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SPECIAL ARTICLE

MATHEMATICAL APPROACH TOWARDS RECENT INNOVATION IN COMPUTATION AND ENGINEERING SYSTEM (MATRICS)

AN APPLICATION OF RADIAL BASIS NEURAL NETWORK FUNCTION FOR RAINFALL PREDICTION

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ABSTRACT

This research work deals with the prediction of annual rainfall of Chennai city, India using Neural Network algorithm. Chennai is one of the metropolitan city in India where disaster management is in need of knowing the extreme precipitation in advance for the control of floods and droughts. For this purpose, the monthly rainfall of Chennai is modeled using the Neural Network algorithm. The experimental result shows that the proposed neural network algorithm gives better accuracy. The error measures indicate the proposed model's performance accuracy.

KEY WORDS
Chennai, rainfall, prediction, neural network algorithm, error measure

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INTRODUCTION

Rainfall prediction is one of the most important and challenging task carried over by meteorologists all over the world. Rainfall prediction is also useful for disaster management in tackling the extreme precipitations. There are many forecasters doing lot of research to obtain more accuracy in the model they construct. There are many factors which affect rainfall prediction such as temperature, humidity, wind speed, pressure, dew point etc. and hence prediction becomes more complicated for them since the real life data are nonlinear in nature. Nowadays Artificial Neural Network algorithms are applied to time series analysis.

Artificial Neural Network plays a major role in learning and capturing the characteristics of any nonlinear natural phenomena. MoniraSumi et al [9] made an attempt for deriving forecasting models for average daily and monthly rainfall of the Fukuoka city in Japan using the artificial neural network, multivariate adaptive regression splines, the k-nearest neighbor and radial basis support vector regression together with preprocessing techniques like moving average method and principal component analysis. The K-nearest neighbor, artificial neural network, and extreme learning machine were applied for the seasonal forecasting of summer monsoon (June-September) and post-monsoon (October-December) rainfall for the Kerala state of India by Yejnaseni Dash et al and proved that extreme machine learning performed better when compared to the other two models [12]. FhiraNhita et al constructed a forecasting system with evolving neural network algorithm to forecast the monthly rainfall of Bandung Regency in Indonesia [4] and were successful by arriving a forecast accuracy of 70%. Duong TranAnh et al [3] combined two preprocessing methods seasonal decomposition and Discrete Wavelet Transform to decompose the monthly rainfall series in Vietnam and constructed the prediction models based on Artificial Neural Network and Seasonal Artificial Neural Network. Kavitha Rani et al developed Artificial Neural Network based rainfall prediction model with teaching learning optimization algorithm to improve the accuracy of the model [7]. A feed forward neural network with back propagation and Levenberg-Marquardt algorithms based prediction models were constructed by Neelam Mishra et al for forecasting one-month and two-month ahead rainfall of Northern India [10].

In this study, a prediction model for annual rainfall in Chennai is constructed using Radial Basis Function (RBF) algorithm of Neural Network structure. For this purpose, the various parameters for the prediction of rainfall used are ElNino 3.4, Maximum Temperature, Minimum Temperature, Vapour Pressure and Cloud Cover as these factors play major role particular area.

MATERIALS AND METHODS

Chennai is the capital city of Tamil Nadu state in India. Its geographic location is 13°04'N latitude and 80°17'E longitude [5]. According to the 2011 Indian census, it is the sixth-most populous city and fourth-most populous urban agglomeration in India.Chennai has a tropical wet and dry climate.. The hottest part of the year is late May to early June with maximum temperatures around 35 °C – 40 °C (95–104 °F). The coolest part of the year is January, with minimum temperatures around 19 °C –25 °C (66–77 °F). The lowest recorded temperature was 13.9 °C (57.0 °F) on 11th December 1895 and 29th January 1905. The highest recorded temperature was 45 °C (113 °F) on 31 May 2003. The average annual rainfall is about 140 cm (55 in). The city gets most of its seasonal rainfall from the north–east monsoon winds, from mid–October to mid–December. Cyclones in the Bay of Bengal sometimes hit the city. The highest annual rainfall recorded is 257 cm (101 in) in 2005 (Table 1). Prevailing winds in Chennai are usually southwesterly between April and October and north-easterly during the rest of the year.

