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Weather Forecasting: A Comprehensive Exploration of IoT and Machine Learning

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Abstract - Weather forecasting play an important role in human lives.It is impacting on various human activities such as agriculture and transportation.Changes in climate conditions often lead to unpredictable weather. Conventional forecasting models sometimes provide inaccurate predictions because they don't adapt well to the dynamic nature of climate.The integration of (IoT) and Machine Learning (ML) technologies has revolutionized weather forecasting methodologies.This paper explores how combining Machine Learning (ML) algorithms with Internet of Things (IoT) devices improves weather forecasting accuracy and efficiency. By analyzing real-time data and historical patterns, this paper shows how IoT and ML can offer more accurate and timely forecasts compare to the limitations of traditional methods.Accurate weather forecasts are really important for things like farming, transportation, saving energy.In this paper the effectiveness of the algorithm is evaluated using various performance metrics including r2 score comparison,mean square error comparison.

Key Words: IOT,Machine Learning,Support Vector Machine

1.INTRODUCTION

Weather forecasting has always been a critical aspect of human life, influencing everything from agriculture to transportation, and even impacting on human daily activities. Traditional methods of weather prediction have relied heavily on historical data, mathematical models, and meteorological expertise. However, using IoT and machine learning, a new techniques of weather forecasting promising higher accuracy and improved understanding of weather patterns.In this review paper, they focus on a comprehensive exploration of how IoT and ML technologies are revolutionizing weather forecasting.The integration of IoT devices, which collect large amounts of real-time data from various environmental sensors like pressure, temperature,wind speed, and humidity .With the help of IOT devices and machine learning approaches real time weather prediction can be achieved with greater accuracy as compared to traditional methodologies.The main objective of this review paper is to provide cost effective and readily accessible solution and also evaluate the accuracy of the weather prediction.This paper introduce various weather forecasting techniques including manual observations,numerical weather prediction models,IOT and machine learning algorithms.This paper used DHT 11,BME 280 and Raindrop sensor for environmental monitoring in IOT applications.It also uses various machine learning approach like ANN,Random forest,support vector machine, and Linear Regression for prediction.Main objective is to used IOT and machine learning techniques for accurate weather prediction.weather forecasting which helps to understand impact on environment.So accurate weather forecasting is very important in our daily lives,which allows to make proper decision on our daily activities and protect from potential hazards.So traditional forecasting methods often encounter limitations due to the complex and dynamic nature of atmospheric processes.So using IOT to gather real time data from different sources such as sensors and weather station. These data are then processes and analyzed using advanced learning algorithm , like support vector machine and random forest.So weather forecasting plays a very important role in various sector such as agriculture,transportation and disaster management.

2. Literature Survey

Author[1] introduced a technique for weather forecasting using IOT and Machine Learning algorithm.Author uses IOT and Machine learning to provide accurate analysis of weather forecast and give cost effective solution to individuals and communities.Using different IOT based Sensors like DHT11 ,BME280 and Raindrop sensor collect real time data based on parameters like humidity,temperature,pressure and raindrop precipitation.using a (ESP8266) Wi-Fi module this collected data transferred to cloud platform Thingspeak.After that trained machine learning model based on retrieved features

and using mean square error and R square error analyze the performance of algorithm.

Mohammad Bannayan and Gerrit Hoogenboom[2] explain about KNN Approach for weather forecast, first it give historical and target year weather data as user input files .Gather historical weather data including parameter such as atmospheric pressure, humidity, wind speed, temperature.After preprocessing Choose relevant features that contribute to weather prediction accuracy. To guarantee that every feature contributes equally to the distance calculation, normalize the characteristics. Training a KNN entails storing the feature vectors together with the labels that go with them. Determine the distance between each new weather observation and every other data point in the training set using the selected distance metric (such as the Euclidean distance).Based on the estimated distances, choose the K closest neighbors (data points) to the new observation.

Author[3] explain about how to predict accurate rainfall prediction with the help of ANN and deep learning Neural Network . Now a days unpredictable rainfall results in flooding, affect on various human activities,sewage networks,public infrastructure and crop cultivation.So in this paper they comapre ANN and Deep Learning method in terms of their efficiency.So it showing ANN is outperformed than Deep Learning.

