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ANALYSIS OF SEISMIC SIGNAL AND DETECTION OF ABNORMALITIES

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ABSTRACT

Seismic signals are ground vibrations used to detect seismic events. However, seismic signal captured from sensors is distorted signal contains noise and makes actual event detection difficult. In most cases, external noise such as manmade or any heavy vehicle vibration always overlaps with the seismic reflections over time. The presence of noise in the seismic signal makes it difficult to determine the magnitude at which the seismic events have occurred. The aim of our study is to process the signals received from seismic sensor and identify it as seismic events signal and non-seismic events signal based on the magnitude. The authors propose a robust noise suppression method using bandpass filter, IIR Wiener filter and event detection using recursive Short-Term Average (STA)/Long Term Average (LTA) and Carl Short Term Average (STA)/Long Term Average (LTA). The proposed study determines reference magnitude to distinguish seismic and non-seismic activity. The projected study is based on the analysis of seismic signal received from single sensor and sensor networks (SN) and determines the magnitude to distinguish seismic and non-seismic events and time of an actual earthquake event. The experimental dataset is a broadband seismic signal from BSVK and CUKG station sensors located at Basavakalyan, Karnataka, and the Central University of Karnataka respectively. The proposed approach helps to extract the information about pre-seismic event, actual seismic event, post-seismic event activities and identify the abnormal pattern that supports to detect heearth's activities before the actual seismic event.

KEYWORDS

Seismic signal, non-seismic signal, Carl STA/LTA, Abnormal pattern.

1. INTRODUCTION

The seismic station captured the signal continuously at a high sampling frequency. Such a huge amount of data is challenging to store. This issue motivates the creation of seismic data acquisition.Thatwillprocessalltheseismicsignalswithoutcontinuousstorage. A trigger algorithm aids in the detection of abnormal activities in the ever-present seismic noise signal. When a seismic event is recorded, incoming signals are stored and stop when the signal reaches the background noise level [1]. Seismic noise is significant for microzonation studies and surface-wave to mography[1,2].The detection of earthquakes above background noise is required for the study of earthquakes or the imaging of the Earth with seismic wave arrivals. Depending on the location, season, time of day, and weather conditions, the levels of natural ambient noise in seismic records can vary by 60 dB (a factor of 1000 in amplitude). This is equivalent to variations in seismic arrival detection thresholds of around three magnitude units. Therefore, it is crucial to first investigate the noise levels at prospective recording locations. [1].A seismic network is made up of numerous stations (receivers) spread out over a large area, each of which has a seismometer that continuously records ground motion. An energy detector such a short-term average (STA) or long-term average(LTA) is typically used to detect an earthquake at one station at a time. As these windows move through the continuous data, STA/LTA calculates the ratio of the STA energy in a small time window to the LTA energy in a larger time window. When the STA/LTA ratio surpasses specific criteria, detection is reported [3,4]. The next step is to analyse whether detections at various stations around the network are consistent with a seismic source using an association algorithm. Let's say that a seismic event is picked up by at least four stations. In that instance, it is listed in an earthquake catalogue, a database that lists the place, date, and magnitude of all previously recorded earthquakes. Earthquakes are successfully identified using STA/LTA.

The outline of this paper is as follows: in Section 2, summarize the prior art and related work by the researchers Section 3,shows the detailing of the real time dataset for the experimental testing. The proposed work and methodology are discussed in section 4. The experimental testing and the results section 5, focuses on the magnitude and time detection of the seismic event. Distribution patterns to distinguish seismic event and abnormality. Finally, a conclusions are drawn in Section 6.

2. LITERATURE SURVEY

To effectively and efficiently reduce seismic random sounds, Fangyu Li et al. (2021) [5] offer a unique seismic signal processing method. The author focuses on how the design of traditional filtering operators "regularises" the denoised outcomes. The efficiency of denoising is increased by the resampling process. Random noise has been decreased using the suggested method, resulting in an improved recovery of the intrinsic seismic signal components. Excellent achievements are shown by qualitative and quantitative demonstrations using synthetic and field data. A residual neural network for detection is proposed by Abdullah Othman et al. in 2021 [6]. In comparison to previous denoising approaches, this method along with the IIR Wiener filter-based denoising method produces better results.

A stochastic signal analysis method is used in Jae Sang-Moon and Mintaek Yoo's (2020) [7] study to make use of the smartphone sensors for the quick EEW system. The virtual earthquake detection data in the train by smartphone sensor has been built from the train vibration data from the poor fidelity on-board accelerometer. The produced data's stochastic features have been examined using the short-time Fourier transform (STFT) method. stochastic methods that effectively analyse low fidelity sensor data, like that from a smartphone, for the quick EEW. A denoising technique based on IIR Wiener filters was proposed by Iqbal et al. in 2018 [8]. The second-order statistics of the noise and the observations, which are easily derived from the time-series data that have been recorded, serve as the direct foundation for the suggested method. When there is low SNR, the proposed approach performs admirably. This is advantageous for the applicability of the denoising method to field data gathered in a variety of seismic noise situations because the filter does not presume any specific noise statistics.

