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IOT Based Automated Weather Report Generation and Prediction Using Machine Learning

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***Abstract* - Predicting the amount of rain is crucial to people's daily lives. Since the current technologies cannot accurately estimate when it will rain, many different types of individuals have been experiencing inconvenience. Commencing with the farmers who suffer the most, their crops are harmed by intense and unpredictable rainfall. Accurate forecasts are also necessary for city dwellers who commute to work in order to organize their schedules, modes of transportation, and numerous other daily activities. Thus, there is an urgent need for an early warning system that can precisely forecast when it will rain. Our aim is to use machine learning (ML) and Internet of Things (IOT) algorithms to build a system that can accurately predict rainfall. This consist of a microcontroller (Arduino UNO) which records atmosphere parameters with help of three sensors namely DHT11, MQ2 and rain sensor while they are working on the field. These values are logged into THINGSPEAK via the internet with help of a Wi-Fi module called ESP8266.These values are recorded at different instances throughout the day and are fed into the machine learning algorithms. The data is collected and pre-processed to train machine learning models, specifically Support Vector Machine (SVC), XGBoost Classifier, and Logistic Regression, to predict short-term rainfall events. The system aims to compare the machine learning techniques in terms of their accuracy of prediction, with XGBoost surpassing the other two algorithms with an accuracy of 99%.**

Keywords: Machine Learning, SVM, XGBoost Classifier, Arduino, IoT, etc.

I. INTRODUCTION

Rainfall is not just water falling from the sky; it's the lifeblood of our planet. It sustains ecosystems, nourishes agriculture, and supports countless human activities. Its importance cannot be overstated. However, predicting when and where rain will fall has been a challenge, one that impacts various sectors crucial for a nation's development, including agriculture, tourism, aviation, and water resource management. The ability to forecast rainfall accurately and early is not just a matter of convenience; it's a matter of resilience against natural calamities like storms, floods, and droughts.

Traditional methods of rainfall forecasting often fall short in providing precise and localized predictions. These techniques, while valuable, tend to focus on large-scale patterns, neglecting the intricate atmospheric factors that determine weather conditions in specific locations. This gap between data collection and actionable insights highlights the urgent need for innovative solutions.

In this context, the convergence of Internet of Things (IoT) technology and machine learning emerges as a game-changer. By harnessing IoT devices equipped with sensors capable of capturing real-time atmospheric data, coupled with advanced machine learning algorithms, we unlock a treasure trove of insights hidden within vast datasets. This marriage of technology not only enables quicker and more automatic responses but also empowers better decision-making in the face of uncertain weather conditions.

Our project seeks to leverage this transformative potential by developing a field-deployable equipment solution. This equipment is designed to autonomously record key atmospheric characteristics—such as temperature, humidity, gas composition, and rainfall—directly into the THINGSPEAK cloud platform. By seamlessly integrating data collection and storage, our solution lays the foundation for comprehensive and real-time analysis.

Central to our innovation is the implementation of a trained machine learning model capable of predicting rainfall probabilities based on the collected atmospheric data. This predictive model, continuously refined through iterative learning processes, holds the promise of delivering more precise and localized forecasts. By accurately forecasting the likelihood and quantity of rainfall, our project aims to provide advance information crucial for mitigating potential losses,

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particularly for farmers whose livelihoods depend heavily on agriculture.

In essence, our project represents a step forward in the quest for resilient and sustainable development. By harnessing the power of IoT and machine learning, we aim to revolutionize rainfall prediction, empowering stakeholders with actionable insights that pave the way for smarter, more adaptive responses to the challenges posed by an ever-changing climate.

II. LITERATURE REVIEW

The Internet of Things (IoT), a cutting-edge and practical method of connecting sensors to the cloud that can store real-time sensor data and connect anything in the world to a network, is used in the proposed system [1] Algorithms like multiple regression and linear regression are used for prediction. Data on temperature, humidity, air pressure, and air quality are all provided by the system. The findings are shown in the Arduino IDE, RStudio, mobile app view, and Thing Speak WebView.

