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IDENTIFICATION OF EARTHQUAKES USING WAVELET TRANSFORM AND CLUSTERING METHODOLOGIES

R Gangadhar Reddy
Department of ECE, Institute of Aeronautical Engineering, Hyderabad, India

M. Srinivasa Reddy
Department of ECE, MLR Institute of Technology, Hyderabad, India

P R Anisha
Department of CSE, Stanley College of Engg. & Tech. Hyderabad, India

Kishor Kumar Reddy C
Department of CSE, Stanley College of Engg. & Tech. Hyderabad, India

ABSTRACT

An earthquake is the shaking and vibration at the surface of the Earth, caused by energy being released along a fault plane, at the edge of a tectonic plate or by volcanic activity in the earth crust. They are one of the most powerful natural forces on earth and regularly affect people, animals, aquatic life and so on around the world. The size of an earthquake is referred to as its magnitude on a scale ranges from 1 – 10. Magnitudes as low as 1 are measured in mines due to rock bursts and the maximum magnitude possible is less than 10. Determining earthquake magnitudes quickly is of great utility in disaster prevention. Many researchers have put forward their utmost effort for the prediction of earthquake. Detection of earthquake was done earlier based on W-MLP and MLP, Wavelet-Aggregated Signal and Synchronous Peaked Fluctuations model, detection using the P wave 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 prediction. In the present research work, Sym wavelet transform is used over the seismic signals (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)) of earthquake and are processed through MATLAB and WEKA tool in order to generate the magnitude and the prediction accuracy, recall and precision performance measures. The obtained results 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.

Key words: Earth quake; FFT spectrum; Sym wavelet; Primary waves; Secondary waves; Seismic signals; Surface wave magnitude.

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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., 6000^0C. 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. After some millions of year's earth's core cooled down due to continuous loss of energy which resulted formation of several layers, apart from core, such as crust and mantle. Earth's crust is the topmost layer and supported life due to various geographical divisions such as biosphere, lithosphere, atmosphere and hydrosphere.

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.

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.

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.

Table 1 Death Toll Caused By Earth Quakes

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 2 Property Toll Caused By Earth Quakes

Year	location	Property damage	Magnitu de
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

2. RELEVANT WORK

Earthquake predictions (may be short-term, long-term) are being the research domain for several years. Several researchers contributed their related work in the field of earth sciences to predict the earthquake.

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 METHODOLGY

The research methodology adopted for the detection of earthquakes is shown in Fig.1. 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.

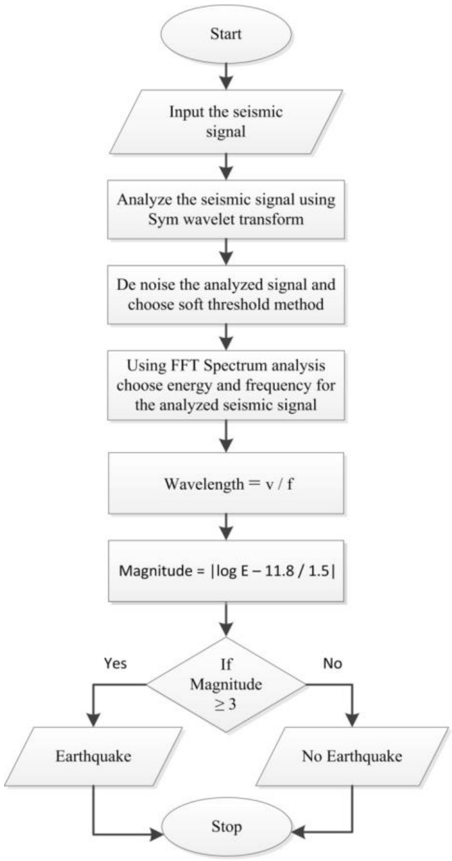

Figure 1 Flow chart diagram representing experimentation methodology

The process of noise removal is generally referred to as signal processing or simply de-noising [13-17]. 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, Sym wavelet [23-30] is used for the de-noising of signal. 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 Sym wavelet transform and the input seismic signal is shown in Fig 2. The input signal is read into Sym wavelet and is analyzed using FFT Spectrum with level 6 and the decomposition in the signal is observed with 6 different variations, shown in Fig 3.

