

Smart Weather Monitoring & Forecasting using ML

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Abstract— Predicting climatic conditions plays a very vital role in the different prominent industries including farming, transportation in affiliation with supply chain, construction, travel and tourism industries, etc. Capturing the changes in the weather is necessarily important and highly efficient for predicting the upcoming changes in the atmosphere. Hence the developed framework approach monitors the weather using the IOT technology along with an approach to forecast and predict it with efficient accuracy. The system is distinctly useful for smaller areas. Similarly, the system emphasizes weather prediction using different ML algorithms using Multiple Linear Regression, Random Forest Classifier, Decision Tree, and Gradient Boosting in a phased manner. Additionally, it searches for the best algorithm with the maximum prediction accuracy. The system compares the performances of the ML algorithms. The system works on the patchwork of IOT technology and ML algorithms to create a platform to view the weather conditions and predict the weather conditions. The combination of both technologies gives insights to users about weather conditions and predictions on the same platform.

Index Terms— IoT, Weather forecasting, Machine Learning algorithms

I. INTRODUCTION

Smart weather monitoring using IoT and forecasting using ML algorithms is a modern approach to weather forecasting that leverages the power of IoT and ML to collect and study data in real-time to provide accurate weather forecasts. Data on temperature, humidity, air pressure, wind speed, and precipitation are collected using IoT-based sensors.. This data is then sent to a central location where it is analyzed via ML algorithms to generate accurate weather forecasts. Machine learning algorithms like regression analysis, decision trees, and neural networks are used to analyze enormous amounts of weather data in order to detect patterns and forecast future weather conditions. These algorithms can use historical data to produce accurate forecasts of future weather patterns. By combining IoT and machine learning, smart weather monitoring systems can provide accurate and up-to-date weather information to a wide range of stakeholders, including farmers, transportation companies, and emergency services. This information can be used to make better decisions about crop management, transportation planning, and disaster response. Overall, smart weather monitoring using IoT and forecasting using machine learning algorithms has the potential to revolutionize the way we forecast weather, providing more accurate and timely information to help us make better decisions about how we interact with our environment.

II. LITERATURE REVIEW

The suggested system is a smart weather monitoring system that makes use of sensors to keep an eye on things

