Machine learning based smart weather prediction

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ABSTRACT

Weather forecasting refers to the prediction of atmospheric conditions depending on a given time and location. Weather prediction is essential and it plays a significant role in many sectors namely energy and utililities, marine transportation, aviation, agriculture and forestry to a greater extent. Accurate weather forecast mechanism help the farmers for suitable planning of farming operations that will prevent crop losses. In this work, the weather parameters namely precipitation, relative humidity, wind speed and solar radiation were predicted for few Indian locations using the conventional temperature based empirical models and machine learning algorithms such as linear regression, support-vector machine (SVM) and decision tree. Forecasting of weather parameters, on which agriculture depends, will increase the overall yield and it helps farmers and agricultural-based businesses to plan better. From the current results, it is observed that machine learning (ML) based methods had a better prediction results than the physics based conventional models for weather forecasting with mean square error of 0.1397 and correlation coefficient of 0.9259. The objective of this work is to arrive at an optimized end result and a better weather prediction using the Machine learning models with lesser computational effort.

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1. INTRODUCTION

Agriculture and farming are chiefly dependent on various weather parameters. Weather prediction is necessary to find out future climate changesand it plays a significant role in many sectors namely renewable energy, transportation, manufacturing, supply chain management, agriculture and forestry.Accurate weather forecasting helps farmers for suitable planning of farming operations. So, accurate weather prediction is necessary for the farmers to get the maximum yield in agriculture and also to prevent the crop wastage. For country like India, it is difficult to predict and forecast the weather parametersaccurately for various seasons and climates due to the complexity of weather events. In earlier days, there is no better understanding of weather forecasting due to the limited network of weather stations.Sometimes losses may occur in the agriculture crop due to the false prediction of waether. India has witnessed an increase in the mean temperature since the mid of 20th century. Also man-made climate change is likely to continue apace during 21st century. To improve the accuracy of future climate predictions, it is important to develop various approaches for improving the knowledge of earth atmosphere system. Researchers have developed different models to forecast the weather parameters commonly using random numbers and they are relatively similar to the climate data. Various climate models such as mathematical model [1], empirical model [2], ARMA [3], artificial intelligence-based models [4]-[7], fuzzy and ANFIS [8], [9], datamining and internet of things (IoT) based forecasting models [10], [11] are reported in the literatures. Recently machine learning (ML) [12]-[18], deep learning [19] and hybrid models [20], [21] are widely applied for weather forecasting. In this research work, theweather prediction model is developed using machine learning algorithms like support-vector machine (SVM), linear regression and decision tree. The proposed method usesmeteorological data collected from few selected regions within India to predict the weather parameters.

2. OVERVIEW OF MACHINE LEARNING BASED WEATHER PREDICTION MODELS

Machine learning algorithms are categorized into twoclassifications namely supervised learning and unsupervised learning. The clustering algorithms come under unsupervised machine learning category. Ahmed and Mohamed [22] used linear regression machine learning model to estimate the rate of precipitation (PRCP). Srivastava *et al*. [23] predicted monthly precipitation using various ML algorithms such as Support vector machine (SVM), linear regression, artificial neural network (ANN) using back propagation and long short-term memory network (LSTM) for early warning oflandslide occurrence. Devi *et al*. [24] usedback propagation neural network to provideearly warning of landslideswith combination of meansquare error and correlation coefficient as the performance metrics. Sakthivel *et al*. [25] used intense neural network mining with combination of mean square error (MSE) and root mean square error (RMSE) to achieve preprocessed rainfall data with reverse mapping values. Basha *et al*. [26] utilized autoregressive integrated moving average (ARIMA) model, artificial neural network, support vector machine with combination of MSE and RMSE as the metrics to predictrainfall for agricultural related applications. Babu and Arulmozhivarman [27] applied ANN models for effective wind speed forecasting. Table 1 can be seen in *appendix*, presents the literature survey of weather prediction models along with the methodology and the performance metrices.

