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RESEARCH ARTICLE

AWARE-AGRI: REAL TIME SENSORS-BASED ADAPTIVE WEATHER FORECASTING FOR AGRICULTURE

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Abstract – Weather and climate conditions have become more erratic and unpredictable, both domestically and internationally, which might have a devastating effect on agricultural output. Numerous climatic elements, including temperature, humidity, precipitation, air quality, and many more, are constantly altering in a frighteningly unpredictable way. Having a local weather station that can provide farmers with up-to-date information on the weather is crucial. It is essential to have a nearby, real-time weather station that can inform farmers of the present weather. In order to overcome these issues, a novel Adaptive Weather forecasting Application using REal time sensors for AGRIculture (AWARE-AGRI) technique has been proposed in this work. The proposed AWARE-AGRI technique monitors the weather in real time by using Stacked convolutional neural network (SCNN) based Bidirectional Long Short-Term Memory (BiLSTM) technique for classifying weather data. An Android application has been deployed for tracking the weather online, which can access a dedicated server. MATLAB has been used to evaluate the proposed technique. Certain metrics, including accuracy, precision, f1-score, and recall have been used to evaluate the performance technique. The proposed AWARE-AGRI will give farmers more hope that they will be able to complete their agricultural responsibilities in real time.

Keywords *– Agriculture, Sensors, Weather Forecasting, Stacked Convolutional Neural Network.*

1. INTRODUCTION

Farmers are realizing that farming is no longer a viable or sustainable option. Despite their best efforts, farmers are not benefiting from the expected results of modern agricultural approaches. There is tremendous pressure on farmers to meet the growing demand for agricultural products. At the close of the 1800s, weather forecasts were entirely dependent on observational principles and were not influenced by specific physical mechanisms or weather expertise. Every scheduled activity that is done in daily life is greatly impacted by the weather conditions that are present.

Innovation is crucial in today's age of modernization and technology advancement to make daily living easier. In the age of technical advancement and modernization, innovation is crucial to simplifying daily living. The Internet of Things makes it possible for a large number of different application devices to coordinate their interactions using the same protocols. The impact of IoT creates a new framework for upcoming services and applications.

The fundamental building blocks of the Internet of Things are a variety of items, such as sensors, cell phones, radio frequency identification (RFID) tags, and so forth. At the moment, both the technique and the sensors are more costly. Developing a low-cost weather forecasting and monitoring system that would inform farmers of local and present climatic and meteorological conditions is the only way to guarantee that the majority of agricultural tasks are completed on time and with the fewest possible early losses. To overcome these drawbacks, a novel Adaptive Weather forecasting Application using REal time sensors for AGRIculture (AWARE- AGRI) technique has proposed in this paper. The major contributions of the proposed work are as follows.

- The proposed work uses various sensors for sensing the environmental parameters like temperature, humidity, oxygen, pressure, wind, visibility and moisture.
- The sensed datas are gathered and converted into CSV format and the datas are pre-processed using data cleaning and normalization, which helps in attaining accurate result.
- The pre-processed datas are classified by SNN-LSTM technique and collected datas are passed to the Arduino, which will be transmitted to the farmers

The remainder of the research is organized in the following manner. The literature review is represented in section II. The suggested AWARE-AGRI approach is represented in detail in section III. Section IV represents the experimental results, and Section V represents the conclusion and future work.

2. LITERATURE SURVEY

In 2022, Bolla, et al. [1] developed a novel approach to identify the climate data collected using a variety of sensors placed throughout a city. By minimizing loss, the projected task determines the weather and hazards that save lives and property. The results show that the recommended method performs faster and more accurately than the traditional methods. To increase its accuracy by using a different categorization scheme.

In 2020, Sampathkumar, et al. [2] proposed a framework for monitoring environmental parameters with wireless sensors connected to the Internet. Proposed a method for multiple controllers in an SDN-based ad hoc architecture. Additionally, this proposed idea can be used to the Internet of Things and ad hoc networks. According to the results, the approach focuses on the different security threats and problems in the IoT and SDN domains. Despite its many advantages, security remains the main concern in the SDN domain.

