Comparision of Haar and SYM Wavelet Tranforms in the Detection of Magnitude for Earthquake Using Seismic Signals

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ABSTRACT: *Natural disaster is a foremost undesirable event resultant from natural processes of the Earth and causes loss of life or property damage. Earth quakes are among the most damaging event caused by the earth itself. As urbanization progresses universally, earthquakes pose severe risk to lives and properties for urban areas and all the subduction zones. Short term earthquake prediction, months in advance, is an elusive goal of earth sciences, of great importance for fundamental science and for disaster preparedness. Detection of earthquake was done earlier based on W-MLP and MLP, Wavelet-Aggregated Signal and Synchronous Peaked Fluctuations model, detection using the P waves of the earthquake, prediction based on radon emissions, EEW algorithm, M8 algorithm, prediction using extraction of instantaneous frequency from underground water, but neither of them could provide an effective and efficient result. In the present research, seismic signals are analyzed by using Haar wavelet transform and SYM wavelet transform in order to evaluate the energy, frequency, magnitude of the signal. The minor quakes are neglected and the surface wave magnitude of the quakes that show impact on earth's surface is calculated and found as 3.0. The obtained results from Haar and SYM wavelet transforms are taken up as datasets and are tested using classification algorithms such as J48, Random Forest, REP tree, LMT, Naïve Bayes and Back propagation model of neural networks to evaluate the accuracy, precision and recall performance measures.*

Keywords: Earth quake, FFT spectrum, Haar wavelet, Primary waves, Secondary waves, Seismic signals, Surface wave magnitude, SYM wavelet

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1. Introduction

Earth is said to be the only planet in the solar system know to nurture, cherish and shelter the entire mankind. All the things required for the survival is provided beneath a thin layer of atmosphere that separates us from the decrepit space. As earth is made up of obscure and interactive systems hence it is quite unpredictable. Air, water, land, and life including humans combine forces to create a constantly changing world that we are striving to understand. The formation of earth is believed to be took place around 4.54 billion years ago and there are many theories that support this formation. The Big Bang theory is one among such theories where a star collapsed forming earth's core which is at temperature equal to surface of the sun i.e., 60000C. From space earth looks like a big blue blob with white swirls, the lush land in green, the deserts in brown and the cloud, ice and snow in white. As one third i.e. 71 percent of the earth's surface is covered with water hence it is also called a blue planet. Earthquakes are usually caused when the rock underground suddenly breaks along the fault and the stresses and pressure among the rocks and the outer layer pushes the sides of the fault together. Due to these stress the rock slips suddenly, with a release of energy in the form of waves through the earth's crust and this results in the vibrations and shaking over the earth surface. Usually large earthquakes usually begin with slight tremors but within no time would form in to a violent shock and ends with a vibration of gradually diminishing force called aftershock. The subterranean point of origin of an earthquake is called its focus; the point on the surface directly above the focus is the epicentre. Due to the sudden release of energy in the energy in the earth crust, it creates seismic waves which make the ground shake.

Volcanic eruptions, rock falls, landslides, and explosions can also cause a quake, but most of these are of only local extent. Earth's activity can be categorised into three events specifically foreshock, the energy released from earth's core but with less due to weak strength they cannot reach earth surface. Main Shock, the strength in energy is much stronger enough to hit the earth surface and causes damage. Aftershock, the event which occurs after the main shock i.e. earthquake had occurred. Shock waves from a powerful earthquake can trigger smaller earthquakes in a distant location hundreds of miles away if the geologic conditions are favorable. The surface of the Earth is made up of a collection of large plates that does not reside in fixed positions, they move, and they frequently press up against one another with great force. Two plates moving away from each other create a divergent plate boundary, a rift in the Earth's crust. When two plates push against each other, this is a convergent plate boundary. At a convergent boundary, one plate will usually slide underneath the other and melt into magma below. If neither plate can slide underneath the other, the two plates sometimes create a mountain range. When plates slide in opposite directions while pressed against each other, this is called a transform boundary. A lot of tension builds at the seismic faults around these boundaries, which can lead to earthquakes.

When there is an earthquake there will be moment of waves on the earth surface called seismic waves. The study of such waves is called as seismology. There are different types of waves released after the earthquake had occurred which include primary waves, secondary waves, Love waves, Rayleigh waves, stoneley waves; among these p-waves and s-waves travels inside the earth called as body waves and are stronger enough to study the earthquake activities. The remaining waves travel along earth surface they are called as Surface waves.

Earthquake prediction is the branch of seismology, which can be done by the following prediction methods.

Animal Behaviour [2]: Abnormal behaviour in animals can be helpful to predict the forthcoming disaster, as they behave in unusual manner and disappear from the region where the earthquake occurs.

Radon Emissions [9] [10]: There are different rocky materials inside the earth which emits certain gases, the amount of such emission is extremely concentrated and yields spikes when recorded on the graph during the earthquake.

Study of Waves: Study of p-waves and s-waves helps in predicting earthquake, as these waves carries earthquake energy. Various parameters can be extracted from these waves and are to be analysed. When earthquake occurs over a region these waves are emerged from earth's core and reaches the earth's surface. The two different surface waves; p-waves - travels inside earth in both liquid and solid interfaces and they are the faster among all waves and s-waves - travels in both solid and liquid interfaces but are slow than p-waves. These surface waves are recorded to measure the earthquake intensity using a device called seismogram. Seismogram records response of these waves in a visual form called seismographs. Seismic parameters [4] such as frequency, wavelength, energy, magnitude can be extracted from the seismographs.

Earthquake has caused the greatest loss of life, causing a powerful and deadliest loss at heavily populated areas or the oceans; earthquake which occurs in the form of tsunami in the ocean areas causes the greatest loss by devastating the communities thousands of kilometres away. It is estimated that around 500,000 earthquakes occur each year among them only 100,000 of earthquakes can be felt. Table I gives the census of the drastic death toll that took place at various locations due to the heinous earthquake. Table II gives the property damages that occurred due to earthquakes. This motivates to present a prediction methodology for earthquake so as to reduce the risk and to control the live and property loss to the possible extent.

The rest of the paper is organized as follows: Section II gives a glance to all the recent research carried on for the prediction of earthquake. Section III describes experimental methodology. Section IV illustrates the experimental results and finally Section V concludes the paper.