3. RESEARCH METHODS

In this section, the methodology and the results of the weather prediction models are discussed. Various weather parameters namelyminimum temperature (°C), maximum temperature (°C), mean temperature (°C), relative humidity (%), wind speed (m/s) and solar radiation data (w/m^2) are used to build the machine learning models. Decision tree and linear regression-based ML models are used to predict the weather parameters namely precipitation, wind speed, relative humidity and solar radiation which play a vital role in agricultural field. In addition to the ML models, temperature based empirical models namely Hargreaves and Samani and Bristow and Campbell models are also utilized to predict solar radiation for selected Indian locations namely Trivandrum, Chennai and New Delhi and precipitation for Trichirapalli. Empirical model is mathematics intensive and is based on coefficient estimation. Prediction of wind speed and percentage relative humidity was done for Bangalore and New Delhi.

3.1. Collection of data

The data set for building the machine learning model were taken from Indian Meteorological Department, Pune and from AQUASTAT website. The Dataset was prepared by combining the monthly data of Indian locations namely New Delhi, Bangalore, Hyderabad, Trivandrum and Mumbai and eight locations within the state of Tamilnadu namely Chennai, Coimbatore, Kodaikanal, Madurai, Ooty, Pondichery, Ramanathapuram, Salem and Tiruchirappalli. The input parameters for predicting the Precipitation (mm/d) areminimum temperature (°C), maximum temperature (°C), mean temperature (°C), relative humidity and wind speed (m/s) for wind speed prediction relative humidity is excluded. The research indicated that all the above-mentioned input parameters have significant importance in the prediction.

All the input parameters were put together in a comma separated values (CSV) file for forecasting of wind speed. The complete dataset is divided into three sets such as training set, validation set and testing data set. It is further processed with the help of two empirical models and ML models. Spyder an open-source cross-platform integrated development environment (IDE) for scientific programming in the Python languageis used for developing the computer codes for empirical and ML models. Further, the machine learning models were validated using the experimental IMD testing dataset. Table 2 presents the input parameters considered for the prediction of weather parameters.

3.2. Data splitting

The complete dataset is divided into three sets namely training, teasting and validation data set; i) Training Set: The training part of dataset will be of 70 percentage of total dataset; ii) Test Set: The validation part of the data set will be of30 percentage of total dataset; iii) Validationset: This set can be realtime data or recorded data from IMD, Pune by which the model’s final performance is evaluated.

3.3. Model selection

Linear regression and decision tree algorithm were used for the prediction of precipitation, relative humidity, wind speed and solar radiation. Also, the temperature based empirical model namely the Hargreaves and Samani and Bristow and Campbell models are used to estimate the solar radiation. The decision tree algorithm was used in the prediction of wind speed.

Table 2. Input parameters considered for the prediction of wind speed

Month number	Maximun Temperature (°C)	Minimum Temperature (°C)	Relative Humidity (%)	Surface pressure (kPa)
1	20.64	7.28	41.28	99.13
2	25.31	11.00	38.25	98.91
3	31.18	15.90	27.27	98.58
4	37.62	21.99	18.96	98.15
5	40.50	26.30	20.99	97.69
6	40.12	28.55	31.41	97.34
7	36.46	28.00	56.27	97.33
8	34.38	26.72	70.01	97.58
9	33.80	24.60	67.58	97.98
10	33.09	19.00	46.01	98.60
11	28.60	13.07	38.49	98.92
12	20.64	7.28	41.28	99.13

3.3.1. Linear regression

Linear regression algorithm represent a linear relationship between a dependent and independent variables. Since linear regression shows the linear relationship,it will value the dependent variable in response to the changes in value of the independent variable. Equation for linear regression (1):

$$y= a_0+a_1x+ \varepsilon \tag{1}$$

- Positive linear relation: The linear relation is said to be positive when dependent variable increases on an axis (*y*) so does the independent variable on an axis (*x*).
- Negative linear relation: The linear relation is said to be negative when dependent variable decreases on an axis (y) as the independent variable getting decreased on an axis (x). Figure 1. gives the pictorial representation of the positive and negative linear relation.

