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DEVELOPMENT AND COMPARISON OF HYBRID RAINFALL PREDICTION MODEL

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ABSTRACT

Rainfall prediction is very essential for every country because it decides each country economy. Since weather affects everyone irrespective of political boundaries, the application of Information and Communication Technologies (ICT) has helped to establish and share data and best practices adopted by developed countries and standard operating procedures to all. Considering the present availability of technology, data reception tools and computational power, researchers are developing different direct and indirect high resolution approaches like: deterministic approach using numerical weather models for rainfall prediction for short and medium range forecasting; and statistical approach using neural networks, fuzzy classification systems and genetic algorithms.

The present work is an attempt to develop and evaluate three hybrid rainfall forecasting model: Neural Network and Fuzzy Expert System, Domain Expert System(DES) and Neural Networks (NN) and Combination of Fuzzy Expert System and Data Mining using observations from Automatic Weather Stations (AWS) collected from National Climatic Data Centre (NCDC) for the period 2000-2014. The three statistical models were developed using WEKA &Java and MATLAB, respectively. Past works have commonly used five critical meteorological parameters like: Temperature, Dew Point, Mean Sea-level Pressure (MSLP), Wind speed, Humidity to correlate it with precipitation. In the present study, the data and the techniques were evaluated for four selected cities in India located in four different geographical regions of the country. The results were quite interesting and the rainfall prediction made combination through Neural Network and Fuzzy Expert System for all four regions were reasonably accurate compared to the other models.

I. INTRODUCTION

Why rainfall forecasting is a challenging job in India? The whole of India has a tropical monsoonal climate, since the greater part of the country lies within the trophies, and the climate is influenced by the monsoons. The

position of the mountain ranges and direction of the rain-bearing winds are the two main factors that determine the climate of India.*Factors Affecting the Climate of India:*Latitude: India lies between 8 0N and 37 0 N latitudes. The Tropic of Cancer passes through the middle of India, thus making the southern half of India in the Torrid Zone and the northern half in the Temperature Zone.*Himalaya Mountains:* The Himalayas play an important role in lending a sub-tropical touch to the climate of India. The lofty Himalaya Mountains form a barrier which effects the climate of India. It prevents the cold winds of north Asia from blowing into India, thus protecting it from severely cold winters. It also traps the Monsoon winds, forcing them to shed their moisture within the sub-continent.*Altitude:* Temperature decreases with height. Places in the mountains are cooler than places on the plains.*Distance from the sea*: With a long coastline, large coastal areas have an equable climate. Areas in the interior of India are far away from the moderating influence of the sea. Such areas have extremes of climate. *Western Disturbances:* The low pressure systems that originate over the eastern Mediterranean region in winter and move eastwards towards India passing over Iran, Afghanistan and Pakistan are responsible for the winter rain in northern India. *Conditions in the Regions Surrounding India*: Temperature and pressure conditions in East Africa, Iran, Central Asia and Tibet determine the strength of the monsoons and the occasional dry spells. For example, high temperatures in East Africa may draw the monsoon winds from the Indian Ocean into that region thus, causing a dry spell. *Conditions over the Ocean*: The weather conditions over the Indian Ocean and the China Sea may be responsible for typhoons which often affect the east coast of India. *Jet Streams*: Air currents in the upper layers of the atmosphere known as jet steams could determine the arrival of the monsoons and departure of the monsoons.

II LITERATURE SURVEY

Sharma, A., and G. Nijhawan (2015) The paper describes the implementation of Back Propagation algorithm and its two derivatives using a multi-layered Feed Forward Network (FFN) architecture on 1-year daily observation data from Delhi to predict rainfall. The authors classified the observation data over Delhi as seasonal (i.e due to monsoon) and non-seasonal. The authors implemented the algorithm in MATLAB and evaluated the three algorithms: Back Propagation, Cascaded Back Propagation and Layer Recurrent Network with the Mean Square Error (MSE) as the metric. With their dataset, their major findings were: 1) the Back Propagation Algorithm was better than the other two; 2) Increasing the number of neurons in the network decreases the MSE, and hence performs of all the three selected algorithms is better.