In 2023, Bernardes, et al. [3] proposed an open-source Internet of Things (IoT) system and commercial off-the-shelf (COTS) technology were used to create the Low-Cost Automatic Weather Station (LCAWS). Cost reduction enables quick maintenance and increased network coverage, providing redundancy for malfunctioning equipment. The authoritative resource for tracking natural disasters was able to produce meteorological measurements that were just as accurate as the intended LCAWS. However, LCAW is subsequently created to be integrated into Cemaden's pipeline for monitoring natural disasters and deployed on its observational network.

In 2022, Kamarudin, et al. [4] developed an Arduino UNO SMD Rev3-based Internet of Things weather monitoring device solution is demonstrated. A weather information monitoring system is suggested in order to effectively track current weather conditions and send out alert alerts via email, SMS, and the mobile Blynk app. The OLED and mobile application successfully received the data from all of the sensors, including temperature, humidity, rain, and CO AQI. It is possible to achieve better outcomes by implementing notable improvements in hardware design.

In 2022, Haq, et al. [5] introduced MIT App Inventor service to control the hardware and remotely monitor sensor data. Constructing a gadget that can track the weather in real time is the aim. The project system has demonstrated its strength, affordability, and dependability for anyone with a few well-functioning sensors. To detect the direction and speed of the wind, a few more sensors will be installed.

In 2023, Nerella, et al. [6] introduced an IoT and LoRa-based lightning/weather alert system prototype that uses a variety of alert techniques to notify rural residents. At the deployed area, this prototype can locally monitor weather and lightning conditions. It also uses LoRa connectivity to send sensor data to gateways. According to the analysis, an announcement system that uses loudspeakers to warn and for rural inhabitants, it is advantageous to increase safety knowledge of lightning and other severe weather events beforehand. Unable to notify people beforehand to prevent weather-related disasters like lightning.

In 2022, Barthwal and Sharma [7] introduced a mobile-sensing-enabled, location-aware Internet of Things system to track, quantify, and evaluate the existence and severity of the UHI effect across different geographic areas. Contemporary smartphones, wireless sensors, various communication modules, cloud-based storage, and new system-on-a-chip technologies have made it feasible to create innovative, low-cost IoT systems that track, evaluate, and analyze urban temperatures and their impacts. The greatest surface UHI intensity was recorded at 8.8, while the average intensity was reported at 6.06. The method that makes the fewest big mistakes is the Quatile regression method.

3. AWARE-AGRI FRAMEWORK

In this section, a novel Adaptive Weather forecasting Application using REal time sensors for AGRIculture (AWARE- AGRI) technique has proposed for transmitting weather information to the farmers. The proposed work uses various sensors for sensing the environmental parameters like temperature, humidity, oxygen, pressure, wind, visibility and moisture. The sensed datas are gathered and converted into CSV format and the datas are pre-processed using data cleaning and normalization, which helps in attaining accurate result. The pre-processed datas are classified by SNN-LSTM technique and collected datas are passed to the Arduino, which will be transmitted to the farmers. Fig 1 shows proposed flow of the architecture of AWARE-AGRI.

3.1. Data Collection

At the initial stage of the architecture the datas are collected from various sensor devices to obtain the information from the field. Temperature, wind, humidity, pressure, oxygen, visibility and moisture sensor. Thermocouple sensor is used to identify the temperature which helps to improve in crop health and yield. Farmers can use temperature sensors to monitor the temperature of the soil and air where their crops are growing. A physical tool called a wind speed sensor is used in agriculture to measure wind speed. This sensor gathers and examines data from the various wind gusts. Humidity sensors are able to identify the ideal growing conditions for plants and modify agricultural methods accordingly. which helps the farmer to improve in water management, irrigation, plant growth and harvest quality. The health of the soil can also be tracked with XIDIBEI's pressure sensors. Farmers can assess if the soil has adequate moisture or is compacted by monitoring the pressure within the soil. Oxygen sensor is designed for measuring oxygen levels in soils. It helps in determining respiration rates from measuring $O2$ usage from soils. Visibility sensors measure the clarity of light beams as they pass through the atmosphere. That helps the farmer to the presence of fog, smoke, or dust, which can limit crop yield. A soil moisture sensor, monitors the moisture levels in the soil. This tool in irrigation system may allow for more precise watering scheduling. By using this various sensor, the information about the weather is transmitted.