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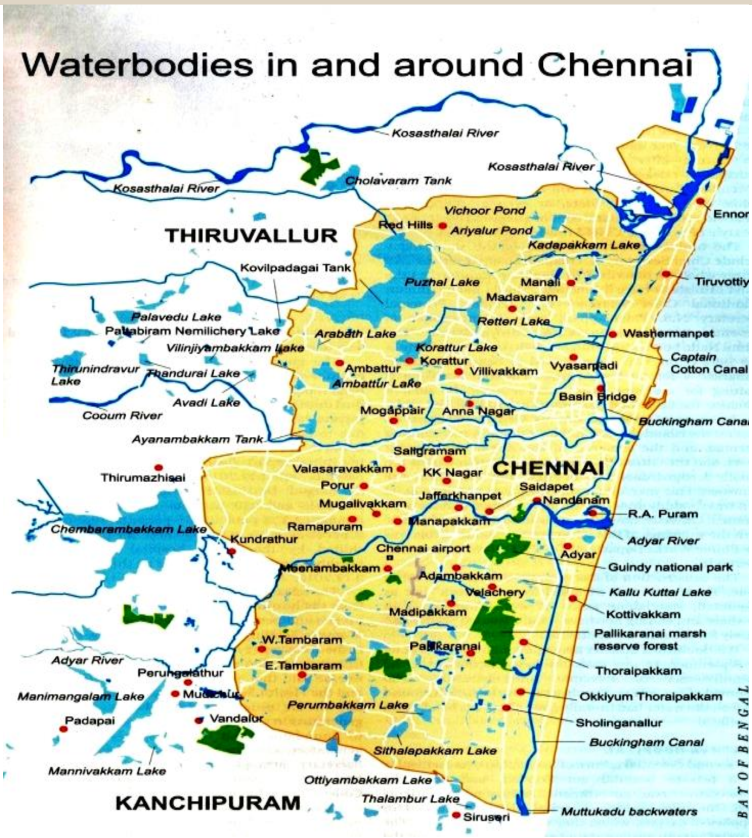

Fig. 1: Boundaries and water bodies of Chennai. (Source Maps Chennai.com)

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Chennai has relied on the annual rains to replenish water reservoirs, as no major rivers flow through the area. Chennai has a water table at 2 metres for 60 percent of the year. Two major rivers flow through Chennai, the CooumRiver through thecentre and the Adyar River to the south (Fig.1). A third river, the Kortalaiyar, travels through the northern fringes of the city before draining into the Bay of Bengal, at Ennore. All the three rivers are heavily polluted by the industrial wastages and hence the water is not suitable for the use of public.

As Chennai is one among the metropolitan city in India, it depends entirely on rainfall to fulfil the daily needs of water for its people. Due to extreme precipitation during December 2015, the people in Chennai suffered for many days without food and drinking water. Many lost their lives, their belongings during the flood. Hence the knowledge of flood or drought is necessary for disaster management to take necessary precautionary actions to manage both.

This research article develops a prediction model based on Neural Network for predicting the annual rainfall in Chennai using the parameters like ElNino 3.4, Maximum Temperature, Minimum Temperature, Vapour Pressure and Cloud Cover. Table 1 gives the details of the parameters for predicting the annual rainfall in Chennai. For this purpose, a dataset containing the monthly rainfall of chennai, maximum temperature of the year, minimum temperature of the year, vapour pressure and cloud cover from the year 1901 to 2017 were obtained from India Meteorological Department, Pune, India and India Water Portal. The Sea Surface Temperature of Nino 3.4 (120°W-170°W and 5°S- 5°N) indices were obtained fromNational Oceanic and Atmospheric Administration, US for the same years.