Taksande et al., (2014) has analysed the commonly adopted data mining algorithms for rain fall prediction. The five commonly adopted data mining algorithms namely Neural Network (NN), Random Forest, Classification and Regression Tree (CRT), Support Vector Machine (SVM) and k-nearest neighbour, used for forecasting. They adopt a ANN and GA for rainfall forecasting are tested. Using data of temperature, air pressure, rainfall, relative humidity and wind speed, it is observed that the neural nets performed the best in the group. The paper then develops a HMM based GA and compares the predictability with the best performer of the commonly adopted data mining ANN models. It is observed that the result from HMM based GA outperformed those from the ANN models.

Indrabayu et al., (2013) proposed a hybrid approach (SVM-Fuzzy) that integrates the Support Vector Machine with Fuzzy Logic methods. Using the data for the region Makassar Indonesia for 10 years (2001-2010) with

predictor variables, such as temperature, wind speed, humidity and rainfall, observe the proposed SVM-Fuzzy method to outperform the Neuro-Fuzzy approach. The proposed hybrid approach, SVM-Fuzzy approach not only is found to be accurate but also observed to follow the trend of actual data. The accuracy of the SVM-Fuzzy approach are found to be superior to the Neuro-Fuzzy approach.

Hemachandra et al., (2013) The objective of this study is to develop an algorithm to predict electric load forecasting using Neuro-Fuzzy Systems. They have discussed various techniques like Regression method, Fuzzy logic approach, Neural Network approach, Neuro-fuzzy approach etc. They suggest a hybrid model of Neural Network and Fuzzy (Neuro-Fuzzy) for short-term load forecasting. The mean error from the Neuro-fuzzy model is found to be -0.0040 which is much superior to 1.70274 that from the multiple linear regression model, thererby indicating the superiority of the Neuro-fuzzy model vis-a-vis the multiple linear regression in forecasting at short-term.

Rao et al.,(2013) have developed an Enhanced Support Vector Regression (ESVR) model and finds a critical modelling design using the non linear regression namely Support Vector Machines. Comparing the input parameters of weather like temperature, water vapor, atmospheric pressure, dew point, wind speed, wind direction, rainfall with a MLP (Multi-Layer preceptron) classification. The outcome of this study is the algorithm frames a class label and do categorical classification and report the current weather and predicate the future occurring conditions of weather.

Ranjan et al.,(2012) analyzes the impact weather on crop yield, in Orissa region, using Aridity Index. They find that rainfall and temperature are the two important factors that affect crop yields. This study, using multiple regression analysis, has negated the method of direct use of meteorological factors (either monthly or seasonal), to measure weather impact on crop yield. They advocate the incorporation of 'aridity index' variable in the regression model to simplify the econometric analysis and also found to improve results.

Kumar et al.,(2012) developed a statistical model to improve the operational forecast accuracy. The author used 8-parameter and 10-parameter power regression models from 2003 to 2006 for Long Range Forecasting and new statistical ensemble forecasting system are explained. The model equations are developed by using the linear regression and neural network techniques. The outcome of this study is that the skill of the forecast attained through this method is found to be generally better as compared to the skill of the forecast obtained from the models attempted by other authors in the past.

III STUDY AREA

The present study focuses on observation data from India. The selected study sites are from four distinct geographic locations, with each city experiencing rainfall in different monsoon phases and exhibiting different climatic zones. The selected cities are: Patiala, Kolkata, Mumbai and Chennai, located in Northern, Eastern, Western and Southern regions of the country, respectively.

The city of Patiala is located in Punjab at about 30 °N latitude and according Köppen-Geiger climate classification (KGCCS; [Peel et al., 2007]), it is classified as *BSh*, which corresponds to *Steppe* or *semi-arid climate*. It experiences very harsh summers with temperatures touching 40 °C and pleasant winters with an

average temperature of 8 °C. The average annual rainfall is about 754 mm, with most of the rains occurring in July, August and September months, i.e., SW monsoon period.

Kolkata is located at about 22 °N latitude and according to KGCCS; it is classified as *Aw*, which corresponds to *Tropical Wet and Dry Climate* or *Tropical Savanna*. The temperature ranges from a record high of 43.7 °C in June to a record low of 6.7 °C in January. The average annual rainfall is about 1735 mm, with rainfall over 100 mm occurring between May and October [IMD].