Ashkan Safari,Amir Aminzadeh Ghavifekr[4] explain about Quantum Neural Network used in weather prediction in smart grids.Quantum technology, how it can be used to predict the weather for smart grids.It analyze what's happening in this field right now and in the future.Smart grids are really important for smart cities,factors like Demand response and weather forecasting are crucial elements that play a big part.So for weather prediction it uses highly accurate model to predict weather,so they combined AI and NN which is more efficient.But smart grid which having large amount of data,so AI and ANN approach is inefficient.So in this paper they combined Quantum technology and QNN which having the potential to predict weather with higher accuracy and execution speed.So in this paper they comare QNN and ANN in terms of accuracy for large amount of data.

Kalpana Murugan,Ravi Kiran Tiruveedhi,Dinesh Reddy Ramireddygari,Deepika Thota,Chandralekha Neeli author shows[5] comparitive study for weather monitoring system.Multiple existing systems are available for weather monitoring and control but they are facing cost challenges due to their broad city wide coverage rather than focusing on specific locations . So in this paper author suggests an economical and effective way to monitor the weather.Using image classification and processing to monitor weather conditions accurately.Rather from being a binary choice, weather monitoring is typically an analytical and statistical instrument.It is necessary for the expansion and development of sectors such as logistics, manufacturing, and agriculture.It is necessary to make an intelligent prediction using AI weather monitoring.Using different AI techniques like Machine Learning and Deep Learning response to the challenging recent demands in weather monitoring and weather forecasting.In this paper a unique, most economics and simplified weather monitoring system is proposed through image classification techniques.The proposed system integrates Internet of Things (IoT) and AI technologies to automate the model development process.Specifically, the system utilizes the teachable machine platform for weather condition detection,integrate system by the ESP32 camera module. The captured images are then transmitted to the virtual display of the Blynk application, offering a user-friendly interface for visualizing the output.so in this paper author shows proposed system which gives accuracy about 95% to 100% as in contrast to current system accuracy such as 5% to 10% accurate.K. Bala Maheswari ,Dr. S. Gomathi[6]In this author introduces innovative deep neural network algorithm for weather prediction.It has potential to revolutionize weather prediction.To capture complex relatioship between various weather variables is use of deep learning for weather prediction.In traditional approach Models used to predict weather are based on physical quations that explain the changes in the climate.This equation is very hard to be solved accurately and it captures only limited number of variables.deep learning offers the advantage of forecasting over extended timeframes. While traditional weather prediction models typically exhibit accuracy within a limited temporal window of a few days, deep learning methodologies demonstrate prowess in making reliable predictions over more extended periods.

author explain[7] about development of IOT based Weather reporting system.Protect from potential hazards and plan how to execute our daily acitivity,weather forecasting play important role by providing essential information to us.It is very useful in agriculture field,where meteorological parameters such as temperature,rainfall and humidity,profoundly influence crop yeilds and harvest outcomes.In this paper, a hardware module, incorporating an ESP-32 controller and various sensors, has been developed to capture diverse meteorological parameters. Subsequently, these parameters are uploaded to a cloud-based MYSQL database. Additionally, historical weather data spanning 21 years, sourced from the Data Access Viewer (DAV) website, has been accumulated. A cloud database housing this historical data from January 1, 2001, to January 1, 2022, has been established. This database undergoes periodic updates with real-time sensor data captured by the hardware module on an hourly basis.Machine learning algorithms have been employed to forecast weather parameters for user-specified durations. Furthermore, recommendations regarding feasible crops for cultivation are provided based on the analyzed data. An HTML web page featuring a user interface has been developed to facilitate the collection of user queries, display predicted weather parameters, and offer suggestions regarding suitable crops for cultivation in a given region.author explain[8] Significant fluctuations in climate conditions reflect an unpredictable behavior of weather posing substantial challenges in daily life.Traditional forecasting techniques can't adjust to dynamic climate shifts, they frequently produce projections that are off. In response, This research presents an improved method of weather monitoring that combines a variety of sensors with inexpensive GPS-enabled Internet of Things devices. Data collected from these sensors is centralized on a server for analysis, enabling the prediction of important meteorological factors such air pressure, humidity, and temperature within a specified

geographical area of interest. To achieve this, several soft computing techniques including Deep Neural Networks (DNN),Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Ridge Regression, Linear Regression, and Artificial Neural Networks (ANN) are employed to establish correlations between current weather conditions and future forecasts for the designated location.