A range of techniques, including K-Nearest Neighbors (KNN), Decision Tree Classifier (DT), Logistic Regression (LR), Support Vector Machine (SVM), and Random Forest Classifier (RFC), have been employed in supervised learning to train the data. It forecasts when it will rain by using the DHT11 sensor to measure temperature and humidity in real time. The authors in [2] give a comparison of the algorithm's accuracy. Random forests and decision trees are the most accurate models—they are nearly 100% correct.

Real-time weather monitoring is facilitated by IoT. Different types of data from multiple sensors are transmitted to a webpage using the HTTP request protocol on the web server.

The system measures temperature and humidity using a DHT11, measures barometric pressure with a BMP180, and detects rain with a rain sensor. The system finds all of these variables at three locations in Gorakhpur. They have analyzed the data and arranged all of the values in tables according to the time and date. When compared to the real data, the accuracy of the proposed model [3] is nearly flawless.

The machine learning approach employed in this weather forecasting system, the random forest method, is based on the ensemble learning principle, which entails combining multiple classifiers to solve a complex problem and improve the model's performance.

The system uses DHT11 to measure temperature and humidity, and BMP180 to display barometric pressure. The proposed system [4] highlights the importance of these features in rain prediction. The most important factor is humidity, which is followed by pressure and temperature.

The authors in [5] tested data mining techniques for weather forecasting using the Time series algorithm with SARIMAX in this suggested system using a sample dataset. The proposed methodology uses SARIMAX (Seasonal Auto-Regressive Integrated Moving Average with EXOGENOUS components), a notable adaption of the ARIMA version, as a time series set of rules. The object that is returned after fitting the data can be used to forecast using the SARIMAX predict () and forecast () functions. They indicated the exogenous variable that will be used to construct the projections, the start and end dates, and they used predict (). We may also supply exogenous factors and phases and use forecast (). SARIMA is combined with a numerical model primarily based on time-series observations to forecast an environment of a region with 96% accuracy.

The authors in [6] discuss the development of an embedded weather monitoring system for industrial applications. The system utilizes a pair of sensors to monitor temperature, gas, and humidity, along with an LPCC1768 microcontroller (arm9). The collected data is stored in an Excel document, and the system is designed to send SMS messages to mobile devices. The microcontroller communicates with LabView through serial communication, and the embedded C programs are created using the Keiluvision4 IDE. The programming is loaded into microcontrollers using JTAG. The focus is on creating a compact and efficient system for monitoring crucial weather parameters in industrial settings during hazardous situations.

The paper [7] introduces an innovative weather monitoring technology that utilizes the Internet of Things (IoT) to track and display weather data from any location globally. IoT is highlighted as a powerful method to connect objects, creating a network for various devices, sensors, and electrical equipment. The system [7] employs sensors to monitor and control environmental factors such as temperature, relative humidity, light intensity, and CO2 levels. The gathered data is transmitted to a web page, where graphical statistics are generated to visualize the sensor data. The emphasis is on leveraging IoT technology for comprehensive and accessible weather monitoring.

The objective of the study [8] was to develop a machine-learning-driven predictive model capable of accurately and efficiently estimating monthly rainfall with minimal error. In order to assess and validate the training dataset, a comparative

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analysis between observed data and anticipated outcomes was conducted. Furthermore, feature extraction was employed to enhance the precision and accuracy of the predictive results. The machine learning methodologies utilized encompassed random forest, decision tree, logistic regression, and Artificial Neural Network algorithms.

The paper [9] presents a refined approach for temperature forecast prediction leveraging machine learning methodologies, with a particular focus on Long Short Term Memory networks (LSTM). The primary objective of this investigation [9] is to provide accurate forecasts of temperature parameters, thereby enabling farmers to make informed decisions and mitigate potential losses through proactive measures. The study compares the performance of the ARIMA model against LSTM in predicting average daily temperatures at specific stations during distinct seasons.