2. Relevant Work

Year	Location	Death	Magnitude
2005	India	80,000	7.6
2004	Sri Lanka	2,83,106	9.3
2001	Gujarat	20,000	7.7
1950	India	1,526	8.5
1935	England	60,000	7.7
1934	Nepal	8,100	8.7
1905	India	20,000	7.8
1819	India	1,543	8.2

Table 1. Death Toll Caused By Earth Quakes

Year	location	Property damage	Magnitude
2011	Japan	$235 billion	9.0
1995	Japan	$100 billion	6.9
2008	China	$75 billion	8.0
2010	Chile	$30 billion	8.8
1994	United States	$20 billion	6.7
2012	Italy	$13.2 billion	5.9
2011	New Zealand	$12 billion	6.3
1989	United States	$11 billion	7.1
1921	Taiwan	$10 billion	7.6
1906	United States	$9.5 billion	7.9

Table 2. Property Toll Caused By Earth Quakes

P.Shebalin, V.Keilis-Borok, A.Gabrielov, I.Zaliapin, D.Turcotte [1], used an data mining approach to predict earthquake using a technique called RTP (Reverse Tracing of Precursors) in which they observe and analyze the premonitory patterns of seismicity and the RTP method is applied to reconstruct those patterns. Neeti Bhargava, V.K.Katiyar, M.L.Sharma and P.Radhan [2], used an analytical approach to predict the earthquake based on the study on anonymous behavior of animals before the earthquake occurs. G.Molchan and L.Romashkova [3], characterized the prediction of earthquake using a two-dimensional error diagram approach in the field of data mining using M8 algorithm. Sajjad Mohsin, and Faisal Azam [4], compared different seismic algorithmic approaches for earthquake prediction to predict true occurrence of earthquake.

Chieh-Hung Chen, Chung-Ho Wang, Jann-Yenq Liu, Chen Liu, Wen-Tzong Liang, Horng-Yuan Yen, Yih-Hsiung Yeh, Yee-Ping Chia, and Yetmen Wang [5], identified the earthquake signals which can cause earthquake using an image processing technique called HHT transform (Hilbert-Huang Transform). Claudio Satriano, Yih-Min Wu, Aldo Zollo, Hiroo Kanamori and W.H.K. Lee and J.M Espinosa-Aranda [11], worked on the concept called EEW (Early Earthquake Warning system) based on the waves analysis, they suggested that prediction of earthquake is much stronger when ground motion is analyzed based on study of Waves (p-waves and s-waves). Lynn R. Sykes, Bruce E. Shawet [18], introduced different time scales in earthquake prediction. Robert J.Geller [19], discussed the probability of correct prediction rate of earthquakes. Stefan Wiemer [20], done his research on worldwide earthquakes and collected statistical data and tried to predict the upcoming quake with his calculated statistics. Hiroo

Kanamori [21], worked on real time quakes occurred and tried to forecast in same area based on previous disaster. Toshi Asada [22], discussed the types of quakes occurred in Japan and tried to predict the quakes using precursors technique. C. G. Sammis and D. Sornette [23] came forward with the new concept of Positive feedback and memory for predicting the earthquakes.

Till date, many of the researchers applied different techniques like prediction based on radon emissions [9-10], EEW algorithm, M8 algorithm [3], prediction using extraction of instantaneous frequency from underground water [5], Earthquake early warning [6] [12], but neither of them could provide an effective and efficient result. In this paper a contemporary approach is introduced to detect the earthquake using Data mining and Image processing techniques.

3. Experimentation Methodology

The research methodology adopted for the detection of earthquakes using Haar [14-16] and SYM [24-27] wavelet transforms are shown in Fig.1 and Fig.2 respectively. Initially, the seismic signals are taken as input for the experimentation, as these are the only signals that are feasible for a proper detection of earthquake occurrence. In general, no particular data is that accurate as it consists of some sort of discrepancies in them, correspondingly these signals may also include jangles within them. Since noise corrupts the signals in a significant manner, therefore it must be removed from the data in order to proceed with further data analysis. The process of noise removal is generally referred to as signal processing or simply de-noising [13-17] [24-27].
Figure 1.