B.K.Sharma et al.,(2010)[9]give an overview of the different detection algorithms used for seismicsignal detection. Event detection algorithms have already been created by numerous researchers for seismic data from earthquakes and explosions. The method based on the Short Term Average to Long-term Average (STA/LTA) principle is suggested to be more effective in detecting earthquakes and strong motions. It also puts light on the performance of the standard STA/LTA algorithm and the recursive STA/LTA-based earthquake detector algorithm, which is more commonly known and frequently used.

According to Withers et al. (1998) [4,] the best output for a global correlation-based event-detection and location system was found to be produced by a STA/LTA algorithm that incorporates adaptive window lengths controlled by non stationary seismogram spectral characteristics, even though no algorithm was clearly optimal under all source, receiver, path, and noise conditions tested.

Polkowski et al. and the Passeq Working Group (2016) [10] classified and located the events using standard STA/LTA triggers (Carl Johnson's STA/LTA algorithm) and grid search. The outcome was manually verified. Real-Time Recurrent Network (RTRN) detection was used in the second approach (Wiszniowski et al. 2014) [11]. Both methods produced similar results, revealing four previously unknown seismic events in the Gulf of Gdansk area of the southern Baltic Sea. Both detection methods are discussed in this paper, along with their advantages and disadvantages.

A summary of the literature survey indicates that most of the author uses the STA/LTA algorithm for seismic detection, but the analysis of seismic signal before the actual seismic event is missing which is very much important to give early warning about the actual seismic event, that motivates us to focus on the characterization ofpre, actual, post-seismic signal with the non-seismic signal. This analysis also distinguishes the abnormal event which is not an actual seismic event.

3. Dataset Description

The data is collected from the School of Earth sciences of Swami Ramanand Teerth Marathwada University, Nanded, Maharashtra, India. The data is collected from stations such as Basavakalyan (BVSK) the Central University of Karnataka, and Gulbarga (CUKG) located at different places.
The experimental dataset is a broadband seismic signal from BSVK and CUKG station sensors located at Basavakalyan, Karnataka, and the Central University of Karnataka respectively. It is a broadband seismological sensor (Trillium 120QA) with sensitivity 2000V/m/s and data collected at 100samples/s.Its natural period is 120seconds. The signal used in this paper is of total 5-hour duration and analysed for every one-hour duration segments sampled at 100Hz. Seismic signal is recorded on 12-10-2021 from 0:00:00-4:59:59 hours, and non-seismic or noise signal is recorded on 9-7-2021 from 0:00:00-4:59:59 hours. The analysis is performed on each station's individual recorded signal and then combined to extract additional information for the detection of abnormality and actual seismic event. The seismic institute records two events, one at 2:36AM with a magnitude of 3.6 and one at 2:47AM with a magnitude of 2.8.Table 1 gives the detail of the earthquake event.Thecaptured non-seismic signal from the respective stations is showninfigure1.

Table 1. Seismic event details

Origin Time	Station	Latitudede	Longitudee	Depth	Magnitude
2021.12. 10 02:36:27 UTC	BSVK &CU KG	17.36	77.3	5KM	3.6
2021.12. 10 02:47:42 UTC		17.33	77.29	10KM	2.8

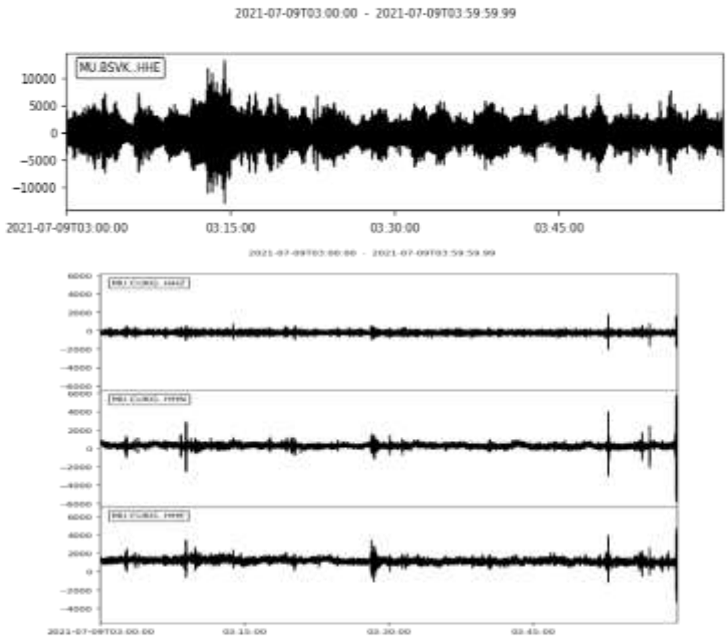


Figure 1. The non-seismicsignal recorded at BSVKand CUKG

4. PROPOSED WORK

Figure 2 shows the flow of detection of seismic event. The recorded signals is pre-processed and filters to reduce the noise . Applied the STA/LTA algorithm on the filtered seismic signal for magnitude detection.

