Applying Neural Network to Discriminate Earthquake from Quarry Blast

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ABSTRACT

In recent years the study to discriminate mining blast and earthquake has increased. This contamination represents a source of error and falsify the seismicity rates and hence the micro seismicity analysis would be misinterpreted. There are various methods that are used for discrimination based on time and frequency analysis. It also includes using neural network that are trained based on the available data from past records and teaming up with interfaces that uses Fuzzy logic. Different parameters like maximum amplitude S/P, Complexity C, Spectral ratio Sr and Time Frequency analysis are incorporated.

KEYWORDS *Earthquake, mining blast, quarry blast, neural network*

INTRODUCTION

Earthquakes are the most dreadful pest to human because they would strike anytime without any prior knowledge and at any unpredictable place. The mining blast or the quarry blast done for mining rocks are very similar in nature to this earthquake. The earthquakes are recorded by the seismometers and along with this, waves created due to blast are also recorded. This contaminates the earthquake catalogue and hence would represent a source of error and falsify the seismicity rate. Hence it is necessary to discriminate between the two.

There are various methods incorporated like time and frequency analysis to find the distinguishing features among the blast and earthquake. Research up till now show that parameters like Complexity C, Spectral ratio Sr, origin time of event, magnitude of event, maximum amplitude of p-wave, s-wave and depth of event can be useful to differentiate.

Artificial neural networks are a family of statistical learning models that are inspired by biological neural networks and are used to estimate or approximate functions that can depend on a large number of inputs that are generally unknown[9].

Seismology is the scientific study of earthquakes and the propagation of elastic waves through the Earth or through other planet-like bodies [14]. There are two types of body waves, P-waves and S-wave and two types of surface waves, Love-wave and Rayleigh-waves

Seismometers are sensors that sense and record the motion of the earth arising from elastic waves, which may be deployed at the Earth's surface, in shallow vaults, in boreholes, or underwater [15]. Seismic station consists of a seismometer, data acquisition system, and communication equipment buried in a sealed, thermally insulated chamber, or vault, about six feet below the surface. The seismic station also includes a solar panel to power the batteries and a freestanding communications module to transmit real-time data via satellite, phone, or Internet

Neural technologies are appealing solutions to afford the design of an innovative seismograph due to uncertain algorithms, noise in the signal, and adaptability to environmental conditions, classification, sensors fusion, and high parallelism for real-time operation[4].

RELATED WORK

Study as in [1] shows identifying the underground nuclear explosions that occur along with a large number of natural earthquakes. The method uses image compression neural network that has a data compression capability of mapping original data to a feature space of reduced dimensionality. The feedforward backpropagation learning algorithm is used in training the neural network.

The study concludes that an Explosion wave generates only compressional waves, while an Earthquake generates shear wave along with a compressional wave. Explosions have a significant fraction of their total signal energy concentrated in the early, mostly compressional-wave portions of the signal, whereas earthquakes have relatively more energy concentrated in the later portions comprised mostly of shear waves and surface waves.

Later in 2006 Carly M. Nickerson, Laurie L. Bloomfield, and Michael R. W. Dawson conducted a study [6] to discriminate black-capped chickadee (*Poecile atricapillus*) call notes. In this study artificial neural networks were trained to discriminate between two different notes from the "chick-a-dee" call of the black-capped chickadee *Poecile atricapillus*.

The extent to which the responses of the birds correspond to the responses of the ANNs is the extent to which error evidence supports these networks as models of the bird behaviour. The high degree of correspondence that was observed between the two types of data which indicates that these ANNs are excellent models of chickadee discriminations between note types.

Meanwhile in 2012[2] a study that discriminates quarry blasts from earthquakes in the eastern Black Sea region of Turkey using 186 seismic events recorded by the Karadeniz Technical University and Bogaziçi University Kandilli Observatory Earthquake Research Institute stations was conducted.

For the discrimination of quarry blasts from earthquakes, both statistical methods (calculation of the maximum ratio of S to P waves (S/P), complexity (C)) and spectral methods (spectrogram calculation) are used.

