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Application of nature-inspired computing and implementation of algorithm for earthquake detection

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सार – सीखने की तकनीकों में सुधार करना और संदर्भ एन्ट्रॉपी तैयार करना जो सूचना सिद्धांत के क्षेत्र से मापता है, आम तौर पर दो संभाव्यता वितरणों के बीच अंतर की गणना करते हुए एन्ट्रॉपी का निर्माण करता है। सुप्रचालन समाश्रयण और कृत्रिम न्यूरल नेटवर्क जैसे वर्गीकरण मॉडल को अनुकूलित करते समय क्रॉस-एन्ट्रॉपी का उपयोग लॉस फ़ंक्शन के रूप में किया जा सकता है। इस शोध में क्रॉस एन्ट्रॉपी के संबंध में प्रस्तावित तंत्रिका नेटवर्क को प्रस्तुत किया गया है। अधिक डेटा और अनुकूलन को शामिल करके प्रदर्शन में सुधार किया जा सकता है। प्रस्तावित अनुसंधान कार्य का उपयोग भूकंपीय घटना (भूकंप) जैसी घटनाओं का पता लगाने और अनुमान के समय श्रृंखला डेटा के लिए किया जाएगा। इस अध्ययन का उद्देश्य विनाशकारी भूकंप की घटनाओं का सार्थक पता लगाने और उचित समय पर जनता को चेतावनी देने के लिए उपयुक्त एल्गोरिदम को ट्यून करना है।

ABSTRACT. Improve learning techniques and to prepare reference entropy which measures from the field of information theory, building upon entropy generally calculating the difference between two probability distributions. Cross-entropy can be used as a loss function when optimizing classification models like logistic regression and artificial neural networks. The performance of the proposed neural network with respect to cross entropy is presented in this research. The performance can be improved by including more data and optimization. The proposed research work will be used for time series data of events detection and prediction such as seismic event's (Earthquake).The point of the present work is to tune the suitable algorithms for meaningful detection of the disastrous earthquake events and to generate the proper timely warning to the public.

Key words – Artificial neural network (ANN), Machine learning model (MLP), Multivariate regression analysis (MVRA), Sigmoid activation technology (SAT), Cross-entropy, Mean square error (MSE) and Logistic regression (LR).

1. Introduction

Nowadays nature inspired techniques are used to find out optimal or pseudo-optimal solutions to many complex optimization problems. In catastrophic event situations, which present an exceedingly powerful nature, are one of these regions of use that can benefit from nature inspired algorithms. In a decade ago, the exploration is invigorated on new figuring ideal models and after effect of this exertion is the rise of new critical thinking procedures like nature inspired algorithms, developmental registering. Nature enlivened enhancement systems are broadly used to take care of troublesome issues.

India has a history of wrecking earthquakes in its subcontinent. The significant purpose behind the high recurrence and power of the seismic tremors is that the Indian plate is crashing into Asia at a pace of around 47 mm/year. Geological measurements of India show that practically 54% of the land is defenseless against earthquakes. India has an extremely high recurrence of extraordinary seismic tremors with magnitude exceeding 8.0, for example, during 1897 to 1950, the nation was hit by four incredible earthquakes and the recurrence of moderate seismic tremors (size 6.0 to 7.0) in the nation is somewhat low. Moderate seismic tremors make mindfulness and lead to upgrades in development. We have not had a seismic tremor of greatness more prominent than 7.0 over the most recent 40 years. Expert research have recognized seismic tremor shaking power of more than VIII or IX over the most recent 40 years. Lastly, with the exception of the Jabalpur seismic tremor

(1997), the other late moderate quakes have not hit any of the enormous urban areas. This has prompted smugness in our quake readiness. We presently have requests of extent more elevated levels of man-made development and a fundamentally bigger populace than what we had at the hour of incredible tremors of 1897, 1934 or 1950.