The sample dataset [10] served as the basis for evaluating data mining methodologies in weather forecasting, employing the Time Series algorithm with SARIMAX. Predictions regarding temperature and rainfall patterns in a given locale were derived from various indicators, including minimum and maximum temperatures, relative humidity, and atmospheric pressure. A numerical model, predominantly reliant on time-series data, was employed to forecast environmental conditions within a specific geographical area over a defined period.

The paper [11] utilizes a rudimentary Machine Learning error correction model to post-process Numerical Weather Prediction (NWP) forecasts demonstrates a notable enhancement in Normalized Root Mean Square Error (NRMSE) within tropical regions. The mitigation of systematic errors across various radiation models diminishes inter-model disparities, thereby possibly obviating the necessity for tailored model adjustments. This revelation represents a novel contribution of the present study, heretofore unexplored in prior literature pertaining to hybrid forecasting methodologies, as far as the authors are aware.

The study [12] was conducted to assess the efficacy of Artificial Neural Networks (ANNs) and Deep Learning Neural Networks (DLNNs) in rainfall forecasting. The Deep Learning Neural Network (DNN) achieved an accuracy of 92.59%, while the Artificial Neural Network (ANN) exhibited a higher accuracy of 95.68%. Statistical analysis using the SPSS program revealed a significance ratio of 0.034 ($p < 0.05$). Consequently, it is concluded that the ANN algorithm surpasses the DNN method in predicting rainfall within the framework of advanced weather forecasting techniques.

The study [13] conducted short-term temperature prediction experiments by employing various weather attributes as inputs through the implementation of a Long Short-Term Memory (LSTM) model tailored to the Colombo weather station in Sri Lanka. Through rigorous evaluation, the LSTM model demonstrated consistently low Root Mean Square Error (RMSE) and Mean Absolute Error (MAE) values for temperature predictions on the test dataset. Notably, the LSTM model yielded a prediction error of approximately 1.21% for temperature forecasts, underscoring a nominal average disparity between actual observations and LSTM model predictions within the test set.

III. SOFTWARE DESIGN

Machine Learning Algorithms:

An extensive examination of literature on rainfall prediction has been conducted in order to select the most suitable machine learning algorithms for the predictive analysis. XGBoost classifier, SVC, and logistic regression are some of the three methods that were selected for the experiment in order to forecast the daily intensity of rainfall based on real-time environmental data. In order to identify the most effective algorithms for predicting the amount of rainfall that falls each day, the three machine learning algorithms were tested and compared.

XGBoost Classifier:

Because atmospheric circumstances are complex, predicting the current status of rainfall is a difficult undertaking. An effective remedy in this context is provided by the ensemble learning algorithm XGBoost, which is well-known for its strong performance in classification tasks. A number of factors influence its overall performance, including how well it predicts the current status of rainfall.

First off, modelling the complicated correlations between rainfall occurrence and meteorological variables is a good use for XGBoost due to its capacity to handle high-dimensional data with complex interdependencies. XGBoost can detect interactions and nonlinearities in the data by utilising an ensemble of decision trees, which helps it to produce precise predictions even when complex patterns are present.

SVC (Support Vector Classifier):

A strong machine learning technique called Support Vector Classification (SVC) is frequently used for classification tasks, such as forecasting the amount of rainfall for the current day. Its efficacy in this particular environment is contingent upon multiple pivotal aspects, all of which augment one another.

SVC functions by determining which hyperplane in the feature space best divides various classes. When predicting the

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state of rainfall, this entails developing a decision boundary based on input meteorological characteristics that efficiently separates rainy days from non-rainy days. SVC is appropriate for capturing complicated relationships in the data since it can handle both linear and nonlinear decision limits.

Logistic regression:

A basic approach for classification, logistic regression can also be used to forecast the amount of rainfall for the current day. Several important criteria, each of which adds to its overall efficacy, determine how well it performs in this activity.