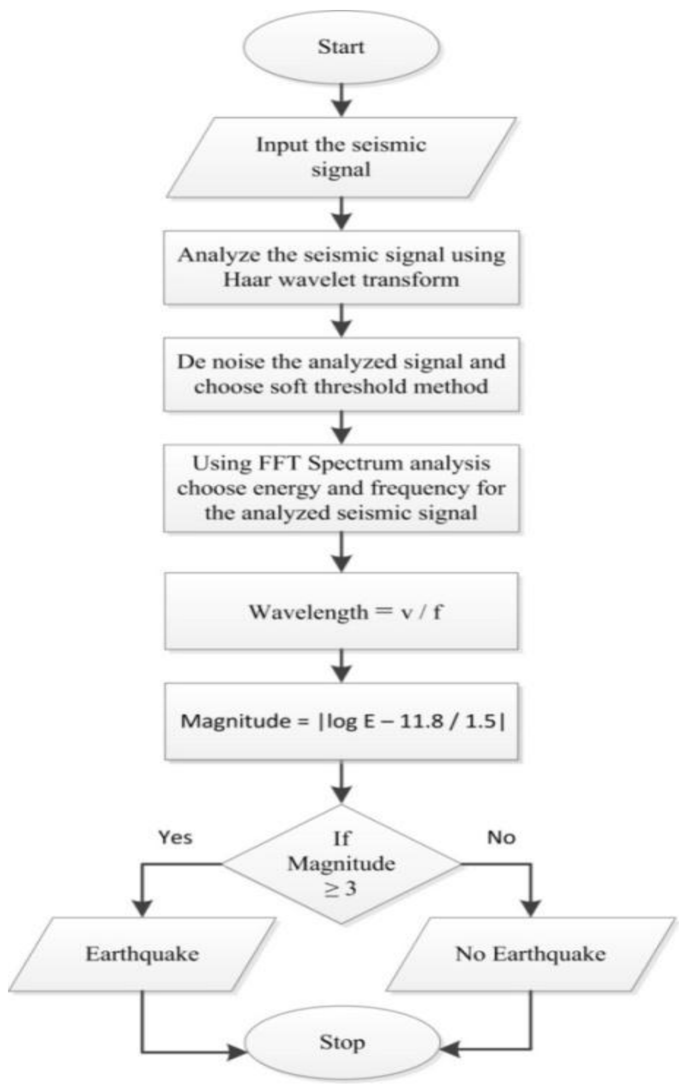

Figure 1. Experimentation methodology using Haar

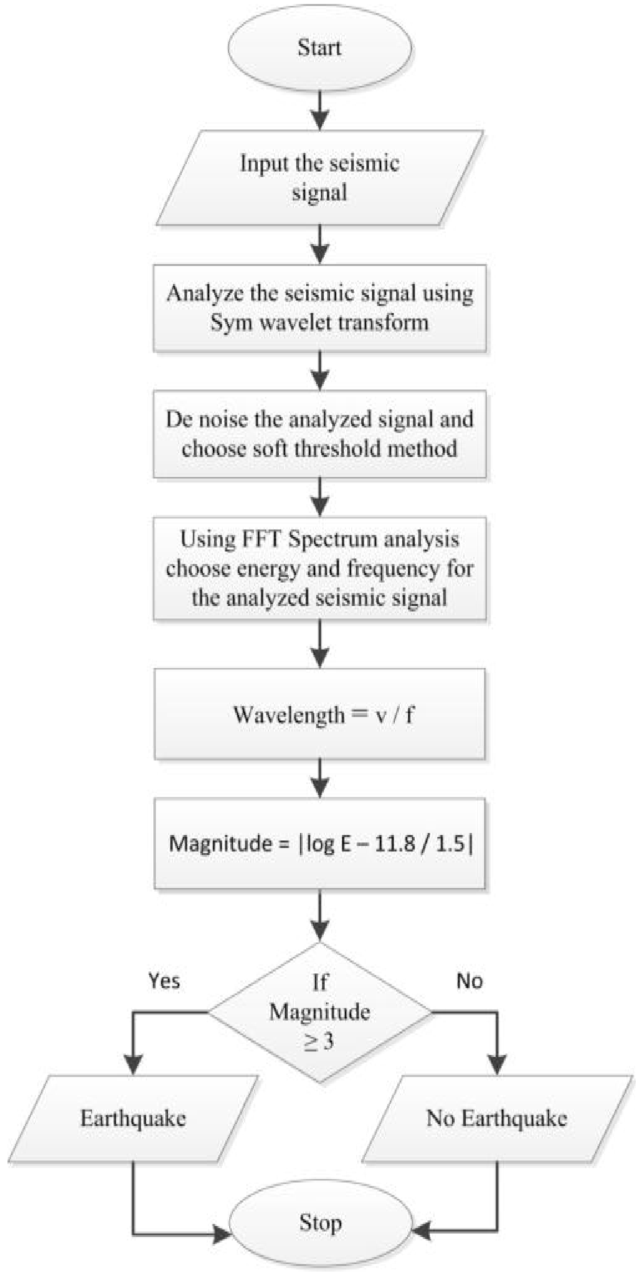

Figure 2. Experimentation methodology using SYM wavelet

For this purpose wavelet transformations, are adopted to de-noise the signal. The wavelet transform [13] acts as a tool for signal and image processing that have been successfully used in many scientific applications such as image and signal processing, image compression, computer graphics, and pattern recognition method. In the present research, Haar wavelet [14-16] and SYM wavelet [24-27] are used for the de-noising of signal and compared with each other for the better prediction.

FFT spectrum analysis [17] is adopted in order to analyze the signal parameters such as energy and frequency. Once these parameters are analyzed, other parameters such as wavelength, magnitude are computed by using equations (1) and (2) respectively, illustrated in this section. Seismic waveform in wave signal format (.wav extension) is considered as input parameter to the research, and is analyzed in the FFT spectrum in Haar wavelet transform and SYM wavelet transform and the input seismic signals are shown in Fig. 3 and Fig. 4 respectively.

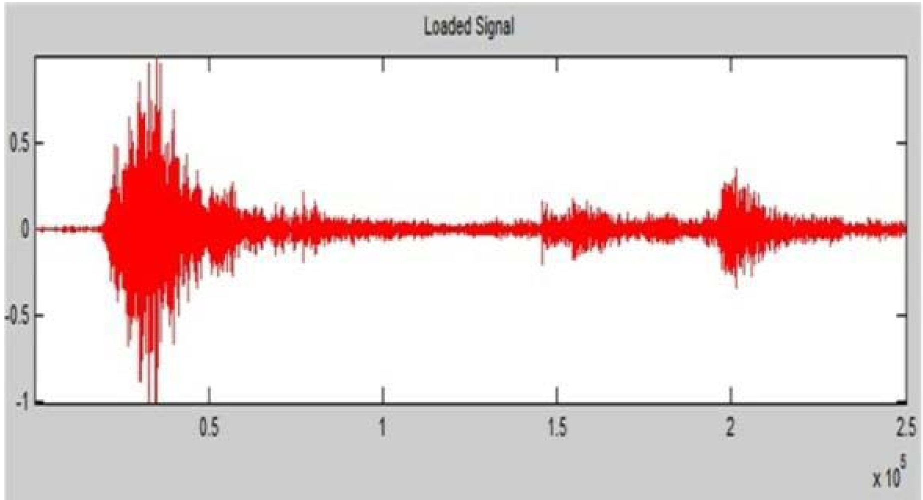

Figure 3. Input Seismic signal for Haar wavelet

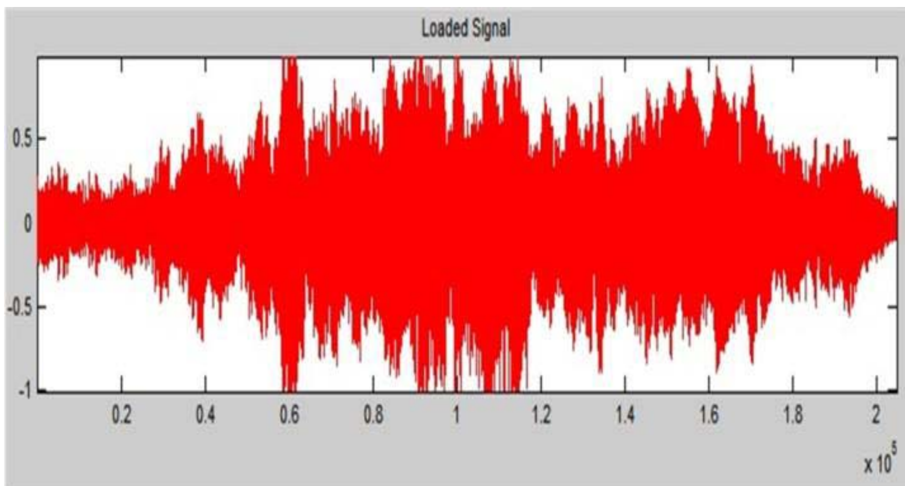

Figure 4. Input Seismic signal for SYM wavelet

The input signals are read into Haar wavelet and SYM wavelet transforms and are analyzed using FFT Spectrum with level 6 and the decomposition in the signals are observed with 6 different variations, shown in Fig. 5 and Fig. 6 respectively.