like temperature, humidity, and CO levels at a particular location. The system gathers information from various sensors and connects to and is controlled globally using IoT technology. The technology provides a fast and sophisticated way to access real-time weather information. The system receives data from sensors and does statistical analysis using an IDE. The analyzed data is subsequently wirelessly transmitted to the end user. [1]The AT Mega 328 controller controls all of the sensors, receives data from them, and transmits it to the end user through the cloud. Overall, the proposed system provides an efficient method for monitoring weather conditions in a specific region and providing accurate and up-to-date meteorological information to end users. The use of IoT technology enables remote monitoring and control, making it a valuable tool for a wide range of applications.[2]The suggested system provides real-time data across a wide range of characteristics by utilizing IoT technology. The device can track temperature, humidity, wind speed, wetness, light intensity, UV radiation, and carbon monoxide levels, employing a range of sensors. Sensor data is uploaded to a website and presented as graphical statistics that may be seen from anywhere in the world. The technology is less expensive and requires less maintenance than other gadgets on the market. The proposed technology could be applied to weather stations, aviation and maritime sectors, agriculture, and meteorological organizations. [3]The proposed system eliminates certain limitations existing in the current system. Firstly the system is highly accurately suitable for predicting the weather of small and specific zones. Similarly, the system forecasts the weather conditions on the web. The system gives a cogent view of the atmospheric condition. The current system framework reinvigorates the past system by developing a cost-efficient and reliable web GUI that shows up precise weather data. The built system is space efficient and easy to use. Due to its lightweight nature, it is highly eligible to get set up at the rooftop. Similarly, the authors discuss the importance and future scope of IOT services and gadgets. The development of a forecasting system predicts the rainfall on the basis of the following parameters including temperature, humidity, and atmospheric pressure. [4] The system architecture includes raspberry pi 3 B and DHT11 and BMP 180 sensors to monitor the weather condition of specific zones precisely and uses the Random Forest Classifier to classify that the particular zone is eligible for rainfall in the future. The system gives binary output to henceforth predict the probability of rainfall. By dividing the dataset into 75% training and 25% testing, the generated model achieves an accuracy of 87.90%. The model's error evaluation was done using a confusion matrix that maps out the actual yes and no corresponding with predicting yes/no. [5]The proposed system describes a smart system cloud-based weather station that collects and observes weather data using Raspberry Pi and various sensors. For forecasting the effects of weather changes, the system stores and processes data in the cloud. The system is developed with low-cost technology to monitor ambient weather conditions, making it cost-effective and low-maintenance.[6]The proposed system has applications in several areas, including homes, industries, agriculture, stadiums, and others that require real-time weather prediction. The ESP8266-01 module and NodeMCU are utilized for efficient data transfer and analysis, while the DHT11 and LDR sensors are used to capture temperature, humidity, and light intensity data. The system employs machine learning algorithms to predict real-time values based on pre-recorded sensor data, thereby providing accurate weather information for a particular location.[7]The focus of this study project was on rainfall prediction in Anand, Gujarat, India, due to the major impact of rainfall on industries such as agriculture, fisheries, aviation, and irrigation. For the prediction, a multilayered neural network with the Backpropagation learning technique was used. Two types of neural networks were configured and tested: Feed Forward and Cascade. The initiative made use of data readings of numerous parameters from June to September, which are the monsoon months in Anand. Temperature, relative humidity, and vapor pressure were found to be the most relevant elements for rainfall prediction after independently assessing their accuracy.[8]This study focuses on atmospheric conditions and the prediction of future weather based on location. It underlines the importance of collecting data on the current state of the atmosphere in order to increase the effectiveness of weather prediction systems. The research evaluates various weather forecasting methodologies in order to identify an accurate and dependable weather forecasting model. The study concludes that the Hybrid MLR_ANN model.[9] The reason behind this research is to create a multiple linear regression model for forecasting the precipitation rate (rainfall rate) in Khartoum state. The results show that using the same amount of data for training and testing improves the average mean square error by 85% during the testing phase.[10] The goal of this study is to develop a multiple linear regression model for forecasting the precipitation rate (rainfall rate) in the state of Khartoum. The model incorporates weather factors such as temperature, wind speed, and dew point as independent variables. The data used in the study came from the National Climatic Data Centre's website. The model's efficiency is determined by comparing the mean square error of the training and test data. The results show that using the same amount of data for training and testing improves the average mean square error by 85% during the testing phase.[11] This study describes a cloud-based smart weather station system. For gathering and monitoring meteorological data, the system makes use of a Raspberry Pi, numerous sensors, and cloud storage. The goal is to create a low-cost, low-maintenance system that requires little manual intervention. Raspberry Pi Zero W boards capture sensor data