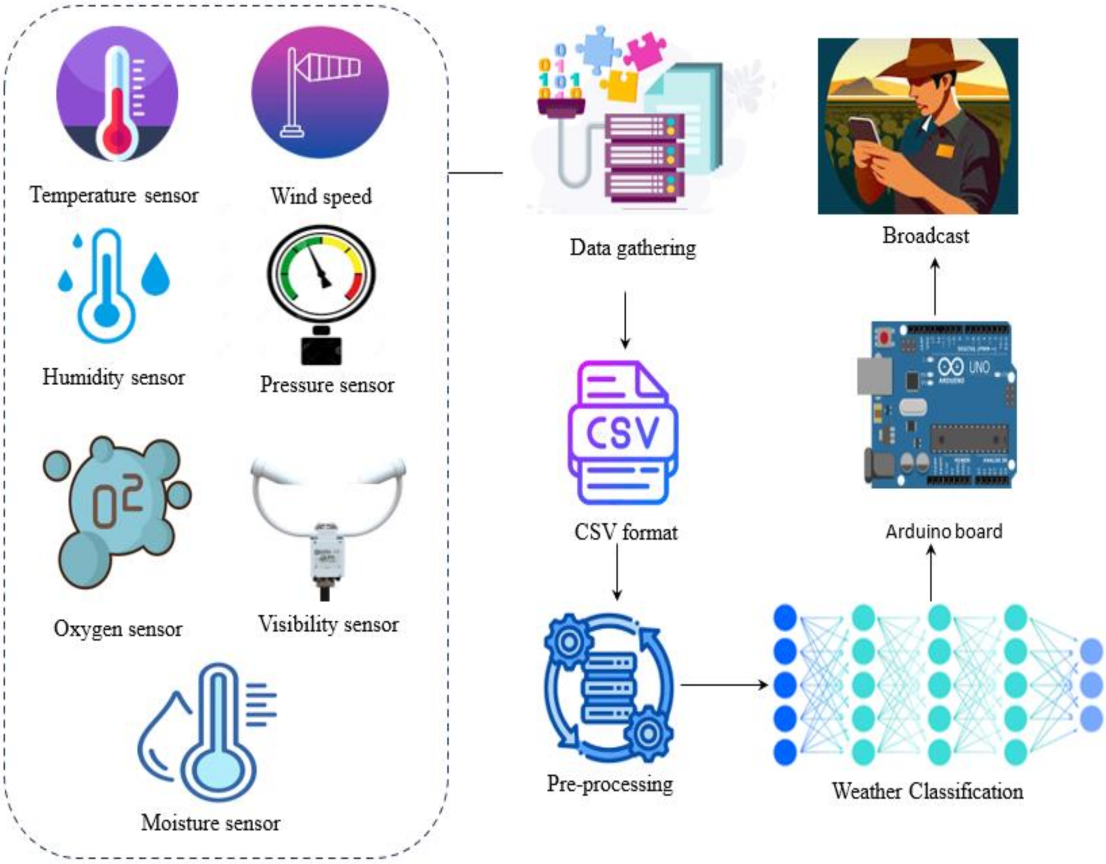

Figure 1. Architecture of AWARE-AGRI

3.2. Pre-Processing

The information or data is collected through the sensor. The gathered information is formatted in CSV format. Comma-separated values (CSV) is file where the data is input as data separated by commas. At the next stage the datas are preprocessed by two methods Data cleaning and Normalization

The process of fixing or removing inaccurate, incomplete, or duplicate data from a dataset. It is essential for ensuring the quality and reliability of data used for analysis. A data preprocessing method called normalization is used to increase accuracy and performance by converting feature values in a dataset to a standard scale. Both dataset's normalized data values are examined using the Min–Max Scaler, which also computes the coefficient. The empirical mode decomposition technique and Principal Component Analysis (PCA) are two advantages of this framework. It effectively chooses relevant feature datasets for categorizing various DDoS attacks.

3.3. Weather Classification

The proposed AWARE-AGRI uses SCNN- BiLSTM for weather forecasting. The SCNN- BiLSTM captures temporal dependencies.