In order to extort the parametric value, the decomposed signal is compressed and its residual is analyzed, On analysis certain view access such as histogram, autocorrelations, FFT spectrum are obtained. Among them FFT spectrum can provide the parametric values of energy and frequency readily therefore its view axes is selected for the seismic signals and are shown in Fig.7 and Fig.8 respectively.

Fig. 7 and Fig. 8 describes the relation between the energy and frequency distribution from which the highest peak energy and peak frequency is extracted with their related values. As the basic parametric values are obtained, using these values, other parameters such as wavelength, magnitude and rupture are computed by using equations (1), (2) and (3) respectively.

A. Wavelength Vs Velocity Vs Frequency

$$\lambda = v/f \qquad (1)$$

Where λ is wavelength in meters, v is the velocity of wave and f is the frequency of wave in Hz. .

B. Magnitude Vs Energy [7][8]

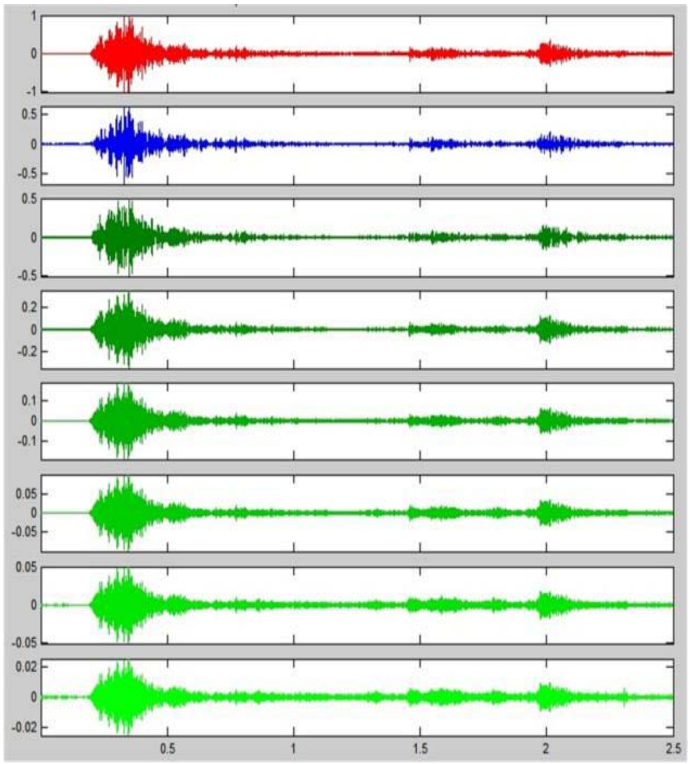

Figure 5. Denoising using Haar wavelet transform

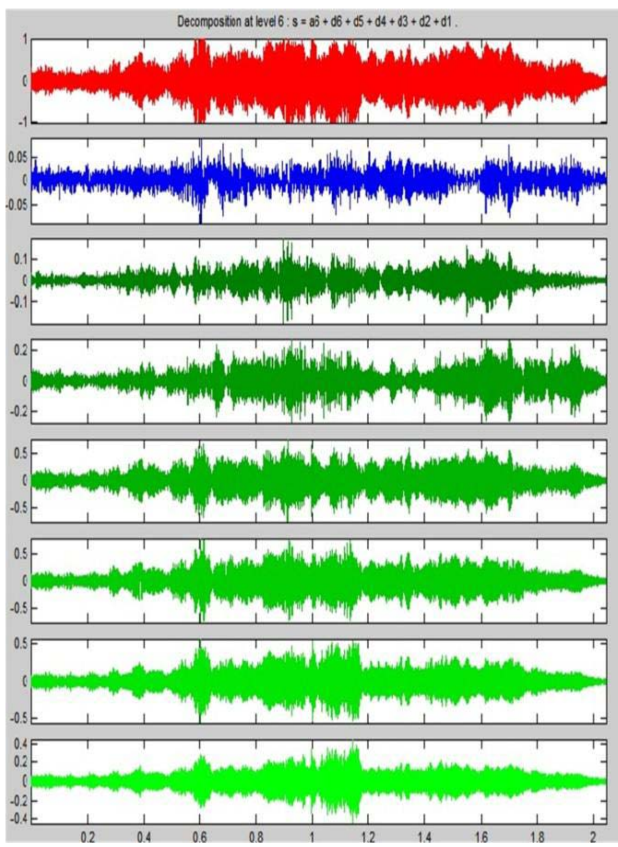

Figure 6. Denoising using SYM wavelet transform

(2) $log_{10}E = |1.5M_s + 11.8 |$

Where E is the energy in ergs and M_s is the surface wave magnitude

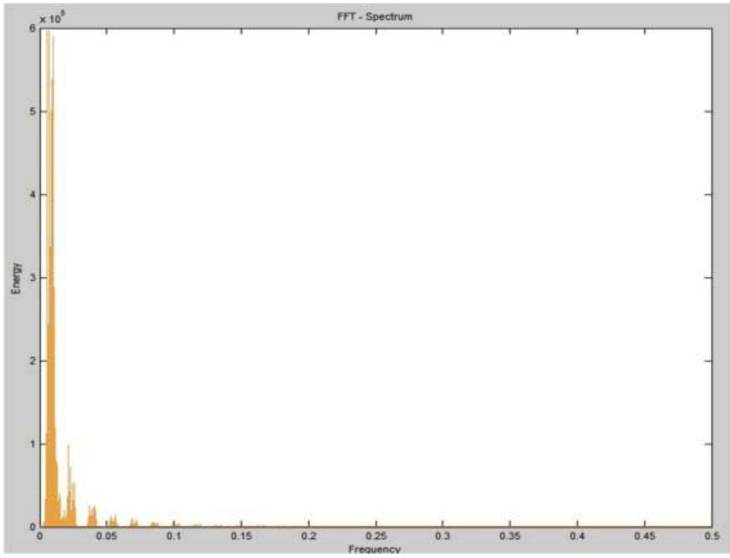

Figure 7. Haar FFT spectrum analysis

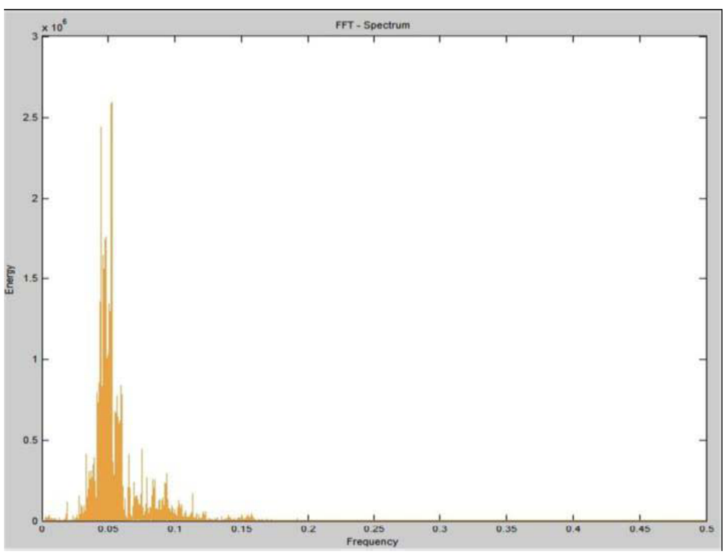

Figure 8. SYM FFT spectrum analysis

C. Magnitude Vs Rupurture Area [8]
(3) $log_{10}A = |1.02M_s + 4.01 |$

Where A is the Rupture area and M_s is the surface wave magnitude.

4. Experimentation Results

Earthquakes are considered as the natural calamities; therefore it is to be predicted at the initial stages so that the losses both to property and life can be controlled to a greater extent. But in spite of several researches skirmish effort most of their attempt failed to provide an accurate model. There forth in this experimentation, seismic signals are considered to be one of the efficient sources for the prediction of earthquake. The seismic signals are obtained from USGS (United States Geological

Survey), SSA (Seismological Society of America), SCEDC (Sothern California Earthquake Data Center), and JMA (Japan Metrological Agency). These signals are analyzed and seismic parameters are extracted. Theoretical observations on earthquake yielded that the magnitude is the deciding factor for the detection of earthquake. Experimental results concluded that the extracted parameter i.e. surface wave magnitude is the substantial attribute to detect the earthquake. Based on the experimental analysis over 140 seismic signals the minimum