Mumbai is located at latitude of approximately 19 °N and according to KGCCS, Mumbai's climate is classified as *Am*, which corresponds to *tropical wet climate* or *tropical monsoon and trade wind littoral climate*. The coastal and tropical nature of the city modulates the temperatures, hence the mean maximum summer temperature is about 32 °C with a mean minimum winter temperature is about 30 °C, while the record maximum and minimum temperatures are 42.2 °C in April and 7.4 °C in January, respectively [IMD]. Mumbai city experiences lot of rainfall with an annual average of 2258 mm, with more than 100 mm between May and October.

The city of Chennai is located at approximately 13 °N latitude and according to KGCCS, it is classified as *Aw*. Chennai is located on the "thermal equator", with a record maximum and minimum of 45 °C in May and 13.9 °C in January, respectively. The mean annual rainfall is about 1400 mm, with peak rain season during the retreating monsoon phase (NE monsoon) during November. This is in marked contrast with the other three selected stations.

IV METHODOLOGY

Criteria for selection of the critical parameters:

From the recent works 13 parameters were found to influence rainfall amount, of which top five independent variables (parameters) were considered based on reported correlation. They are: Temperature, Dew Point, Mean Sea Level Pressure (MSLP), Wind Speed (WS) and Humidity.

Data collection and preparation: Fifteen years of daily data (2000-2014)have been collected from NCDC and the data were quality controlled for missing data. The data was collected for the above mentioned four cities of India.

Neural Network and Fuzzy Expert System Hybrid

A neuro-fuzzy system is a fuzzy system that uses a learning algorithm derived from or inspired by neural network theory to determine its parameters (fuzzy sets and fuzzy rules) by processing data samples. (Indrabayu, 2013)

A neuro-fuzzy system is based on a fuzzy system which is trained by a learning algorithm derived from neural network theory. The (heuristical) learning procedure operates on local information and causes only local modifications in the underlying fuzzy system. (Hamdan, 2013)

A neuro-fuzzy system can be viewed as a 3-layer feedforward neural network. The first layer represents input variables, the middle (hidden) layer represents fuzzy rules and the third layer represents output variables. Fuzzy

sets are encoded as (fuzzy) connection weights. It is not necessary to represent a fuzzy system like this to apply a learning algorithm to it. However, it can be convenient, because it represents the data flow of input processing and learning within the model. (Roy, 2005)

Learning method in Fuzzy Neural Network

Supervised learning in FNN consists in modifying their connection weights in a such a manner that an error measure is progressively reduced

Its performance should remain acceptable when it is presented with new data

Set of training data pairs (xk, dk) for k=1,2..n

wt+1=wt + Dwt, where weight change is a given function of difference between the target response d and calculated node output y Dwt=F(|dt-yt|)

Mean square error E – measure of how well the fuzzy network maps input data into the corresponding output