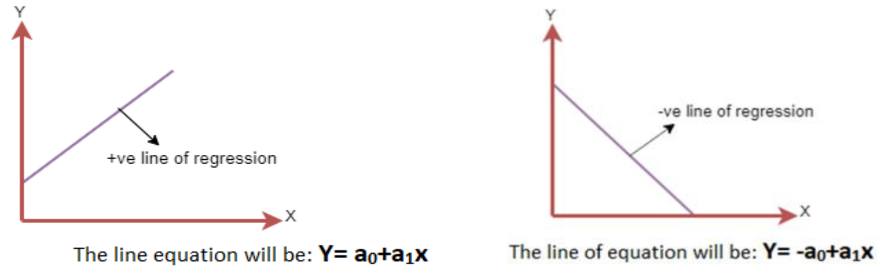


Figure 1. Positive and negative linear relation

Hargreaves and Samani Model [28]

$$\frac{H}{H_0} = a\ \Delta T^{0.5} \tag{2}$$

Bristow and Campbell model [29]

$$\frac{H}{H_0} = a(1 - exp(-b\Delta T)^c) \tag{3}$$

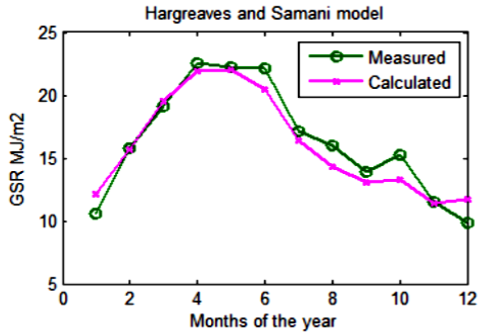
where ΔT is the difference between the maximum and minimum temperature.
a, *b* and *c* are the empirical constants determined by using statistical regression technique.

3.3.2. Decision tree

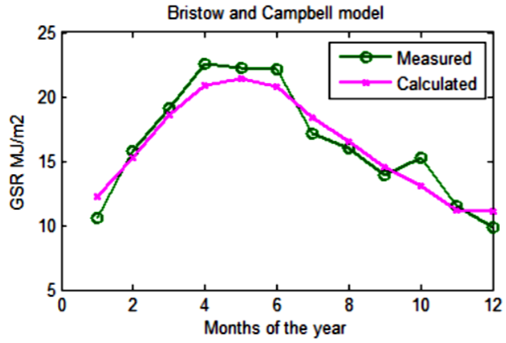
Decision Tree is one of the most popularly used, workable approaches to supervised machine learning. A decision tree model can be used in regression as well as a classification problem [30]. It works by breaking the data up in a tree like structure into smaller and smaller subsets. It is a peculiar type of probability tree that allows us to make a decision about our process.

4. RESULTS AND DISCUSSION

The weather parameters can be estimated with better accuracy using ML based models in comparision with empirical models. Figure 2 shows the comparision between the estimated and measured solar radiation, IMD, Pune values for the location New Delhi using the temperatre based empirical model namely the Hargreaves and Samani and Bristow and Campbell models. Figure 3 shows the comparision between the estimated and measured solar radiation, IMD, Pune values for the location Trivandrum and Chennai using the ML model.

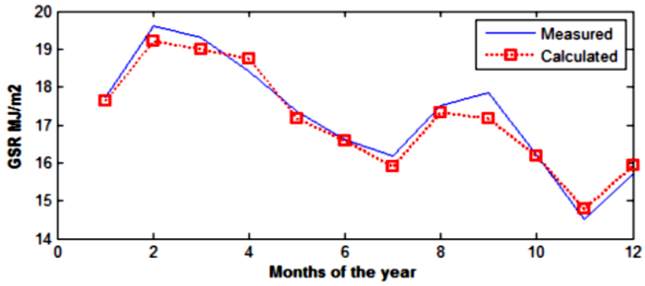


Solar radiation–New Delhi

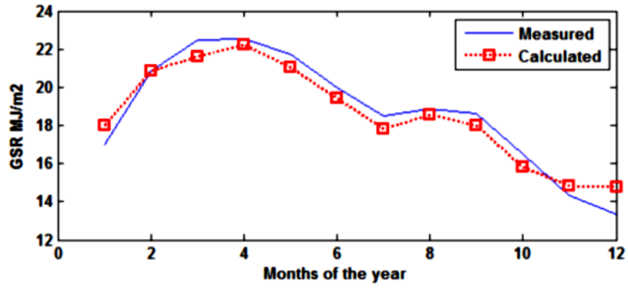


Solar radiation-New Delhi

Figure 2. Soalr radiation estimation using Hargreaves and Samani model and Bristow and Campbell model



