Seismic Noise Removal and its Applications – A Review of Exploring Wavelet Transform in Civil Engineering

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Abstract –
The purpose of this study is to provide a guideline for the effective selection of wavelet type in Civil Engineering applications. Seismic denoising is the process of removing noises, ie., the unwanted disturbances present in seismic waves are removed. In seismic exploration, seismic signals are affected by a variety of interference, disturbance and noises, its related seismic data resolution to be reduced. Therefore, denoising is necessary in terms of seismic data processing, so explained in this paper.

Keywords – *Seismic Waves, Seismic Noises, Fourier Transform, Wavelet Transform, Application*

I. INTRODUCTION

The survey of the literatures show that wavelet transform is useful to mathematically address a range of problems, with the specific applications of the wavelet transform in civil engineering as denoising, discontinuity detection, feature extraction, frequency identification, system modeling, and data compression. The result of the study is expected to help civil engineers to choose the right type of wavelet transform for the particular field of civil engineering (Byungil Kim et al., 2017). Wavelet transform is a new method of technique, because of it is based on time-frequency analysis and other characteristics which have been widely applied in the signal de-noising.

II. SEISMIC NOISES

In geology and other related disciplines, seismic noise is a basic for a relatively persistent vibration of the ground which are unwanted component of signals recorded by seismometers. Seismic noise consists mostly of surface waves and Low frequency waves and microseisms are waves below 1 Hz and micro tremors are high frequency waves above 1 Hz. Its causes include nearby human activities, winds and other atmospheric phenomena, and ocean waves. Seismic raw data will always be contaminated by unwanted energy. This unwanted energy is denoted noise, and it represents a challenging problem in seismic exploration.

III.CLASSIFICATION OF NOISES

A. *Coherent Noise*
B. *Random Noise*
C. *Ambient Noise*

A. Coherent Noises

Coherent noises are components of the waveforms which are mostly generated by the seismic source during the survey, but are unwanted and of no interest for the final data (Kearey, et al., 2002). The phase is consistent from trace to trace (Schlumberger, 2009). Coherent noise can be divided into two sub categories, say linear and non-linear.

Following are the source of coherent noise,

- Multiple reflections
- Refracted events
- Diffraction events
- Ground Role
- Direct arrivals
- Side-Swipe

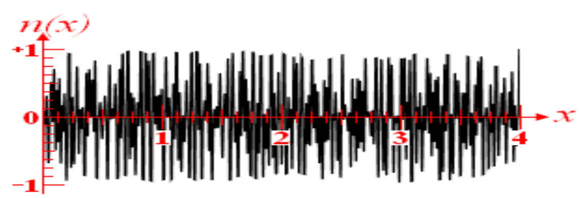

Fig. 1 Coherent Noises

B. Random Noises

Random noise includes noise in the temporal direction, and spatially random noise that is uncorrelated from trace to trace (Yilmaz, 2001). The signals are not generated by the survey itself. Quite often there can be noise from the vessels propeller and the streamer if they are moving. Random noises made up of irregular un related waves such as thermal, shot, magnetic fluctuations, modulation noises, pulses which can be caused by any of the following,

- Wind noise
- Water flow noise
- Small movements within the Earth
- Local noise (people, traffic, etc)
- Bad geophone noise
- Short wavelength propagating noise.

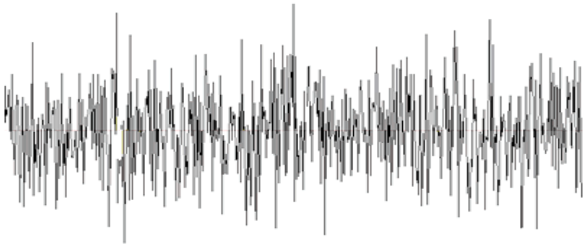

Fig.2 Random Noises

C. Ambient Noises

Ambient Noises occurred due to Wind Currents, Traffic - Cars and Vehicles, Animals, People, Noise from Power Line, Hydraulic Structures etc.

IV. SEISMIC DENOISING METHODS

Seismic denoising can be done by following methods

A. Fourier Transform

The Fourier transform decomposes a signal into the frequencies that make it up. The Fourier transform of a function of time itself is a complex valued function of frequency, whose absolute value represents the amount of that frequency present in the original function.

