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Research Paper



Application of klauder wavelet for generation of synthetic seismic signals

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Abstract

Analysis of reflected seismic waves gives the information about the earth and its inner core. This aids in monitoring earthquake, petroleum exploration, determination of the earth's core structure, etc. Wavelet transforms is an efficient tool for analysis of seismic reflected signals. These transforms helps in complete extraction of the seismic signal buried in noise. In this paper an attempt is made to analyze a synthetic seismic signal by using Klauder wavelets. The synthetic seismic signal is extracted by convoluting with the Klauder wavelet. Noise is completely removed as the wavelet spans a large spectrum of signals.

Keywords: *Convolution; Klauder wavelet; Seismic signal; Synthetic signal.*

1. Introduction

The key parameter in analysis of seismic reflected signals is onset time , p-wave arrival amplitude ,time period and their polarity. Many other waves such as Rayleigh waves , low waves along with noise and dispersion of waves. The spectral analysis of the waves helps us in accurate detection of seismic signals .This largely depends on the spectral signal to noise ratio (snr) of the signals. Wavelets aids in faithful extraction of signal buried in noise.[1]
The non-stationary seismic reflected signals could be analyzed by using wavelet transform .Wavelet transform is an advanced tool for signal analysis; wavelets provide localization of time and frequency which could not be achieved by the traditional signal processing techniques. Fourier transforms could not provide the spectral analysis of transients present in the signals.
Wavelet provides a flexible window for both time and frequency which provides a highly relivable spectrum of the input signal. The time frequency window is automatically narrowed while analyzing low frequency components and widen in analyzing high frequency components.

2. Methodology

Fourier transform is better tool for analyzing components of a stationary signal. But fail's in analyzing the non-stationary signal, where as wavelet transform allows the components of a non-stationary signal to be analyzed, especially for short time analysis of seismic signals. The advantage of this method is to drive low frequency components considerably with good resolution [2].

The wavelet transform suffers from four fundamental shortcomings.
1. Oscillations, 2.Shift variance, 3.aliasing, 4.Lack of directivity
Complex wavelet is a simple solution to these four DWT shortcomings. [3]

Wavelet transform method involves Scattering and shifting properties to generate a wavelet and it is limited to a specified length. The process includes two steps
1) Shifting the function of wavelet and
2) Making product with an inner scale function.

$$WTx(\alpha,\tau) = \frac{1}{\sqrt{\alpha}}\int_{-\infty}^{\infty} x(t)\left(\frac{t-\tau}{\alpha}\right)dt, \text{ a>0} \quad (1)$$

The equivalent express in the frequency domain, the formula as follows

$$WTx(\alpha,\tau) = \frac{\sqrt{\alpha}}{2\pi}\int_{-\infty}^{\infty} X(\omega)\varphi(\alpha\omega)e^{j\omega\tau}dt \quad (2)$$

α is a scale factor which is always bigger than zero, and displacement is mirrored by τ
From equation (2) , $X(\omega)$ and $\varphi(\omega)$ are fourier tranform of X(t) and $\varphi(t)$ respectively.[4]

The wavelet initially oscillates at zero amplitude and increases thereby decreasing the initial oscillated amplitude to zero. To get information from an unknown signal a wavelet can be convoluted with portion of a known Signal. Convolution is a mathematical way of combining two signals in order to form a third signal. The technique is popularly used for processing the signals digitally (DSP). The method involves in finding the zero phase of a given signal

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The wavelet used in this paper is Klauder wavelet. It represents the autocorrelation of a linearly swept frequency-modulated sinusoidal signal and defined by its terminal low frequency, "f1"; and terminal high frequency, "f2"; the duration of the input signal "T", is often 6 or 7 seconds. The real part of the following formula will generate a Klauder wavelet.[5]

$$\boldsymbol{Klauder(t) = real\left[\frac{sin(\pi kt(T-t))}{(\pi kt)exp(2\pi ifot)}\right]} \quad (3)$$