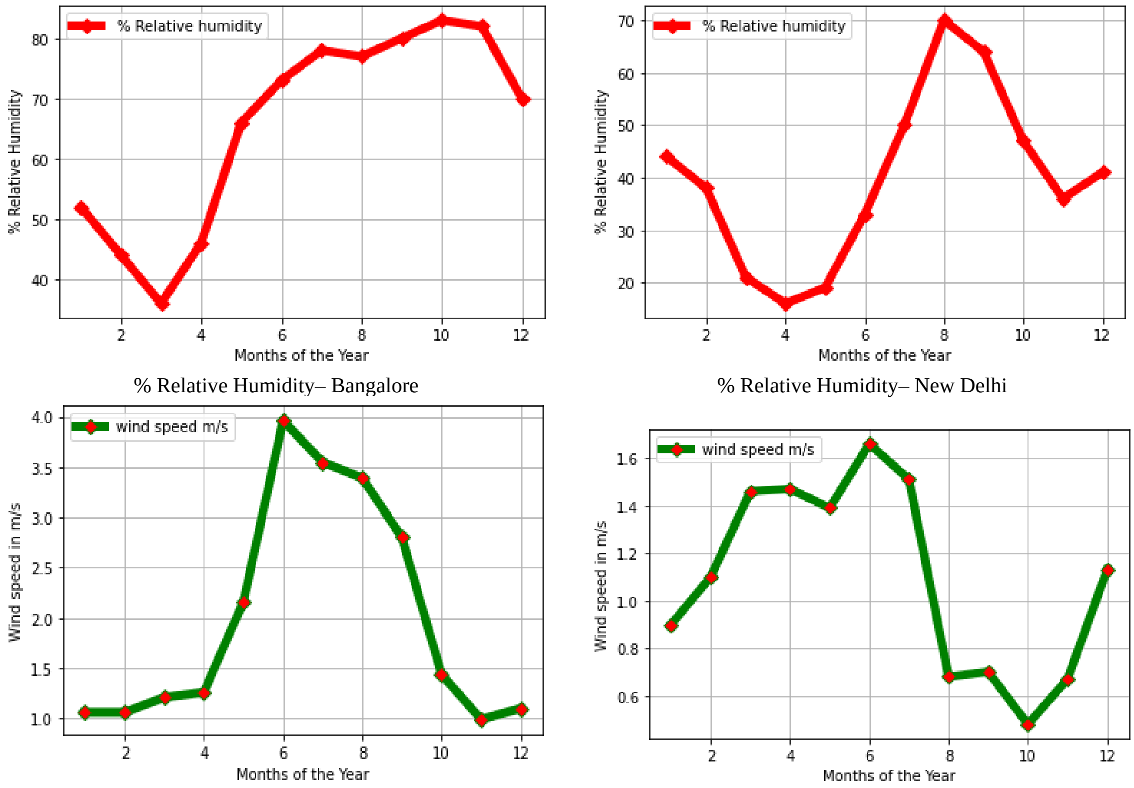
Solar radiation–Trivandrum



Solar radiation-Chennai

Figure 3. Solar radiation estimation using decision tree ML model

Figure 4 shows the predicted weather parameters namely % relative humidity and wind speed using ML models for the locations Bangalore and New Delhi.The performance metrics used to validate the proposed ML models are mean squared error (MSE) and the correlation coefficient. MSE which is the mean of squared error occurred between the estimated values and real recorded values. A low error value is desired to get the accurate model. For better prediction, correlation coefficient should approach to unity as close as possible. From the performance metrics Table 3, it is concluded that the weather parameters can be predicted with better accuracy using ML based models in comparision with empirical models.