Alyona Galkina and Natalia Grafeeva (2019) had approached a machine learning technique to provide help in earthquake detection using weak motion and strong motion sensors data to calculate velocity and acceleration values. Galkina and Grafeeva have used open-source earthquake catalogs and databases for maintaining a "benchmark" earthquakes proper and qualitative database that can be used to assess the quality of various earthquake detecting systems. The database set includes immediate effecting or active areas and seismic zones of Central Japan and Sicily Island situated in East Asia and Europe. Performance of proposed methods can also be evaluated using the "benchmark" database set. Focusing on the most complex and important task of detecting earthquakes of high and extreme magnitudes (equal to or greater than 5.5). Making attempts to solve the problem of earthquake detection in its original form, as determined by geologists and researchers who is working in this field; using proper information of the simultaneous specification of magnitude, place and time of seismic events with certain possibilities.

A Genetic algorithm has been used to find the optimal features subset of the seismic parameters that minimizes the computational cost and maximize the classification performance. A well labeled data set used for supervised learning (example classification and regression) and unlabeled data set for unsupervised learning like clustering, association and dimension reduction *etc*. The Artificial Neural Networks Earthquake patterns have been classified with respect to identified features using ANN based networks. Both supervised and unsupervised techniques are utilized for prediction purpose. Dangerous earthquakes can be identified by developing a reliable activation or threshold function in the network. For example earthquakes with high magnitude and minimal depth can be most dangerous. However, the earthquakes with larger magnitude and larger depth are often less dangerous. Although, such earthquakes may cause inner energy release patterns or may affect other layers but their affect is not spontaneous. Earthquakes with smaller magnitude and small depth may be sensitive if they prolong over a certain period of time.

Association Rule Mining is a unique approach for earthquake dissemination. Significantly useful results are obtained by with help of Association Rule Mining.

Feed forward neural network is able to predict both short duration termers and long duration termers.

Clustering is a big data set of unsupervised form is divided in cluster form.

2. Literature review

The proposed genetic algorithm and evolutionary algorithms produces optimized outcomes (better speed models recreation with respect to both adequacy and shape) that the standard least-squares technique for seismicity. Additionally, the proposed hybrid evolutionary algorithm consolidates the advantages of a worldwide and a nearby improved technique and is actualized in mathematical laboratory for multicore-engines to take care of enormous dimensional issues and accomplish quick area of worldwide minima, giving vigorous and solid tomographic pictures. It ought to be additionally noticed, crossover GA can better recreate the minimized speed model regions than the customized algorithms and customized least square strategy approach. The last speed model got by this algorithm is essentially free of the underlying model, while the algorithm requires generally less information to acquire reasonable and solid models, a preferred position which can be very significant in genuine world investigation cases; this is described by Pantelis in 2011.

Genetic Algorithms (GAs) have been first time presented by Holland (1975), have a place with the gathering of stochastic worldwide enhancement techniques (randomized pursuit strategies, for example, Monte Carlo and reenacted strengthening. The GA idea depends on organic development has higher likelihood of endurance and multiplication, while others have lower probabilities. The fundamental preferred position of these strategies is that they can characterize the worldwide least, on the off chance that it exists in the inquiry space. Notwithstanding, a suitable hunt space based on the form the earlier data gave by the client can be characterized, permitting the proficient inference of the populace of conceivable model arrangements. For the GA application, an underlying populace comprising of a fixed number of people (speed models for our situation) is arbitrarily produced. Every single actual boundary is joined as chromosomes to speak to a condition of the model. The assortment of models establishes a populace. After this progression, the forward problem using beam following count is settled and the disparity among noticed and determined information is assessed. The wellness is then utilized in the progressive determination and hybrid cycle. The best people (for example the speed models with the littlest mistake) are chosen to produce the following qualities (posterity).

