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A Study on Earthquake Prediction Using Neural Network Algorithms

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***Abstract*—** Data mining is a result of advancement in information technology. It is a progression of discovering knowledge from large databases. Earthquake prediction is one of the major issue in seismology. The intention of the prediction is to make possible emergency measures to reduce death and demolition, breakdown by giving forewarning about earthquake. Now a day's neural network plays a vital role in the prediction of earthquake. Back propagation is a neural network learning algorithm is used to analyze the relationship between the earthquakes. This analysis is performed with the parameters such as date, time of the event, latitude, longitude, depth and magnitude of past earth quake events. This set of data converted into seismic indicators by doing mathematical calculations and given to the input layer of neural network. The output of neural network is used for prediction. In this paper, various research articles deals with earthquake which are using neural network algorithms are studied and the accuracy rate of the prediction is compared.

***Keywords*—**Backpropagation, Neural network, Earthquake, Prediction

I. INTRODUCTION

Data mining is the process of discovering perceptive, remarkable, and new patterns, as well as descriptive, reasonable and predictive models from significant data[1].It is an integral part of knowledge discovery in databases (KDD), which convert the raw data into functional information using the transformation steps, from data pre-processing to post-processing. There are two main tasks in data mining such as Descriptive task and Predictive task. The Descriptive task derives the patterns based on the database. The Predictive task builds a Predictive model based on the attributes in the database. In the prediction model the target variable (attribute to be predicted) and the explanatory variables (given input attributes) are used for making the prediction[2].

Natural disaster is a major incident caused by nature. It includes floods, hurricanes, cyclones, drought, earthquakes, and tsunamis. Earthquakes are one of the major catastrophes faced by the world. Apart from the earthquake the other disasters are predicted and tracked weeks or days in advance. But the earthquake hit completely without warning. The exact prediction of earthquakes is not possible, but towards the back look through the past seismic record allows geologists to discover some distinct patterns.

Various Mathematical computations and Statistical techniques were used by a lot of researchers for the prediction of the earthquake. Due to the uncertainty, the complete study and analysis of earthquake are very much important for the prediction. Prediction using intelligent computational methods is increased nowadays. These methods are used to extract the relationships between different earthquakes happened at different times and locations. It helps us to know the happening of earthquakes. The early prediction is used to prevent the human life loss and damages[3].

Various Data mining algorithms are used to develop the predictive model for natural disasters that predicts the future events using historical data. Some of the the techniques used for forecast are classification, regression, supervised and unsupervised learning algorithms, support vector machine and artificial neural netwroks[4]. Many researchers use clustering and classification algorithms for earthquake prediction. In supervised learning algorithm, the training process evaluates the data pattern and recognizes the similar pattern[5]. The support vector machine is another algorithm which contains different kernel functions, produces the accurate prediction in the catastrophe flood[6]. Three layered artificial neural network back propagation learning is used to predict the rainfall in the Udupi district of Karnataka [7].

Reachers also done a comparative analysis for prediction of rainfall using various algorithms and gave the conclusion that the performance of the neural network algorithm is having more accuracy than the other algorithms[8]. Neural network algorithms are naturally parallel. The computation process could be speed up by parallelization techniques. This aspect contributes the value of the neural network for classification and prediction in data mining [9]. Nowadays, a

large number of machine learning and neural network algorithms are used to develop the multiple prediction models which improves the efficiency of the prediction. The objective of this paper is to study the various neural network algorithms, identify the seismic parameters of the earthquake and find out the more accurate neural network model for the prediction. The rest of the paper is organized as follows. Section II explain the basic concepts of neural network, Section III contain the earthquake prediction methodology, Section IV dicussed the Result with the classification of prediction accuracy measures from various research works and finally in the Section V conclude the paper and give the future scope.

II. NEURAL NETWORK

2.1 Neural Network in Data mining

A neural network consists of simple processing units, the neurons, and directed, weighted connections between those neurons. The strength of a connection between two neurons i and j is referred to as $W_{i,j}$,which is called weight[10]. The application of neural networks in the data mining is extremely large and it is used for classification, clustering, feature mining, prediction and pattern recognition. During the training process of neural network, the neural network method progressively calculate the weights by using repeated iteration [11].