Table 1: Chennai climate data (1981-2010)(source: India Meteorological Department)

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Year
Record High Temp (^{0}c)	34.4	36.7	40.6	42.8	45	43.3	41.1	40	38.9	39.4	35.4	33	45
RecordLow Temp (^{0}c)	13.9	15	16.7	20	21.1	20.6	21	20.6	20.6	16.7	15	13.9	13.9
AverageHigh Temp (^{0}c)	29.3	30.9	32.9	34.5	37.1	37	35.3	34.7	34.2	32.1	29.9	28.9	33.1
AverageLow Temp (^{0}c)	21.2	22.2	24.2	26.6	28	27.5	26.4	25.9	25.6	24.6	23.1	21.9	24.8
AverageRainfall (mm)	25.9	3.4	3.5	14.4	34.2	86.2	275.45	210.5	183.5	375.25	400.56	368.57	1981.43
Average Rainy days	1.4	0.8	0.3	0.8	1.8	4	10	11.5	10.7	17.8	21.5	19.5	100.1
Average Relative Humidity (%)	73	72	70	69	62	57	64	66	72	77	78	77	70
Mean Monthly Sunshine (Hrs)	268.3	268.1	293.6	290.2	279.9	202.6	185.2	193.6	198.6	194.6	182.7	204.3	2761.7

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Artificial Neural Network (ANN)

An Artificial Neural Network is a computational model inspired by biological neural networks both structurally and functionally [11]. Many Neural Networks has been constructed by researchers for predicting the time series. It models the time series with various forms of activation functions by considering the underlying complex mathematical relationships between the input and output time series. Neurons are the group of interconnected computation units.

The two major types of Artificial Neural Networks are Multi-Layer Perceptron (MLP) networks and Radial Basis Function (RBF) networks which are applied by many researchers for predicting complex real life time series since they do not have any stationary constraint on the time series to be learned and predicted. The main aim of applying a neural network is to train the system to produce appropriate output patterns for the corresponding input patterns. The training algorithm has a set of training rules which varies as the algorithm varies. The learning algorithm and the neural network architecture varies according to their applications.Recent studies focus on the problem of weather forecasting using Radial Basis Function Network. The complex nature of the system can be modeled by RBF due to its nonlinear approximations. Generally RBF is applied in function approximation and time series prediction.

The design of RBF network is an approximation problem in a high dimensional space and the learning is equivalent to finding a surface in a multidimensional space that provides a best fit to the training data. The normalized Gaussian radial basis function network is applied to model the nonlineartime series. The data is fed into the hidden layer from the input layer.In the hidden layer the data is processed and transported to the output layer. The weights between the hidden layer and the output layer are modified during training. Each hidden layer neuron represents a basis function of the output space, with respect to a particular centre in the input space. The Gaussian function is used as the transform function in the hidden layer which is represented as

$$\phi_j(x) = \exp\left[\frac{-\|x - c_j\|^2}{2\rho^2}\right] \quad (1)$$

where x is the training data, ρ is the width of the Gaussian function. This kernel is centered at the point in the input space specified by the weight vector. The closer the input signal is to the current weight vector, the higher the output of the neuron will be. Therefore the k^{th}output of the network $y_k$is represented as

$$y_k = w_0 + \sum_{1}^{M} w_{jk}\phi_j(x) \quad (2)$$

Where$\phi_j(x)$ is the response of the j^{th} hidden unit and w_{jk} is the connecting weight between j^{th} hidden unit and the k^{th} output unit and w_0 is the bias term.

RESULTS

A time series plot (Fig.2) is used to display the time variation against the annual rainfall series. The dataset series related to Chennai was splitted into two:

1. Training Data consists of 100 years (1901 - 2000)
2. Testing Data consists of 17 years (2001 - 2017)

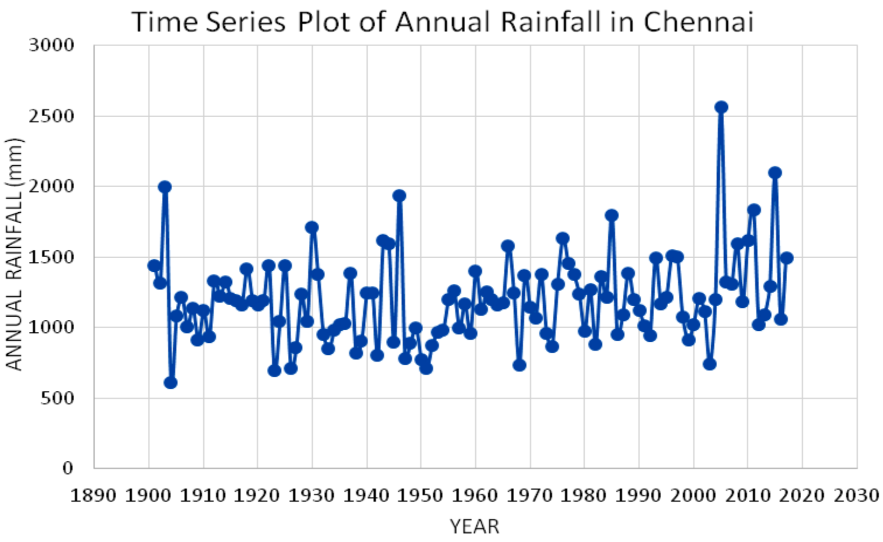

Fig. 2: Time series plot of annual rainfall in Chennai

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Table 2: RBF network information

Layer	No of units	Activation function	Rescaling method
Input	6	-	Normalized
Hidden	1	Softmax	-
Output	1	Identity	Normalized

The RBF neural network architecture considered for this application was a single hidden layer with Gaussian Radial Basis Function (Table 2). Gaussian type Radial Basis Function is chosen here because it is similar with the Euclidean distance and it gives better smoothing and interpolation when compared to the other basis functions. The fully supervised learning algorithm is presented for the parametric estimation of the Radial Basis Neural Network.

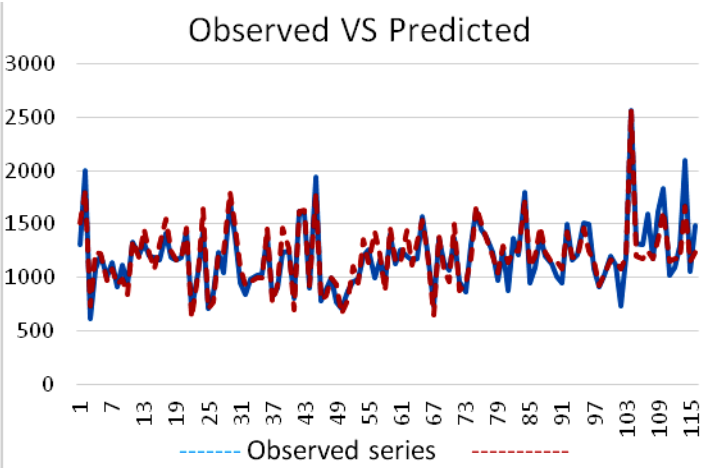

Fig. 3: Observed vs predicted annual rainfall series.

The RBF architecture consists of six units in the input layer, one unit in the hidden layer and one unit in the output layer [2]. After training, the network is tested with the test data set. For fitting a best model among the available models for a time series data, error measures are used. The Mean Average Percentage Error (MAPE) was used as forecasting accuracy measure in this analysis. The MAPE values of training data and test data are 0.0706 and 0.1266. The observed and predicted data is plotted (Fig.3) for visual inspection.

CONCLUSION

Traditional statistical time series forecasting methods, including moving average, exponential smoothing, and Auto-Regressive Moving Average, all assume stationarity and linearity of the time series. Artificial Neural Networks does not require any stationarity constraint on the time series to be learned and predicted. The highly flexible nonlinear regressive structure of Artificial Neural Network fit the target pattern space. In this research article, a prediction model based on rainfall parameters using RBF algorithm was constructed and the error measure shows the performance of the model. For some real world problems, Artificial Neural Network will never replace the existing conventional techniques but because of the fast growing applications it can be an alternative to those existing techniques.

CONFLICT OF INTEREST

There is no conflict of interest.

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FINANCIAL DISCLOSURE

None.

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