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WEATHER PREDICTION USING REGRESSION ALGORITHM AND NEURAL NETWORK TECHNIQUE

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Abstract- Weather forecasting is a practice of science and innovation to predict environmental conditions at a particular location using data of previous days' weather conditions. This study aims to develop a novel algorithm to predict the weather and furnish the most accurate forecast. To achieve this, initially the historical weather data for the region has been collected and later that data has been used to train and test the algorithms for better forecasting. The gathered data set has been split in the ratio 80:20 for testing and training respectively. This research work proposes following two algorithms for weather forecasting: Linear Regression; and Artificial Neural Network. The performances of the algorithms have been compared using numerous performance metrics. Linear Regression model demonstrates values MSE=0.00977262 and $RMSE$=0.0988565, while ANN technique depicts the performance as MSE=0.001260 and $RMSE$=0.035507. ANN has illustrated better performance and has proved to be more effective in weather forecasting.

Keywords: Data Mining, Deep Learning, Artificial Neural Network, Linear Regression, Functional Regression.

1. INTRODUCTION

Weather forecasting is used to predict the conditions of the environment for a certain area and time [1-3]. Climate conjectures are made by gathering quantitative information about the present condition of the environment at a given spot and utilizing meteorology to extend how the atmosphere will change [4]. There are different tools which have been used for weather forecasting such as barometer, thermometer and even computer models and technologies to process data obtained by recording different observations. The major sectors where the prediction of weather is of utmost importance are agri-business, travel industry, healthcare, aeronautics business etc. [5, 6].

The first step in predicting the weather is to collect data. Since past patterns may indicate future events, we need to collect historic weather data of the area [7]. Then various techniques can be employed to predict the weather, some of which are: data mining like linear regression, logistic regression, ANN, random forest, SVM, Multivariate Adaptive Regression splines. Weather condition prediction can be done using neural networks and fuzzy inference systems. Linear and functional Regression, Data Mining, Incremental K-means clustering, Time Series Analysis, MLP, and RBF based Hybrid Neural Network Model [8].

This paper presents the results of using Linear Regression and Artificial Neural Networks for predicting weather conditions. First, more than 96000 data elements are given as input to the Linear Regression model. 80% of the dataset is trained and linearly fitted. The remaining 20% is used as the test set. The values of the test set are then predicted using the trained model. Additionally, ANN is used to enhance the model's accuracy. Section 2 gives the various literature surveys. Section 3 discusses the methodology. The results and analysis have been furnished in the Section 4. Finally, in section 5, The results obtained in this study and future studies planned are summarized.

2. LITERATURE REVIEW

Authors in [9] discussed the commonly used techniques of data mining such as classification, clustering and decision trees. The basic elements of non-linear ANN model are (i) Synapses linking the obtained weights (ii) Additional input signals which are weighed by a neuron's synapses (iii) An activation function that restricts a neuron's output. It also tells us about the technique sequence of machine learning. The parameters considered in the paper are temperature, wind speed, rainfall and evaporation. has utilized the profound figuring out how to make a weather estimating model. The principle analyze stages are: Training period of RNN and CN models and testing every one of these models [10]. The information is climate time arrangement information gathered from various climate stations of different areas.

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Models are prepared and tried utilizing foreordained climate set and afterward model's exhibition is assessed utilizing K-fold cross approval strategy. The arrangement of autonomous factors utilized are: wind SOI, SST, and OLR and anticipated determined factors are mean temperature, most extreme temperature, precipitation, relative stickiness and mean sea level weight. has discussed seven techniques for data mining like regression, logistic regression, ANN, random forest, SVM, Multivariate Adaptive Regression splines [11]. It talks about a multi-layer perceptron ANN model for weather prediction. It takes temperature, rain and wind as input and is trained through back propagation algorithm. The parameters considered are minimum and maximum temperature, rainfall, evaporation and speed of wind.

