# AN IOT BASED WEATHER STATION USING AN EMBEDDED SYSTEM

OLANRELE, O. O.[1*] – ADEAGA, O. A.[1] – ADEYEMI, O. A.[2] – AJAYI, O. K.[3] – MOWEMI, A. O.[4]

[1] *Faculty of Engineering and Technology, First Technical University, Oyo State, Nigeria.*

[2] *School of Physics, Engineering and Computer Science, University of Hertfordshire, Hertfordshire, United Kingdom.*

[3] *Faculty of Engineering and Technology, Obafemi Awolowo University, Osun State, Nigeria.*

[4] *Faculty of Engineering, The Polytechnic Ibadan, Oyo State, Nigeria.*

**Corresponding author*
*e-mail: oladeji.olanrele[at]tech-u.edu.ng*

(Received 13th July 2022; accepted 23rd September 2022)

**Abstract.** This paper is about the development of an internet-based weather station system to monitor temperature, humidity, light intensity and predict the possibility of whether it will rain or not. The real-time monitoring system was connected to a microcontroller embedded with a Wi-Fi module (NodeMCU/ESP8266), a temperature and humidity sensor (DHT 11), and a light-dependent resistor (LDR). This device is designed as a platform to provide adequate information for immediate and future weather forecasts. The measured parameters are sent to an open-source IoT analytics platform (ThingSpeak), recorded in the channel, and were downloaded for analysis purposes. The temperature and humidity level was monitored using the Things View Android application and can be accessed by anybody once given the Thing Speak channel ID. Weather data was easily viewed and it can aid in appropriate planning. This IoT-based system will help keep up with the demand of the ravaging global warming with the provision of real-time data for planning towards land preparation and crop planting and for other purposes that are weather dependent.
**Keywords**: *smart system, ESP8266, DHT 11 Sensors, ThingSpeak, microcontroller*

## Introduction

The Internet of Things (IoT) enables the communication between, mechanical and signal or data machines. Devices connected to IoT communicates with human and computers, are assigned online protocol addresses, and can send information on the network (Laghari et al., 2021). IoT is an extensive networked system made up of connected devices. The devices collect information, process, distribute, utilized, and execute a specific job (Aloi et al., 2017). Our smartphones, electromechanical appliances, and other devices which have internet capabilities are IoT-enabled, and therefore in a way intelligent. An IoT facility consists of internet-enabled devices that use add-on systems, like processors, sensors, and interactive physical parts, to bring together, relate, and analyze obtained data. IoT devices show data obtained by the sensor put together through an IoT entry or related input device, and the data obtained were forwarded to the cloud for analysis (Himmat et al., 2022). Now and then, these mechanism interact among others affiliated with them and respond based on the data obtained. Human interaction is limited as the system is self-operated (Pinto and Prazeres, 2019; Zhou et al., 2019).

Node Microcontroller Unit (NodeMCU) is a development board that is essentially a mini-computers built-in support for wireless networks, can interact and be coded by a computer. NodeMCU is LUA technology with a 2.4 GHz Wi-Fi development board known as ESP8266 which works with the internet to upload data, and LUA is a straightforward scripting language. NodeMCU is an embedded chip that is made up of many pins, and the pins have different functions (Gunge and Yalagi, 2016; Teymourzadeh et al., 2013). NodeMCU is a microcontroller, it is portable and programmable, and can connect to the internet through wireless networks. NodeMCU hardware design is available for editing, modification, and building (Singh, 2019). “The embedded system typically has one application and one application only, which is permanently running. The embedded computer may or may not have an operating system, and rarely does it provide the user with the ability to arbitrarily install new software. The software is normally contained in the system’s nonvolatile memory, unlike a desktop computer where the nonvolatile memory contains boot software and (maybe) low-level drivers only” (Catsoulis, 2005).

In this era, monitoring weather parameter conditions is part of a significant issue, due to many hurdles. This system resolves this concern and monitors real-time weather conditions, it also operates a client-server system based on IoT, and it contains various sensors which will monitor the weather condition of the system. The sensor collected the required information sent it to the NodeMCU controller. Arduino IDE monitor was used as a link between the sensor and cloud, the HTTP protocol provides a view of the information on a web platform. The data is shown on a web platform and monitors the first-hand weather parameters. With the incorporation of a display, anyone can observe the weather’s condition remotely (Sharma and Prakash, 2021; Huang et al; 2020; Rao et al., 2019; Strigaro et al., 2019; Kodali and Mandal, 2016).