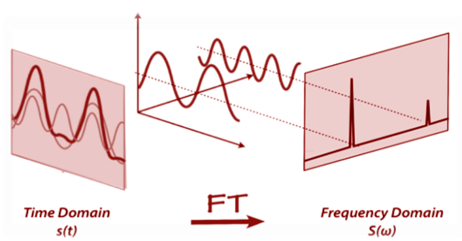

Fig.3 Fourier Transform

B. Wavelet Transform

A wavelet is a mathematical function used to divide a given function or continuous time signal into different scale components. A wavelet transform is the representation of a function by wavelets. The wavelets are scaled and translated copies as daughter wavelets and the mother wavelet.

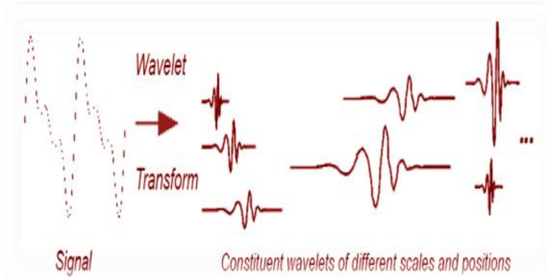

Fig.4 Wavelet Transform

Adeli and Kim (2004) explained their use of the wavelet transform in structural engineering to eliminate dynamic environmental disturbance signals, or the lower frequency components, from ground acceleration signals of a civil engineering structure, using Daubechies wavelets with three vanishing moments. Adeli and Jiang (2006) described a signal processing method they developed to smooth contaminated data in acceleration responses of the structure under earthquakes, based on the discrete wavelet packet transform using a Daubechies wavelet of order 4. Jiang and Mahadevan (2008) also employed the same methodology to remove noise from signals for the nonparametric identification of structures. Rizzo et al. (2005) explained the use of the discrete wavelet transform (db40) for signal denoising in the tone burst signals of very small structures with dimensions less than 1mm. The reason why this study employed a high order wavelet, as opposed to the previous two studies, was that it had a more narrowband character that could match the tone burst signals in the study.

Table. 1 Difference Between Fourier Transform Verses Wavelet Transform

S.N	FOURIER TRANSFORM	WAVELET TRANSFORM
1	Suitable only for stationary signals.	Suitable for stationary signals and non stationary signals.
2	It is not suitable for study of local behavior of signal.	It is suitable for study of local behavior of signal
3	The input can be real or complex function but the output is always complex.	The input can be real or complex function but the output maybe real or complex.

4	In Fourier analysis, the signal is converted into sine and cosine waves of various amplitude and frequencies.	In wavelet analysis the signal is converted into scaled and translated version of mother wavelet.

V. JUSTIFICATION FOR WAVELET TRANSFORM

- Wavelet analysis is often very effective and simple for dealing these situations.
- It also provides us with new methods for removing noise from signals that complement the classical methods of Fourier analysis where they handle well in approximating signals with sharp spikes or signals having discontinuities according to scale or resolution.
- For managing non-stationary signals like seismic data, Fourier has been nearly outdated by wavelet.
- The choice of mother wavelet and its order generally depends on this denoising wavelet situation.

VI. WIDE FOCUS OF WAVELET TRANSFORM

A. Discontinuity detection: The use of wavelets to detect discontinuities in a signal

B. Feature extraction: The use of wavelets to derive mid-level data that are fed into a reasonably complex decision making process

C. Frequency identification: The use of wavelets to identify the main frequency component in a signal

D. System modeling: The use of wavelets for system prediction

E. Data compression: The use of wavelets to represent a signal with fewer coefficients.

F. Denoising: The use of wavelets to attenuate white noise in a signal

A. Discontinuity Detection

Liew and Wang (1998) adopted a harmonic wavelet transform, which combines the advantages of the short-time Fourier transform and the continuous wavelet transform, to identify the location of cracks in structures without mathematical and computational burdens. Their primary concern was to overcome inaccuracies in the high-order mode of eigenvalue analysis. Hou et al. (2000) and Hera and Hou (2004) used the Daubechies wavelet with four vanishing moments to detect a sudden structural damage and its location, as indicated by a peak in the high-resolution wavelet details of the acceleration response data. Melhem and Kim (2003) used the Daubechies wavelet with four vanishing moments to detect structural damage or a change in a concrete structure based on the wavelet contour map of the acceleration response data.