Proposed a method for weather condition prediction using neural networks and fuzzy inference system [12]. The parameters taken into consideration are pressure, humidity, visibility, temperature, wind speed and dew point. The method proposed used open-source data of last five years. A database is then created. Loading and reading from the database is enabled. Then monthly clusters are created within the database to make predictions faster. All the past weather details are then available in the database. The six parameters taken from the past weather details are provided to fuzzy inference system. The system then provided with the prediction of past weather conditions based on certain rules imposed on it. The system used neural network to predict the values of the six variables for predicting the weather. A different neural network is created for each parameter. This system gave prediction of the next five years. The model showed that the combination of neuro-fuzzy system enhanced accuracy, reliability and consistency

Proposed a model for weather forecasting. It used back propagation algorithm and artificial neural network [13]. It described the nature of a feed forward network as 'layered'. The first step in training is creating a network. Feed forward networks allowed only one way travelling. Input and output are provided to initialize weight and bias values and determining the size of the output layer. The aim is to reduce the mean squared error, so the weights are adjusted accordingly. The three layers of the network, namely - input, hidden and output are described. The back propagation neural network is discussed later in the paper. It is powerful but has large computational requirements. The system is based on supervised learning strategy. Lastly, it explained the steps of solving a problem with back propagation. The parameters used in this model are: relative temperature, minimum-maximum temperature and average wind speed.

Have taken various parameters under consideration, such as [14]: maximum-minimum temperature, average humidity and mean atmospheric pressure. The paper discussed two algorithms for its model for weather prediction. The first is linear regression. It predicted high and low temperature as a linear combination of all features. It then discussed the next algorithm which is functional regression. It used past weather patterns that were similar to today's weather patterns to predict future weather conditions. Neural network model is used to train from 80% of data values and remaining 20% is used for testing.

Have taken atmospheric pressure, dew point, temperature and wind as input parameters [15]. The proposed model consolidated a bottom-up indicator for every factor with a top-down profound conviction organize that demonstrated the joint measurable connections between them. The approach of the model is to incorporate temporal mining, spatial interpolation and intervariable interactions. There are three components of the model. The first are the individual predictors for weather variables which are trained using historical data. The second component data kernel to align the inferences with physical laws. Lastly, the third component is the deep belief network which instils the joint statistics in the weather model.

Described a project in this paper which provides the information for future weather by changing some parameters [16]. The data transfer is done using wireless systems in which sensors are used for the detection of wind, rainfall, temperature, humidity, etc. It classifies and predicts weather by changing any one parameter by using ANN and back propagation technique. Described a system in this paper which provides the information of future weather conditions by using the data of air molecules in the atmosphere [17]. The technique used are data mining and incremental K-means clustering. The air molecule's data is collected periodically every hour. Then K-mean algorithm is applied to the data recorded. In the K-mean algorithm the data is organized into clusters. Incremental K-mean algorithm is used for the addition of any new data. In the end, priority-based algorithm is used for the prediction of future weather predictions.

Did an experiment on weather forecasting. In their model, first, data is collected from Toronto Lester B. Pearson Int'l A, Ontario, Canada from period 1999-2009 [18]. Then, data is used to train the ANN that can predict weather components. From the data, only max temperature is considered for training. Also 60% is used as training data, 20% as test data and the final 20% as validation data. The training of the ANN is done using the Leverberg Marquaendt Algorithm. Eventually, the final result is produced on the basis of *MSE* minimization criteria. The parameters considered in the model are maximum-minimum temperature, humidity and wind speed.

Took the required data from meteorological department of India and used the technique is ARIMA [19]. The dataset includes attributes like min temperature, max temperature, wind pressure, precipitation, sunshine, humidity and evaporation. According to the attributes the data is categorized into one of the following: normal, cloudy, depression, severe depression and cyclonic storms. The forecasting model is used to identify the initial estimates and by using partial auto-correlation intermediate weather changes are estimated. Applied back propagation algorithm to data retrieved via wireless medium from sensors detecting the aspects such as rainfall, temperature, wind speed etc. [20]. It compares, classifies and predicts any possible relation by changing the value of any particular parameter. It follows a 3-layered Neural Network Model that devises a relationship between the parameters to predict the future temperature. It is among the most powerful prediction algorithm used in Machine Learning.

Have used Time Series Analysis, a Machine Learning approach which focuses on capturing data groups and the required data variables in a specified time period [14]. The results here are obtained by the generalization capacity of the model and with the help of proposed network. Thus, it provides wonderful accuracy when the actual and predicted temperature values are compared. Proposed a model which is based on Hybrid Neural Network Model based MLP along with Radial Basis Function [21]. This Supervised Machine Learning approach uses Root Mean Square Error (*RMSE*), Scatter Index and Correlation Coefficient as accuracy measurement tools. The Input - Output exchange occurs with the help of single hidden layer applied on the training data. The output neurons yielded are - Dry and Rainy weather. Thus, this model can help in enhancing the accuracy in Weather forecasting. The various parameters considered in this model are minimum temperature, maximum temperature, normal wind speed, average dewpoint average temperature, high wind speed, average relative moistness, precipitation and average cloudiness.