Figure 2. Proposed work flow

The paper proposes the analysis of the seismic signal, its characteristics, and how it is different from the non-seismic signal. Further, the analysis emphasizes on accurately detecting actual earthquake magnitude w.r.t. time. As per [6] to verify the seismic event, the time difference of seismic event in all directions should be low, and the corresponding trigger ratio should be high.

The main aim is to verify the actual event w.r.t magnitude and time. The actual seismic event occurred between 02:00:00- 2:59:59 dated 12-10-2021, so the given seismic signal is divided into 3 cases pre, actual seismic, and post-seismic signals. Sample of pre-seismic at the CUKG station is shown in figure 3.

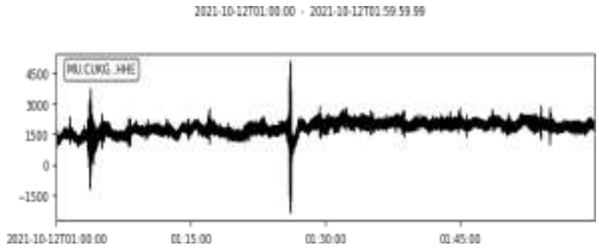
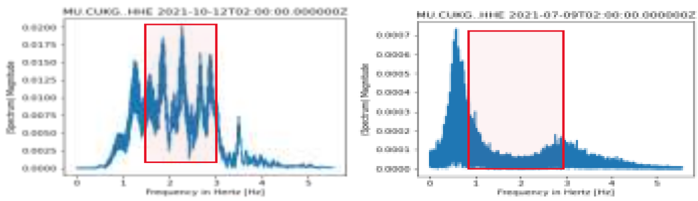


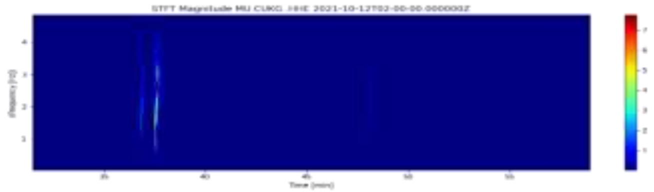
Figure 3. The pre seismicsignal recorded at CUKG

To verify the seismic event, the pre-seismic case is considered (01:00:00AM-01:59:59AM). The signal is detrended linearly and tapered with 5% tapering with the Blackman window. This process will make the signal linear, and the corners are tapered. The pre-processed signal is band passed with the frequency band of 0.001-5Hz, to remove the low noise component. After that, IIR Wiener filter is applied on the band passed filtered signal with a mask size of 73 to reduce the noise level. (Filter mask value must be odd, and after few iterations of different random values such as 5, 25, 53, and 73, 117 the mask size is set to 73) The clean signal will give the idea about the few high peaks i.e., abnormal conditions before the actual earthquake. The frequency domain magnitude spectrum of seismic signal shows the frequency peaks in the lower frequency range and in the higher frequency bands. The seismic event is seen at the lower frequencies and its effect is extended to the higher frequencies [12,13]. This leads us to examine the magnitude spectrum of FFT, and the STFT and Wavelet Spectrograms carefully in the frequency range of 0.001-4 Hz.The figure 4 gives the difference between the FFT, STFT and wavelet spectrum of seismic and non seismic signals.

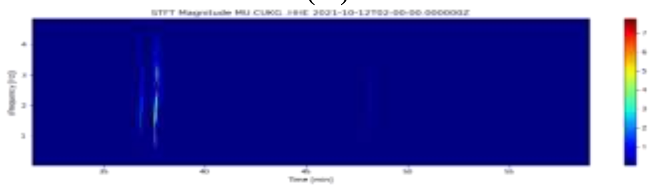


(a) (b)

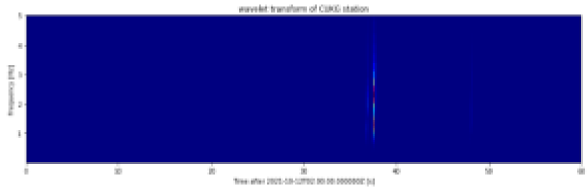
The above figure clearly indicates the difference between seismic event and non-seismic event frequency. The difference is clearly seen between the frequency range from 1-3Hz as highlighted by red box.