Besides this in [3] a study was conducted and presented an adaptive neuro-fuzzy inference system (ANFIS) for classification of low magnitude seismic events used to evaluate seismic discriminants. For this features like origin time of event, distance (source to station), latitude of epicentre, longitude of epicentre, magnitude, and spectral analysis (fc of the Pg wave) were used as inputs to increase the rate of correct classification and decrease the confusion rate between weak earthquakes and quarry blasts.

In 2012 Kekovalı K, Kalafat D and Deniz P conducted a similar research [4] in Tehran region that developed time and frequency techniques to characterize.
The results of this research have shown that Pe could be useful for distinguishing mining blasts and earthquakes.

Recently in 2015 Alex Alexandridis, Eva Chondrodima, Evangelos Efthimiou, Giorgos Papadakis, Filippos Vallianatos, and Dimos Triantis conducted a study for Large Earthquake Occurrence Estimation Based on Radial Basis Function Neural Networks [5]

The study in this paper presents a novel scheme for the estimation of large earthquake event occurrence based on RBF neural network models.

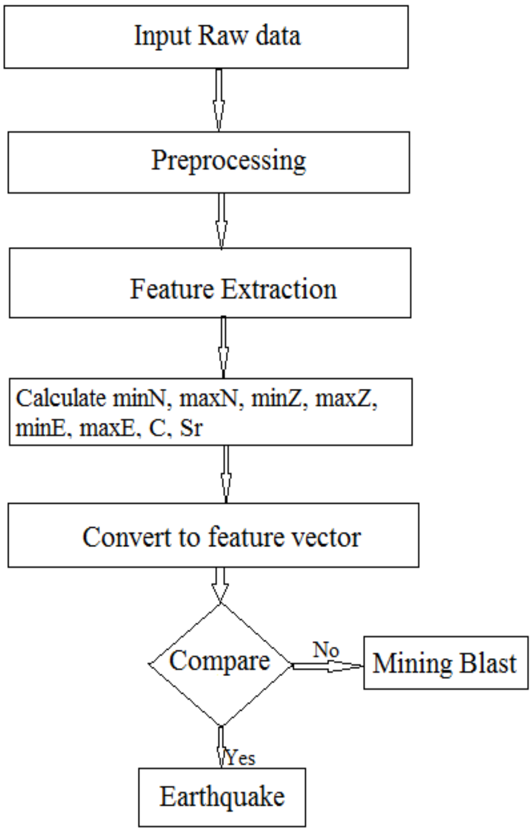
PROPOSED WORK

The proposed work flow of the system is as shown in the figure. It starts by gathering the raw data that is the catalogue of the data recorded by the seismic sensors that have been placed at various predefined latitudes and longitudes. This data contains the recorded Earthquakes, Mining blast occurring in that region, and the other noisy data like the signals generated due to the movement of the heave vehicles.

Data here is the .wav file that the seismometers measure and transmit it from sites to ISR data centre. This .wav file is first of all converted to .saf file that we can understand. This .saf file consists of amplitudes of component vector of each signal. This is called pre-processing.

Feature extraction is the process where in the parameters like origin time, minN, maxN, minZ, maxZ, minE, maxE, complexity and spectral ratio are calculated using the Seisan software and matlab program. Then this features are converted into feature vector. This feature vectors are input to the neural network and it is trained based on the data that is specifically Earthquake and Mining Blast.

After this the new input are compared to the trained neural network to categorize if they are Earthquake, Mining Blast or other noisy data. This result of the comparison is our final discriminated result.



Proposed Work flow

IMPLEMENTATION

Start by adding .wav file into a folder. Then using command prompt type the command **seisei** it would prompt to return if you want to split or merge the file, choose to **split**, then according to your selection enter the name of .wav file. Then it would extract all the files of each station.

Again write **seisei** and this time select merge to **merge** the 3 files of particular station into 1. Tis file is still not human readable so convert it into asci form using the command **seisaf.** This gives the .saf file.