Talked about how the utilization of heterogeneous information causes expanded vulnerability, where huge measure of information ought to be prepared; this strategy is tedious and needs exceptionally ground-breaking PCs [22]. A viable technique is proposed dependent on Fuzzy c-mean bunching and type-2 fuzzy logic. This proposed technique is successful on vulnerability information which lead to genuine expectation. Type-2 FLS have been utilizing in the neighborhood it isn't pertinent for enormous measure of information due to now is the right time devouring strategy. The outcomes demonstrated half breed strategy is appropriate for both nearby and worldwide zone.

Table 1. Construction cost of 230 kV

Ref.	Technique	Parameters	Ref.	Technique	Parameters
[9]	Data Mining with ANN	Temperature, wind speed, rainfall evaporation	[17]	Data Mining, Incremental K-means clustering	Temperature
[10]	Deep Learning	Mean and maximum temperature, relative humidity, precipitation, mean sea level pressure	[18]	Artificial Neural Network	Maximum temperature, minimum temperature wind speed, humidity
[11]	Data Mining Research Based on Cloud Computing.	Minimum and maximum temperature, rainfall, evaporation and wind speed	[19]	ARIMA	Minimum temperature, maximum temperature, wind pressure, precipitation, sunshine, humidity, evaporation
[12]	Neural networks and fuzzy inference system	Humidity, wind speed temperature, pressure, dew point and visibility	[20]	Back Propagation Algorithm Prediction	Wind, Rain etc.
[13]	ANN and back propagation	Maximum and minimum temperature, relative humidity and mean wind speed	[21]	Time Series Analysis	-
[14]	Linear and functional Regression	Maximum - minimum temperature, average humidity and mean atmospheric pressure	[22]	MLP and RBF based Hybrid Neural Network Model	Minimum-maximum and mean temperature, high wind speed, relative moistness, average dew point, precipitation, normal wind speed, high wind speed and average cloudiness.
[15]	Deep Hybrid model using deep belief network, data-centric kernel and base-level predictors	Parameters: Dew point, Atmospheric pressure and temperature, wind	[23]	Fuzzy c-mean, Type-2 Fuzzy Logic	-
[16]	ANN by back propagation	Rainfall, wind, temperature and humidity	This work	Linear Regression and ANN	Date, summary, precipitation type, apparent temperature, wind speed, humidity, pressure wind bearing, visibility

The presented work helps in predicting the weather with the help of models which have applied the techniques of Linear Regression and Artificial Neural Network. The details are presented in section 3.

3. METHODOLOGY

Linear Regression Mode is initially applied to the dataset and the results are analyzed [24]. After that, Artificial Neural Network is applied to improve the accuracy [25]. This section contains the details about both the applied models.

3.1. Multivariate Linear Regression Model

Supervised Learning approaches applied to this project and thus accuracy improvement of the model is the objective. Figure 1 depicts the basic flow of methodology using Linear Regression. The Data Set consisting of 96453 data entries is taken from Kaggle, containing the following independent variables:

- Date
- Humidity
- Summary
- Precipitation Type
- Apparent Temperature (degree)
- Pressure
- Daily Summary
- Wind Bearing
- Cloud Cover
- Wind Speed (km/h)
- Visibility (km)

We predict the Temperature (degree C) based on these independent variables. The following variables are removed from the dataset during the Data Cleaning phase:

- Formatted Data
- Cloud Cover
- Daily Summary

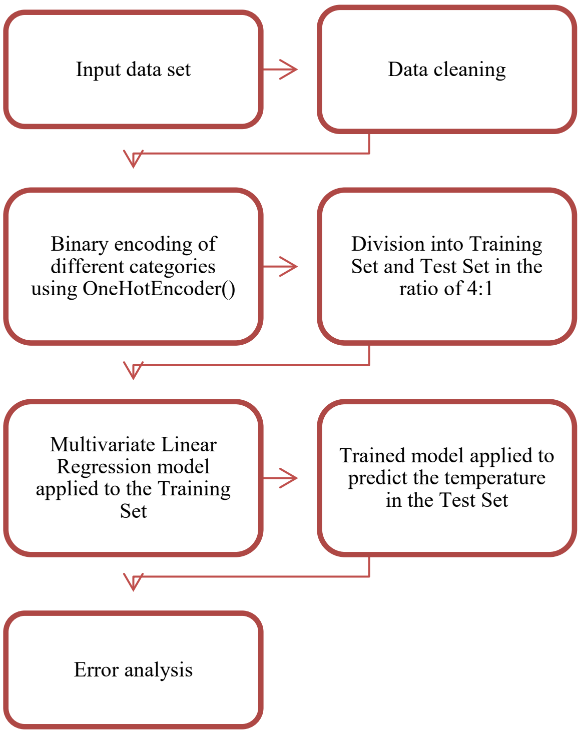

Figure 1. Linear regression

There are two categorical variables in our dataset - Summary and Precipitation Type. Summary is divided into 28 different categories which are shown in Table 2. The two categories for Precipitation Type are rain and snow. Notably, a column for category has been removed from the dataset in order to prevent Dummy Variable Trap [26]. The NULL values in the dataset are replaced by the mean value of the corresponding independent variable. All the categorical variables are label encoded using Column transformer () and furthermore binarily encoded [27].

Table 2. Categories with occurrences

S no.	Category	Occurrence
1.	Partly Cloudy	31733
2.	Mostly Cloudy	28094
3.	Overcast	16597
4.	Clear	10890
5.	Foggy	7148
6.	Breezy and overcast	528
7.	Breezy and Mostly Cloudy	516
8.	Breezy and Partly Cloudy	386
9.	Dry and Partly Cloudy	86
10.	Windy and Partly Cloudy	67
11.	Light Rain	63
12.	Breezy	54
13.	Windy and overcast	45
14.	Humid and Mostly Cloudy	40
15.	Drizzle	39
16.	Breezy and Foggy	35
17.	Windy and Mostly Cloudy	35
18.	Dry	34
19.	Humid and Partly Cloudy	17
20.	Dry and Mostly Cloudy	14
21.	Rain	10
22.	Windy	8
23.	Humid and overcast	7
24.	Windy and Foggy	4
25.	Breezy and Dry	1
26.	Windy and Dry	1
27.	Dangerously Windy and Partly Cloudy	1

The Dataset is splinted into Training and Test Set in the ratio of 4:1, respectively. Finally, Multivariate Linear Regression model is applied to the Training Set containing 77162 training examples that is four-fifth of the initial dataset. The trained model is now applied to the Test Set, containing the remaining one-fifth of the dataset. This is done in order to predict the Temperature for the Test Set values. The temperature that individuals can perceive is the apparent temperature. depending on various atmospheric factors.

Table 3. Correlation matrix of the variables

Index	Temperature (°C)	Apparent temperature (°C)	Humidity	Wind speed (km/h)	Wind Bearing (°)	Visibility (km)	Pressure (millibars)
Temperature (°C)	1	0.992629	-0.632255	0.00895697	0.299882	0.392847	-0.00544711
Apparent temperature (°C)	0.992629	1	-0.602571	-0.0566497	0.0290305	0.381718	-0.000219
Humidity	-0.632255	-0.602571	1	-0.224951	0.000734645	-0.369173	0.00545426
Wind speed (km/h)	0.00895697	-0.0566497	-0.224951	1	0.103822	0.100749	-0.0492628
Wind Bearing (°)	0.299882	0.0290305	0.000734645	0.103822	1	0.0475942	-0.0116509
Visibility (km)	0.392847	0.381718	-0.369173	0.100749	0. 0475942	1	0.0598184
Pressure (millibars)	-0.00544711	-0.000219	0.00545426	-0.0492628	-0. 0116509	0.0598184	1

Figure 2 represents the plot between actual and apparent temperature. Predicted temperature is the one which the model has predicted using linear regression. Figures 3 and 4 show that the plot between apparent and actual temperature with predicted temperature, respectively. The plot does not show much variation between the two. Finally, error analysis of the model is done by evaluating the following error metrics:

- *MSE*
- Root Mean Square Error (*RMSE*)
- R-Squared Score
- Adjusted R-Squared Score

3.2. Artificial Neural Network (ANN)

Model with Deep Learning approach is applied to the model in order to further minimize the calculated error metrics, in turn improving the performance of the model. Figure 5 demonstrates the flow of methodology used with ANN. All the Data Pre-processing [26] steps are conducted, similar to Multivariate Linear Regression Model while applying the Artificial Neural Network. Moreover, the data has been segregated into the ration of 80:20 for training and testing, respectively.