(c)



(d)



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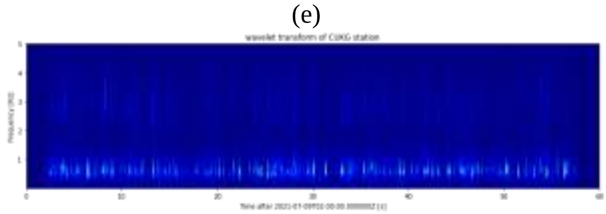


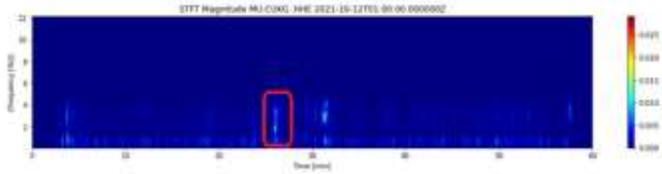
(f)

Figure 4. Magnitude spectrum of seismic and non seismic event (a)(b)FFT(c)(d) STFT(e)(f) Wavelet Spectrum

The magnitude spectrum of non-seismic signal is crowded with noise component. The maximum energy of this spectrum is concentrated at very low frequency. Whereas, the magnitude spectrum of the seismic event signal shows the maximum energy during 2:35:00-2:40:00AM. This energy is spread from 1Hz to 4Hz. Both Wavelet magnitude spectrum and STFT magnitude spectrum indicates the same results.

Frequency domain analysis done using FFT, STFT [7], and wavelet figure 5(a),(b),(c) respectively shows that the high energy levels between 0.001 to 4Hz which proved that the few abnormal activities occurred before the actual seismic event.

(a)



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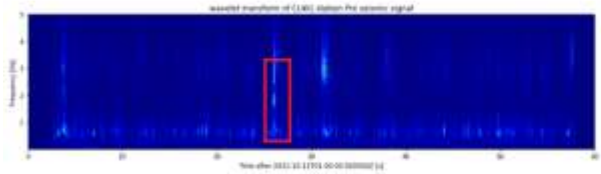


(c)

Figure 5. Frequency domain analysis of pre seismic

4.1. Methodology

Magnitude and time are the important parameters to ensure the abnormal change in the amplitude of event. This paper focuses on three mechanisms w.r.t. magnitude and time parameter help to classify the abnormal activity before the actual earthquake. The STA/LTA algorithm evaluates the ratio of short- to long-term energy density. The filtered data are then scanned using a recursive STA/LTA algorithm to obtain trigger times of potential events [4]. The STA/LTA threshold to declare a trigger depends on the signal-to-noise ratio. The recursive STA/LTA [9] is like the standard STA/LTA except that for each successive time step, a fraction of the average data value, rather than a specific data point value is removed[14].

$$\text{Standard } STAi+1 = STAi + \{x(i) - x(i - NSTA)\}/ NSTA \qquad (1)$$

Where NSTA denotes the number of STA points and i denotes the set of STA point data values. Seismic data is recorded if the STA/LTA is equal to or greater than the pre-set value for the true condition of the event. In the proposed method, the event time is recorded as the time where the trigger ratio value is maximum. Both the Recursive STA/LTA and carl STA trigger algorithm are applied on the signal. The values are recorded before and after applying IIR Wiener filter. Also, the event time is recorded as the time where the amplitude of the STFT magnitude spectrum is maximum. SNR values are recorded after pre-processing, Bandpass filtering and after wiener filtering. This techniques applied on non-seismic and seismic signal.

4.2. Recursive STA/LTA [14]

Developed at the University of Wisconsin, Madison recursive STA/LTA is a method used for triggering tele seismic and was used by L. Powell in a portable data acquisition system. Statistical independence from

$$\frac{STA_{I+1}}{LTA_{I+1}} = \frac{\frac{1}{N_{STA}} * X_I 2 + \left(1 - \frac{1}{N_{STA}}\right) * STA_I}{\frac{1}{N_{LTA}} * X_I 2 + \left(1 - \frac{1}{N_{LTA}}\right) * LTA_I} \quad (2)$$

Where xi is time series amplitude, NSTA*sampling rate, and NLTA*sampling rate. The recursive STA/LTA is smoother than the standard STA/LTA algorithm.

4.3. Carls STA/LTA

The majority of seismic detectors employ a relationship between the short-term average (STA) and the long-term average (LTA). This algorithm computes four moving averages using two parameters: eta, star, ratio, ltar, abs sta, and lta quiet [10].

$$ETA = STAR - (RATIO * LTAR) - ABS(STA - LTA) - QUIET \quad (3)$$

where eta is the detector response – a value over 0 means detection, STAR is the short-term moving average of signal, LTA is thelong-term moving average of signal, the star is the short-term moving average of the absolute value of signal and LTA difference, LTAR is the long-term moving average of star, ratio, and quiet-sensitivity parameters.