In order to do logistic regression, a logistic function is used to predict the likelihood that a given input belongs to a specific class. Estimating the likelihood of rain based on input meteorological features is what this means when projecting the state of rainfall. Logistic regression, in spite of its simplicity, is capable of capturing linear correlations between features and the likelihood of precipitation.

Methodology:

Data Collection:

Raw data for this study were gathered from Pune City, India's regional weather station. There were ten data features: day, pressure, temperature, minimum temperature, humidity, cloud cover, rainfall, sunshine, wind direction, and wind speed. Directly from the station's gadgets, the meteorological station records the environmental variable's values daily for the entire year. Next, the information was entered into a Microsoft Excel file using a tabular structure. The study made use of the station's ten-year (2008–2018) worth of raw data.

Data Pre-processing:

Data conversion, managing missing values, category encoding, and separating the dataset into training and testing datasets were all included in the data pre-processing step. Data from the meteorological office were gathered for a period of ten years, from 2008 to 2018. The target variable's missing values were eliminated and the other features were filled in using the data mean since the raw data comprised missing values and values that had been incorrectly encoded. Data were transformed from Excel to CSV in the meteorology office.

The dataset was first encoded before being made ready for the experiment. The dataset was divided into 80% for training and 20% for testing, with the relevant features for rainfall prediction being chosen. This dataset was then used as an input for the model

EDA (Exploratory Data Analysis):

EDA is a method of data analysis that makes use of visual aids. With the use of statistical summaries and graphical representations, it is utilised to find trends and patterns as well as to verify assumptions. We'll look at how to check the skewness and imbalance of the data here.

- Following EDA on the dataset that the metrological department supplied, we were able to create a pie chart that showed 68% of the probability of rainfall and 32% of the likelihood that it won't.

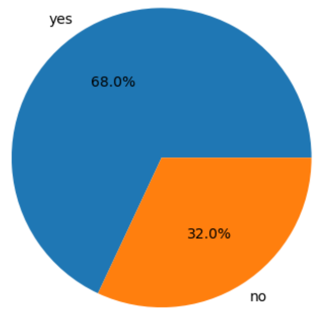

Figure 1: EDA (Exploratory Data Analysis)

- Other insights include:
  1) The maximum temperature is typically lower on days when it rains.
  2) Days with rainfall have greater dew point values.
  3) Days with a predicted rainfall are high in humidity.
  4) Rainfall obviously requires the presence of clouds.
  5) Days with rain also have less sunshine.
  6) Days with rain are associated with increased wind speeds.

Our observations, derived from the aforementioned dataset, closely align with real-world observations.

Model:

A machine learning technique was used in this paper to forecast possibility of rainfall. Three machine learning techniques, namely the logistic classifier, SVC, and XGBoost classifier, were examined. These algorithms utilised input data that were significantly and moderately correlated with environmental factors linked to rainfall

Model Evaluation:

Confusion Matrix

A tabular format that makes it possible to visualise how well a classification method is working is called a confusion

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matrix. It displays the number of predictions the model made that were true positives (TP), true negatives (TN), false positives (FP), and false negatives (FN).

True Positives (TP) are examples of data that the model accurately anticipated to be positive.

True Negative (TN): Examples where the model accurately anticipated the data to be negative.

False Positive (FP): Those cases when the model mis predicted the data to be positive (Type I error).

False Negative (FN): Examples of data that the model mis predicted as negative (Type II error).

The model's predictions can be evaluated for accuracy using the confusion matrix, especially with regard to sensitivity (recall), specificity, precision, and overall accuracy. It can help discover areas for improvement, such resolving class imbalances or modifying the classification threshold, and provide insights on the model's performance across several classes.