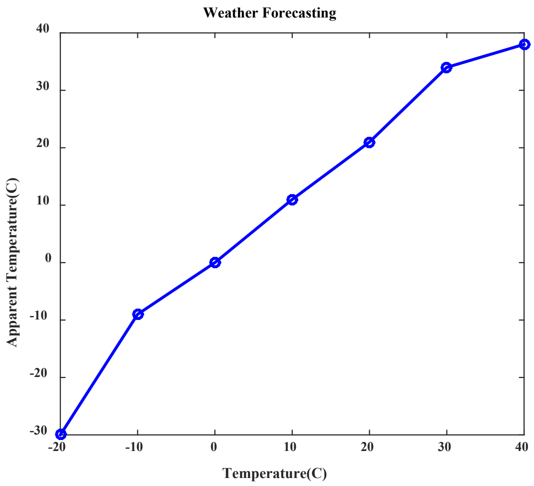

Figure 2. Radial-velocity profiles for different ξ rates

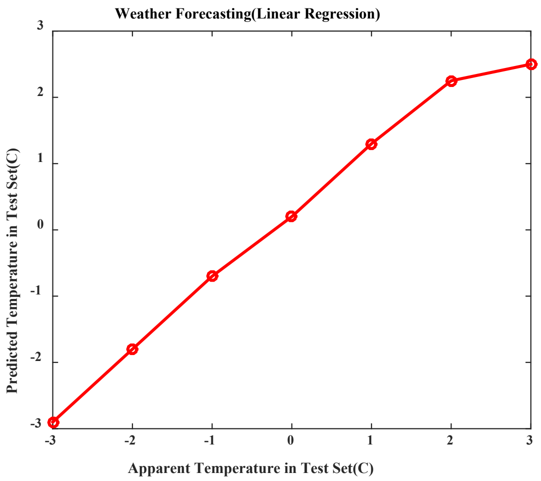

Figure 3. Apparent Temperature vs Predicted Temperature in Test Set

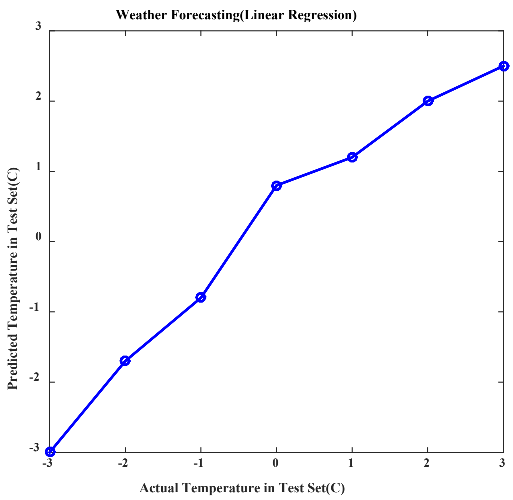

Figure 4. Actual Temperature vs Predicted Temperature in Test Set

Keras Library has been used for the construction, application and compilation of Artificial Neural Network to our dataset. A three-Layered Neural Network is constructed such that:

1) Input Layer: The Input Layer contains 33 Input Neurons [25]. This includes independent variables such as Apparent Temperature, Wind Speed, Humidity, Visibility, Wind Bearing, Pressure along with the categories of Summary and Precipitation Type.

2) Hidden Layer: The Hidden Layer contains 17 neurons [25]. The Rectified Linear Unit Activation function, defined as Equation (1) and is used between Input and Hidden Layer.

$$y = \max(0, x) \tag{1}$$

3) Output Layer: Lastly, the Output Layer contains one neuron which predicts the Temperature based on the constructed model, by learning from training data. The Linear Activation function, defined as in Equation (2) and is used between Hidden and Output Layer.

$$y = cx \tag{2}$$

Figures 6 and 7 depict the plot of actual temperature with predicted temperature and apparent temperature with predicted temperature in test data set respectively. The plot is constructed using the results from output layer. The error minimization is achieved with the help of Mini Batch Gradient Descent with a Batch Size equal to 32.