surface wave magnitude for the detection of earthquake is chosen as 3. The seismic signals are further initiated and processed through MATLAB R2011a in order to evaluate the parameters required for prediction and the parameters are shown in Table III using Haar wavelet transform and in Table IV using SYM wavelet transform. From Table III, consider signal 1, its calculated magnitude is 2.85, which does not fall within the estimated range. Hence it is considered as non earthquake. Similarly consider signal 10, it's computed magnitude is 3.08, that falls within the estimated range. Hence, it is considered as earthquake. From Table IV, consider the signal 12 where in the magnitude is about 3.13 in contrast to the same consider signal 13 whose magnitude is 2.83 and is said to be a non earthquake signal.

On further computation, the values generated are taken up as datasets which are categorized as training set and testing sets. These training and testing sets are processed through WEKA 3.6 and various classification algorithms such as J48, Random Forest, REP tree, LMT, Naive Bayesian, Back Propagation model of neural networks are applied on both Haar wavelet transform results and SYM wavelet transform results in order to analyse the prediction accuracy, precision and recall performance measures and the results are shown in Tables V and VI respectively. The results clearly shows that the performance measures such as accuracy, precision and recall using Haar wavelet transform provides are more when compared with SYM wavelet transform.

Figures 9 and 10 shows the accuracy graph for various classification algorithms using Haar and SYM wavelet transforms. It is clearly visible that Figure 9 is performing outstanding results when compared with figure 10. Figures 11 and 12 shows the precision performance graph for various classification algorithms using Haar and SYM wavelet transforms and finally figures 13 and 14 shows the recall performance measure for various classification algorithms using Haar and SYM wavelet transforms.

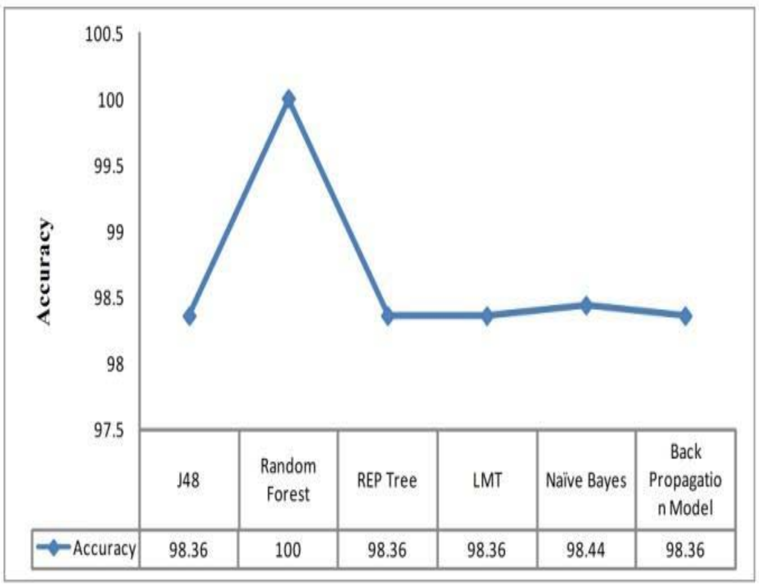

Figure 9. Comparison graph for accuracy using Haar

5. Conclsion

As earthquake is among the most damaging events caused by the earth itself, in order to reduce the risk it is necessary to predict where and when a future large earthquake may occur. As urbanization advances rapidly worldwide, earthquakes causes a serious threat to lives and properties. The mitigation of the seismic risk is a complex task, which requires the cooperation of scientists, engineers and decision makers, and that has to be approached at different time scales.

