APPLICATION OF BARTLETT ALGORITHM FOR SPECTRAL ANALYSIS OF SEISMIC DATA DURING AN EARTHQUAKE

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Abstract: Seismology is a study of earthquakes. Earthquakes are inevitable disasters in nature. Whenever an earthquake occurs, abnormal energy will be emerged in terms of seismic waves from earth’s surface and are highly associated with ambient noise. The very nature of seismicity will be conceded and thereby making the SNR of the seismic signals very feeble. An attempt is made in this work to improve the SNR in term reducing the associated noise. Finally, an analysis is made by applying Bartlett algorithm to derive the power spectrum for identification of dominant frequency components present in the seismic signals caused by an earthquake. This approach will be useful for the prediction of an earthquake.

Keywords: Seismicity, Statistical signal processing, SNR, Power Spectrum.

1. INTRODUCTION

Earthquake is an underlying physical phenomenon in lithosphere caused due to the movement of tectonic plates releasing abnormal energy in terms of seismic waves. Seismometer is a device to sense the seismic waves depicting as seismogram. The seismic waves are embedded with seismic signals of low strength. As the seismic signals emnates from earth’s surface, they are associated with the local noise there by making seismic signals hidden in the local noise with low energy. In order to evolve the seismic data to remove the noise and evolve the intensity of seismic content in the presence of noise due to an earthquake[12-21].

2. Signal pre-processing techniques

There are many signal processing techniques that are applied to extract seismic information from seismograms. But very few sophisticated techniques, will give more seismological features and exhibit the nature of an earthquake. Analysis of seismograms is a challenging task to derive the seismicity present in the seismic signals with low energy. Consequently, the SNR of such signals is very low. In order to enhance the SNR, various methods of signal processing are used to trace out the degree of seismicity. For which, prior processing methods are used to smooth out the seismic data and reduce the associated noise by subjecting the data to FIR BPF. Seismic data is analysed using the Bartlett algorithm to derive the power spectrum of seismic signals and find out the frequency components and predict the very nature of an earthquake.

3. METHODOLOGY

The major drawback of periodogram is that, it cannot give stable estimates of power spectrum. For which, a non-parametric method is proposed and implemented to smooth out and average for power spectral estimation[1-11]. For the estimation of time domain signals and find out the noise associated with that autocorrelation is being used. In order to find out the frequency component, non-parametric methods are deployed to eliminate the redundancy of the data as in periodogram. For the power spectral estimates, Bartlett is a refined method to have better power spectrum estimation by detrending the data so as to reduce the variance of seismic signals through band pass filters. In the Bartlett method the periodogram averaging is discussed, the estimated power spectrum is produced. If the data length N reaches to infinity value of periodogram expected is converges up to $P_x(e^{jw})$.

$$\lim_{n \to \infty} E\{P_{per}(e^{jw})\} = P_x(e^{jw}) \quad (1)$$

If the mean of consistent estimate is determined, $E(P_{per}(e^{jw}))$, will be the $P_x(e^{jw})$’s consistent estimate. By using periodogram averaging random process, power spectrum is estimated as $x$.

$$P_{per}(e^{jw}) = \frac{1}{L} \sum_{n=0}^{L-1} x(n)e^{-jnw}^2 \quad (2)$$

The average of periodograms is $P_x(e^{jw}) = \frac{1}{K} \sum_{k=1}^{K} P_{per}(e^{jw}) \quad (3)$

By evaluating we get

$$E\{P_x(e^{jw})\} = E\{P_{per}(e^{jw})\} = \frac{1}{2\pi} P_x(e^{jw}) * W_b(e^{jw}) \quad (4)$$

$W_b(e^{jw})$ is the Bartlett window’s ($W_b(K)$) Fourier Transform. In additions to our assumed data records, $P_x(e^{jw})$ is unbiased and uncorrelated. The $P_x(e^{jw})$’s variance is given as:

$$\text{Var} \{ p_x(e^{jw}) \} = \frac{1}{K} \text{Var} \{ p_{per}(e^{jw}) \} \quad (5)$$

L and K goes to the infinity as the $P_x(e^{jw})$ is the power spectrum estimation. The $x(n)$ in Bartlett method is partitioned into K number of non-overlapping sequences which consists of the length L. Here N=LK.

$$x(n) = x(n+L) \quad \text{where} \quad n=0,1,\ldots,L-1. \quad (6)$$

Hence the Bartlett estimate is found as

$$P_b(e^{jw}) = \frac{1}{N} \sum_{n=0}^{N-1} \sum_{R=0}^{L-1} x(n+iL)e^{-jnw}^2$$
$(7)$ $P_b(e^{iw})$ is a periodogram which is asymptotically unbiased, used in this are computed to find out the resolution given below using length $L$,  
$$\text{Res}[P_b(e^{iw})] = 0.89 \left( \frac{L}{2} \right) \quad (8)$$

As $K$ is inversely proportional to the variance,  
$$\text{Var} \left[ P_b(e^{iw}) \right] = \frac{1}{K} \text{Var} \left[ \text{per}(e^{iw}) \right] \quad (9)$$

4. Simulation and Results

Basically seismic signals are of random nature and are stochastic and deterministic. It is therefore FFT cannot be used. Further, the seismic data is associated with noise and is very complex to analyse. For which the seismic data is smooth out by using band pass filter.

The following are the steps followed to perform pre-processing of the seismic data.

Step 1: A synthesized signal is subjected to Bartlett algorithm and the results are plotted in Fig.1. showing magnitude and sample number.

Step 2: Fig.2. shows the overall view of 50 Bartlett estimates with regard to synthesized signal.

Step 3: Now the seismic data which is original is considered and is given in Fig.3.

Step 4: Fig.4. shows detrended signal by removing the mean due to shift or bias present in the random signal.

Step 5: Fig.5. shows the power spectrum of raw seismic data and presence of frequency components over distributed energy.

Step 6: Fig.6. shows the response of band pass filter restricted to its bandwidth giving the desired output. Further, applications for BPF results in normalized frequency in the range of 0.03 to 0.269 Hz.

Step 7: Fig.7. depicts the convolution of FIR BPF and the detrended signal and removes noise present in particular frequency. Here, $8^{th}$ order FIR is being used having 8 filters to filter out the detrended signal.

Step 8: FFT is applied after passing through BPF and the plot is shown in Fig.8. Power spectrum is shown in Fig.9. Here, the normalized frequency obtained is 0.078.

where,

$$w = \frac{2\pi f}{f_0} = \frac{2\pi}{500} \times \frac{0.078}{2} = 0.078 \pi$$

Hence, Total frequency $f = 0.078 \times \frac{500}{2} = 19.5$ Hz
4. Conclusion
By applying Bartlett algorithm, it is observed that the large fluctuations of the periodogram are being eliminated. Passing the data through FIR, there is reduction in the band pass noise as there is increase in the SNR ratio. The power spectrum of seismic signal is being analysed for identification of dominant frequency components in the power spectrum well correlated with that of frequency components present due to an earthquake.

5. References
[21] D. Venkata Ratnam,