwise thresholding function for image denoising. Luisier et al (2010) used SURE-LET method for orthonormal wavelet domain video denoising.

Methodology and Approaches

Wavelet-based noise removal techniques including assumptions for the data are as follow (Luisier et al., 2007):

1. The statistical description of the distribution coefficients
2. A non-linear estimation of statistical parameters,
3. Finding the best noise attenuation algorithms for a variety of statistics

For example, Chang et al. (2000), in The Bayes shrink approach, modeled wavelet coefficients of each sub-band with a general Gaussian distribution (GGD). Then the threshold is obtained for each sub-band for the Bayesian framework. For the SURE-LET method, the previous assumption of the noise-free signals is avoided. This method acts by calculating the unbiased estimates of the mean square error between the signal and denoised signal. There are other methods using SURE approach. For example, the sensitivity of the soft thresholding function to the upper limit of the threshold, in the minimization, does not give suitable results. Luisier et al. (2007) to optimize SURE, used another principle so that the noise attenuation as a linear combination of denoising elements (LET) was expressed. In fact, by combining the SURE and LET and solving a system of linear equations, the noise is attenuated.

Results and Conclusions

The SURE-LET method comprises of two main sections: noise attenuator that consists of the interscale LET, and then, the linear parameters for minimizing of SURE between noisy and noise-free signals. Regarding secondary order estimation (MSE), the parameters are improved easily by solving a LET. The results of this study shows that Symlets and Coiflets provide better results using SURE-LET method for denoising non-stationary seismic signals.