E(w) = ½å(dk-yk)2

Gradient descent Dwi,j=-n ∂E/∂W

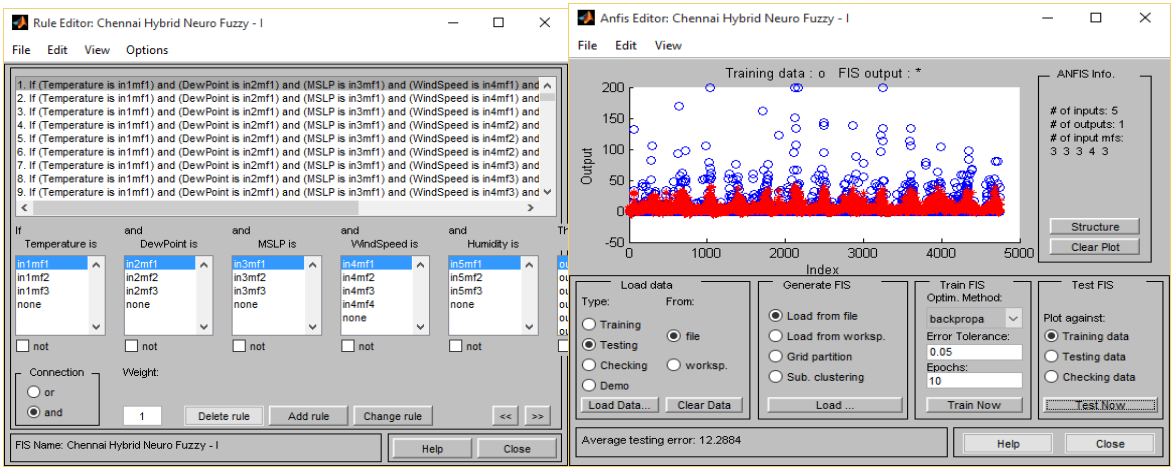
A neuro-fuzzy system that can identify parameters by using supervised learning methods and also Sugeno-type fuzzy system has the learning capabilities. This system has the following qualities (i) It is a first order model. (ii) Nodes have the same function for a given layer but are different from one layer to the next. (iii) Learning algorithm is a hybrid supervised method based on gradient descent and Least-squares. (iv) Forward phase: signals travel up to layer 4 and the relevant parameters are fitted by least squares. (v) Backward phase: the error signals travel backward, and the premise parameters are updated as in back-propagation (Hamdan, 2013). (vi) Fuzzy toolbox MATLAB. (vii) Mackey-Glass prediction / excellent non-linear fitting and generalization / less parameters and training time is compared with ANN methods:

Neuro-Fuzzy System Model Applied in Various Research Applications:

Sl, No	Author	Area	Technology Used	Parameter used	Data used
1	Indrabayu (2013)	A new Approach of Expert System for Rainfall Prediction Based on Data Series	i) Neural Network,(NN), MATLAB tool (ii) SVM-Fuzzy method, NN-Fuzzy method	Temperature, Windspeed, and Humidity	10 year data (2001-2010)
2	Hemachandra(2013)	Electric Load Forecasting using Neuro-Fuzzy Systems	Regression Method Fuzzy Logic Approach Neural Network Approach Hybrid(Neuro-fuzzy approach)	Temperature Wind Speed Dew Point MSLP	2000-3000 data points

3	Hamdan(2013)	An Exploration of the Adaptive Neuro-Fuzzy Inference System (ANFIS) in Modelling Survival	Neuro-Fuzzy	Cancer Data sets and related Parameters	10 year data
4	Roy (2005)	Design Of Adaptive Neuro-Fuzzy Inference System For Predicting Surface Roughness In Turning Operation	Neural Network Sugeno Model Back propagation	Cutting parameters Cutting speed, feed rate, depth of cutting	6 years
5	Sharma(2007)	Artificial Neural Network Fuzzy Inference System (ANFIS) For Brain Tumor Detection	KNN and FCM	M R Brain Tumor Images	Four types of tumor images. Training and Test data

Fuzzy logic and neural networks are natural complementary tools in building intelligent systems. While neural networks are low-level computational structures that perform well when dealing with raw data, fuzzy logic deals with reasoning on a higher level, using linguistic information acquired from domain experts. However, fuzzy systems lack the ability to learn and cannot adjust themselves to a new environment. On the other hand, although neural networks can learn, they are black-box to the user.



Artificial Neuro-Fuzzy Inference System (ANFIS) is the fuzzy-logic-based paradigm that grasps the learning abilities of ANN to enhance the intelligent system's performance using the knowledge gained after learning. Using a given input-output data set, ANFIS constructs a fuzzy inference system whose membership function parameters are tuned or adjusted using a hybrid type of neural algorithms. (Patel, 2014)

Neural networks and fuzzy systems can be combined to join its advantages and to cure its individual illness. Neural networks introduce its computational characteristics of learning in the fuzzy systems and receive from them the interpretation and clarity of systems representation. Thus, the disadvantages of the fuzzy systems are compensated by the capacities of the neural networks. These techniques are complementary, which justifies its

use together. A neuro-fuzzy system can be interpreted as a set of fuzzy rules. This system can be total created from input output data or initialised with the à priori knowledge in the same way of fuzzy rules. The resultant system by fusing fuzzy systems and neural networks has as advantages of learning through patterns and the easy interpretation of its functionality