2.2 Neural Network models

The neural network model can be divided into the following three types[10].

(a) **Feed-forward networks**: In this architecture, the multi layer perceptron (MLP) and the back-propagation model are mainly used in prediction and pattern recognition.

(b) **Feed-back network**: The Hopfield discrete model and continuous model are used for associative memory and optimization calculation.

(c) **Self-organization networks**: Adaptive resonance theory (ART) model and Kohonen's self-organizing Map(SOM) are the representation of this architecture. It is mainly used for cluster analysis.

The neural network model is a dominant computational model which acquire the knowledge throughout the training process.

2.3 Neural Network Training Algorithms

A neural network learning process is carried out by the training algorithms.There are numbers of training algorithms are available with different characteristics and performance. The learning problem in a neural network is formulated in terms of the minimization of loss function.At each iteration, the loss will be decreased by adjusting the network parameters. In each iteration the error is checked. When it attains a specified condition the training algorithm will be stopped. The following are the important training algorithms for neural network.

a. Gradient descent
b. Newton's method
c. Conjugate Gradient
d. Quasi-newton
e. Levenberg Marquardt

Each algorithm has different characteristics and performance[12].

III. PREDICTION METHODOLOGY

3.1 Back propagation Neural Network

Backpropagation is one of the most commonly used neural network learning algorithm. The backpropagation algorithm performs learning on a multilayer feed-forward neural network. It iteratively learns using a set of weights for prediction. A multilayer feed-forward network consists of an input layer, one or more hidden layers, and an output layer [9].

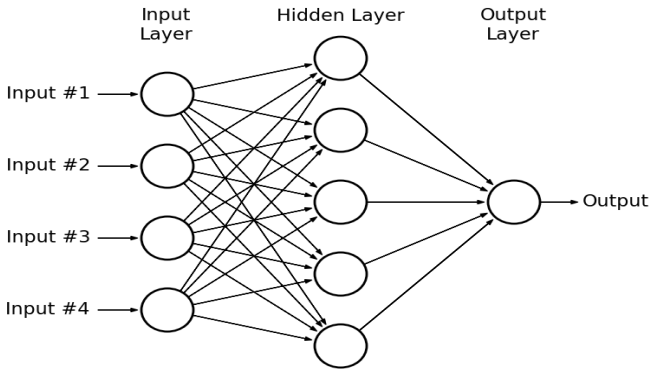

Figure 1. A multilayer feed-forward neural network

In the above Figure 1, each layer is made up of units. The input to the network corresponds to the attributes measured for each training tuples. The Neural network learning process requires a set of data for the training process before its testing. The training algorithm is used to train the model.The trained system is expected to acquire the ability to predict outputs based on any given inputs. The common method to evaluate the performance of the Neural network system are Mean-Squared-Error (MSE) and Coefficient of Correlation (R) computed after the feed-forward calculations[13].

The Backpropagation neural network algorithm consists of two calculation phases: Feed-forward calculation and Back propagation calculation. In Feed-forward processing, input data is fed into the input layer, and then the calculation is continued until it reaches the output layer during the feed-forward calculation. The error value is calculated using the difference between the predicted output value and the target value. In the Backpropagation calculation, the error value obtained in the previous phase is used to modify the weight factors of each neuron in the output layer, then the hidden

layer. The completion of one Feed-forward and Back propagation calculation for each data set is called one epoch[12].The feed forward calculations uses the (1) and (2) to compute the value of the neurons.

$$I_j = W_{ij} O_i + \theta_j \quad (1)$$

$$O_j = \frac{1}{1 + e^{-I_j}} \quad (2)$$

Where,

I_j = net input.
W_{ij} = Weight of the connection from I to J.
O_i = outout of unit I from previous layer.
Θ_j = Bias of the unit
O_j = Output of the activation function.

Back probagation neural network model can be used for prediction in any applications using input parameters.

Earthquake prediction using Backpropogation model

The following Figure 2 shows the Neural network Earthquake architecture model with several input and single output[14].