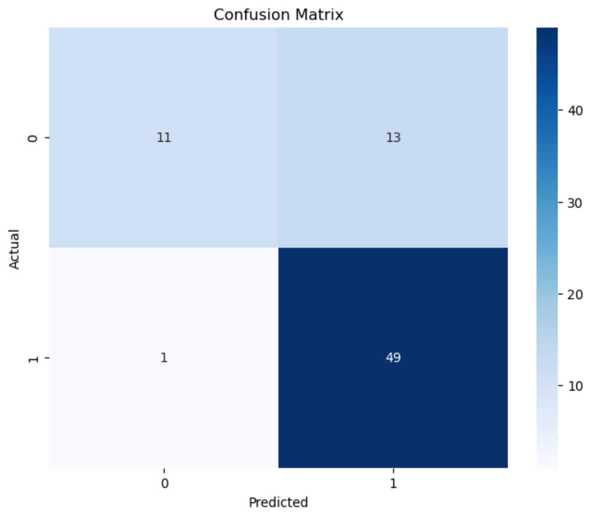

Figure 2: Confusion Matrix

To calculate recall, accuracy, precision, and error rate from the given confusion matrix:

True Negative (TN) = 11
False Positive (FP) = 13
False Negative (FN) = 1
True Positive (TP) = 49

Findings:

1) Recall= 0.98
2) Accuracy= 0.81
3) Precision-0.79
4) Error Rate = 0.19

IV. SYSTEM DESIGN

In the proposed model a microcontroller called ATMega328 is connected to the Wi-Fi module ESP8266. Different sensors are connected to the microcontroller such as the rain sensor, DHT11, BMP180 and MQ135 which collect data from the surroundings in accordance with the range of each sensor.

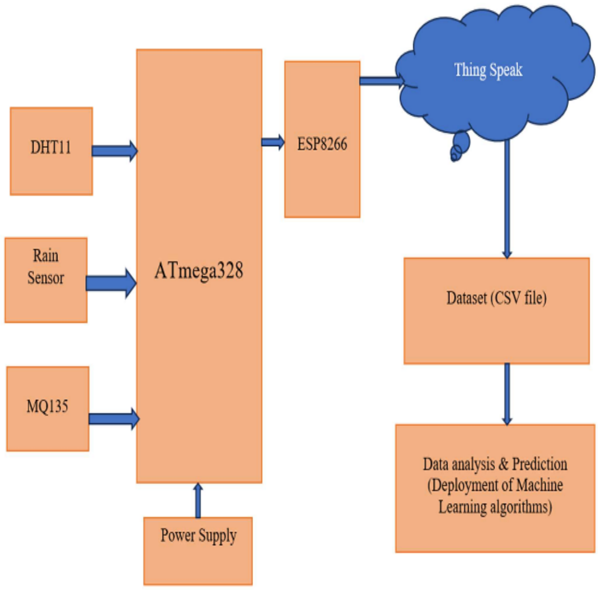

Figure 3: Block Diagram

This real-time data collected by the sensors is further stored in a cloud using the Wi-Fi module ESP8266.

To have a visual representation of this data a channel on the Thing speak web application needs to be created and feeding the ESP8266 with the API key of the channel created.

This data can be extracted from ThingSpeak in the inthe.csv file format.

To train the information so as to get the analysis and prediction we will take previously collected data from the metrological department.

To test the model, we will use the data collected by out proposed model by deploying it in 3 different locations for an about 20 days.

The model will able to predict the weather for the next day with accuracy by the deployed machine learning algorithm.

Following figure shows the flowchart of the system:

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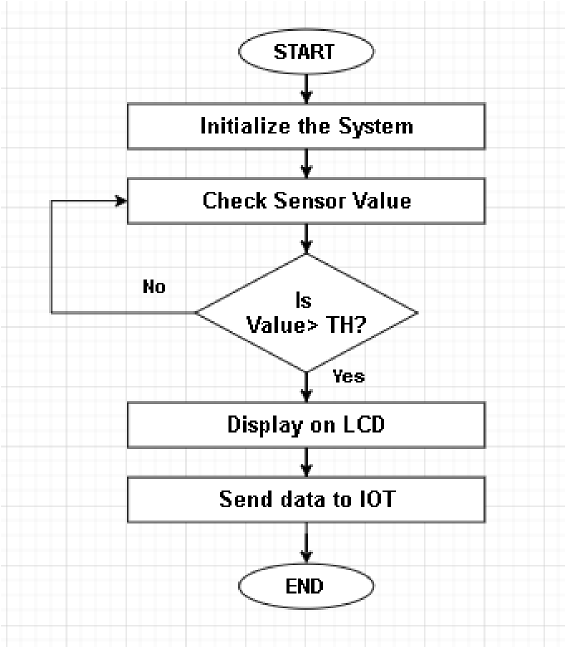