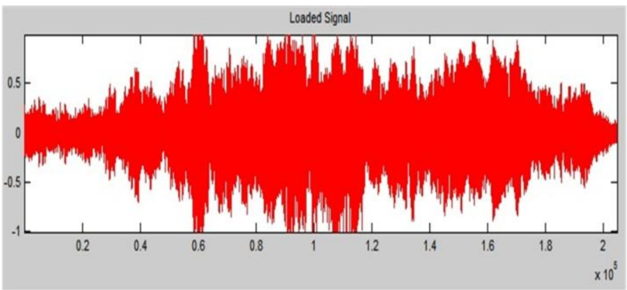

Figure 2 Seismic signal

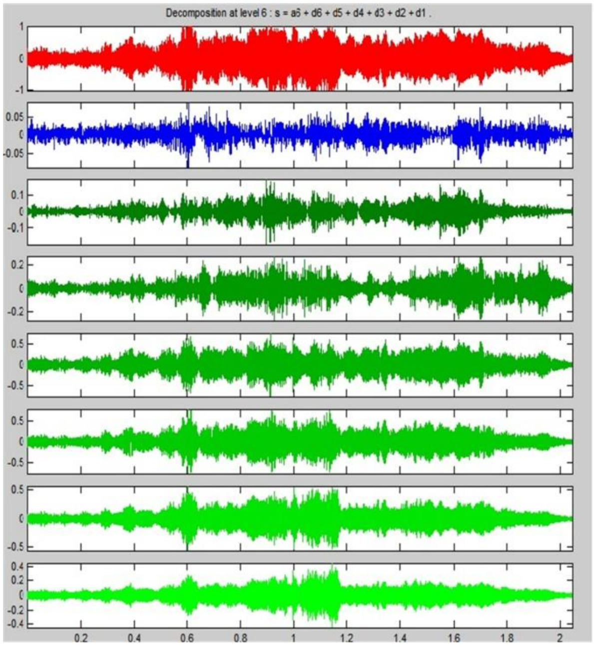

Figure 3 Denoising using Sym wavelet transform

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 signal and is shown in Fig.4.

Fig. 4 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.

Wavelength Vs Velocity Vs Frequency

$$\lambda = v / f \tag{1}$$

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

Magnitude Vs Energy [7][8]

$$\log_{10} E = |1.5M_s + 11.8| \tag{2}$$

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

Magnitude Vs Rupurture Area [8]

$$\log_{10} A = |1.02M_s - 4.01| \tag{3}$$

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

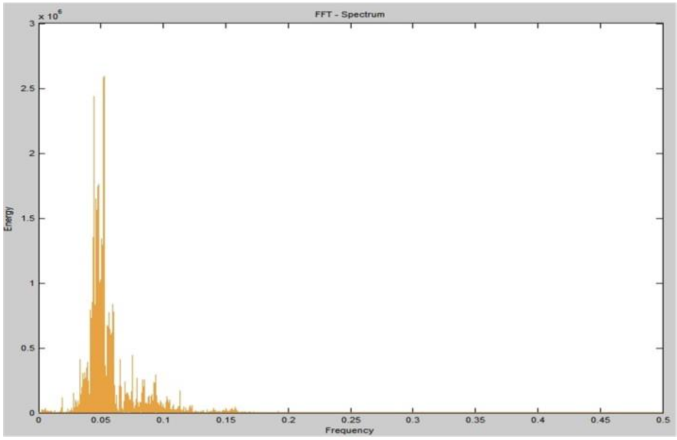

Figure 4 FFT spectrum analysis

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. Consider signal 13, its calculated magnitude is 2.83, which does not fall within the estimated range. Hence it is considered as non earthquake. Similarly consider signal 1, it's computed magnitude is 3.19, that falls within the estimated range. Hence, it is considered as earthquake.