Where k = (f2-f1)/T (rate of change of frequency with time)

fo =(f2+f1)/2 (mid frequency of bandwidth)

i = $\sqrt{-1}$ (an imaginary number)

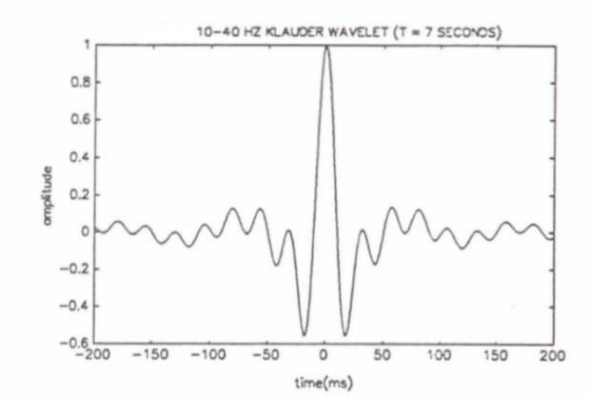


Fig. 1: A Klauder wavelet is symmetrical about a vertical line through its central peak at time zero

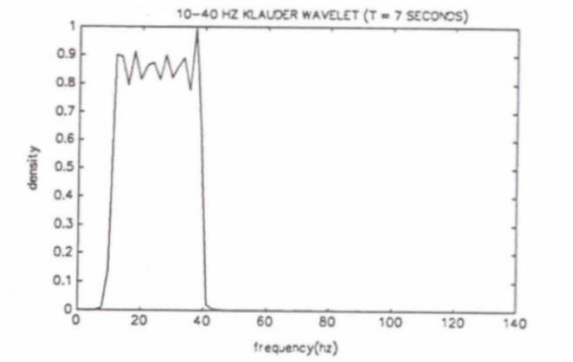


Fig. 2: The frequency spectrum of a Klauder wavelet shows the substantial similarities between a Klauder and an Ormsby wavelet**.**

As there are many software's like 'c', 'Fortran' but we are going for 'mat lab' (MATRIX LABORATORY) because of it overcomes the disadvantages of other two languages. The CREWES mat lab is a large collection of geophysical routines in which each module has been checked for consistency and accuracy. More algorithms are upgraded and transferred to this crewes MATLAB.

3. Result and discussion

A Klauder estimate based on the zero phase synthetic with multiples(fig.3). Their deconvolutions spike at the same positions and are effectively identical. This similarity is also reflected in Figure Here, the band limited reflectivities are shown and they too are effectively identical.

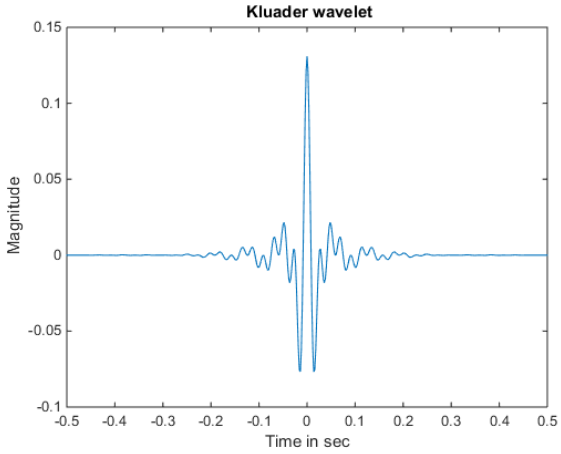


Fig. 3: Representation of a klauder wavelet

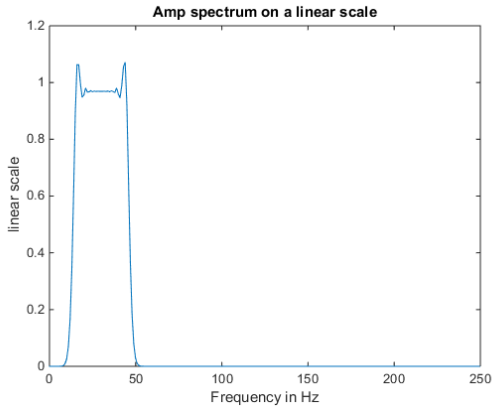


Fig. 4: Amplitude spectrum of a synthetic signal on a linear scale

Amplitude spectrum of a synthetic signal on a linear scale
A linear sweep has an instantaneous frequency which is a linear function of time(fig.4).