The present-day weather is stochastic, to be exact, because of the drastic climate changes. A weather forecast system is mainly used for real-time monitoring of ever-changing atmospheric conditions over houses, industry, farmlands, etc. The Internet of Things (IoT) platform used is ThingSpeak, which can display the weather parameters and the information can be accessed on any internet-enabled device anywhere in the world, it's also displayed on a screen with two-way microcontroller communication via Wi-Fi hotspots (Pauzi and Hassan, 2020). Unpredicted variations in weather, significant rises in temperature, and rainfalls, adversely affect the biodiversity and depreciate the already predominant exertion on water supply. This further worsens the exposure of the farmers and makes vulnerable most African countries to the effects of changing climate, knowing it largely depends on the water made available through rainfall, which contains a good percentage of nutrients needed by the plants to grow, and on which soil productiveness highly depends (Abegunde et al., 2019; Ngwira et al., 2012).

The scope of this paper is to propose an intelligent device used for appropriate planning for rural dwellers, most especially farmers who need to predict the right time for land preparation and planting of crops. It is a portable system that can be placed on a desk or hung on the wall, project real-time weather details (Temperature, Humidity, and Light intensity), and predict the possibility of rain falling.

## Materials and Methods

This research focuses on the development of a weather station that uses the ThingSpeak IoT platform as a display. Consists of two parts namely, the hardware part, which involves circuit construction, and the software part, which entails coding, circuit schematic diagram, simulation, and data collection. A DHT11 sensor and a light-dependent resistor (LDR) was incorporated to monitor the required weather parameters (Temperature, Humidity, and Light intensity). The weather condition will be analyzed based on the sensor value at each point in time. The data will be controlled by a microcontroller (ESP8266) and displayed on the Arduino IDE serial monitor. The graphical data representation will be displayed as well on the ThingSpeak channel, and this enables the user to have a real-time experience of the sensor data.

***Hardware development***

This weather monitoring system uses Temperature and Humidity sensors (DHT11) and a LDR. LDR is a resistor whose resistance increases or decreases based on the light intensity and its value can be used in conjunction with temperature and humidity to predict the possibility that it will rain or not. NodeMCU stands as the link between the system and the environment, data will be forwarded to the ThingSpeak channel, where it is displayed and downloaded as an Excel CSV file for further analysis. NodeMCU is shown in *Figure 1* below, and the system is connected to a lithium battery as its source of power, enough to supply the required 3.3V to power the microcontroller. Arduino IDE platform was used for the programming of the setup. The overview of the interaction between ThingSpeak and intelligent connected devices is shown in *Figure 2*.