Hybrid Neural Network and Fuzzy Expert System prediction results

Station/Day	1 Day	3 Days	7 Days	14 Days	28 Days
Chennai	4.58	7.25	8.72	7.26	6.19
Kolkata	6.28	9.39	20.93	28.9	39.19
Mumbai	16.55	14.79	17.07	21.64	36.5
Patiala	2.58	2.92	10.61	13.61	20.02

Domain Expert and Neural Network Hybrid Model

Here both Neural Network Techniques and Domain Expert knowledge (rules) are combined to increase the quality of input data and output information. Domain Expert knowledge (rules) is integrated into the Neural Network to obtain the following results. Normalizing the data to facilitate the Neural Network System to read. Defining the both Neural Network and Domain Expert System data and create the membership functions. Defining the input for member function and defining as GRID Partition. The input and output member function defined as TRIMF and LINEAR. Applying the Neural Network predicted output in the Domain Fuzzy Inference System and generate the Hybrid Neural Network and Domain Inference System (HNNDES). Train the data (13 year) with hybrid Domain FIS system and apply back propagation algorithm and test with 2 yr. data.

The hybrid model (Combining both Domain Expert System and Neural Network technology) is a hybrid environment within which neural network and expert system technologies are combined to develop intelligent applications that outperform either model alone. An expert system is useful in applications for which the expertise of a domain expert is available, or the domain knowledge can be described as a set of rules and facts. Neural Network is useful in applications for which there is no structured domain knowledge. Most real life problems fall somewhere between these two realms and therefore the hybrid environment which integrates both technologies is desirables. The new hybrid model is such a hybrid environment, the functionality of which has been enhanced. (Depold, 2007)

The ANNs and KBES can be integrated to strengthen the best features of each. The pursuit of symbiotic system architectures which integrate multiple modalities may provide enhanced inference functionality and dynamic control of those architecture portions that change through time. Examples of some possible ways to integrate ANNs and KBES are explained below:

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Development of innovative knowledge acquisition strategies using ANNs to extract and synthesize the knowledge. The knowledge acquired could be translated to rules and therefore the KBES would provide a better human-machine symbiotic system--justification and explanation mechanism support [Romaniuk,1990].

Domain Expert and Neural Network System Applied in various Research Applications

Sl.no	Author	Area	Technology Used	Parameter used	Data used
1	Depold(2007)	The Application of Expert Systems and Neural Networks to Gas Turbine Prognostics and Diagnostics	i) Neural Network,(NN) ii) Expert system iii) Decision-MakingTools	Input parameter for developing the new tools	650 data points
2	Devi(2011)	The Expert System Designed to Improve Customer Satisfaction	Neural Network Approach Fuzzy Delphi Expert system	Customer details	1200 data points
3	Nagasaka(2013)	A Neural Network and Expert Systems Based Model for Measuring Business Effectiveness of Information Technology Investment	Expert System Neural Network Back error propagation	Business data sets	200 data points
4	Basheer (2005)	Integration of Artificial Neural Network and Expert System for Material Classification of Natural Fibre Reinforced Polymer Composites	Artificial Neural Network KBMS Expert Neural Classifier	Density, Tensile strength and Young's modulus of the candidate materials	120 Data sets
5	Jimmy Singla (2014)	Medical Expert Systems for Diagnosis of Various Diseases	Neural Network and Expert System module	Disease symptoms	150 Data Set

Both systems can handle incorrect rules. The difference is that Fuzzy points out exactly which rules cause a discrepancy with the provided data set. This adds an extra dimension to the system because the expert can verify his knowledge rules. The KBANN system just lets the weights of a certain connection drop to zero, when there is a low correlation between two concepts. The network performs well, but it is hard to tell which initial rules were wrong. Whether this is a problem depends on the goal of the implementation: if you want to verify your rule set with actual data, the Fu system would be more appropriate. If your goal is to make a network that simply does the job, the KBANN black box is suitable. (Basheer, 2007)