4.4. Wiener Filter [8]

Wiener filter on the band passed filtered signal with mask size is 73. It is observed that after few iterations of different values of mask the noise is much reduced at window 73. Figure 6(c) shows the filtered signal which is much clean as compared to the original signal. Let x be the input signal, then the output is

$$= \begin{cases} \frac{\sigma^2}{\sigma_x^2} m_x + \left(1 - \frac{\sigma^2}{\sigma_x^2}\right) x & \sigma_x^2 \geq \sigma^2, \\ & m_x \sigma_x^2 < \sigma^2, \end{cases} \quad (4)$$

Where m_x is local estimate of the mean,σ_x^2 is local estimate of the variance $\sigma^2$is threshold noise parameter, Ifσ is not specified, the average of local variances is used.

4.5. Short Term Fouriertransform [7]

The STFT and wavelet Transform are used to analyses the filtered seismic signal. The STFT is a popular method for detecting changes in the characteristics of time-history data over time. A short-time Fourier transform is a series of Fourier transforms of a windowed signal (STFT). STFT provides time-localized frequency information in situations where a signal's frequency components vary over time.

5. RESULT AND DISCUSSION

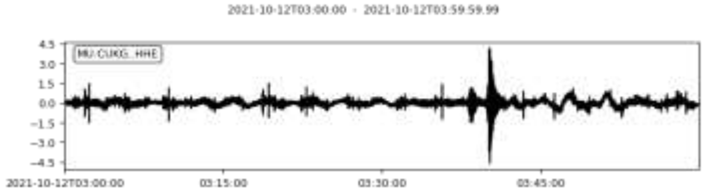
The sensor recorded signal usually consist of seismic activities occurred as well as the noise captured by the sensor. Our method of double filtering i.e., Bandpass filtering followed by Wiener filtering reduces the noise level of this signal as seen in figure 6. This noise reduction can also be observed in the form of Signal-to-Noise ratio (SNR) as shown in table 2. Here, the SNR value of the two different seismic event signals (dated 12-10-2021 and 5-2-2022), pre-seismic signal (dated 12-10-2021) and a non-seismic signal (dated 9-7-2021) is tabulated.

The Signal to noise ratio is computed at two stages; after pre-processing the recorded signal and after the application of the wiener filter. As seen in the table 2, for both the seismic signal, the SNR after wiener filtering is improved. For the seismic signal dated 12-10-2021 the E channel SNR is -96.784dB after pre-processing and it improves to -93.23dB after wiener filtering, whereas for seismic signal dated 5-2-2022, the SNR for the channel E is -104dB and it is seen to be improved after wiener filtering to -74.177dB. On first seismic signal, the improvement of SNR or the reduction of noise level is seen lower as compared to the second seismic signal due to the intensity of the seismic event. This seismic event is much higher than the intensity of noise present during the occurrence of the event. However, for the non-seismic signal, the SNR for channel E is -76.65dB after only pre-processing. After filtering it is improved to-51.672dB. Regarding the filtered pre seismic signal, the SNR results are also improved for the channel E is -48.923dB. The SNR values plays important role to distinguish between the non-seismic and pre seismic signals. This indicates that the wiener filtering approach for the noise reduction is well suited to detect the seismic event at micro levels which may overlapped with the noise.

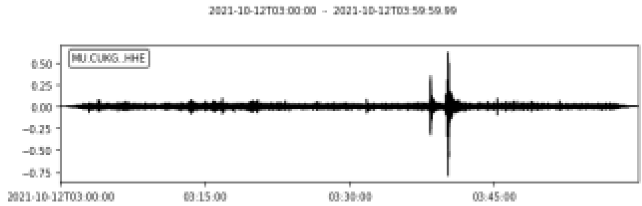
Table 2. Signal to noise ratio of seismic signals

Date of signal	Signal description	Signal Direction	Preprocessed signal	Weiner filter
12.10.2021	Seismic Signal 2:00:00-2:59:59AM	Channel E	-96.7840772	-93.23006368
		Channel N	-93.9575872	-84.66193295
		Channel Z	-117.660792	-105.5039059
5.2.2022	Seismic Signal 4:00:00-4:59:59AM	Channel E	-104.644850	-74.17694689
		Channel N	-82.9156196	-64.84117933
		Channel Z	-108.996821	-64.74540369
12.10.2021	Pre seismic signal 1:00:00-1:59:59AM	Channel E	-72.4549477	-48.92333690
		Channel N	-68.5076916	-51.85429384
		Channel Z	-99.8091052	-55.81923965
9.7.2021 2:00:00-2:59:59AM	Non-Seismic Signal 2:00:00-2:59:59AM	Channel E	-76.6532701	-51.67205549
		Channel N	-91.2910149	-60.11111956
		Channel Z	-107.307856	-57.92206705

The figure6 shows the sensor recorded signal and filtered signal. It can be seen that double filtering significantly drops the noise level of the signal; thus aiding for better detection of the events. Same effect of the filter is seen on the non-seismic signals.