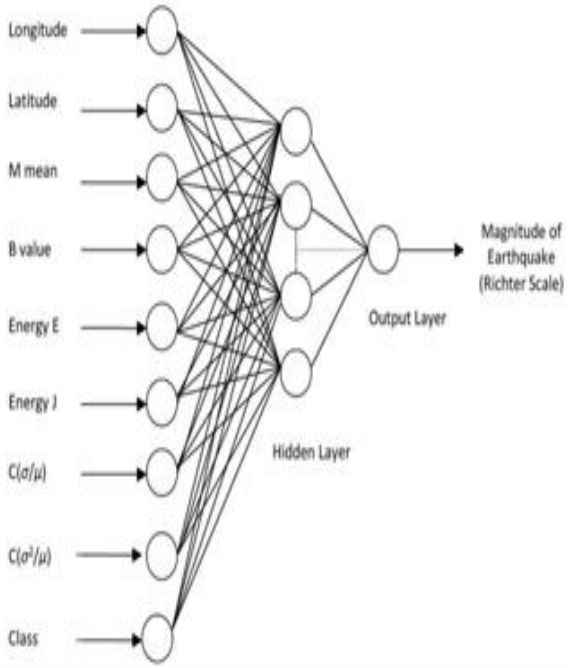

Figure 2. Neural network Earthquake architecture

In the above Figure 2., The seismic indicators such as latitude,longitude,b-values, Gutenberg-Richter inverse power law curve for the n events, the rate of square root of seismic energy released during the n events, energy released from the event, the mean square deviation about the regression line based on the Gutenberg-Richer inverse power law for the n events, coefficient of variation of mean time and average value of the magnitude for last n events are taken as input and developed the neural network architecture [14].

The earthquake data are available from the various resources such as USGS (United States Geological Survey), NCEI (National Centres for environmental Information), and IMD (India Meteorological Department) .These repositories contains the seismic indicators such as Date, Time, Latitude, Longitude, Magnitude and Depth of the event. The detail of input seismic indicators are given below.

Longitude & Latitude

Longitude and latitude are the earth's location coordination number.

Mmean

It is the magnitude mean value.

b-value

The parameter b is related to the tectonic parameter.The b-value evaluate[15] the relative number of small to large earthquakes that occur in a given area in a given time period. The b value is computed as follows,

$$b = \frac{1}{M_{mean} - M_{\min}} \log e \quad (3)$$

M_{mean} is the mean magnitude and M_{min} is the minimum magnitude of the given sample.

Energy E

Most calculations of the magnitude-energy relation depend directly or indirectly on the Equation (3) for a wave group from a point source [15], (E in ergs)

$$\log E = 5.8 + 2.4m \quad (4)$$

Where m is the magnitude Richter scale value.

Energy J

Seismic wave energy J(ergs) has been computed from the magnitude M from the (5)

$$\log_{10} J = 9 + 1.8M \quad (5)$$

C(σ /μ)-The coefficient of variation of the mean time is σ / μ where σ —SD/ M_{mean} and μ — Mean Time in days (time period between two events) and SD –Standard Deviation.

C(σ^2/n)-Mean square deviation is (σ^2/ n)where n-Number of earthquakes above M_{mean} between two events.

Class intervals

Class intervals are separated based on the magnitude interval (Example: Class1 is the magnitude<3.0,Class2 is >3.1 and <5.0 ,etc.,)

IV. RESULTS AND DISCUSSION

The results are based on different machine learning methods used by the various researchers. The research articles related to the prediction of earthquake is analyed here. In Table 1, various neural network model along with region and yearwise dataset are given. Also in some research work, the Neural network algorithms are compared with KNN, SVM, a Bayesian network and decision tree algorithms. In this

analysis, the performances of prediction accuracy in every algorithm is measured. Each algorithm produces a successful prediction rate. Most of the prediction findings using neural network algorithms give above 75% of prediction accuracy. It proves that neural network methods increase the scope at some extent in prediction. If we combine more neural network methods, that will achieve better result in prediction and overcome any existing short comes.