Figure 4: Flowchart of the System

V. RESULT AND DISCUSSIONS

The primary focus of this study revolves around predicting the occurrence of rainfall on a given day based on sensor data. The dataset was partitioned into a training set comprising 80% of the data and a test set containing the remaining 20% using the sklearn.model_selection module. The splitting process was randomized to ensure an unbiased distribution of data between the training and test sets. Using the accuracy_score() function from sklearn.metrics, the accuracy of the machine learning model was evaluated. Remarkably, a high accuracy of 99% was achieved, indicating the model's proficiency in accurately predicting rainfall occurrences.

A comparative analysis of three different models—Support Vector Classifier (SVC), Logistic Classifier, and XGBoost Classifier—was conducted, highlighting their respective training and validation accuracies. The SVC model demonstrated a training accuracy of 87% and a validation accuracy of 90%. The Logistic Classifier exhibited a training accuracy of 88%, matching its validation accuracy. Notably, the XGBoost Classifier outperformed the others with a training accuracy of 99% and a validation accuracy of 88%.

In conclusion, the study successfully developed a robust machine learning model capable of predicting rainfall occurrences with exceptional accuracy. The evaluation of various models provided insights into their individual performances, with the XGBoost Classifier emerging as the most accurate predictor.

Table 1: Result Table

Model	Training Accuracy	Validation Accuracy
SVC	**87%**	**90%**
Logistic Classifier	**88%**	**88%**
XGBoost Classifier	**99%**	**88%**

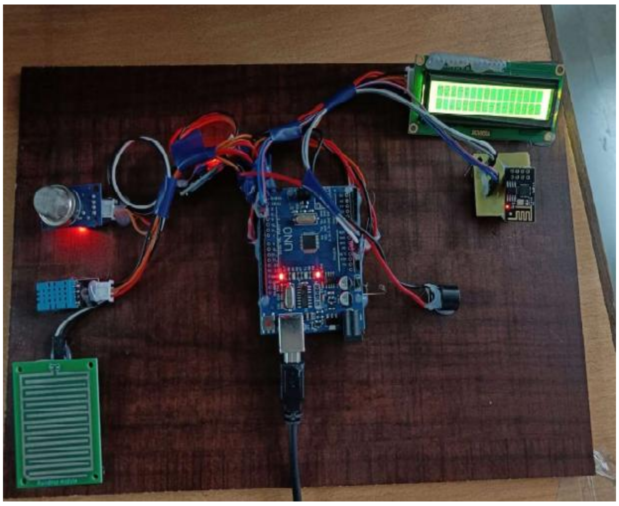

Figure 5: Hardware Setup

Figure 5 depicts the hardware design incorporating the ATmega328 microcontroller, ESP8266 module, and sensors DHT11, MQ02, and Rainfall Sensor, alongside an LCD display. The schematic illustrates the connections between these components, showcasing how sensor data is collected and transmitted, with the LCD display providing real-time feedback on environmental conditions.