Hybrid Domain Expert and Neural Network System prediction result

Station/Day	1 Day	3 Days	7 Days	14 Days	28 Days
Chennai	7.01	8.17	9.37	7.94	7.08
Kolkata	14.09	12.85	24.39	31.50	40.9
Mumbai	13.61	15.99	20.08	25.05	38.89
Patiala	10.84	10.27	12.03	15.29	19.71

Data Mining and Neural Network Hybrid Model

Neural Network Model is designed to train along with data mining rainfall output data and tested with test data set. The Neural Network learns the input-output relationship through the training process. The learning process in the Neural Network is an interactive procedure in which its connection weights are adapted through the presentation of a set of input-output training example pairs. The Network technique used "Feed-forward of input data and back-propagation of errors" and training function used hyper sigmoid. The Artificial Neural Network (ANN) models were selected through a process of iterations for the number of nodes, and the Neural Network parameters to provide higher accuracies for the training

Adaptive Learning in Hybrid system

(i) Adaptive learning rate algorithms are usually based on the following approaches: (i) start with a small learning rate and increase it exponentially, if successive iterations the error, or rapidly decrease it if a significant error increase occurs.(Battiti, 1989)

Data Mining and Neural Network Model Applied in various Research Applications

Sl no	Author	Title of the paper	Techniques/ methods	Feed Forward Algorithms
1	(Gaur, 2012)	Neural networks in data mining	Classification, clustering, feature mining, Prediction and pattern recognition.	yes
2	(Aleem Ali,2012)	A concise artificial neural network in data mining	Statistical Method, Production rule IF– THEN, Decision Tree, Genetic Algorithms, Artificial Neural Network.	yes
3	(Sonal kadu,1996)	Effective Data Mining and Neural Network	Neural network method DM	yes
4	(Xianjun ,2010)	Research of Data Mining Based on Neural Network:	Neural network method Backpropagation	yes
5	(Paulo Certez,2012)	Data mining with neural network and support machine using the r/miner tool	Data Mining	No
6	(Ogasawara, 2013)	Neural network Cartridge for Data Mining on Time Series:	Min-Max, Z-Score, Decimal Scaling Normalization.	No
7	(Wang, 2012)	Data Mining Using Dynamic Constructed Recurrent Fuzzy Neural Network:	Symbolic decision tree, feed forward neural network	No

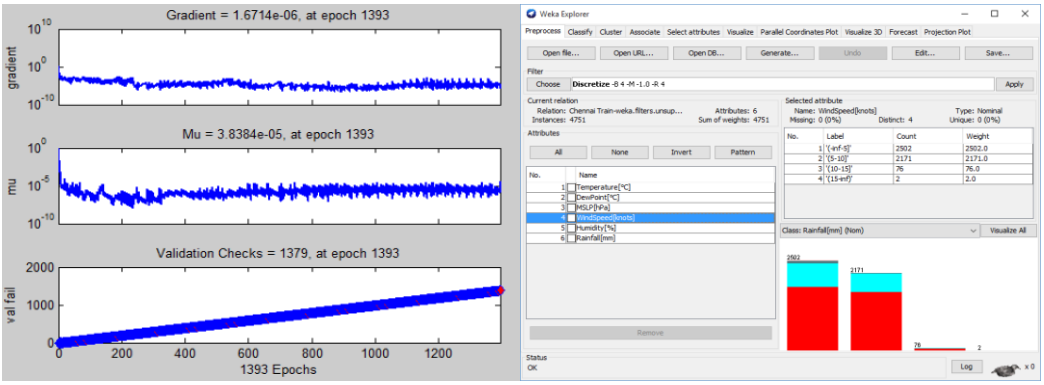
(ii) Start with a small learning rate and increase it, if successive iterations keep gradient direction fairly constant, or rapidly decrease it, if the direction of the gradient varies greatly at each iteration (Fallside, 1987)

(iii) For each weight, an individual learning rate is given, which increases if the successive changes in the weights are in the same direction and decreases otherwise. The well-knownDelta-bar delta method (Williams, 1990) and Silva and Almeida's method (Silva,1990). Follow the last approach. Another method of this group, named quick prop, has been presented in (Fahlman, 1989). Quickprop is based on independent secant steps in the direction of each weight (Vrahatis, 2000b). Riedmiller and Braun in 1993 proposed the Rprop algorithm (Riedmiller,1993). The algorithm updates the weights using the learning rate and the sign of the partial derivative of the error function on each weight. This approach accelerates training, mainly, in the flat regions of the error function (Pfister, 1996).