and transfer it to the central Raspberry Pi 3 board, which then sends the data to a cloud database over WiFi. The acquired data is utilized to train machine learning models that are deployed in the cloud for weather prediction and pattern analysis. Customers can gain remote access to real-time meteorological data and insights using a web application created with the Django Framework and deployed in the cloud. [12] In the framework, this study uses low-powered sensor devices to solve the difficulty of weather forecasting. The objective is to develop efficient algorithms that are appropriate for IoT devices and less prone to prediction errors. Many structural and time series forecasting techniques are evaluated in the study, including linear regression, multiple linear regression (MLR), support vector regression (SVR), and auto-regressive integrated moving averages (ARIMA). The study's main objective was to assess the predictive power of several algorithms that may be used on servers or low-powered devices.[13]The goal of this study is to forecast temperature using Long Short-Term Memory (LSTM), a deep learning technology. Particularly for farmers whose agricultural activities rely on weather information, the goal is to provide trustworthy temperature forecasts that are crucial for planning daily tasks. The use of an LSTM model in conjunction with IoT sensor devices is covered in the study to produce precise temperature forecasts. The experimental results illustrate the LSTM model's superior performance over alternative approaches, demonstrating its efficacy in accurately forecasting temperature. Overall, this study introduces a temperature forecasting model that makes use of IoT sensor devices and LSTM, delivering accurate temperature predictions that can aid numerous applications and decision-making across diverse industries.[14] The automatic weather stations (AWS) established by the Indian Space Research Organisation are the primary source of temperature data for time series forecasting in this study. In this study, four separate stations—Ahmedabad, Balasore, Coimbatore, and Udaipur—are used to test the applicability of several machine learning methods for temperature prediction. Some of these methods include convolutional neural networks (CNN), long short-term memory (LSTM), and autoregressive integrated moving averages (ARIMA). The temperature information is logged once an hour. The study examines the algorithmic prediction accuracy utilizing several datasets with a range of recorded values, locations, and input data types (daily or hourly). The study emphasizes the connection between mean square and means bias errors (MSE and MBE), respectively, and accuracy. The study recommends using two-dimensional datasets to compare the prediction accuracy of machine learning algorithms as a feasible strategy in the future.[15] In particular, the issues associated with landslides and floods are discussed in relation to climate change and human activity. It might be difficult and ineffective to monitor environmental characteristics using conventional approaches, such as collecting data on rainfall. To overcome these limits, the study proposes a flexible and effective Wireless Sensor Network (WSN) for detecting rainfall-induced landslides. The proposed WSN design provides high-quality rainfall monitoring at a low human and capital expenditure. It transmits and gathers real-time data using a cellular network and GPRS (General Pocket Radio Service). After then, the information is transmitted to Weather Underground's web server for archival, processing, forecasting, and analysis. In conclusion, this work proposes a thorough approach for rainfall monitoring using a WSN architecture and cellular technology.[16]The purpose of this study is to forecast the usual rainfall in the Karnataka district of Udupi using artificial neural network models. To examine the effects of the hidden neurons' number on performance, a three-layered network is built. The experimental investigation makes the following discoveries: As the number of neurons in an artificial neural network rises, the Mean Squared Error (MSE) gets smaller. among the three algorithms that were looked at, Back-Propagation In conclusion, the study investigates how artificial neural networks with back-propagation might be used to forecast average rainfall. Through experimentation, the ideal setup and features are discovered, improving performance and lowering MSE. The report focuses on applying artificial intelligence (AI) and data mining approaches to analyze weather and precipitation data in Jordan. A dataset is produced by compiling weather-related data from nearby and online sources. A tool is created to get weather information from several sources. [17] Based on past data, algorithms for data mining and artificial intelligence are used to predict future precipitation. The study provides an initial outline of an effort to develop a Jordan-specific numerical weather forecast model, which is an area with little existing research. Data collecting, creating a thorough historical dataset, and dealing with partial or unreliable information are all difficulties.[18]The proposed effort attempts to construct an intuitive system for forecasting India's weather using Artificial Neural Networks (ANN), a soft computing technology. For farmers to increase crop yield and for the industrial sector to make wise decisions, accurate weather forecasting is essential. In the study, the significance of mean sea level pressure (MSLP) and minimum and maximum temperatures is emphasized. The proposed method of forecasting the weather by combining the Back-Propagation Algorithm (BPA) and Multilayer Feedforward Neural Network (MLFFNN) produced encouraging results. The study emphasizes the significance of optimal ANN design, dataset selection, input variable selection, and proper input parameter selection in order to get the best forecasting outcomes.[19] A practical Internet of Things (IoT)-based weather forecasting system is suggested in this study. A Raspberry Pi 3 Model B+, numerous sensors, and a weather forecasting system are all utilized in the concept. By accumulating data on air pressure and temperature,