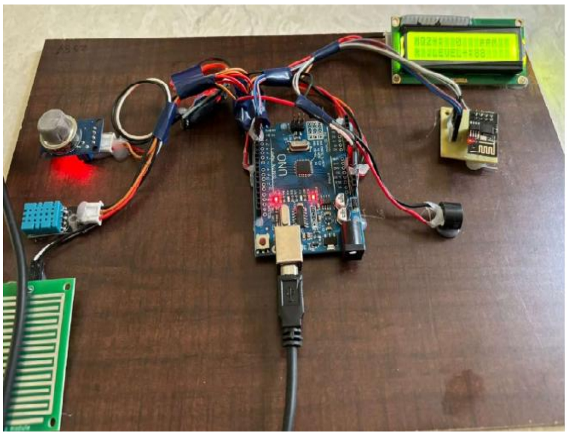

Figure 6: Gas and Rainfall Detection

Figure 6 displays the data output from the MQ2 gas sensor and the rainfall level sensor. It visually represents fluctuations in gas concentrations detected by the MQ2 sensor and changes in rainfall levels measured by the rainfall sensor over time.

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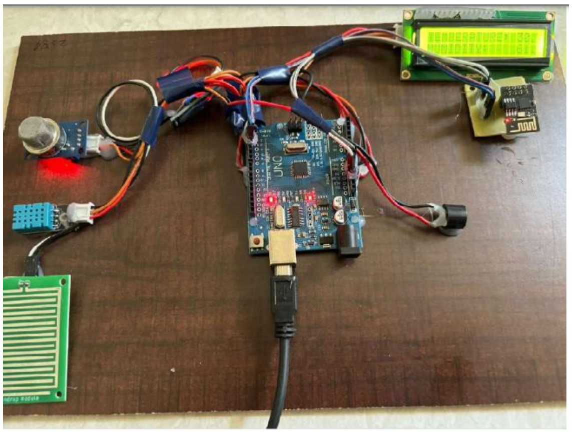

Figure 7: Temperature and Humidity Detection

Figure 7 presents real-time temperature and humidity data obtained from the DHT11 sensor. These real-time results enable continuous monitoring and prompt response to changes in temperature and humidity, essential for the rainfall predictions.

VI. CONCLUSION

In conclusion, the development of an accurate rainfall prediction system holds paramount importance, given its far-reaching implications across various sectors of society. The inconvenience caused by unreliable rainfall forecasts affects diverse individuals, from farmers contending with crop damage to urban commuters needing to plan their daily routines. Recognizing this pressing need, our project integrates machine learning (ML) and Internet of Things (IoT) technologies to create a robust system capable of precisely forecasting rainfall events. At the heart of our system lies a microcontroller, Arduino UNO, strategically equipped with three sensors—DHT11, MQ2, and a rain sensor—designed to capture crucial atmospheric parameters while deployed in the field. These sensors continuously monitor temperature, humidity, gas concentrations, and rainfall levels, transmitting real-time data to the cloud-based platform THINGSPEAK via the ESP8266 WiFi module. This seamless data acquisition process ensures a comprehensive dataset for subsequent analysis and prediction. Harnessing the power of machine learning algorithms, namely Support Vector Machine (SVC), XGBoost Classifier, and Logistic Regression, we meticulously train and fine-tune our models using the collected data. By preprocessing and feeding the dataset into these algorithms, our system learns to recognize patterns and correlations indicative of impending rainfall events. Through rigorous evaluation, we ascertain the performance of each algorithm, with the XGBoost Classifier emerging as the standout performer, boasting an impressive accuracy rate of 99%. The efficacy of our rainfall prediction system extends beyond the agricultural realm, benefiting urban communities by providing invaluable insights for efficient resource management and daily planning. With the ability to accurately anticipate rainfall, individuals can optimize their schedules, transportation arrangements, and other activities, thereby mitigating potential disruptions caused by inclement weather conditions. In essence, our project underscores the transformative potential of integrating ML and IoT technologies to address pressing societal challenges. By delivering precise and reliable rainfall forecasts, our system empowers stakeholders across diverse sectors to make informed decisions, fostering resilience and sustainability in the face of dynamic weather patterns. As we continue to refine and optimize our approach, we envision a future where advanced forecasting systems contribute to enhanced societal well-being and environmental stewardship on a global scale.

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