Predicting the earthquake before it strikes is helpful to reduce its negative impact on human life. Prediction is done previously based on animal behavior, radon emissions, pattern recognition methodologies, but they couldn't predict the perfect occurrence of the earthquake and produced false alarms. So, in this research, seismic signal parameters such as energy, frequency, wave

S No.	Energy	Frequency	Wavelength	Magnitude	Experimental Result
1	1080.00	1000.00	4.80	2.85	Non Earthquake
2	1150.00	2.00	2400.00	2.88	Non Earthquake
3	1170.00	1.50	3200.00	2.89	Non Earthquake
4	1220.00	2.00	2400.00	2.91	Non Earthquake
5	1386.00	24.15	13.66	2.96	Non Earthquake
6	1400.00	1.50	220.00	2.97	Non Earthquake
7	1500.00	900.00	5.33	3.00	Earthquake
8	1500.10	872.00	5.50	3.00	Earthquake
9	1550.00	8.00	41.25	3.01	Earthquake
10	1796.00	660.00	7.27	3.08	Earthquake
11	1895.00	1.80	2666.67	3.10	Earthquake
12	2035.00	700.00	6.86	3.13	Earthquake
13	2072.00	16.70	19.76	3.14	Earthquake
14	2123.50	1.45	227.59	3.15	Earthquake
15	2240.00	1000.00	4.80	3.17	Earthquake
16	2260.00	1.60	3000.00	3.18	Earthquake
17	2270.00	1.60	3000.00	3.18	Earthquake
18	2350.00	2.00	2400.00	3.19	Earthquake
19	2350.00	2.00	2400.00	3.19	Earthquake
20	2360.00	1.60	3000.00	3.19	Earthquake
21	2595.00	5.26	912.55	3.24	Earthquake
22	2760.00	1000.00	4.80	3.26	Earthquake
23	2943.60	1.81	2651.93	3.29	Earthquake
24	3040.00	1.10	4363.64	3.31	Earthquake
25	3100.00	1.50	3200.00	3.31	Earthquake
26	3378.00	1.68	2857.14	3.35	Earthquake
27	3400.00	2.00	2400.00	3.35	Earthquake
28	3514.00	1.82	2637.36	3.37	Earthquake
29	3594.00	10.49	31.46	3.38	Earthquake
30	3628.00	1.82	2637.36	3.38	Earthquake
31	3929.70	934.00	5.14	3.42	Earthquake
32	3950.00	1.50	3200.00	3.42	Earthquake
33	4054.00	850.00	5.65	3.43	Earthquake
34	4060.00	1000.00	4.80	3.43	Earthquake
35	4150.00	6.00	55.00	3.44	Earthquake
36	4200.00	6.00	55.00	3.45	Earthquake
37	4240.00	1.09	4403.67	3.45	Earthquake
38	4400.00	1.00	330.00	3.47	Earthquake
39	4423.20	22.86	14.44	3.47	Earthquake
40	4480.00	1.50	220.00	3.47	Earthquake

Table 3. Detection Using Haar Fft Spectrum

S No.	Energy	Frequency	Wavelength	Magnitude	Experimental result
1	2353.50	49.42	6.68	3.19	Earthquake
2	5600.00	3.00	110.00	3.57	Earthquake
3	3520.00	10.50	31.43	3.37	Earthquake
4	1550.00	8.00	41.25	3.01	Earthquake
5	4050.00	1.00	330.00	3.43	Earthquake
6	2075.00	16.60	19.88	3.14	Earthquake
7	2031.00	33.00	10.00	3.13	Earthquake
8	4250.00	6.00	55.00	3.45	Earthquake
9	4200.00	1.00	330.00	3.45	Earthquake
10	4200.00	6.00	55.00	3.45	Earthquake
11	4190.00	1000.00	0.33	3.44	Earthquake
12	2040.00	1.50	220.00	3.13	Earthquake
13	1030.00	900.00	0.37	2.83	Non Earthquake
14	1580.00	900.00	0.37	3.02	Earthquake
15	3370.00	49.00	6.73	3.35	Earthquake
16	4440.00	22.90	14.41	3.47	Earthquake
17	2560.00	2.50	1920.00	3.23	Earthquake
18	2375.00	1.80	2666.67	3.20	Earthquake
19	9030.00	1000.00	4.80	3.78	Earthquake
20	2150.00	1000.00	4.80	3.15	Earthquake
21	1708.00	950.00	5.05	3.05	Earthquake
22	1860.00	2.00	2400.00	3.09	Earthquake
23	2630.00	5.50	872.73	3.24	Earthquake
24	2263.00	1.59	3018.87	3.18	Earthquake
25	1512.00	910.00	5.27	3.00	Earthquake
26	8072.50	990.00	4.85	3.73	Earthquake
27	2263.50	1.50	3200.00	3.18	Earthquake
28	3769.00	1.81	2651.93	3.40	Earthquake
29	4120.00	1.80	2666.67	3.44	Earthquake
30	3612.00	1.81	2651.93	3.38	Earthquake
31	1300.00	2.00	2400.00	2.93	Non Earthquake
32	3065.00	1.15	4173.91	3.31	Earthquake
33	7356.00	1.40	3428.57	3.69	Earthquake
34	3960.00	1.10	4363.64	3.42	Earthquake
35	7900.00	3.40	1411.76	3.72	Non Earthquake
36	1353.00	900.00	5.33	2.95	Non Earthquake
37	3396.00	1.68	2857.14	3.35	Earthquake
38	8400.00	2.50	1920.00	3.75	Earthquake
39	9600.00	1.00	4800.00	3.81	Earthquake
40	8400.00	1.00	4800.00	3.75	Earthquake

Table 4. Detection Using Sym Fft Spectrum

Algorithm	Recall	Precision	Accuracy
J48	98.4	98.6	98.36
Random Forest	100	100	100
REP Tree	98.4	98.6	98.36
LMT	98.4	98.6	98.36
Naïve Bayes	93.4	96.4	98.44
Back propagation	98.4	98.6	98.36

Table 5. Performance Measures Using Haar

Algorithm	Recall	Precision	Accuracy
J48	88.88	79.10	88.90
Random Forest	83.33	78.50	83.30
REP tree	88.88	79.10	88.90
LMT	83.33	75.70	83.30
Naïve Bayes	72.22	77.00	72.20
Back Propagation	77.77	83.40	77.80