TABLE 1

Study of different techniques used in nature inspired computing

Title	Objective	Data	Technique	Results
Using Artificial Bee Colony Algorithm for MLP Training on Earthquake Time Series Data Prediction	To predict time to failure of earthquake	Southern California Earthquake Data Center (SCEDC) holdings for 2011	Multilayer Perceptions (MLP) neural network , Artificial bee colony	99.89 percent accuracy
Hybrid Guided Artificial Bee Colony Algorithm for Earthquake Time Series Data Prediction	To perform earthquake prediction with a novel hybrid ABC algorithm and compare its performance with conventional ABC	The data used from the Southern California Earthquake Data Center (SCEDC) holdings for 2010	Multilayer Perceptions (MLP) neural network , Artificial bee colony	The hybrid guided artificial bee colony gives the best results
Optimized ANN-ABC for Thunderstorms Prediction	To predict time for thunderstorms using ANN optimized with ABC	The Metar and SYNOP data file of Lake Charles airport (LCH)	Artificial neural network, Artificial bee colony	ANN-ABC got the highest recall value (0.708), the highest AUC value (0.803) and TP (68), and got the lowest FP value (28)
Artificial Bee Colony-Optimized LSTM for Bitcoin Price Prediction	To predict the bitcoin price with LSTM and ABC algorithim.	Historical data on downloaded bitcoin prices have daily intervals from December 27, 2013 to January 21, 2019.(coinmarketcap.com)	LSTM, Artificial bee colony	ABC-LSTM RMSE = 189.61 LSTM without optimization RMSE of 236.17
Precipitation forecast of the Wujiang River Basin based on artificial bee colony algorithm and backpropagation neural network	To predict rainfall	Wujiang River Basin data compiled by Guizhou Meteorological Service.	Artificial neural network, Artificial bee colony	The proposed ABC-BP model overcomes the randomness and sensitivity of the initial weights of the BPNN
A Machine-Learning Approach for Earthquake Magnitude Estimation	To predict magnitude of earthquake	Stanford Earthquake Dataset (STEAD)	LSTM	The network is able to predict earthquake magnitudes with a mean error close to zero and standard deviation of ~0.2

The wellness of people is then utilized in the progressive determination measure. The champ of a competition among a number of arbitrarily chose people (for example the speed model with the littlest blunder) has the privilege of passing its qualities to the future. The hereditary data traded between chosen people is figured it out by the hybrid administrator. During the transformation, chosen pieces of offsprings in view of the transformation likelihood, are turned to take into account little bothers of the model boundaries. To pass the fittest individuals of every age to the following one, the elitism methodology is utilized staying away from conceivable loss of good people (Goldberg and Holland (1988), Goldberg 1989; Haupt and Haupt, 1998; Man *et al*., 1999). The cycles of this development hypothesis can be ended after a fixed generation or when the certain error threshold has been meeting with fitness. Artificial bee colony algorithm, Shah, *et al*., (2011, 2012) have been used to solve complicated pattern recognition and classification problems in different domains such as satellite data .Tsunami intensity is also successfully predicted using ABC algorithm. A prediction algorithm using time series data mining based on fuzzy logic is proposed. Earthquake prediction has been done from a synthetic earthquake time series in the year 2009 by Aydin, *et al*. (2009) Time series has been transformed to phase space by using nonlinear time series analysis and then fuzzy logic has been used to prediction optimal values of important parameters characterizing the time series events. A hidden Markov Models is proposed by Beyreuther, *et al*., 2012 for detection of anthropogenic induced earthquakes for which they demonstrate for a period of 3.9 months of continuous data that the single station HMM earthquake detector can achieve similar detection rates as a common trigger in combination with coincidence sums over two locations. To show the general applicability of clustering they have been applied the proposed method on earthquake classification at Indonesia, Mt. Merapi volcano. An advance inversion technique with minimum seismograph recording geometry has been applied by Deep K. *et al*., 2012 and Umadevi *et al*., 2012 to obtain the improved locations of local and regional earthquakes. According to Guo *et al*., 2011, the complex nonlinear relationship of seismic subsidence,