B. Feature Extraction

Hajj (1999) explained the use of the wavelet transform to quantify the level of intermittency of energy-containing scales in the surface layer of the atmospheric boundary layer. Marwala (2000) described the use of wavelet spectrum as input variables for a neural network model to identify damage in a population of cylindrical shells. Sun and Chang (2002) developed a feature extraction methodology to characterize the damage feature based on wavelet packet transform, which enables focusing on any part of the time frequency domain by providing a level-by-level decomposition of a signal (Mallat, 1989). Sun and Chang (2004) also adopted the wavelet packet transform to extract minute abnormalities from vibration signals for structural health monitoring. Both studies used Daubechies wavelets as the mother wavelet. Ren et al. (2008) adopted the wavelet packet transform to characterize damage features as energy components to identify their locations using the Daubechies wavelet with five vanishing moments. Park et al. (2008) developed a piezoelectric sensorbased health monitoring technique using a support vector machine classifier; the Morlet wavelet was used to extract the features that were later fed into the classifier.

C. Frequency Identification

The Morlet wavelet or the complex modified has been widely used as a mother wavelet to identify the characteristic features on the spectral or probabilistic structure of the analyzed signals (Yoon et al., 2000; Gurley et al., 2003; Ji and Chang, 2008). Using graphical representations, such as the scalogram, which describe the signal energy on a domain, previous studies revealed characteristics about non-stationary processes in structural responses. The Morlet wavelet was employed, owing to its good localization in time-frequency domains. Kijewski-Correa and Kareem (2007) evaluated the performances of two different transforms, empirical mode decomposition with Hilbert transform and wavelet transform, when extracting signals embedded in noise. They adopted the Morlet wavelet due to its shape like a frequency-modulated wave. Chakraborty and Basu (2010) adopted a modified form of the Littlewood-Paley basis function to examine the time varying frequency content in the response of primary-secondary systems. Their continuous wavelet analysis clearly showed that the response of the secondary system contained strong frequency non-stationarity.

D. System Modelling

Using the Daubechies wavelets, measured signals can be represented as a series expansion of wavelets (mathematical functions) for the identification of a nonlinear structural dynamic (Kitada, 1998; AL-Qassab and Nair, 2003; Law et al., 2006; Basu and Nagarajaiah, 2010); the computational features of the Daubechies wavelets are recursive, mutually orthogonal, and compactly supported. Conversely, Basu and Gupta (1998) employed a modified form of the Littlewood-Paley wavelet to model ground motions as non-stationary processes in terms of both amplitude and frequency non stationarity because this mother wavelet has an excellent frequency localization despite poor localization in time. Furthermore, it provides numerical computational advantages by enabling the energy scalogram, which describe the signal energy on a domain, previous studies revealed characteristics about non-stationary processes in structural responses. The Morlet wavelet was employed, owing to its good localization in time-frequency domains. Kijewski-Correa and Kareem (2007) evaluated the performances of two different transforms, empirical mode decomposition with Hilbert transform and wavelet transform, when extracting signals embedded in noise. They adopted the Morlet wavelet dueto its shape like a frequency-modulated wave. Chakraborty and Basu (2010) adopted a modified form of the Littlewood-Paley basis function to examine the time varying frequency content in the response of primary-secondary systems. Their continuous wavelet analysis clearly showed that the responseof the secondary system contained strong frequency non-stationarity.

VII.STUDY ON LITERATURE REVIEW

The interference noises are certain in actual seismic data acquisition, therefore data acquisited should been done using denoising processing. Few journal papers referred, its category and remarks are given in the following table.