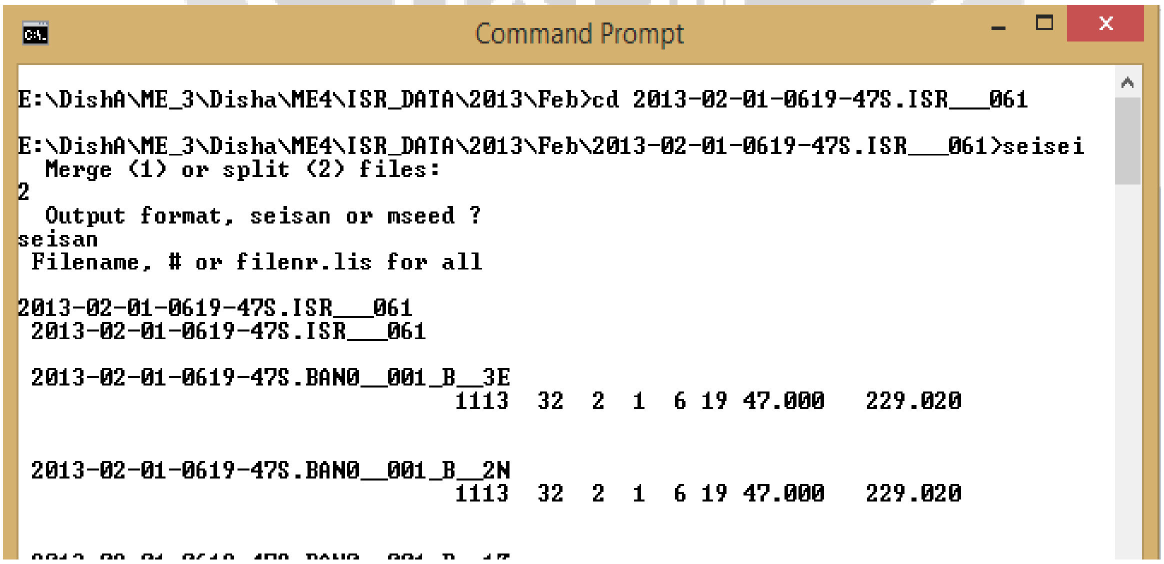


Fig: split .wav file

Then type **dirf *station_name*** in command prompt where station _name is the name of the station you want to work on. Here * means anything before and after the station_name, like dirf *Jun0* it will return the name of 3 files of that station. Again write **seisei** and this time select merge to **merge** the 3 files of particular station into 1. Tis file is still not human readable so convert it into asci form using the command **seisaf.** This gives the .saf file.

```
Command Prompt

E:\DishA\ME_3\Disha\ME4\ISR_DATA\2013\Feb\2013-02-01-0619-47S.ISR___061>dirf *SU
R0*
 #  1   2013-02-01-0619-47S.SUR0__001_B__1Z
 #  2   2013-02-01-0619-47S.SUR0__001_B__2N
 #  3   2013-02-01-0619-47S.SUR0__001_B__3E

E:\DishA\ME_3\Disha\ME4\ISR_DATA\2013\Feb\2013-02-01-0619-47S.ISR___061>seisei
  Merge (1) or split (2) files:
1
  Output format, seisan or mseed ?
seisan
  Give 1-5 letter network code for merged file(s), NSN   is default
SUR0
  Maximum difference (sec) of events to merge, return for default (180 secs)


  Number of files to merge           3
           3  Number of input channels
 Output file name is: 2013-02-01-0619-47S.SUR0__003
 SUR0                           3113  32  2  1  6 19 47.000   229.020


 SUR0B  Z    0.00   229.02 SUR0B  N    0.00   229.02 SUR0B  E    0.00   229.02
```

Fig: Merging 3 files

```
E:\DishA\ME_3\Disha\ME4\ISR_DATA\2013\Feb\2013-02-01-0619-47S.ISR___061>seisaf
 File name, #, ? or filenr.lis for all

2013-02-01-0619-47S.SUR0__003
 2013-02-01-0619-47S.SUR0__003

 Format SEISAN
  Total number of channels available:          3
CHA STAT  COMP  YEAR MO DA HR MI    SEC NSAMP    RATE    DELAY DURATION
  1 SUR0  B  Z  2013  2  1  6 19 47.000 11451   50.000   0.000  229.020
  2 SUR0  B  N  2013  2  1  6 19 47.000 11451   50.000   0.000  229.020
  3 SUR0  B  E  2013  2  1  6 19 47.000 11451   50.000   0.000  229.020
 Output file name: 2013-02-01-0619-47S.SUR0__003_SAF

E:\DishA\ME_3\Disha\ME4\ISR_DATA\2013\Feb\2013-02-01-0619-47S.ISR___061>
```

Fig: Deriving .saf filE

After generating the .saf file for each station, complexity and spectral ration for that particular event is calculated using matlab. For this plot the component signals into matlab and select the range where event occurred to calculate complexity and spectral ratio. Create a database for all the events similar.