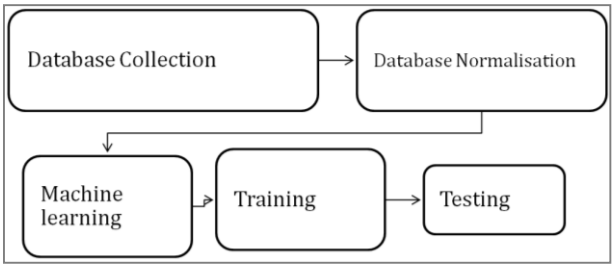

Fig. 1. Process flow for earthquake magnitude prediction

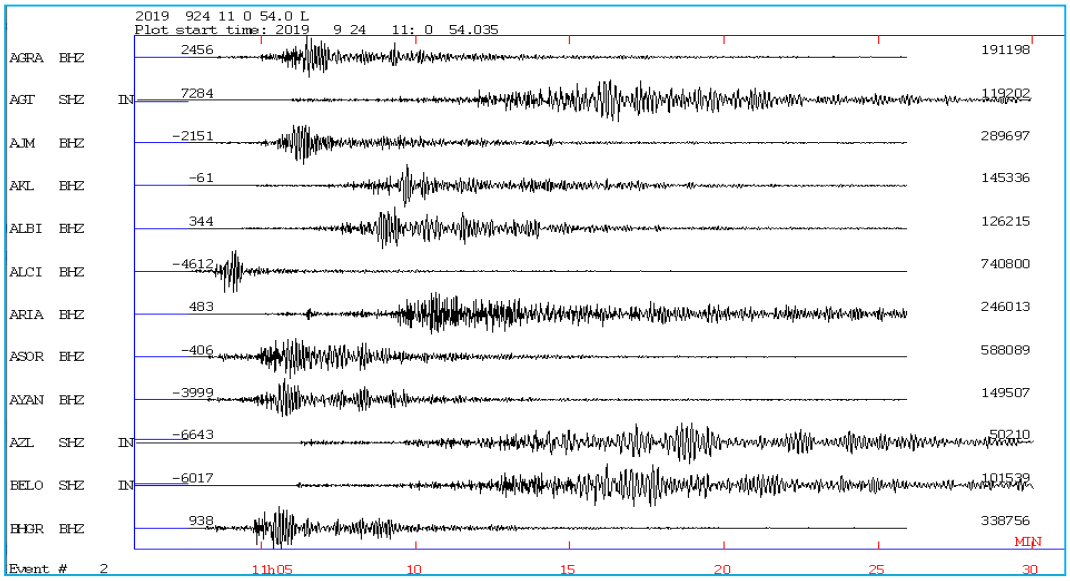

Fig. 2. Vertical component

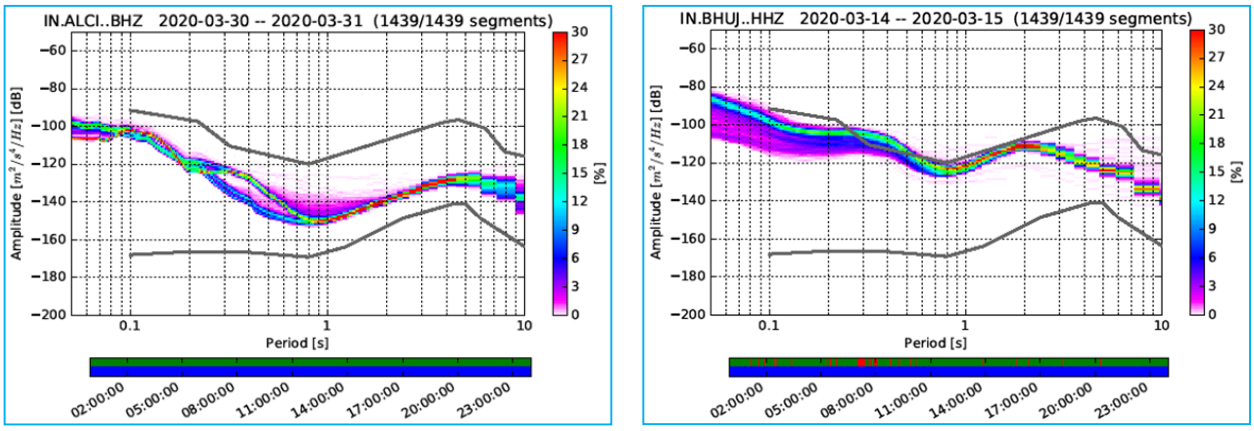

Fig. 3. Probabilistic power spectral density plot of Bhuj and Alchi

seven measured indicators of earthquake liquefaction have selected as key factors to find the building settlements, considering the earthquake magnitude, length height ratio, average pressure, width depth ratio, relative density. Fuzzy-Rule-Based Regression Modeling algorithm for performance and degradation detection is investigated by Li, *et al*., 2010 and Azam *et al*., 2014 have been reviewed on Artificial Intelligence based 2014 techniques were widely used for earthquake time series prediction. Reyes *et al*., 2013 have presented a study of seismic regionalization for continental Chile based on a neural network. Zamani, (2012) presented a review of the recent literature to predict the damage caused by earthquakes using ANNs. The review of the literature showed by

Moustra *et al*., 2011 that ANNs have been applied to predict nonlinear structural time histories under seismic excitation because they have a considerably lower computational cost than the conventional time-consuming methods.

Support vector machine and genetic algorithm improvement methods are used broadly in region of geo-science, common, science, mining, and geo-mechanics. Because of it is more flexible, it is being applied generally in pretty much every field of designing. In this paper, the significant highlights of support vector machine and genetic algorithms are talked about just as forecast of longitudinal wave speed and its focal points over other ordinary forecast strategies, here genetic algorithm is also applied by Nicknam *et al*., 2010 synthesizing strong motion using empirical Green's function and genetic algorithm approach. According to Singh, *et al*., 2016 longitudinal wave estimation is a pointer of peak particle velocity during impacting and is a significant