(a)



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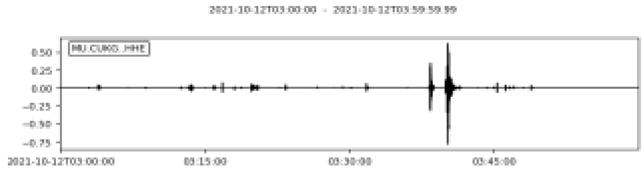


(c)

Figure 6. Pre-processing of seismic signals(a)detrain and tapering (b) Bandpass filtered (c) wiener filtered

5.1. Seismic Event Time Detection

Different detection algorithms are used for event identification. The experimentation uses the Recursive Short Time Average/ Long Time Average (STA/LTA) and Carl Short Time Average/ Long Time Average (STA/LTA) methods. The event detection is observed by both the techniques before and after Wiener filtering. Also, the event detection is compared with the maximum energy time of Short Time Fourier Transform magnitude spectrum. Table 3 shows the event time computed from the different algorithm.

Table 3. Seismic signal time detection

Signal Type	Direction	Recursive STA/LTA	Carl STA/LTA	Wiener filtering and Recursive STA/LTA	Wiener filtering and Carl STA/LTA	Wiener filter and STFT
Pre seismic	E	01:00:29	01:31:34	01:02:37	01:31:34	01:23:50
	N	01:00:29	01:03:45	01:02:34	01:57:36	01:33:43
	Z	01:00:28	01:50:47	01:02:05	01:50:47	01:45:16
Seismic	E	02:36:39	02:37:35	02:36:47	02:37:35	02:37:31
	N	02:36:47	02:37:32	02:36:47	02:37:32	02:37:29
	Z	02:36:47	02:37:35	02:36:47	02:37:35	02:37:31
Post Seismic	E	03:38:23	03:40:14	03:29:15	03:40:14	03:40:07
	N	03:40:06	03:40:08	03:31:55	03:40:08	03:40:07
	Z	03:40:10	03:40:14	03:29:15	03:40:14	03:40:14
Non-Seismic	E	02:00:28	02:25:16	02:02:09	02:25:16	02:56:20
	N	02:00:37	02:03:19	02:02:09	02:09:02	02:33:02
	Z	02:00:36	02:03:56	00:02:07	02:03:56	02:28:03

For pre-seismic and non-seismic signal, the recursive trigger algorithm gives the maximum trigger value at the beginning of each one-hour segment, thus giving the false detection. This can be verified from above table. For the duration of 0:00:00-1:59:59 for seismic signal, for all the directions, the time recorded by recursive algorithm varies. Also, there is a significant difference in the time before filtering, after filtering with STFT detection. Same observation is seen for the non-seismic signal. For seismic and post seismic signal this algorithm picks the p-wave time accurately. The time recorded are more or less same with or without IIR Wiener filter.The Carl STA algorithm does not detect the maximum trigger at the beginning of each segment of preseismic and non-seismic signals, instead it gives the maximum trigger ratio where the signal amplitude is maximum. For preseismic and non-seismic signals, the time detected for the maximum trigger ratio value is almost same before and after wiener filtering. Also, these detections are match with the STFT for few directions. The preseismic signal is highlighted in the table.From the table 4 the seismicsignal (5-2-2022T4:00:00-4:59:59 CUKG Station.) using Carl STA/LTA algorithm gives maximum trigger ratio for s-wave time of the signal. Timing is almost same before and after wiener filtering and with STFT detected time.

Table 4. Seismic signal time detection

Directions	Recursive STA/LTA	Carl STA/LTA	Wiener filtering and Recursive STA/LTA	Wiener filtering and Carl STA/LTA	Wiener filter and STFT
E	04:20:14	04:24:57	04:20:14	04:24:57	04:26:54
N	04:20:14	04:25:33	04:20:14	04:25:33	04:26:45
Z	04:20:14	04:26:21	04:20:14	04:26:21	04:25:51