Table 6. Performance Measures Using SYM

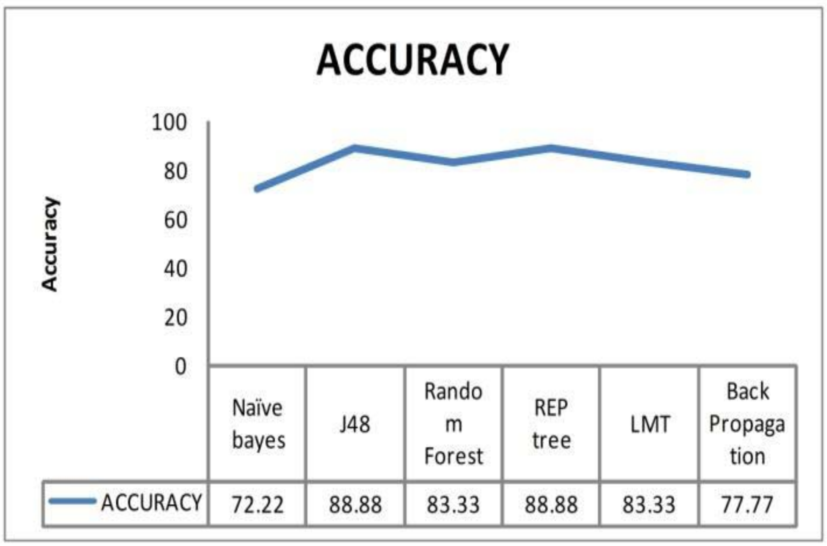

Figure 10. Comparison graph for accuracy using SYM

length and surface wave magnitude are extracted using FFT Spectrum analysis in Haar wavelet and SYM wavelet transforms. Further, these parametric values are considered as datasets which are analyzed using WEKA tool on which different algorithm are implemented. The results clearly shows that the performance measures such as accuracy, precision and recall using Haar wavelet transform provides are more when compared with SYM wavelet transform.

References

[1] Shebalin, P., Keilis-Borok, V., Gabrielov, A., Zaliapin, I., Turcotte, D. (2006). Short-term earthquake prediction by reverse analysis of lithosphere dynamics, *ELSEVIER Tectonophysics*, 63 – 75