boundary to be resolved to limit the harm brought about by ground vibrations. The dynamic wave speed and physico-mechanical properties of rock altogether influence the crack proliferation in stone. GA furthermore, SVM models are intended to anticipate the longitudinal wave speed incited by ground vibrations. Turmoil enhancement calculation has been utilized in SVM to locate the ideal boundaries of the model to build the learning and expectation proficiency. GA model additionally has been created and has utilized a target capacity to be limited. A parametric concentrate for choosing the advanced boundaries of GA model was done to choose the worth. The mean total rate blunder for the anticipated wave speed (V) esteem has been discovered to be the least values 0.258 % for GA when contrasted with result has been gotten by multivariate regression analysis (MVRA), adaptive neuro-fuzzy inference system (ANFIS), support vector machine and artificial neural network (ANN).

3. Framework

3.1. *Raw data and data conversion*

We have taken different weak motion sensors data from around 152 stations. Earthquake data is available in native format after that we have run our program to convert native format to Seisan format and also in DLT format.

The detail of weak motion sensor is as follows: For weak motion sensor (BB Seismo-Meter):

1 count = 1.589 micro volt = 0.7945 nm/sec

NSN : National Seismological Network: There are 78 field stations under National Seismological Network. All these 78 field stations are equipped with Seismic Instruments manufactured by M/s Reftek Inc., USA. It has both weak motion and strong motion sensor connected to 6 Channel Seismic Digitizer. The Model numbers of 6 channel Seismic Digitizer is “Reftek Model No. 130S-01/6”. Weak motion sensor is ‘Reftek 151B-120A’. It has 3dB flat velocity frequency response from 120 sec to 50 Hz. The Generator constant of 2000 v/m/s. Broadband Sensor Model No. Reftek151B-120. Around 20 other stations data of sensors collected from other observatories situated in North-East.