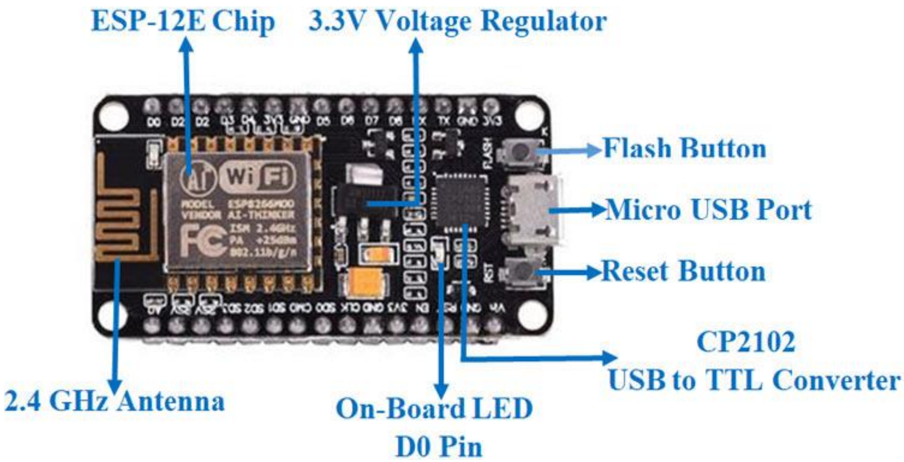


***Figure 1.*** *ESP8266/NodeMCU.*

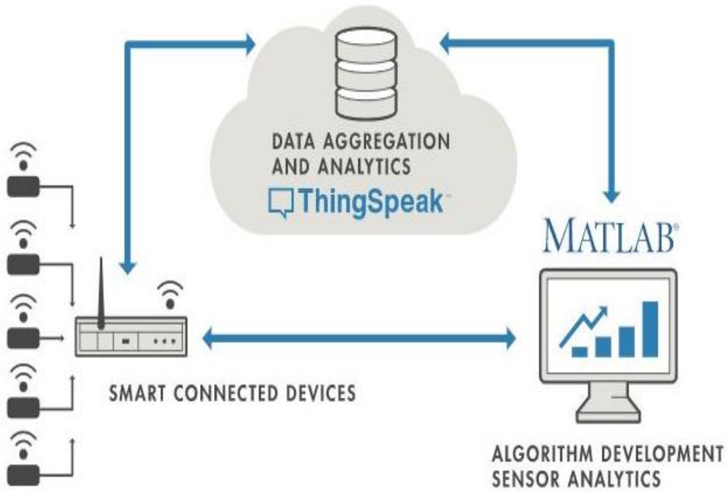


***Figure 2.*** *The overview of the interaction between ThingSpeak and Smart Connected Devices.*

### *System circuit operation*

The system's circuit consists of a weather station that displays all the values of weather parameters and a control unit for controlling all the sensor data and sending it to the ThingSpeak platform. The weather station will communicate with the control unit via a client-server communication channel, where all the data collected by the sensor will be forwarded to ThingSpeak and the serial monitor. *Figure 3* shows the circuit diagram of the system.

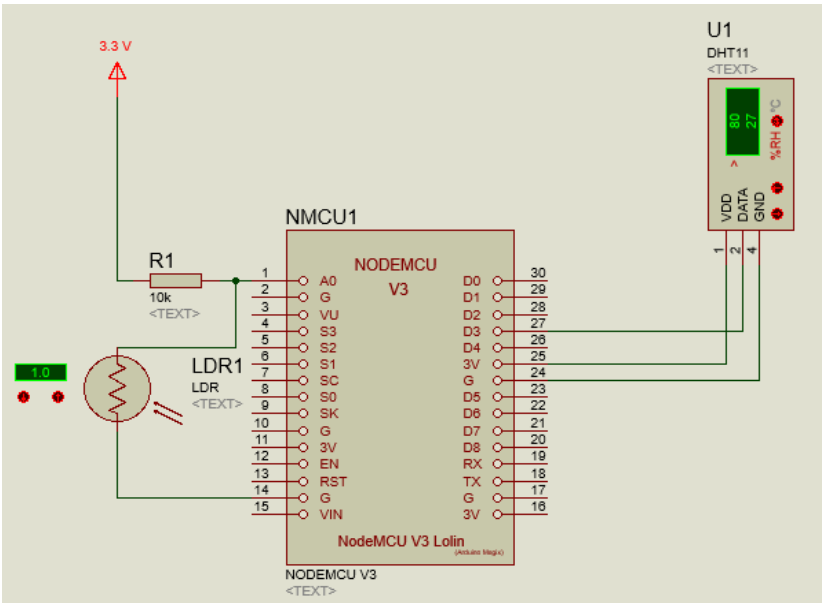


***Figure 3.*** *The System Circuit Diagram.*

The process of the system starts after the microcontroller ESP8266, which is the control unit, configures the sensors and starts to read the data from the sensor. The data is forwarded to the IoT platform via wireless communication. This system operates as a real-time data acquisition and displays the temperature, humidity, and light intensity on a specific ThingSpeak webpage as well as the weather station monitor.