Stacked convolutional neural network (SCNN)

Recently, 1Dimensional-Convolutional Neural Networks (1D-CNNs) were produced as a modified version of 2D CNNs. The one-dimensional (1-D CNN) is a popular deep learning method that is typically an artificial neural feed-forward network composed of pooling and convolution layers. Usually, layers, neurons, and activation processes are employed to process the input using the Rectified Linear Unit (ReLU). In order to avoid overfitting, dropout layers and normalization (Scaling Data) techniques are typically employed. A 1D CNN requires a lot less computing power than a 2D CNN. Networks with 50 neurons or fewer are typically used in the bulk of 1D CNN applications, which frequently employ small topologies. for real-time and inexpensive application, 1D CNNs are particularly well suited, particularly on portable mobile computers. Here are the fundamental mathematical formulas needed to operate CNN:

$$q_{0,g1}^{a} = g\,(\textstyle\sum_{im} q_i^{m-1}) * k_{ip,gm}^{m} + Z^m \quad (1)$$

The output of the l-th layer is denoted by $X_{0,g1}^{a}$, where l is the layer index. An activation function called g(.) is applied to the sum of the input q_i^{m-1}convolutions with the kernel, $K_{ip,gm}^{m}$ and the bias term Z^m .

$$q_0^m = g[max(\textstyle\sum_{in} q_i^{m-1}) + Z^m] \quad (2)$$

In this case, q_0^m is the result of applying max pooling to the (m−1) input total from the preceding layer. After that, the activation function g (.) is applied, and the bias term yl is added.

$$q_0^m = g(q_i^{m-1} * t_{i0}^m + Z^m) \tag{3}$$

In the m th layer, the equation denotes a convolution process. By convolving the input from the (m- 1) th layer, $xl{-}1i$, q_i^{m-1}, with the kernel, the output q_0^m is produced. adding the bias yl, and applying the activation function g (.).

The linear weighted summation of 1D arrays is made possible by the usage of 1D convolutions in CNNs. Resulting in computational effectiveness. These functions are performed simultaneously during the forward and backpropagation phases. overall accuracy and computational cost performance.