the system forecasts weather. The system's scalability would expand with the addition of more sensors, enabling the creation of more accurate and comprehensive weather forecasts. Additionally, the design could be strengthened by substituting a more thorough and educational Graphical.[20] This study recommends an adaptive feature selection method and a multi-dimensional sensor data prediction model for dynamic Internet of Things (IoT) data. Extensive experiments on two real-world datasets, the Intel Berkeley Research Lab data and the Chicago Park District's weather and water data, demonstrate the applicability of the proposed methodology. The model achieves 92% accuracy for weather and water data from the Chicago Park District and 98% accuracy for data from Intel Berkeley Research Lab, according to the findings.

III. METHODOLOGY

The following steps make up the process for putting the smart weather monitoring system into use utilizing IoT and machine learning algorithms:

A. Selection of sensors

The following sensors were chosen:

- a. DHT11- to monitor temperature and humidity.
- b. BMP180-to monitor atmospheric pressure.
- c. Rain sensor- mechanical rain sensor was used.
- d. PCB rain drop sensor-

1. Integration of IoT technology

The sensors are connected using the NodeMCU microcontroller and ESP8266 Wifi module as shown in Fig no 1.

2. Cloud-based data storage

The data collected from the sensors is stored in Think Speak cloud using write API keys.

3. Statistical analysis

The data gathered through sensors is visualized via the graphs for understanding the values.

4. Data retrieval

It involved retrieving the data from the Think Speak cloud using the read API keys, using Python and its libraries. It also involves storing the data in a data frame and then in the dataset.

5. Model building

It involves building ML models including Multiple Linear Regression, Random Forest Classifier, Decision Tree, and Gradient Boosting. The smart weather monitoring system is connected to Thing Speak, allowing the real-time data to be securely transmitted and stored in the cloud. By leveraging IoT sensors and cloud storage, the system ensures accurate and reliable weather monitoring. The collected data can be accessed and analyzed from anywhere, providing valuable insights for weather forecasting, climate studies, and various industries reliant on weather information.

1. *Sensor Data Collection:* IoT sensors for temperature, humidity, rain, and other weather parameters are deployed and connected to a microcontroller or microprocessor unit. These sensors continuously measure the environmental conditions and generate data.
2. *Data Transmission:* The microcontroller or microprocessor device is configured to gather the sensor data and send it through a network like Wi-Fi, Ethernet, or a cellular network to the Thing Speak cloud. Normally, the data is sent in a specified format, such as JSON or CSV.
3. *Thing Speak Integration:* In Python, the Thing Speak API is used to establish a connection with the Thing Speak cloud platform. The API allows for sending data to Thing Speak channels and retrieving data from those channels.
4. *Data Storage:* The sensor data received by Thing Speak is stored in specific channels that correspond to each weather parameter. The data is time-stamped and organized based on the specific channel's structure.
5. *Preprocessing and Feature Engineering:* The Python Thing Speak API can be used to obtain the Thing Speak data that has been captured. After that, the data can be preprocessed by handling missing values, eliminating outliers, and, if necessary, normalizing the data. Techniques for feature engineering can be used to extract more useful features from the raw data.

6. **Machine Learning Model Integration:** A variety of machine learning libraries are available in Python, including sci-kit-learn and Tensor Flow, which can be used to create and train predictive models. The preprocessed data can be fed into these models, along with the corresponding target variables (e.g., temperature and rain), to train the models.
7. **Model Training and Evaluation:** The machine learning models are trained using the preprocessed data and appropriate metrics, such as mean absolute error (MAE) for temperature prediction or accuracy for rain prediction, are used to evaluate their effectiveness. The models can be fine-tuned and optimized using techniques like cross-validation and hyper parameter tuning.
8. **Prediction:** Once trained and assessed, the models can be utilized to make predictions on fresh, unforeseen data. This involves feeding the relevant input features (e.g., current weather conditions) into the trained models to obtain predictions for the next day's temperature and rain likelihood.