% Relative Humidity– Bangalore

% Relative Humidity– New Delhi

Wind speed-Bangalore

Wind speed-New Delhi

Figure 4. Predicted Weather parameters namely % relative humidity and wind speed using ML models

Table 3. Performance metrics

S. No	Hargreaves and Samani model	Bristow and Campbell model	Decision tree regression ML model
MSE	1.5272	1.5423	0.1397
R-Correlation coefficient	0.8921	0.8874	0.9259

5. CONCLUSION

In the presented research work, weather parameters namely rainfall, wind speed, solar radiation and relative humidiy are predicted using the machine learning algorithms such as linear regression and decision tree model. Also the solar radiation for few selected Indian locations were estimated using the conventional temperature based empirical models namely the Hargreaves and samani and Bristow and Campbell model. The empirical and machine learning models are validated using the recorded experimental values obtained from IMD, Pune. From the results, it is proved that ML based results models performed better in comparision with empirical modelswith correlation coefficient 'R' value of 0.9259 and MSE of 0.1397. Thus the research work has arrived at an optimized end result with a better weather prediction with lesser computational effort.

APPENDIX

Table 1. Literature survey of weather prediction models

S. No	Title/Research Area	Input Parameters	Methods and Performance Metrics
1	Prediction of Wind Speed using Artificial Neural Network model [5]	Wind speed and direction, Air temperature, Air humidity, Air pressure.	ANN model Mean Square Error-2.003, R^{2-}0.951
2	Prediction of Rainfall Using ANN models [6]	Temperature, Cloud cover, Vapor pressure andPrecipitation.	Artificial neural networks (ANN)-Feed forward neural network (FFNN).
3	Artificial Intelligence based Weather monitoring-Anandharajan *et al*. [7]	Pressure Temperature Dew points wind speed Precipitation	MLTR model (MULTI-TARGET REGRESSION MODEL) LSTM Epochs-40 Accuracy-87.01, RMSE-0.35, Losses-0.1274, Learning rate-0.5
4	Wind Speed Prediction- Salisu Muhammad Lawan (ELTA) 2018. [9]	Input-Nine meteorological parameters Output-Wind speed.	Radial Basis Neural Network (T-RBNN) RMSE-7.18 % Covariance-0.0098
5	Data Mining Technique based weather forecasting model [10]	Temperature, Humidity Wind direction, Wind speed Atmospheric condition	Hybrid model, Linear regression model and Data mining based predictive model RMSE-3.0-4.45
6	Random forest Machine Learning model for weather prediction. [12]	Minimum and maximum temperature, relative humidity	Random forest and mathematical models
7	Rainfall Prediction using Machine Learning, Grace and Suganya [13]	High temperature, Low temperature, Humidity.	MLR (multiple linear regression)
8	Machine Learning based Heuristic Prediction of Rainfall [14]	Rate of rainfall in previous years.	Linear regression Mean and Standard deviation.
9	SVM based Atmospheric temperature prediction-Radhika *et al*. [15]	Temperature, Humidity, Wind direction Atmospheric pressure, Atmospheric condition	Linear regression method Random forest regression (RFR) Incorporated regression techniques SVR, MLPR, ETR.
10	Weather forecasting using hybrid neural model-Saba *et al*. [20]	Maximum and minimum temperature of the day, humidity	Recurrent Neural Network Model RNN WITH RELU: Epochs-40, Accuracy-86.44, RMSE-0.76, Losses-0.5824, Learning rate-0.9 RNN WITH SILU: Epochs-40, Accuracy-86.91, RMSE-0.76, Losses-0.5769, Learning rate-0.75
11	A deep hybrid model for weather forecasting-Aditya *et al*. [21]	Dry temperature, Wet temperature, Wind speed, Humidity, Pressure and Sunshine	ANN model-Gaussian constant and hyperbolic tangent-range [0.1,0.9]
12	Rainfall Prediction using Multiple Linear Regressions Model [22]	Temperature, wind speed and dew point.	Multiple linear regressions.
13	Machine Learning & Deep Learning Techniques for rainfall prediction [26].	Minimum temperature, Maximum temperature.	ARIMA model, Artificial neural network, Support Vector Machine MSE and RMSE
14	ANN based wind speed Forecasting-Babu [27]	Temperature Humidity Pressure	ARMA model, ANN-BPN model, ANN-GRNN model, ANN-RBFN mode. BPN-Mean Square Error-0.195 Mean Absolute Error-0.302 GRNN-Mean Square Error-0.023 Mean Absolute Error-0.041 RBFN-Mean Square Error-0.009 Mean Absolute Error-0.022

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