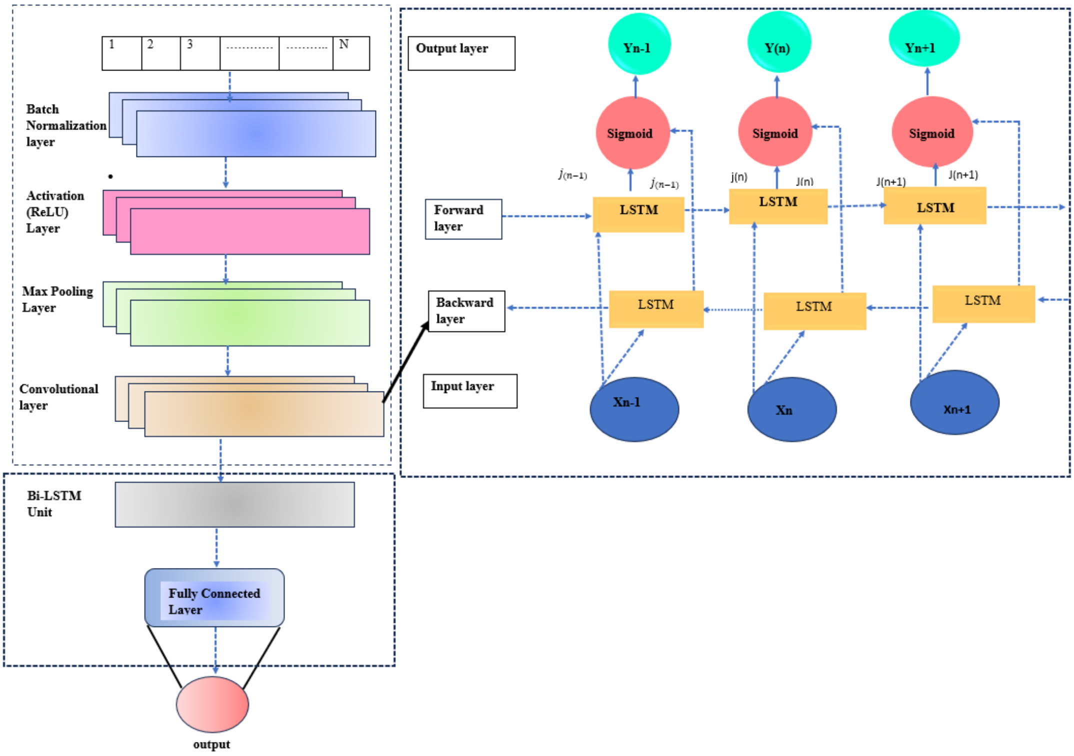

Figure 2. Architecture of SNN-Bi LSTM

The user can update or receive weather condition data through the LSTM method.

The LSTM structure is based on the memory cells that store long-term historical data and the gate mechanism that governs it. A typical LSTM unit contains three different types of gates: input-gatei_t, forget-gatef_g, and output-gate o_n. Each gate in an LSTM classifier uses sigmoid functions and point-wise multiplication to regulate the state of the memory cells. The input data, x_d in the present state, and the output data, j_{n-1} , from the state of the previous layer are processed by the gates.

The "forget gate" determines what data should be kept or deleted. The forget gate's output, represented by the symbol f_g, fluctuates between zero and one. It analyzes both the previously hidden state j_{n-1} and the current input $x_d$using a sigmoid function

$$f_g = \sigma\left(W^f.[j_{n-1}, x_d] + b_f\right) \tag{4}$$

W^f stands for the forget gate's weight, b_f for its bias, and σ for its sigmoid activation function. The operation of the input gate is explained as

$$i_n = \sigma\left(W_j.[j_{n-1}, x_d] + b_i\right) \tag{5}$$

After processing the hidden state j_{n-1} and current input x_d, the tanh function generates a vector of new candidate values, Cn, that could be appended to the state:

$$\overline{C_{v=}} \tanh(W_c.[j_{n-1}, x_d] + b_c) \tag{6}$$

The old state c_{s-1} is multiplied by f_g to update the cell state Cn. Then, the product of in and C_v: is added.

$$C_v = \left(f_{g\odot c_{s-1}}\right) + \left(i_n \odot \overline{C_v}\right) \tag{7}$$

$\odot$ signifies element-wise multiplication and $tanh$ is the hyperbolic tangent activation function. The "output gate" ultimately determines what the subsequent hidden state hn should be. It takes into account both the output from the preceding layer and the cell state:

$$o_n = \sigma\left(W_0.\left[j_{n-1,}x_d\right] + b_0\right) \tag{8}$$

$$h_{n=o_n} \odot \tanh(c_v) \tag{9}$$

The output gate's weights and bias are represented by Wo and bo in these final equations. The output gate determines the final output c_v , which is the next hidden state, using the sigmoid function σ and the tanh function. The hidden state takes the data about the climate problems that the network has observed thus far to the next level. When working with extremely changing data, convolutional neural networks (SCNNs) are a useful tool for identifying prominent features in input sequences. Complex patterns in weather data are easily recognized by the SCNN.

The Arduino, which is connected by application, transmits the weather categorization data. Arduino is an open-source electronics platform built on user-friendly software and hardware. Sensor-based inputs can be read by Arduino boards. The application received an alert message with the most recent weather conditions. Real-time weather conditions are communicated to the recipient through the alert message. The application makes it the simplest approach for farmers to obtain and update weather conditions regarding weather criteria.

4. RESULTS AND DISCUSSION

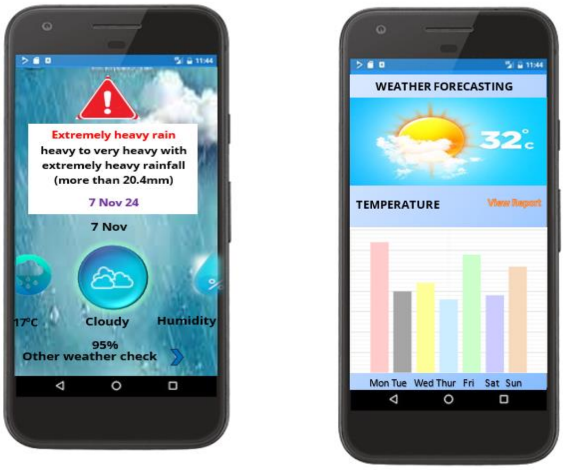

Figure 3. Alert Message Notification

Figure 3 represents the alert message notification system. MATLAB simulator has been used to evaluate the proposed technique AWARE-AGRI.