3.1.1. *Vertical component plotting for earthquake detection and dissemination*

Earthquake occurred on Jammu & Kashmir region has been detected successfully after analyzing preprocessed. DLT file of weak motion sensor of 97 stations with help of SEISAN. All over Indian region have covered for event date 24th September, 2019. Vertical motion of sensor have been shown in waveform form in Fig. 2. It is exactly information of Z direction (Fig. 1) for different stations. This information is very helpful for general people, how earth shaking in up and down motion.

3.1.2. *Check Status of site or station with help of probabilistic power spectral density tool (PPSD)*

With the help of Fig. 3 status of Alchi station find out, which is very near to epicenter. All Spectral frequency is between upper and lower noise model. Alchi site is very less noisy so sensor data is very qualitative. In 30 Minute result windows Alchi waveform is very clear to detect event timing.

4. Data and methodology

Earthquake data consists of features such as magnitude and time of failure. Seismic signals will be used to forecast the timing of laboratory earthquakes. Next step is to segment training data. It's important to predict a single failure time for each seg id in the test folder, which corresponds to the time it takes for a subsequent laboratory earthquake to occur. The expected features in data are:

(*i*) acoustic-data-the seismic signal [int 16]

(*ii*) time-to-failure-the time (in seconds) until the next laboratory earthquake [float 64].

(*iii*) seg-id-the test segment ids for which predictions should be made (one prediction per segment).