By integrating Python with the Thing Speak cloud platform and machine learning models, it becomes possible to collect data from sensors, store it in the cloud, preprocess the data, train predictive models, and make accurate predictions for future weather conditions.

In smart weather monitoring and forecasting using machine learning, various algorithms can be employed depending on the specific task and requirements. Here are some algorithms used in the project:

1. **Linear Regression:** Mathematical Representation: $Y = b_0 + b_1X_1 + b_2X_2 + \dots + b_nX_n$ Using one or more input features and a learning algorithm, a continuous target variable is predicted. The goal variable (Y) and the input variables ($X_1, X_2, \dots, X_n$) are assumed to have a linear relationship. The coefficients ($b_0, b_1, b_2, \dots, b_n$) that the algorithm calculates minimize the sum of squared differences between the anticipated values and the actual values.
2. **Random Forest:** A random forest in the context of weather forecasting is made up of several decision trees. Each decision tree is constructed using a portion of the available meteorological data, and the combined prediction of all the individual trees is obtained. Due to its ability to handle intricate connections between characteristics and the desired variables, it is commonly used to forecast variables like temperature and rainfall.
3. **Support Vector Machines (SVM):** Mathematical Representation: $f(x) = \text{sign}(w^T * x + b)$ The supervised learning method SVM performs classification by dividing data points into various classes using the optimal hyperplane..
4. **Neural Networks:** Neural networks are frequently employed for classification and regression tasks because they are adept at learning intricate patterns and relationships from data.
5. **Gradient Boosting:** Gradient boosting algorithms, such as XGBoost or LightGBM, are powerful machine learning techniques for regression and classification problems. Gradient boosting algorithms :Mathematical Representation: $F(x) = \sum_{m=1}^M \gamma_m * h(x; \theta_m)$ XGBoost: Mathematical Representation: $F(x) = \sum_{k=1}^K f_k(x)$
6. **Polynomial Regression:** The mathematical representation for prediction in polynomial regression can be expressed as $Y = b_0 + b_1X + b_2X^2 + \dots + b_nX^n$. In smart weather monitoring, polynomial regression can be used to model complex relationships between weather parameters and make predictions, such as temperature or humidity, based on the sensor data collected from IoT devices.
7. **Logistic Regression:** $P(Y=1|X) = 1 / (1 + e^{-(b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \dots + b_nX_n)})$ can be used to indicate prediction in logistic regression mathematically. In smart weather monitoring, logistic regression can be applied to predict the likelihood of rain occurrence based on weather sensor data.
8. **Decision Tree:** Decision trees can be used in smart weather monitoring to predict variables like rain, temperature, or wind speed based on the collected IoT sensor data.