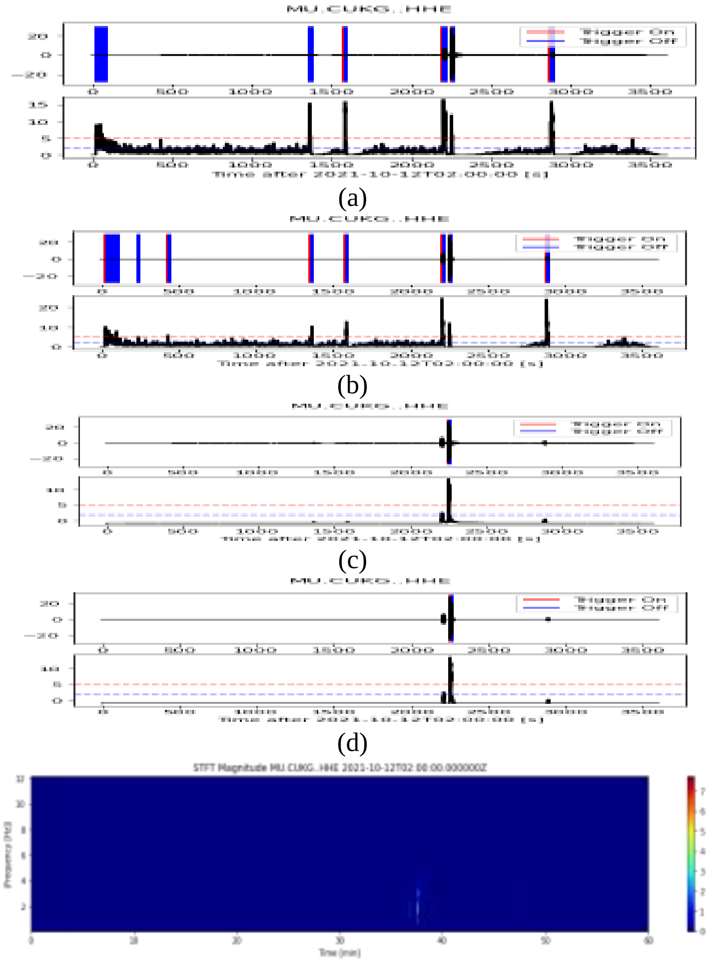


Figure 7. Trigger plots of seismic signals (a) Recursive STA/LTA [sta=1, lta=25], (b) Wiener filtering and Recursive STA/LTA, (c) Carl STA/LTA [sta =1, lta = 3], (d) Wiener filtering and Carl STA/LTA , (e) Wiener filter and STFT

5.2. Seismic Event Magnitude Estimation

Magnitude is an important parameter that forms the base of analysis used for the detection of the earthquake. The actual seismic event was recorded from 2:00 am to 3:00 am duration by BSVK and CUKG stations. To verify the magnitude and corresponding time, the signal is sliced to 15 sec intervals of the signal duration. The Magnitude is calculated using the following formula [15].

$$M\_l=logA+[nlogR100+KR-100+3] \qquad (4)$$

K is attenuation coefficient Hypocentral distance, A = wood Anderson amplitude, n = constant, assumed to be 1. From Table I revised calculation for the hypocentre is as follows

$$\text{Hypocentral Distance (km)(D)} = [(d + \Delta)]0.5 \qquad (5)$$

Where D is the Hypocentral distance (km), Δ is the epicentral distance (km), and d is depth. Table 5 shows the revised parameter of the seismic signalfor magnitude estimation of seismic signals.

Table 5. Magnitude estimation of seismic signal

	Latitude		Longitude	
BSVK	17.814472N		76.90763E	
CUKG	17.433624		76.671061	
	BSVK (km)		CUKG (km)	
EVENT TIME	Epi distance	Hypo distance	Epi distance	Hypo distance
2021-10-12 02:36:27 UTC	65.493812	8.396059	67.272930	8.501348
2021-10-12 02:47:42 UTC	67.384125	8.796824	66.716955	8.758821

The experimental testing of magnitude and time calculations for the station matches with the given magnitude and time. Figure 8-time Vs magnitude, shows the magnitude of 3.60069 at 2:37:30 and 2.819 at 2:48:15 in 0.001 to 4Hz filter band. The BSVK station also shows the similar value of magnitude and time duration. Here, it should be noted that the magnitude is estimated with reference to the Hypocentral value corresponding to the event occurred on 2:36 AM, for the rest of the signal also the same Hypocentral distance is taken as the reference to estimate the magnitude. Hence, the mean level of the estimated magnitude is much higher in the pre, post and non-seismic signal as compared to the seismic signal as seen in the figure 8. These verification graph, interpreted that, the proposed approach of seismic signal analysis detects the event with magnitude value and time accurately.

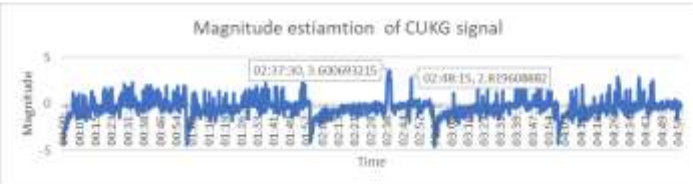


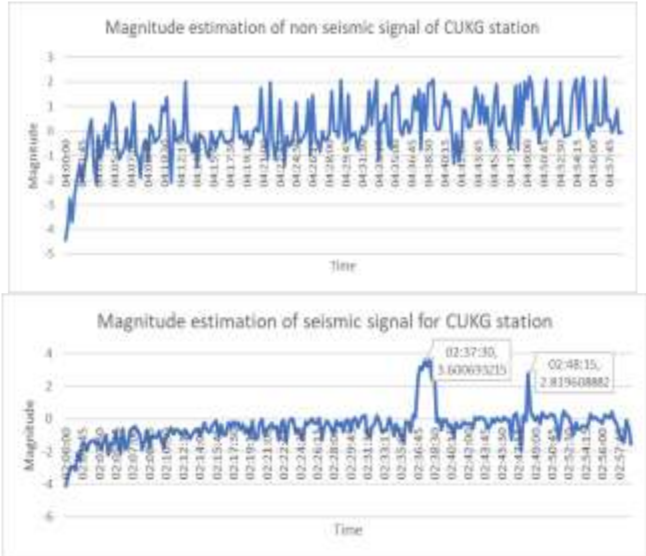
Figure 8. The magnitude Vs Time verification of actual seismic event