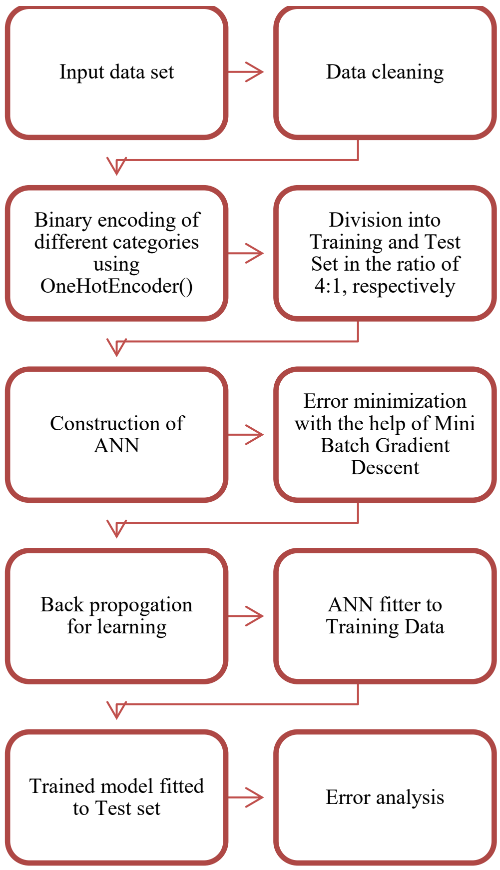

Figure 5. Artificial Neural Network

Mini Batch Gradient Descent is applied here rather than Standard or Stochastic Gradient Descent (SGD) Technique. This is because it avoids the demerits of both Stochastic and Standard Gradient Descent.

$$\Theta = \theta - \eta \times \nabla J(\theta) \tag{3}$$

where, η parameter is the learning rate, the $\nabla J(\theta)$ parameter is the Gradient of Cost function of $J(\theta)$ for parameters θ [2].

It is the most often used optimization algorithm for Neural Network optimization. Gradient descent is fondly used for weight updating of each synapse in a Neural Network Model. Thus, updating and fine tuning of the parameters is done in order to minimize the Cost function. The model first expands by figuring out and examining the dot product of the input signals and their associated weights. In addition, the activation function, which converts an input signal into an output signal by adding it to the sum of products, is required for complex non-linear functions. As a result, non-linearities are introduced into the model, allowing it to learn practically any functional mapping. This technique used in Neural Networks is known as Back propagation technique.

After that, we use gradient descent to propagate backwards in the network while carrying error terms and changing weight values. Here, we adjust the model's parameters (weights in this case) in the opposite direction of the loss function's gradient. The adaptive moment estimation (Adam) optimizer is the one used to calculate learning rate. It computes the adaptive learning rates for each parameter. It maintains an exponentially decreasing average of previous squared gradients, just like Ada Delta. It preserves an exponentially decreasing average of earlier gradients, $P(t)$ [18]. The values of the first and second moments, $M(t)$ and $V(t)$, respectively, are the gradients' mean and uncentered variance. Parameter update is given in Equation (4) [16].

$$\theta_{t+1} = \theta_t - \frac{\eta}{\sqrt{\hat{v}_t + \varepsilon}} \hat{m}_t \quad (4)$$

The values for β_1 are 0.9, β_2 is 0.999, and (10x exp (-8)) for ϵ. Adam works more efficiently compared to other adaptive learning method algorithms. This is due to the fact that the model converges rapidly and learns quite quickly and effectively. Additionally, it fixes all of the issues with other optimization strategies, such as vanishing rearming rate, sluggish convergence, and high variance in parameter updating, leading to rapidly changing Cost function.