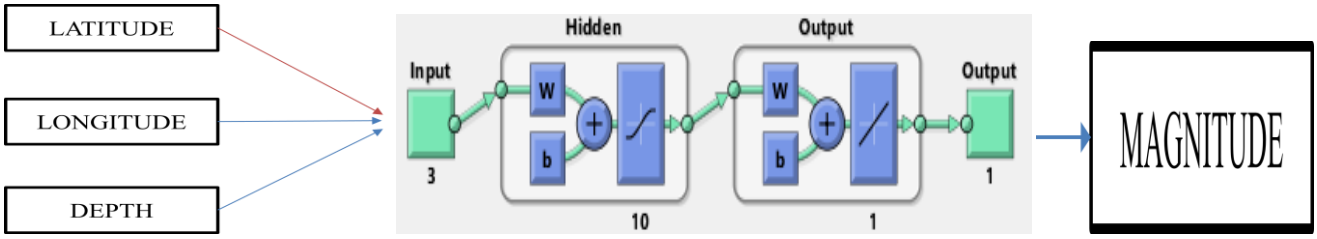

Fig. 4. Architecture of neural network used in this research

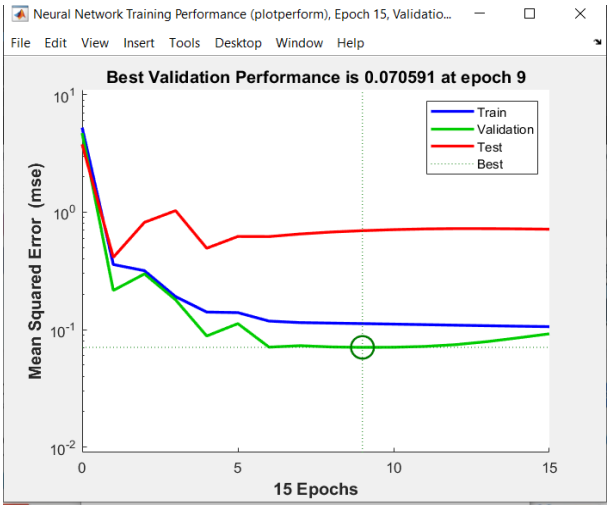

Fig. 5.1. Train, test and validation performance with respect to cross entropy

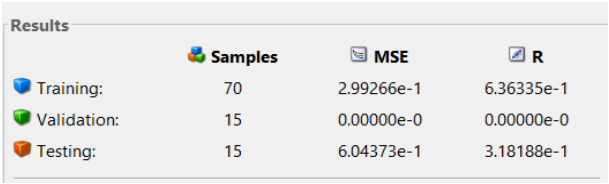

Fig. 5.2. Mean Square Error and R2 score for training, validation and testing

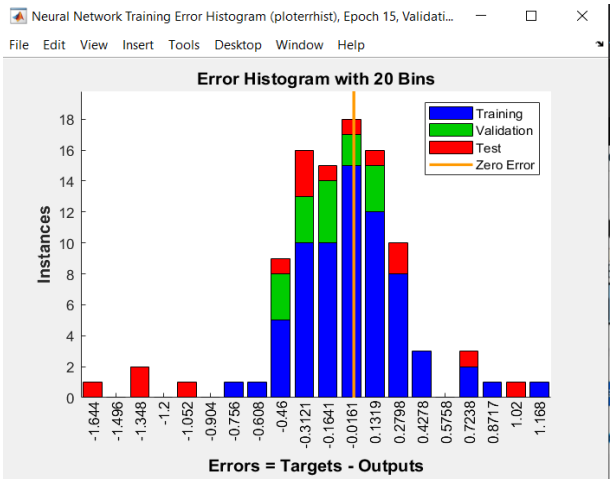

Fig. 5.3. Error histogram, it can be observed that mostly errors are concentrated around 0 error value with few outliers

4.1. *Preprocessing*

Pre processing is necessary to remove duplicates and inconsistencies. In this study, null values were examined first to see if they contained any garbage. These entries have been deleted from the database. It is now possible to extract features and perform machine learning on them.

4.2. *Segmentation*

The time series data is broken down into smaller sequences so that it can be analyzed more effectively. After that, the intervals are subjected to the floor function. There's a NumPy. Floor function that returns the square root of an array's elements.

An integer that is larger than x is called the floor of a scalar. This is followed by a split of the data into training and a testing set.

We used 70% of the data for training and 30% for testing and validation in this study, according to the standard notation.

4.3. *Machine learning model*

In this step a neural network suitable for regression analysis and can be used to generate initial results. Since this is a regression problem the performance matrices can be mean absolute error and R2 score. The performance can be improved by Meta heuristic optimization using appropriate algorithms.

4.4. *Artificial neural network*

A two-layer feed-forward network with sigmoid hidden neurons and linear output neurons can fit multi-dimensional mapping problems arbitrarily well, given consistent data and enough neurons in its hidden layer.

The three input neurons represent latitude, longitude and depth characteristics. The output neuron represents which is predicted by the ANN.