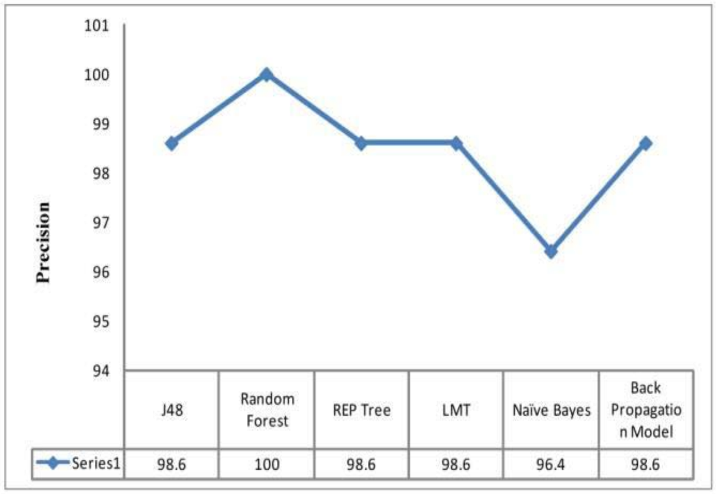

Figure 11. Comparison graph for Precision using Haar

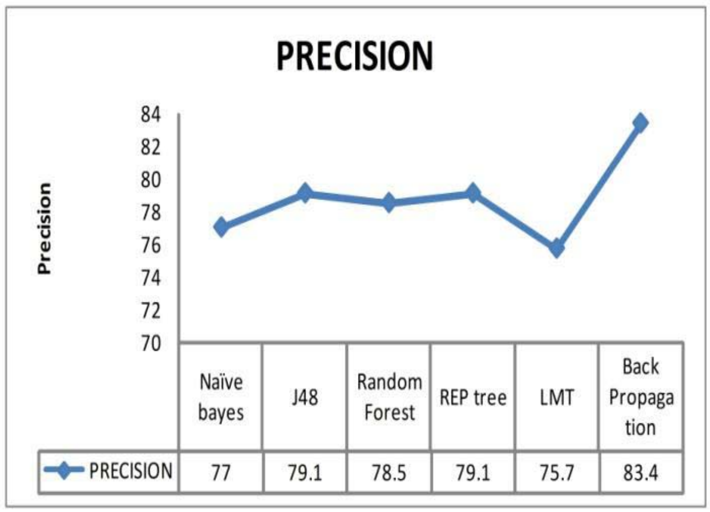

Figure 12. Comparison graph for Precision using SYM

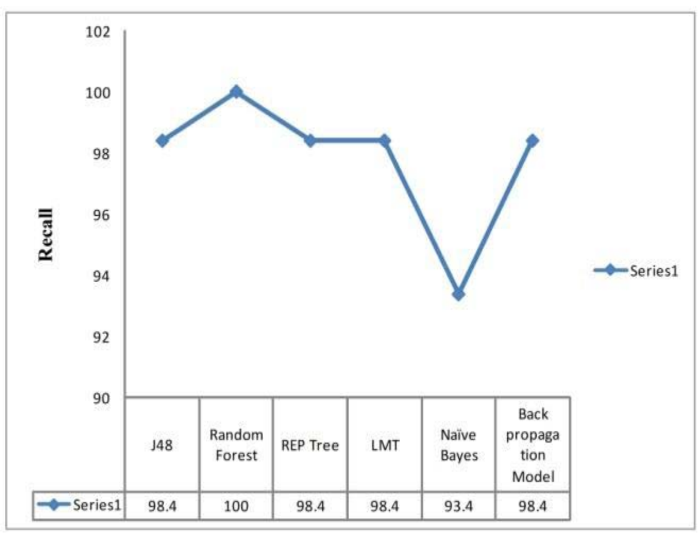

Figure 13. Comparison graph for Recall using Haar

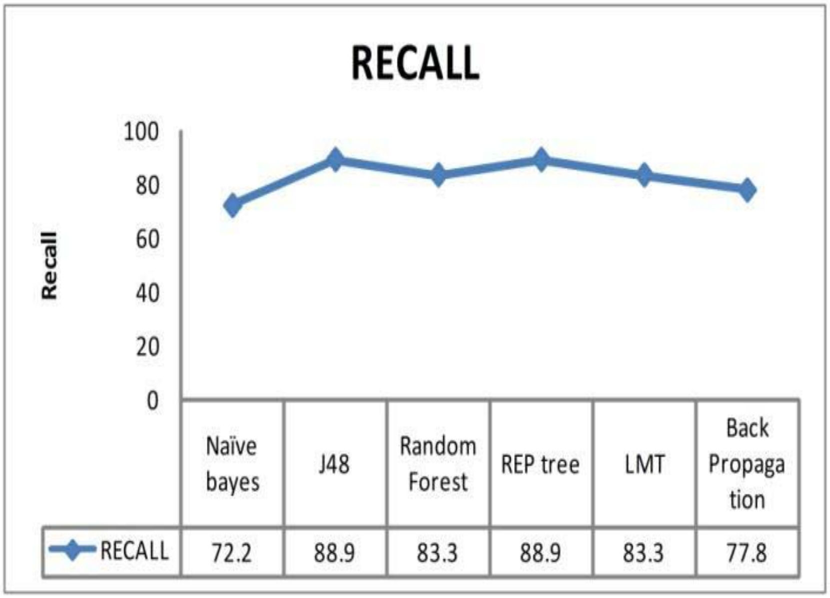

Figure 14. Comparison graph for Recall using SYM

[2] Neeti Bhargava., Katiyar, V. K., Sharma, M. L., Pradhan, P. (2009). Earthquake Prediction through Animal Behaviour: A Review," *Indian Journal of Biomechanics*: Special Issue NCBM, 159-165.

[3] Molchan, G., Romashkova, L. (2010). Earthquake prediction analysis: The M8 algorithm, *physics.geo-physics*, 1-20

[4] Sajjad Mohsin., Faisal Azam. (2011). Computational seismic algorithmic comparison for earthquake prediction, *International Journal Of Geology,* 3 (5), 53-59.

[5] Chieh-Hung Chen., Horng-Yuan Yen., Chung-Ho Wang., Yih-Hsiung Yeh., Jann-Yenq Liu., Yee-Ping Chia., Chen Liu., Yetmen Wang., Wen-Tzong Liang. (2010). Identification of earthquake signals from groundwater level records using the HHT method, *Geophysical Journal International*, 1231–1241.

[6] Claudio Satriano., Yih-Min Wu., Aldo Zollo., Hiroo Kanamori. (2010). Earthquake early warning: Concepts, methods and physical grounds, *ELSEVEIR Soil Dynamics Earthquake Engineering*, 1-13.

[7] Hiroo Kanamori. (1983). Magnitude Scale and Quantification of Earthquakes, *Elseveir Scientific Publishing Company, Amsterdam. Tectonophysics*, 185-199.

[8] John Stockwell. (2001). Some empirical relations in earthquake seismology, *Center for Wave Phenomena Colorado School of Mines*, 1-6

[9] Giuseppina Immè., Daniela Morelli. (2012). Radon as Earthquake Precursor, *Dipartimento di Fisica e Astronomia Università di Catania - INFN Sezione di Catania*, Italy, 143-160.

[10] Arvind Kumar., Vivek Walia., Surinder Singh., Bikramjit Singh Bajwa., Sandeep Mahajan., Sunil Dhar., Tsanyao Frank Yang. (2012). Earthquake precursory studies at Amritsar Punjab, India using radon measurement techniques, *International Journal of Physical Sciences*, 9 November, 5669-5677.

[11] Lee, W. H. K., Espinosa-Aranda, J. M. (2010). Earthquake Early-Warning Systems: Current Status And Perspectives, *United States Geological Survey (USGS)*, 2010, 409-423.

[12] Kuo-Liang Wen., Tzay-Chyn Shin., Yih-Min Wu., Nai-Chi Hsiao., Bing-Ru Wu. (2009). Earthquake Early Warning Technology Progress in Taiwan, *Journal of Disaster Research*, 4 (4), 202-210.

[13] Giaouris, D., Finch, J. W. (2008). Denoising using wavelets on electric drive applications, *ELSEVEIR*, Electric Power Systems Research, 559–565.

[14] Radomir, S., Stankovic., Bogdan, J., Falkowski. (2003). The Haar wavelet transform: its status and achievements, *ELSEVEIR*,

Computers and Electrical Engineering, 25–44.

[15] Burhan Ergen. (2012). Signal and Image Denoising Using Wavelet Transform, Advances in Wavelet Theory and Their Applications in Engineering, *Physics and Technology*, 495-514.

[16] Piotr Porwik., Agnieszka Lisowska. (2004). The Haar–Wavelet Transform in Digital Image Processing:Its Status and Achievements, *Machine Graphics and Vision,* 79-98.

[17] Dr. Micheal Sek. Frequency Analysis Fast Fourier Transform, Frequency Spectrum, Victoria University, 1-12.

[18] Lynn, R. Sykes., Bruce, E., Shaw., Christopher, H., Scholz. (1999). Rethinking Earthquake Prediction, *Pure applied geophysics*, 207–232.

[19] Robert J**.** Geller. (1997). Earthquake prediction: a critical review, *Geophysical Journal International***,** 1997, 425-450.

[20] Stefan Wiemer. (2003). Earthquake Statistics and Earthquake Prediction Research, *Institute of Geophysics*, ETH Hönggerberg, *Zürich, Switzerland*, 1-11.

[21] Hiroo Kanamori. (2003). Earthquake Prediction: An Overview, *International Handbook of Earthquake and Engineering Seismology*, 205-1216.

[22] Toshi Asda. (1988). Earthquake Prediction Study in Japan, *In*: *Proceedings of Ninth World Conference on Earthquake Engineering*, 13-19.

[23] Sammis, C. G., Sornette, D. (2002). Positive feedback, memory and the predictability of earthquakes, 2501–2508.

[24] Jashanbir Singh Kaleka., Reecha Sharma. (2012). Comparitive performance Analysis of Haar , Symlets and Bior wavelets on Image compression using Discrete Wavelet Transform, *International Journal of Computers & Distributed Systems,* 11-16.

[25] Yahya, I., Adedeji, A. A. (2011). Crack detection in Wall Prism adapted to by Wavelet(Symlet) packet, *3rd Annual Conference of Civil Engineering,* 33-41.

[26] Mahesh Chavan, S., Nikos Mastorakis., Manjusha Chavan, Implementation of SYMLET Wavelets to Removal of Gaussian Additive Noise from Speech Signal, *Recent Researches in Communications*, *Automation, Signal Processing, Nanotechnology, Astronomy and Nuclear Physics*, 37-41.

[27] Jaspreet Kaur., Rajneet Kaur. (2013). Biomedical Images denoising using Symlet Wavelet with Wiener filter”, *International Journal of Engineering Research and Applications*, 548-550.