Importing database in matlab and process it using neural network toolbox. Get the result and if it is not satisfactory retrain the network.

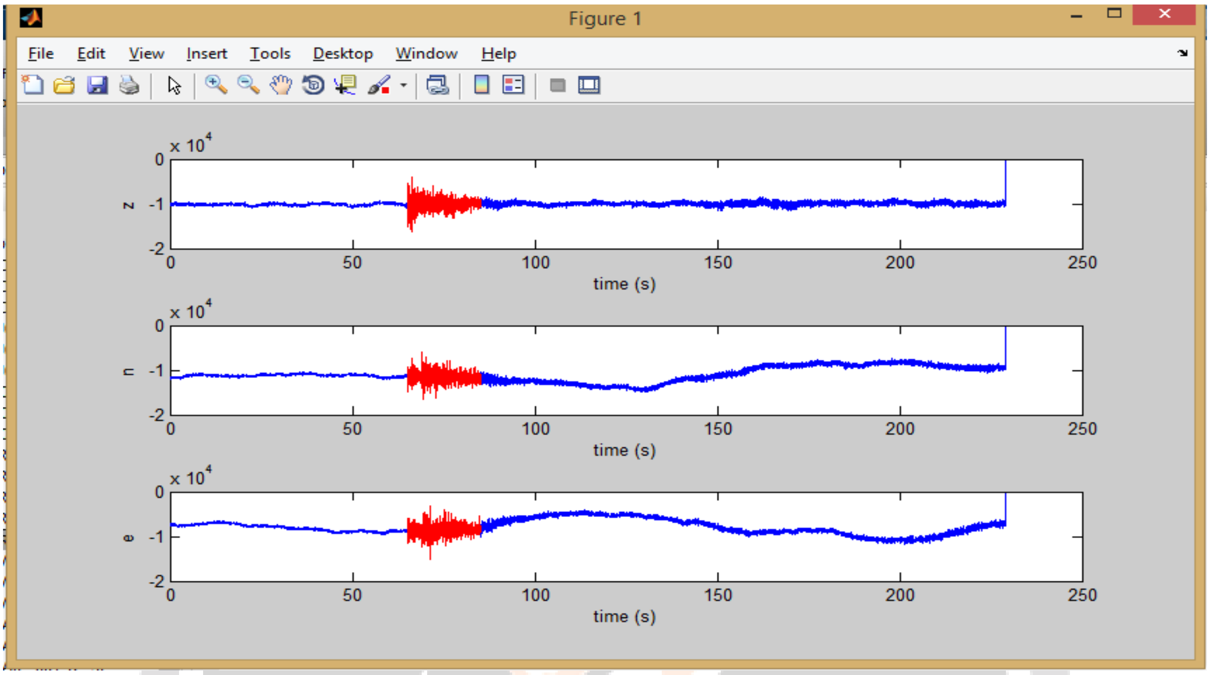


Fig: calculate Complexity

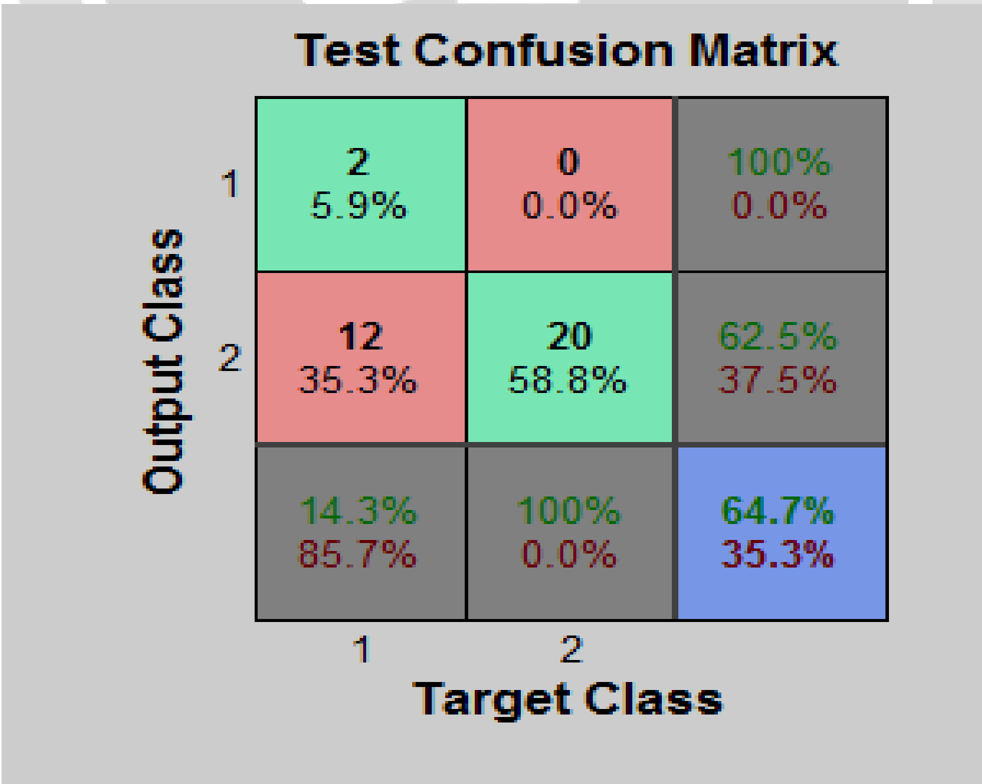


Fig: Confusion Matrix

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CONCLUSION

Methods for discriminating natural and manmade events are widely based on the spectral analysis and by applying different methods to both the time and frequency domain, using Neural Networks can prove to be more effective.

REFERENCES

Papers

[1] Roy C. Hsu, Shelton S. Alexander, "A Neural Network approach to Seismic event identification using reference Seismic Images", IEEE, IEBN: 0-7803-2129-4/94, pp 2108-2113

[2] Şeyda Yılmaz & Yusuf Bayrak & Hakan Çınar, "Discrimination of earthquakes and quarry blasts in the eastern Black Sea region of Turkey", Springer Science + Business Media Dordrecht 2012, DOI 10.1007/s10950-012-9348-x, pp 721-734

[3] Jamileh Vasheghani Farahani & Mehdi Zare & Caro Lucas, "Adaptive neuro-fuzzy inference systems for semi-automatic discrimination between seismic events: a study in Tehran region", Springer Science + Business Media B.V. 2012, DOI 10.1007/s10950-011-9270-7, pp 291–303