This paper introduces a novel approach to weather forecasting by leveraging Neural Network technology. Unlike traditional physical models, Neural Networks offer a simplified yet intelligent framework. They are notably less resource-intensive and can be seamlessly deployed across various computing platforms. Moreover, historical data from adjacent regions, acquired through our self-sufficient weather data collectors, supplement the forecasting process for specific areas. This method proves superior to solely relying on local data by incorporating a broader network of information accessed through web APIs. The IoT devices employed are compact, energy-efficient, and boast exceptional portability and reliability. Among the Recurrent Neural Networks (RNN), and Artificial Neural Network models Long Short-Term Memory (LSTM) algorithms are also use to enhance temperature and humidity predictions, achieving with less error rate.

Comparision between different methods used in wearther forecasting:

Traditional Methods	Paper Title	Techniques used	Limitation	Objective/Aim
manual observations and numerical weather prediction models	Comprehensive Study of Weather Prediction Using IoT and Machine Learning	IOT and Machine Learning Algorithm		The aim is to develop a cost-effective and accessible solution for individuals and communities and evaluate the accuracy of the predictions
Previous research hasn't been able to accurately predict rain because of weather conditions.	Accurate Weather Forecasting for Rainfall Prediction using Artificial Neural Network compared with Deep Learning Neural Network	Deep Learning Neural Networks,ANN-ANN provides more accuracy	This study's restriction is that the characteristic chosen must be the best one for detecting rainfall; else, the detection rate would be lowered.	The goal of this study was to evaluate the potential utility of AI techniques such as (DLNNs) and (ANNs) for rainfall prediction (DNN).
The suggested system's performance is contrasted with that of several other models currently in use, including KNN, ANN, SVM, ,logistic regression and linear regression.	an intelligent weather prediction system based on iot	ANN with LSTM, SimpleRNN, and KNN (generate low accuracy) all yield noticeably better results.	The outcome could be enhanced even further by adding more elements such as wind speed and gust. d	The suggested approach is a clever way to predict daily weather conditions.
bcompile a historical dataset containing all relevant weather, precipitation, and attribute information. It's possible that none of the nearby weather stations have all of those characteristics.	An Interactive Predictive System for Weather Forecasting	Aladin models, High Resolution Limited Area Model (HIRLAM) models, and numerical weather prediction models in Jordan	-compile a historical dataset on the precipitation, temperature, and any other relevant characteristics. It's possible that none of the nearby weather stations have some of those characteristics. There's a chance that some of the data is inaccurate or incomplete.	attempt to develop a numerical weather forecast model in Jordan that accounts for Jordan's annual rainfall.
Conventional weather forecasting methods rely on mathematical formulas that characterize the behavior of the atmosphere.	Analyzing the Performance of Diverse Deep Learning Architectures for Weather Prediction	DL models, such as LSTM or CNN, SVM or ANN models	data cleaning is more important in deep learning algorithm for better performance	The study's main objective is to look at methods for successfully integrating the data's non-linear characteristics into neural network topologies.
ineffective when they collect massive volumes of big data (BD), and traditional neural networks (NN) will not function	Quantum Neural Networks (QNN) Application in Weather Prediction of Smart Grids	Comparision QNN with ANN	This database is updated on an hourly basis using sensor data that is taken in real time utilizing a hardware module.	It contrasts conventional ANN-based methods with the Quantum Neural Networks (QNN) approach for weather prediction.
Previous method provide less accuracy	Development of IoT Based Weather Reporting System	When predicting temperature, GPR has a lower RMSE value than LR and SVM.	The database is updated on an hourly basis using sensor data that is gathered in real time using a hardware module.	using the machine learning algorithm to make predictions after gathering precise and reliable meteorological data from the surrounding area
They are being used throughout the entire city instead of just one location, which makes them costly and outdated.	AI based Weather Monitoring System	deep learning approaches using Teachable Machine	sensors transfer data to the cloud, detect earthquakes, and measure precipitation	The suggested system integrates the ESP32 camera module with a teachable
			levels.	machine platform to detect the weather.
Weather forecasting is challenging because of the large variability of climate information collected in a single day.	IoT Framework for Real Time Weather Monitoring using Machine Learning Techniques	decision trees and the (Random Forest Algorithm-better)	In the future, we can make this imbalanced dataset into a balanced dataset	The goal of this project is to utilize machine learning techniques to accurately anticipate the weather and to forecast the weather characteristics for the next 24 hours using the Auto ARIMA model.
examine their effectiveness in the area of rainfall forecasting.,instrument-based and statistic models	Machine Learning-based Rainfall Prediction from Weather Data: A Comparative Analysis	artificial neural networks (ANN), principal component analysis (PCA) and linear regression, support vector regression (SVR) without PCA, support vector regression (SVR) with PCA, and lastly)	**compare their performance on large amount of data (accuracy of prediction) with respect to validation loss.**	carried out a comparative analysis to understand the algorithms' overall performance and select the most accurate and effective algorithm.