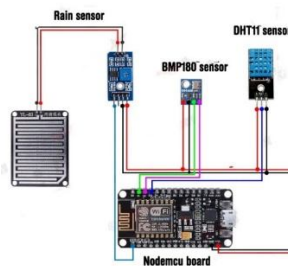


Fig no.1 Circuit Diagram

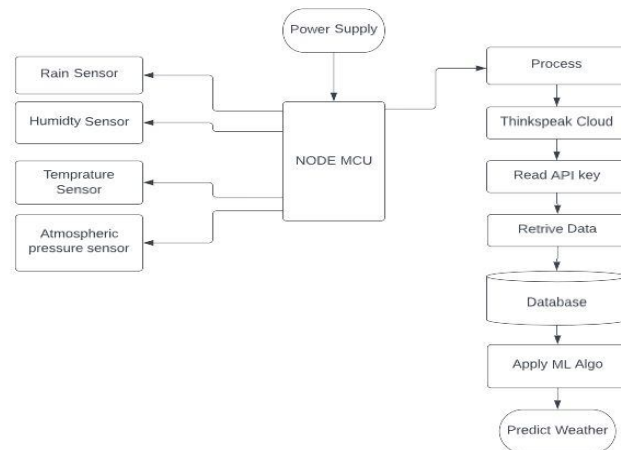


Fig no.2: Flowchart of system

V. RESULT AND DISCUSSIONS

TABLE NO. I: COMPARISON OF ALGORITHMS

Algorithms	Accuracy
KNN	85%
Linear Regression	82%
Logistic Regressor	90%
Polynomial Regression	85%
Decision Tree Classifier	80%
Random Forest Classifier	85%
XG Boost Regressor	96%
Gradient Boosting Regressor	96%
Support Vector Regressor	73%

1) Decision Tree Classifier

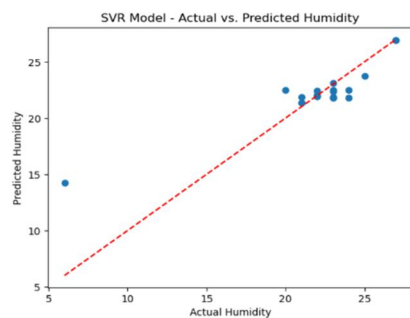


Fig No 3: Scatter Plot

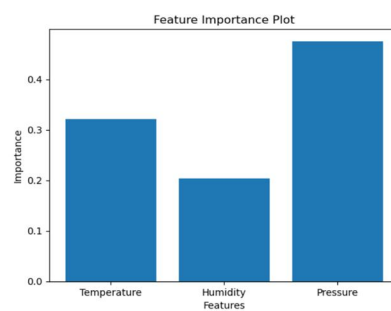


Fig no. 4: Feature Important graph

Accuracy: 0.8
Precision: 0.7157894736842104
Recall: 0.8
F1 Score: 0.7555555555555555