[4] Kekovalı K*, Kalafat D and Deniz P, "Spectral discrimination between mining blasts and natural earthquakes: Application to the vicinity of Tunçbilek mining area, Western Turkey", ISSN 1992 -1950, pp 5339-5352

[5] Alex Alexandridis, Eva Chondrodima, Evangelos Efthimiou, Giorgos Papadakis, Filippos Vallianatos, and Dimos Triantis, "Large Earthquake Occurrence Estimation Based on Radial Basis Function Neural Networks" ISSN: 0196-2892 IEEE Transaction on Geoscience and Remote Sensing. Vol. 52, PP 5443 - 5453

[6] Artificial neural network discrimination of black-cappedChickadee (*Poecile atricapillus*) call notes, 2006 Acoustical Society of America. DOI: 10.1121/1.2211509, Pp 1111–1117

[7] "Earthquake or explosion? The science of nuclear test", Nilo Lindgren, IEEE spectrum August 1966, pp 66-76

Websites

[8] http://www.geo.mtu.edu/UPSeis/waves.html

[9] http://www.psych.utoronto.ca/users/reingold/courses/ai/cache/neural2.html

[10] http://www.neuralpower.com/technology

[11]http://wwwold.ece.utep.edu/research/webfuzzy/docs/kk-thesis/kk-thesis-html/node14.html

[12] http://allshookup.org/quakes/wavetype.htm

[13] http://www.usarray.org/public/about/how#1

[14] http://www.isr.gujarat.gov.in/about_isr.php

Books

[15] Seismographs From IRIS Onepager # 7, "How Does a Seismometer Work?"

[16] Data Mining and Knowledge Discovery Handbook