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 based on the magnitude obtained by calculation. 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. For both the conditions the accuracy, precision and recall performance is measured and the results obtained are shown in Table IV.

On analysis of the earthquake signals it is found that the recall value for J48 and REP tree algorithm are about 88.88%. The precision value for Back propagation algorithm is the highest of about 83.40% and finally the accuracy for the prediction of earthquake by means of J48 and REP tree algorithm among all the other algorithms is obtained about 88.90%.

Table 3 Features Extracted Using FFT Spectrum

S No.	Energy	Frequency	Wavelength	Magnitude	Historical 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 Comparison of Performance Measures

Algorithm	Recall	Precision	Accuracy
Naïve bayes	72.22	77.00	72.20
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
Back Propagation	77.77	83.40	77.80

Figure 5 shows the accuracy graph for various classification algorithms, figure 6 shows the precision performance graph for various classification algorithms and finally figure 7 shows the recall performance measure for various classification algorithms.

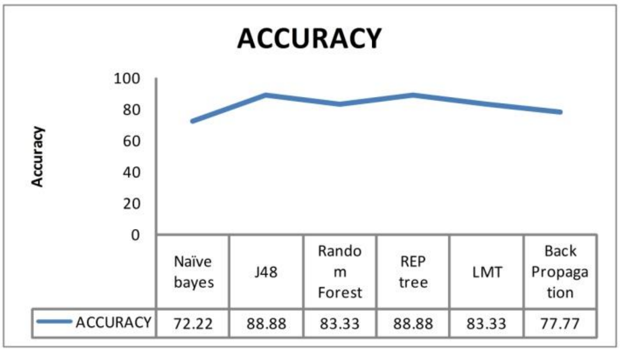

Figure 5 Comparison graph for accuracy

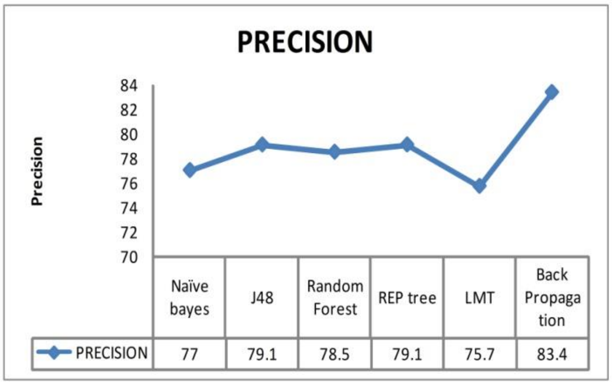

Figure 6 Comparison graph for Precision

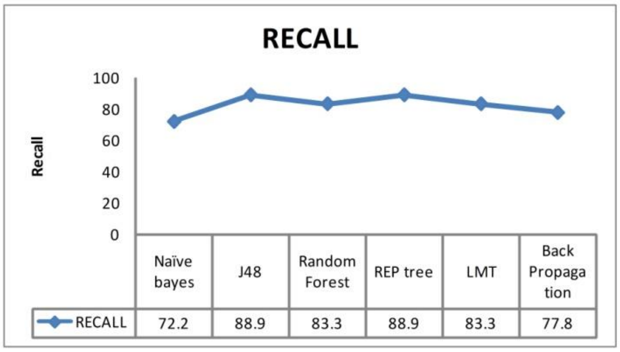

Figure 7 Comparison graph for Recall

5. CONCLUSIONS

Earthquake is a natural calamity effecting human and wild life. Knowing the earthquake disaster earlier helps the mankind to protect their life. 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, wavelength, surface wave magnitude are extracted using FFT Spectrum analysis in Sym wavelet and these parametric values are considered as dataset which is analyzed using WEKA tool on which different algorithm are implemented. Among all the tested algorithms J48 was one of algorithm was observed to provide 88.90% accuracy.

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