3.Proposed Method: In following Fig. 1 illustrates the methodology employed in this paper investigation. Initially, data collection involves gathering numerous meteorological

factors, such as pressure, temperature, humidity, and precipitation, utilizing sensors such as DHT11, BME280, and a Raindrop sensor. Subsequently, the acquired data from these sensors are transmitted to the cloud platform Thingspeak through a Wi-Fi module (ESP8266).

Following data acquisition, the next phase entails extracting features from the collected data. Once the relevant characteristics are identified, a machine-learning model is developed and trained using the data. In this paper , they utilized several machine learning algorithms, including linear regression, support vector machines, random forests, and artificial neural networks. The performance of these trained machine learning algorithms is then assessed using measurements like mean square error and R squared error.After that it display the value of trained model.

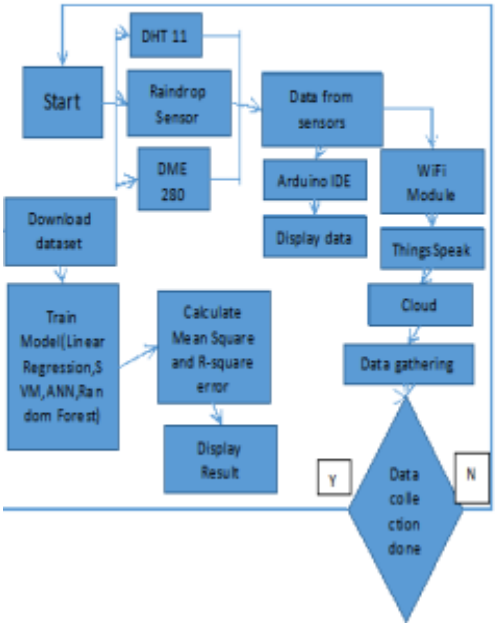

Fig -1: IOT and ML in Weather Forecasting

4. CONCLUSIONS

In this paper they used sensors like DHT11, BME280, and raindrop sensors to gather information about humidity,pressure, temperature, and rain levels.It used different algorithms like Random Forest, ANN, Linear Regression, and Support Vector Machine to predict future weather conditions.By calculating Mean square and R-square error

They compared these algorithms by looking the mean square error, which tells us how accurate they are. However,they found that need more data and other factors to make predictions even more accurate.

Depending on the technique used, the algorithm with the highest R square value and the lowest mean square value is considered the best one. After analyzing results, they concluded that Random Forest is the most suitable algorithm for weather prediction task.

The unique aspect of research is the integration of emerging technologies like IoT (Internet of Things) and machine learning to address challenges in weather prediction, rather than simply comparing these approaches with conventional methods. In this paper they represents a step forward by incorporating IoT technologies, which furnish real-time, high-resolution meteorological data, and by employing machine learning algorithms designed for weather prediction tasks. These advancements allow us to offer cost-effective and readily available solutions, consequently enhancing the accessibility of accurate weather forecasts. Future research may involve further comparative analyses to expand upon findings.In future we ensemble IOT with machine learning and QNN for better accuracy.

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