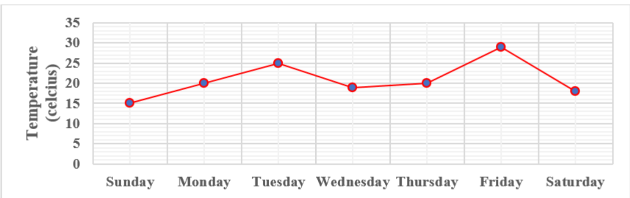

Figure 4. Temperature levels

Figure 4 represents a graphical representation of temperature levels on different week days. Compared to Friday, the temperature is lower on Sunday. In comparison to other days, the temperature in the atmosphere peaked on Friday.

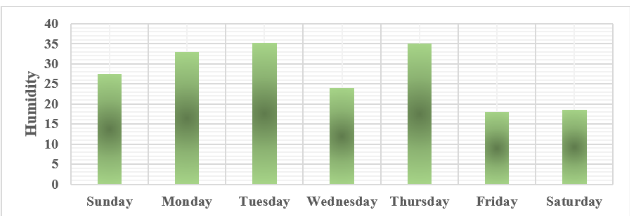

Figure 5. Humidity levels

Figure 5 represents a graphical representation of humidity levels on different days. Friday has lower humidity than other week days. In comparison to other days, Tuesday and Thursday have higher humidity levels.

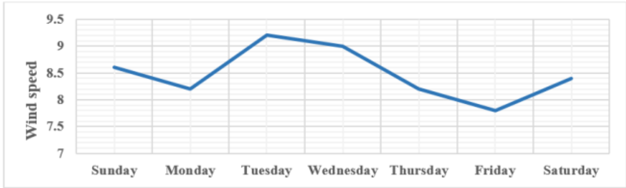

Figure 6. Wind speed

Figure 6 represents a graphical representation of wind speed on different week days. Wind speed is low on Friday compared to other days. The wind speed reached a peak level on Tuesday.

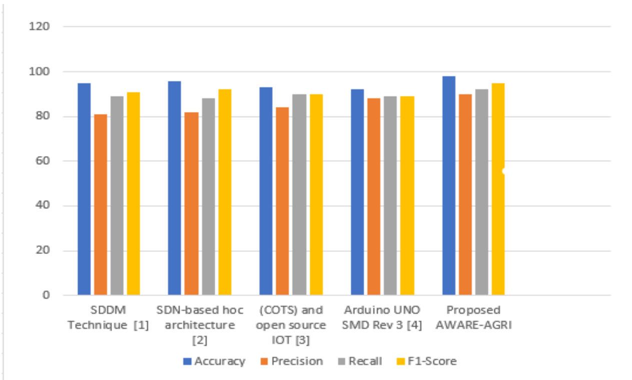

Figure 7. Performance metrics comparison

Figure 7 represents a graphical representation on accuracy, precision, recall, f1-score comparison of the proposed AWARE-AGRI technique with existing technique. The proposed work AWARE-AGRI achieves about 95.5%, 81.2%, 89.5% and 91.3% respectively than the existing techniques.

5. CONCLUSION

In this paper, a novel AWARE-AGRI has been proposed for monitoring and forecasting weather in real-time. The goal of the proposed AWARE-AGRI is to forecast weather, for agricultural applications to reduce crop damage due to weather conditions. The MATLAB simulator will be used to evaluate the proposed method's performance. In order to sense environmental characteristics including temperature, humidity, oxygen, pressure, wind, visibility, and moisture, the suggested method is contrasted with the current approaches, including the SDDM technology, SDN-based hoc architecture, and Arduino UNO SMD Rev 3. Our proposed work weather forecasting accuracy is increased. The proposed work AWARE-AGRI achieves about 95.5% accuracy in weather forecasting. In future work the life time of the sensor can be improved.

CONFLICTS OF INTEREST

This paper has no conflict of interest for publishing.

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Not applicable.

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