2) Random Forest Classifier

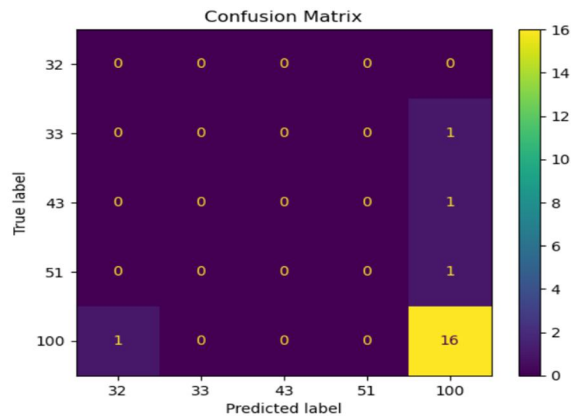


Fig no.:5 Confusion Matrix of Random Forest

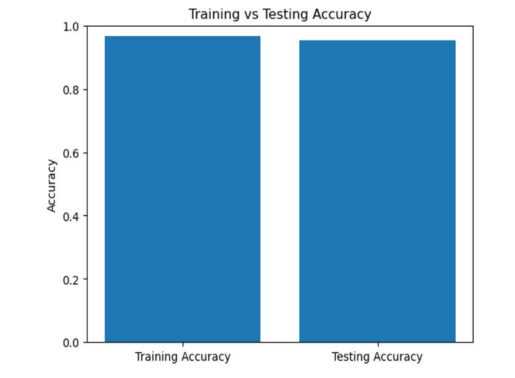


Fig No.:6 Testing vs Training Accuracy i Random Forest

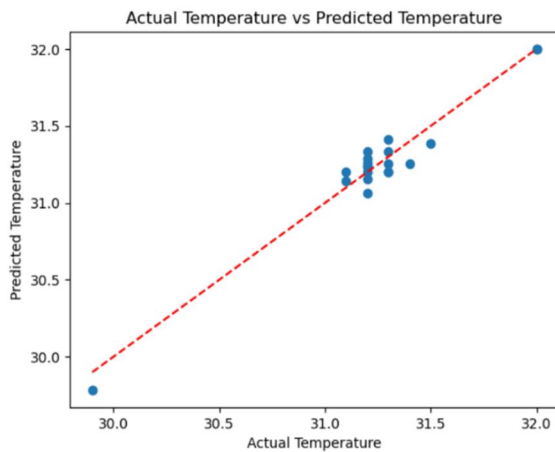


Fig no: 7 Actual vs Predicted value

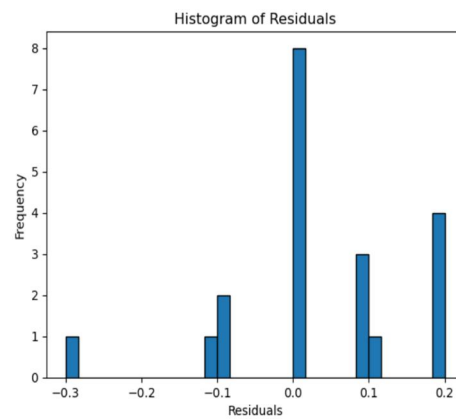


Fig no:8 Histogram

3) Support vector Regressor

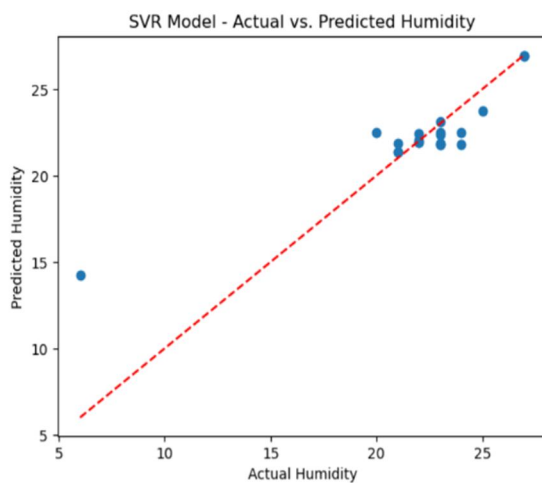


Fig no. 9 Actual vs Predicted value

Mean Squared Error (MSE): 4.450812509762218

R-squared Score (R2): 0.7349128939986767

Evaluation Metrics:

Accuracy: 0.84

Precision: 0.77

Recall: 0.84

F1 Score: 0.8034782608695652

4) XGBoost Regressor

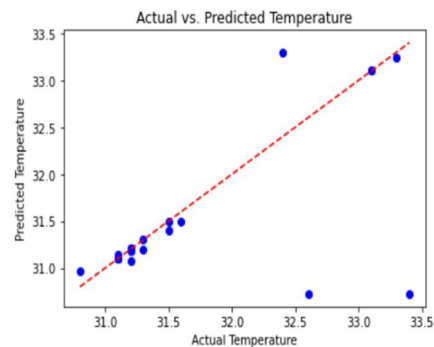


Fig no. 10: Actual vs predicted temperature

VI. CONCLUSION

In conclusion, weather monitoring and forecasting using machine learning (ML) has shown promising results in improving the accuracy and reliability of weather predictions. ML algorithms can process enormous volumes of weather data from a variety of sources and use it to make accurate predictions about future weather conditions. ML models have been used to forecast various weather parameters such as temperature, humidity, and rain. These models can also be used to predict extreme weather events such as rain and temperature. However, it is crucial to remember that forecasting the weather is a difficult undertaking that incorporates numerous elements that might be difficult to anticipate with accuracy. ML models are not perfect and may make errors in predictions, particularly in cases where data is limited or there are unexpected changes in weather patterns. Overall, weather monitoring and forecasting using ML has great potential to improve the accuracy and reliability of weather predictions. Continued field's research and development can lead to significant advancements in our ability to predict and prepare for weather events.

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