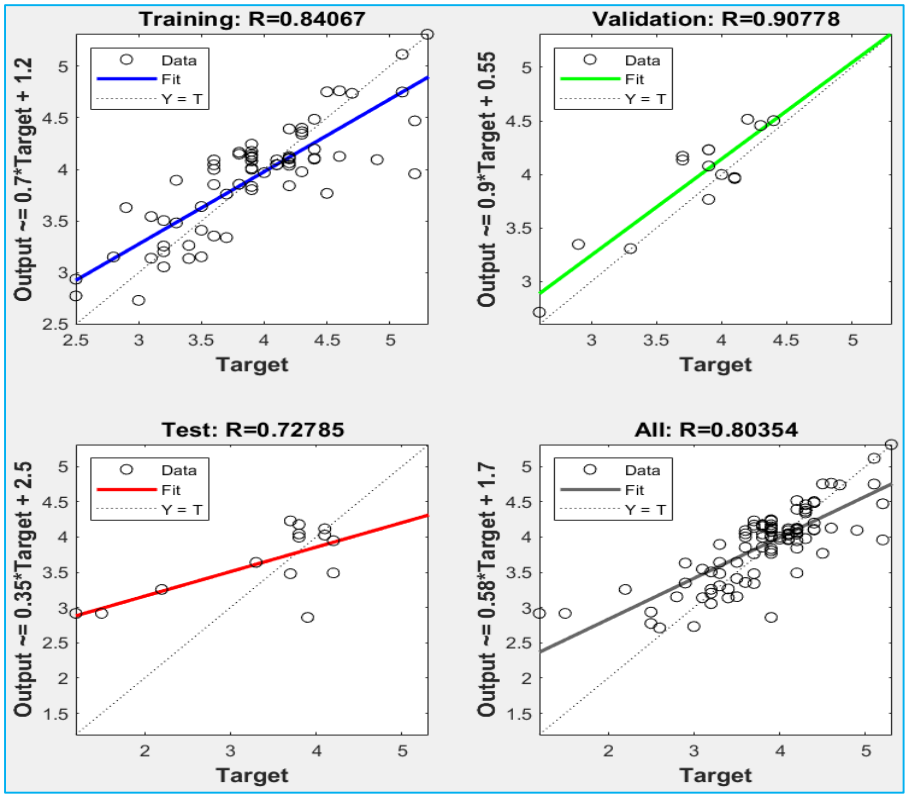

Fig. 5.4. Shows the R2 score. The R2 score obtained in test is 0.727. The performance can be improved by including more data and optimization

The challenge in training phase of the MLP network is to decide the number of neurons in the hidden layer since. There is no general rule available in the literature for selecting optimal number of hidden layer neurons. In the present work, the MLP network was trained by using the Bayesian regularization with momentum and adaptive learning rate back propagation. In this work, the MLP neural network is implemented in MATLAB where the optimal number of hidden layer neurons is obtained by trial and error. Bayesian regularization typically requires more time, but can result generalization for difficult, small or noisy datasets. Training stops according to adaptive weight minimization (regularization). After several trials, the results showed better performance with 10 hidden neurons. MLP neural network is implemented with sigmoid activation technology (SAT).

5. Result

Earthquake detection results generated with cross-entropy is a measure from the field of information theory, building upon entropy and generally calculating the difference between two probability distributions.

Cross-entropy can be used as a loss function when optimizing classification models like logistic regression and artificial neural networks. The performance of the proposed neural network with respect to cross entropy is shown in Fig. 5.1.

Fig. 5.2 shows the obtained performance parameters. Mean Squared Error is the average squared difference between outputs and targets. Lower values are better. Zero means no error. Regression R Values measure the Correlation between outputs and targets. An R value of 1 means a close relationship, 0 a random relationship.

6. Conclusion

There is Bhuj and Alchi stations are best site for earthquake analysis, this is concluded after comparing noise level frequency spectrum (Fig. 3). Nearby 100 Stations are taken (including Fig. 2 to detect an earthquake occurred on 2019:09:24 11:01:54:99 33.078 N 73.794 E 10 Km Mw: 5.4 Region J&K (India). Waveform tendency is very clear to detect different patterns to recognize how far a station from epicenter.

Hybridization is a measure from the field of information theory, making upon entropy generally calculating the difference between two probability distributions. Cross-entropy can be used as a loss function

when optimizing classification models like logistic regression and artificial neural networks. The performance of the proposed neural network with respect to cross entropy is shown in Fig. 5.1 and Fig. 5.2 shows the obtained performance parameters. Mean Squared Error is the average squared difference between outputs and targets that shows the R2 score obtained in test is 0.727 is presented in Fig. 5.4. The performance can be improved by including more data and optimization.

The point of the present work is to optimize ANN with Artificial Bee Colony and conceptualize and an Algorithm to improve prediction of earthquake's magnitude. Error histogram, observed that mostly errors are concentrated around 0 error value with few outliers are shown in Fig. 5.3.

The performance of the proposed neural network with respect to cross entropyis shown in Fig. 4 and Fig. 5.2 shows the obtained performance parameters. MSE is the average difference between outputs and targets that shows the R2 score obtained in test is 0.803. The performance can be improved by including more data and optimization.

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