The second approach is to distinguish the distribution pattern of actual seismic signal with non-seismic signal i.e., abnormal signal due to manmade or vehicle vibration. The actual seismic signal is considered from 2:00 am to 3:00 am. The signal is sliced in the duration of 1 min and computed the magnitude using equation 4.This process is repeated in all the filter bands such as Filter1 (0.001-30Hzband),andFilter2(2-8Hzband).The correlation between actual seismic events with non-seismic events at station CUKG is shown in Table6 and the corresponding magnitude distribution and histogram plots are in figure 9.

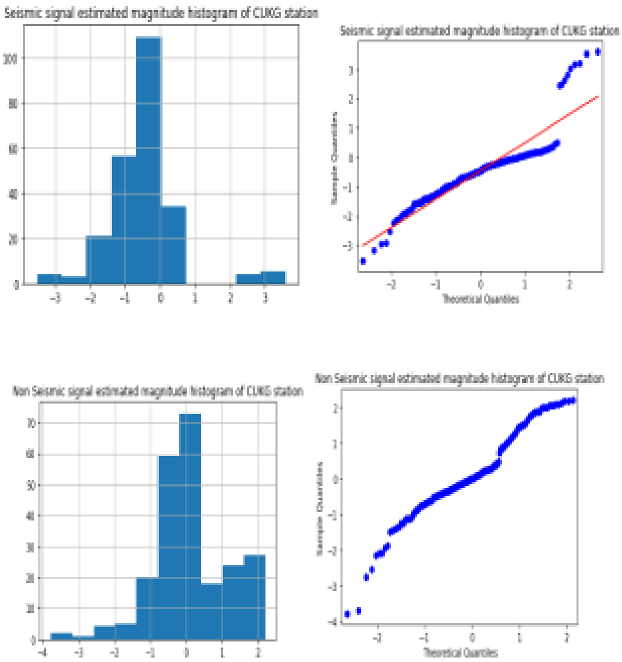
Table 6. Correlation between seismic and non-seismic event

	Filter0.001 to30 HZ		
EVENT TIME	**Non-seismic**	**preseismic**	**seismic**
CUKG seismic	0.161941	0.290694	1.000000
Filter2to8Hz			
CUKG seismic	0.384093	0.364055	1.000000

It is observed that the correlation coefficients of the actual seismic signal are different from the non-seismic/abnormal signals. Seismic to seismic signal autocorrelation is 1. The correlation of pre-seismic in the CUKG station is near to seismic signal which indicates the abnormality before the actual seismic event. From the figure 9 (a)it is observed that the actual seismic event from CUKG stations shows the high peak only when the event happened while the non-seismic/abnormal event shows many peaks during time slots that are not the actual seismic event. Figure 9(b) shows the outliers correspond to the event magnitude values, which can be seen in both filter bands. The same observation can be made with the CUKG station values. These outliers are not seen in the non-seismic and pre- seismic signals.



(a)



(b)

Figure 9. Comparison of seismic and non-seismic event (a) Magnitude and time estimation(b) distribution pattern

6. CONCLUSIONS

The proposed a technique to distinguish seismic and non-seismic event based on the magnitude of the signal. The technique consists of noise removal and determination of magnitude of the signal. During the experimentation, it is observed that the double filtering significantly remove noise. As shown in figure 8 seismic signal analysis matches the estimated magnitude and time with recorded magnitude and time. The correlation coefficient to f pre-seismicis nearest to actual events which can be used as a warning alarm before the actual earth quake event. Such warning will be further helpful for prediction in detail. The recursive STA/LTA triggering algorithm on the non-seismic may give false alarms since the averaging window length has to be manually set. Carl STA/LTA algorithm shows better results than that of the recursive algorithm shown in Table III. The Carl STA/LTA algorithm detects the highest event peak of the S wave of the seismic event same for all the directions and for both the network signals. The proposed distribution pattern of the magnitude of a given seismic signal is helpful to distinguish between seismic and non-seismic events. A few points of the magnitude are the high and low time difference in all directions, especially at pre event which will be helpful to characterize the earth's activity before the actual event. All data points are plotted to show the approximate Gaussian distribution that differs between the seismic and non-seismic events.

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