The Artificial Neural Network (ANN) models were selected through a process of iterations for the number of nodes, and the Neural Network parameters to provide higher accuracies for the training data. The five station data sets with different horizons were normalised for ingesting into hybrid data mining and neural network analysis algorithm. Each training data set, (station-wise) yielded separate neural network architecture. The best

fitted neural architecture was then used with the respective test data sets (two years of data for each station) for model accuracy.

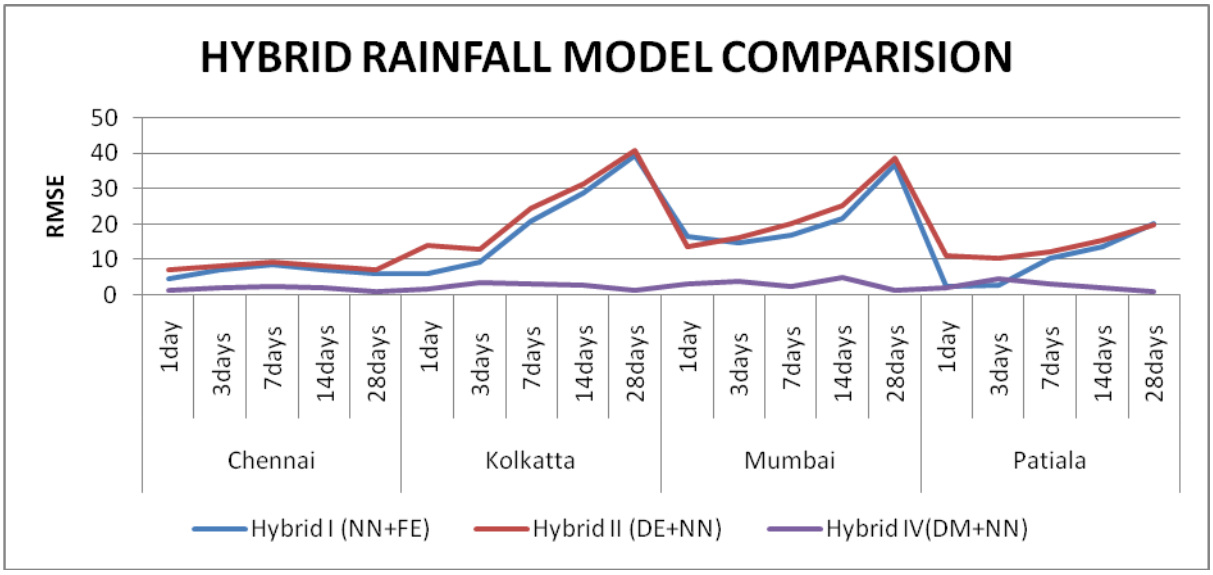
Hybrid NNDM Gradient Chart **Hybrid NNDM Parameter Classification Chart**



Hybrid DataMining and Neural Network hybrid system predicted results

Station	1 Day	3 Days	7 Days	14 Days	28 Days
Chennai	1.58	2.2	2.61	2.06	1.23
Kolkata	1.92	3.48	3.15	2.91	1.42
Mumbai	3.06	3.9	2.41	4.92	1.32
Patiala	2.23	4.57	3.21	2.26	1.14

V COMPARISON OF RESULTS



VI CONCLUSION

The present study has examined three different hybrid model models namely Neural Network and Fuzzy Expert System, Domain Expert System(DES) and Neural Networks (NN) and Combination of Data Mining (DM) and Neural Network using fifteen years daily data for four different geographical locations. Six parameters were used in this study namely Temperature, Dew Point, MSLP, Wind Speed, Humidity and Rainfall. Out of three model prediction the Data Mining and Neural Network hybridmodel predicts the rainfall with high accuracy for all horizons.

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