Table. 2 List of few Literature Review Focused on Wavelet Transform are Shown Below:

S.No.	Category	Journal Papers	Remarks/Keywords
1	Soil Dynamics and Earthquake Engineering	"Correction of highly noisy strong motion records using a modified wavelet de-noising method" Anooshiravan Ansari, Asadollah Noorzad b, Hamid Zafarani a, Hessam Vahidifard (2010)	Time-frequency analysis.
2	Engineering Structures	"Damage detection of structures by wavelet analysis" **(**Hansang Kim, Hani Melhem (2003)**)**	Wavelet analysis is followed by its application to SHM, Specific Applications namely crack detection of a beam etc. are followed.
3	Geoscience and Seismic Exploration	"A new sparse representation of seismic data using adaptive easy-path wavelet transform" **(**Jianwei Ma, Gerlind Plonka, Herve Chauris**)**	EPWT, Seismic processing, Adaptive wavelets, Sparse representation, Curvelets.
4	Computer Science	"Image denoising using wavelet transforms" Dongwook Cho(2004)	I-Part: Complex wavelets, multi wavelets, directional wavelets, II-Part: Specific Shrinkage Algorithms.
5	Journal of Applied Geophysics	"Localization and de-noising seismic signals on SASW measurement by wavelet transform" **(**Alireza Golestani , S.Mahdi S.Kolbadi, Ali Akbar.Heshmati(2013)**)**	Seismic response spectrum, Continuous wavelet transform, Wavelet decomposition, De-noising, Surface waves.
6	Geophysics	"Noise Attenuation: A Hybrid Approach Based on Wavelet Transform" (Rongfeng Zhang and Daniel Trad - University of	The hybrid approach, The original shot gather, 1D WT + PWFD filtering result.

		British Columbia, Geophysics (2002))	
7	International Journal of Emerging technology and Advanced Engineering	"Noises and Image Denoising Techniques: A Brief Survey" Chandrika Saxena, Prof. Deepak Kourav (2014)	Image Denoising, Additive Noises, Multiplicative Noises and Denoising Techniques.
8	Geoscience	"Seismic ground roll time–frequency filtering using the Gaussian wavelet transform"	Seismic processing, Noise filtering, Wavelets, Ground roll.
9	International Journal of Emerging technology and Advanced Engineering	"Signal and Image Denoising Using Wavelet Transform" Burhan Ergen, Fırat	Discrete Wavelet Transform (DWT), Wavelet Packet Decomposition
10	Signal-Processing	"Wavelet-based image denoising in (digital) particle image velocimetry" W.G. Weng, W.C. Fan, G.X. Liao, J. Qin (2001)	Wavelet transform, Image denoising, PIV
11	Applied Soft Computing	"A novel wavelet seismic denoising method using type II Fuzzy" **(**M. Beena mola , J. Mohanalinb, S. Prabavathyc, Jordina Torrents-Barrenad, Domenec Puigd (2016))	Fuzzy method

VIII. APPLICATION OF SEISMIC DENOISING

Seismic denoised waves of earthquake allows us to calculate the position of major boundaries in the Earth's interior, as well as giving us information about the solid versus liquid character of the various layers, and even about some of their physical properties. Artificial Seismic Denoised waves are frequently used to search for oil and natural gas deep below Earth's surface.

In Kathmandu Earthquake, the villagers found many of the carrots that were growing in the fields were brought out of the ground as water flowed up and flooded the fields as liquefaction, where the ground behaves like a liquid. Since the crops cannot be replanted once they are pulled up or pushed up. Thus, the first known earthquake-related incident of "root vegetables ejected out of the ground" was recorded Natural Seismic Denoised waves are used to measure the time travel of earthquake. In Mapping seismic Denoised waves plays the vital role is determining the bedrock topography thus Mapping of soil and rock seismic velocities. Seismic denoised waves of earthquake helps us to identify Seismic noise is relevant to any discipline that depends on

- Seismology,
- Geology,
- Oil Exploration,
- Hydrology,
- Earthquake Engineering,
- Structural Health Monitoring,
- Liquefaction
- Highway
- Water Resources

IX. CONCLUSION

The Earthquake has the largest magnitude that get recorded in the recent epochs. The Earthquake data acquired from USGS is the raw data that should be processed for the study. The process steps involves threshold fixation, Denoising, Time–history analysis and base shear calculation which is processed using MATLAB software. From this process the denoised signal are removed, which is very crucial for current and future in the field of Civil Engineering. Also with the recent projects evolved there is a wide application of Wavelet Denoising in Civil Engineering. This paper highlights the importance of Wavelet transform and its application in the field of Civil Engineering.

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