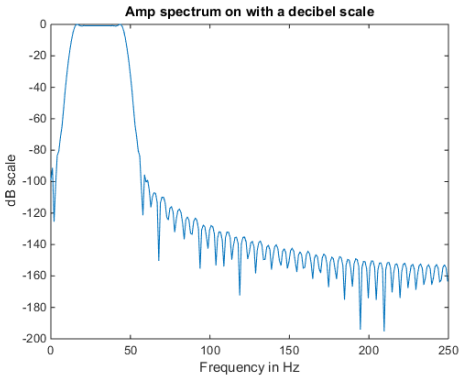


Fig. 5: Amplitude spectrum of synthetic signal on decibel scale

Non-linear sweeps doesn't have a frequency with linear function of time(fig.5). The change in frequency is slow, there will be depressed amplitudes. By using a non-linear sweep , a different wavelet is generated by auto-correlation of the sweep. Different sweeps were used to examine the effect of the sweep shape on the results of cross correlation and frequency domain deconvolution.

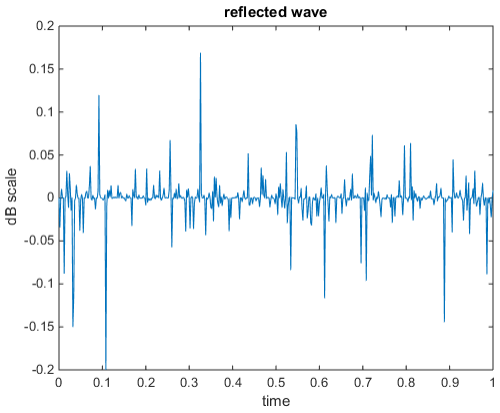


Fig. 6: reflectivity of a synthetic signal

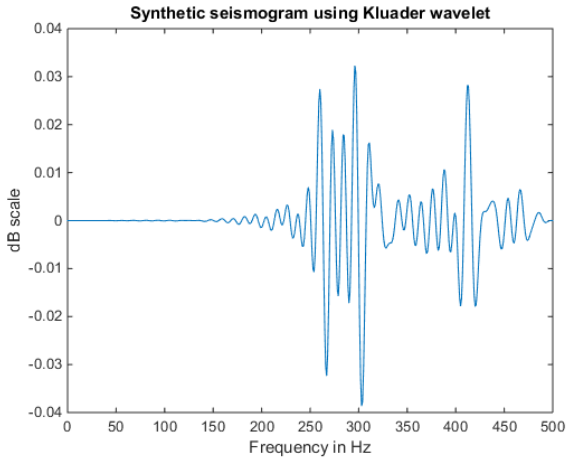


Fig. 7: Convoluted klauder wavelet with the synthetic signal to abtain the synthetiseismogram.

4. Conclusion

In this report wavelet transform method is analyzed and generated different wavelets using 'Matlab'. Each wavelet is convoluted with a synthetic signal in order to generate a synthetic seismogram using a wavelet transform method. The different wavelets have different operating frequencies and are used according to the operating frequency. It also shows that the wavelet transform method has high resolution over Fourier Transform method which is one of the traditional methods to analyze an earthquake signal. The wavelet transform method is one of the modern methods used to analyze an earthquake signal having high time-frequency constant when compared to Fourier Transform method having a constant time- frequency constant. It also shows that wavelet transform method is fine in doing time-frequency analysis of an earthquake signal.

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