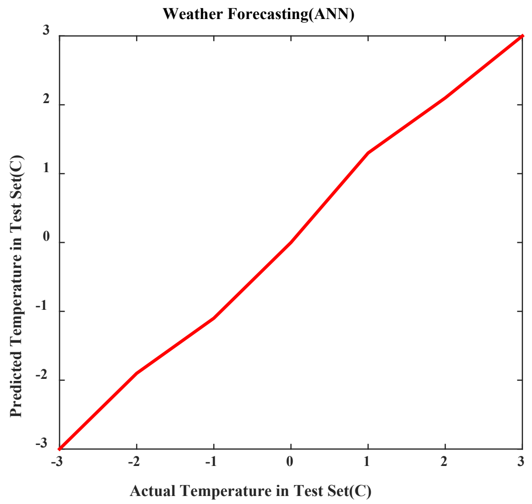

Figure 6. Actual Temperature vs Predicted Temperature in Test Set

Finally, the ANN is fitted to the Training Set such that the minimization of Cost function, that is MSE and $RMSE$ which is run for 100 epochs. Finally, this trained model is fitted to the Test Set to predict corresponding Temperature value for Test Set values. The error analysis is done similar to Multivariate Linear Regression Model by evaluating the following error metrics:

- Mean Square Error (MSE)
- R-Squared Score
- Root Mean Square Error ($RMSE$)
- Adjusted R-Squared Score

Thus, the models are created for Weather Prediction.

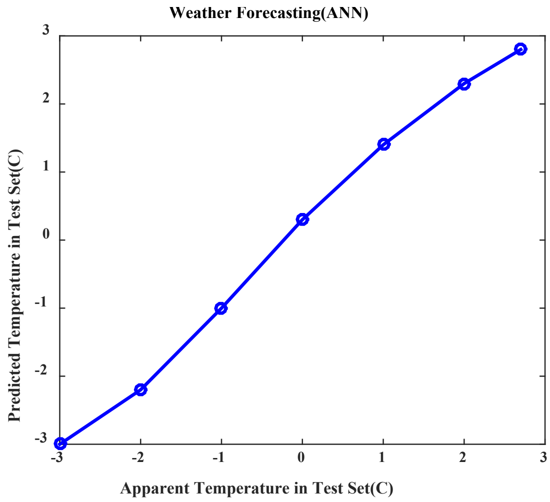

Figure 7. Apparent Temperature vs Predicted Temperature in Test Set

4. RESULTS

The temperature is predicted by training the model on the basis of independent variables such as Formatted Date, Precipitation Type, Summary, Apparent Temperature (°C), Wind Speed (km/h), Humidity, Wind Bearing (degrees), Daily Summary and Visibility (km). The error analysis is done for each model by evaluating the error metrics [27-29] given by the Equations (2)-(5):

1. Mean Square Error (MSE)

$$MSE = \frac{1}{n}\sum_{i=1}^{n}\left(y_i - \bar{y}_i\right) \quad (5)$$

2. Root Mean Square Error ($RMSE$)

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(y_i - \bar{y}_i\right)} \quad (6)$$

3. R-Squared score

$$R^2_{score} = 1 - \frac{\sum_{i=1}^{n}\left(y_i - y_{pred}\right)}{\sum_{i=1}^{n}\left(y_i - \bar{y}_i\right)} \quad (7)$$

4. Adjusted R-Squared score

$$R^2_{adjusted} = 1 - \left[\frac{\left(1-R^2\right)\left(N-1\right)}{N-P-1}\right] \quad (8)$$

These values for Linear Regression Model are given as:
1) Score on training data=0.989912, i.e., 98.99% accuracy
2) Score on testing data=0.989929, i.e., 98.99% accuracy
3) Mean squared error calculated=0.00977262
4) Root mean square error calculated=0.0988565
5) R^2 score = 0.990227
6) Adjusted R^2 score= 0.99021062

The linear line calculated by the model is of the form given in Equation (9).

$$y = c + m_1 x + m_2 x + \cdots + m_8 x \tag{9}$$

The graph given in Figure 8 shows the variation between the actual temperature and the predicted temperature. The results of the graph show little deviation from the actual output. The actual temperature is shown by blue line graph and predicted temperature is shown by red line graph. The values on the x axis denote data points and y axis depicts the values of temperature. The table 6 shows the actual and predicted temperature using Linear Regression for 10 records. The curve given in Figure 8 represents the predicted temperature plotted along with actual temperature for Linear Regression Model for 10 data entries:

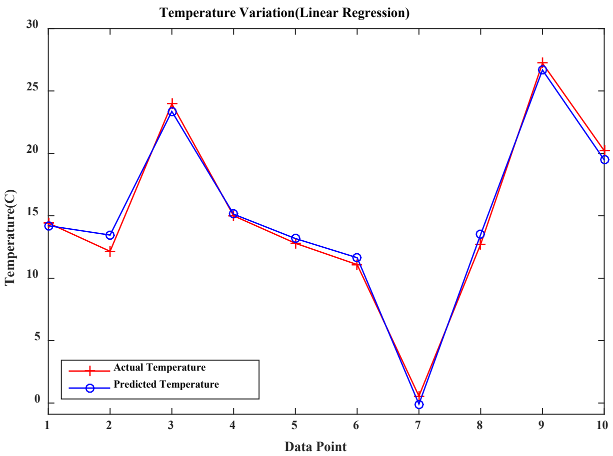

Figure 8. Predicted temperature vs Actual temperature for Linear Regression

Table 4 shows the actual and predicted temperature using Linear Regression for 10 records.

Table 4. Actual temperature vs. Predicted temperature (linear regression)

Actual temperature	Predicted temperature
14.422222	14.207163
12.155556	13.456150
23.961111	23.359100
15.000000	15.128340
12.800000	13.178400
11.088889	11.641854
0.555556	-0.086599
12.733333	13.508942
27.222222	26.678485
20.211111	19.480626

Further to improve accuracy, and to minimize the errors, ANN is applied and the values of error metrics are calculated. The results obtained are as follows:
1. Mean Squared Error calculated = 0.001260
2. Root Mean Squared Error calculated= 0.035507
3. R^2 score = 0.998739
4. Adjusted R^2 score= 0.998737

The graph given in Figure 9 is of apparent temperature versus predicted temperature in case of Artificial Neural Network. Again, the actual temperature is shown by blue line graph and predicted temperature is shown by red line graph. The values on the x axis denote data points and y axis depicts the values of temperature. The curve in Figure 9 represents the predicted temperature plotted along with actual temperature for Artificial Neural Network Model for 10 data entries.

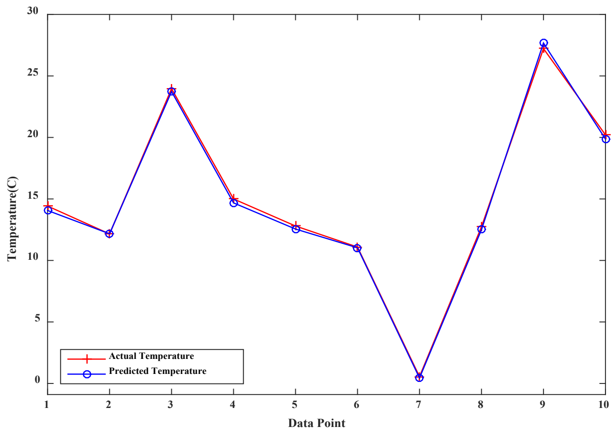

Figure 9. Predicted temperature vs Actual temperature for ANN

Table 5 shows the values of actual and predicted temperature obtained using ANN. The data given clearly shows, that the values of error metrics calculated for ANN model is low as compared to Linear Regression, thereby minimizing error and leading to more accurate results. Thus, ANN performs better and we have been able to predict temperature efficiently.

Table 5. Actual temperature vs Predicted temperature (Artificial Neural Network)

Actual temperature	Predicted temperature
14.422222	14.062407
12.155556	12.168305
23.961111	23.733751
15.000000	14.679248
12.800000	12.553229
11.088889	11.029854
0.555556	0.449805
12.733333	12.507048
27.222222	27.673855
20.211111	19.871607

5. CONCLUSIONS

This research work demonstrates the use of various machine learning and deep learning algorithms for weather forecasting. The approach followed in this study demonstrates the use of linear regression and ANN technique to improve the performance of the forecasting algorithm based on various parameters such as humidity, wind speed, and cloud cover. Different performance metrics have been used to measure and compare the performance of these algorithms using the following performance parameters: *MSE*, *RMSE*, R^2 Score and Adjusted R^2 Score.

For the training and testing phases of the algorithms, the data set was divided into two parts, and the training/test data set ratio was 80:20. Forecasting was obtained with linear regression and ANN. Moreover, the results are compared using *MSE* and *RMSE* performance metrics, which show the dominance of ANN in terms of the cost function for weather forecasting by depicting a reduction in the minimum value. The future direction for this study could be to combine the regression and ANN techniques with other machine learning or deep learning techniques, but the current study is optimal, and the exact needs to be maintained while weather forecasting.

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