Table 1. Classification of neural network methods in earthquake prediction

S.No	Method	Data set/Region(Year)	Findings rate
1	Backpropogation neural network model[14]	India metrological Department/Himalayan Region (2013-2015)	Predictions of small and moderate earthquakes are 66.66% and 75% respectively. Prediction of large quakes are no more.
2	Three layer perceptron neural network with back propogation algorithm [16]	Seismological Institute, National Observatory of Athens/Greece/(1980-2001)	Accuracy Rate calculated based on Mean Absolute Error.The accuracy rate is 84.01*%*
3	Support Vector regressor and Hybrid neural Network [17]	United States Geological Survey(USGS)-Hindukush, Chile and Southern California regions	Prediction accuracy rate of three regions are 82.7%,84.9%,90.6%
4	Feed forward neural network model with multi-hidden layers[18]	Northern California Earthquake Data Centre (NCEDC)/Northern Red Sea region(1969 – 2009).	Neural network model is at least 32% better than other proposed methods.
5	A feed-forward Levenberg-Marquardt backpropagation (LMBP) neural network, a recurrent neural network, and a radial basis function (RBF) neural network[19]	The Southern California Earthquake-Data Centre (SCEC),The United States Geological Survey (USGS)/ Southern California and the San Francisco bay region.(1987-1996)	Recurrent neural network model yields the best prediction accuracies compared with the BP and RBF networks.
6	Artificial neural network (ANN) and fuzzy inference (FIS) systems. (ANFIS)[20]	European-Mediterranean Seismological Centre-Andaman Nikobar Islands.(2004-2016)	ANFIS prediction is much more accurate and precise.
7	Three-layer BP neural network[21]	The Detection of Electro-Magnetic Emission Transmitted from Earthquake Regions (DEMETER) satellite data and seismic belt information(2007).	The accuracy of prediction in the test is 81.2%.
8	Feed-forward neural network,recurrent neural network, random forest, multi layer perceptron, radial basis neural network, and support vector machine[22]	US Geological Survey/ Northern Pakistan (1976-2013)	The Feed-forward neural network was highlighted with the prediction accuracy of 75%.
9	Earthquake Predictor based Artificial Neural Network compared KNN, SVM, Bayesian network and decision tree method[23]	US Geological Survey/Tokyo(2015)	Compared with other techniques the Neural network achieved the prediction rate of more than 70%.
10	Radial basis functions(RBF) neural network[24]	National Centre Earthquake Information (NEIC)/Alaska Aleutian Arc(2000-2010)	RBF neural network predicts large earth quake with 92%
11	Three layer feed-forward artificial Neural network[25]	Chile's National Seismological Service/Chile with four zones(2003-2010)	Prediction for all zones average is 87.2%
12	Recurrent neural network compared with pattern recognition neural network,Random forest,Lp boost algorithm.[26]	Centre for Earthquake studies and United States Geological survey/Hindukush region(1976-2013)	Prediction Accuracy of Recurrent Neural Network is 64%

V. CONCLUSION AND FUTURE SCOPE

Prediction can be achieved using many algorithms. Many researchers applied those alogorithms in their research work. They used worldwide historical data for earthquake prediction. In that neural network techniques are used by many researchers because neural network give more accuracy in earthquake predictions. This shows that, the neural network can do prediction more accurately compare with other methods. The future prediction work in seismology should use the neural network algorithms with statistical testing in order to achieve high precision in prediction accuracy. The high precision accuracy in the prediction of earthquake can help public to reduce the casualties and minimize the loss and economic damages.

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Authors Profile

Dr.K.Mohan Kumar received Master of Computer Science, Ph.D in Computer Science from Bharathidasan University, Tiruchirappalli, India and M.Phil computer science from Manonmaniyam Sundaranar University, Thirunelveli, India. He is currently working in PG and Research Department of Computer Science, Rajah Serfoji Government College, Thanjavur, T.N, India. His main research work focuses on IoT,Big Data Analytics and Computational Intelligence based education. He has published more than 50 research papers in reputed International journals. He has 23 years of teaching experience and 18 years of Research Experience.

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