## Results and Discussion

The intelligent weather station sensitivity and accuracy were tested, the device was used to collect temperature, humidity, and light intensity data for two days (15th and 16th of February, 2022). The humidity and temperature data collected during the 48 hours of testing are presented in *Figures 4* and *Figure 5*, this information was exported from the ThingSpeak channel as an Excel CSV. *Figure 6(a), Figure 6(b)* and *Figure 6(c)* shows the real-time temperature, humidity and light intensity, as obtained from Arduino IDE Serial Monitor. The possibility of whether it will rain or not was determined based on the available data from the system and a combination of conditions. Furthermore, it has been determined by a few lines of codes in the operating programming code for this system. The mean temperature and humidity on an hourly basis for 48 hours, in between 00.00 am to 11.00 pm West Central African Time was compared with that from two notable sources, the IBM weather channel (available at www.weather.com) and AccuWeather (available at www. acuweather.com). The global positioning system (GPS) location set to show humidity and temperature data for Ibadan North, Oyo State, Nigeria. The hourly data collected is in Appendices.

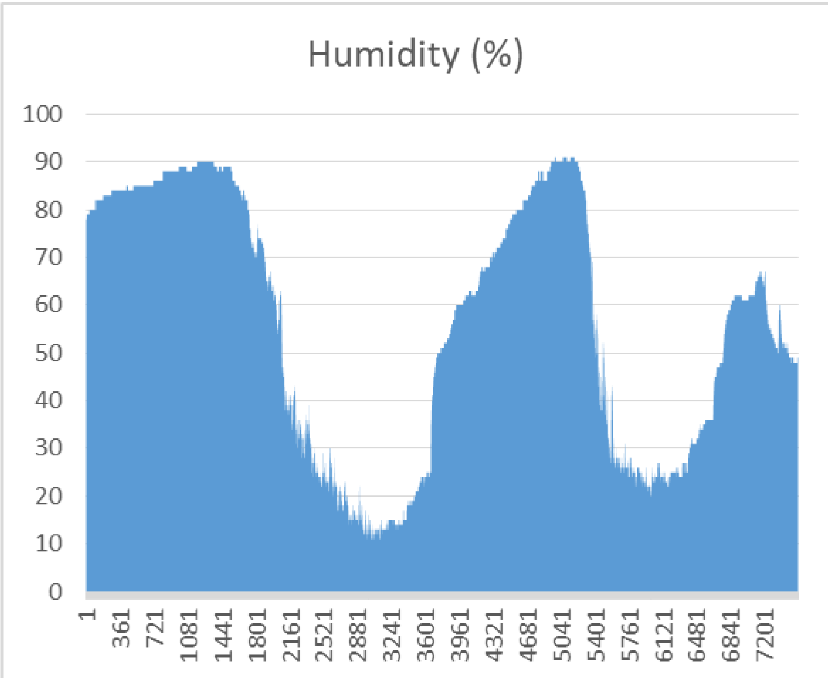


***Figure 4.*** *Humidity data for 48 hours.*

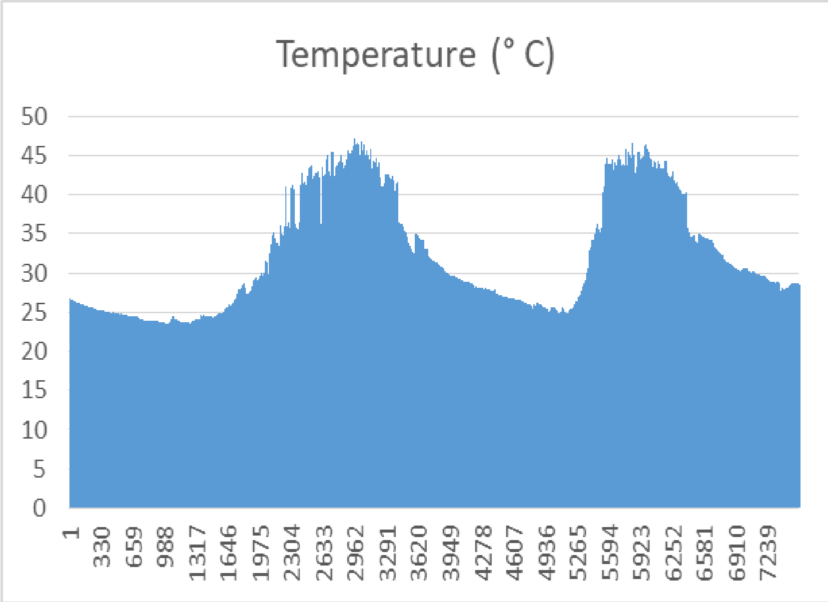


***Figure 5.*** *Temperature data for 48 hours.*

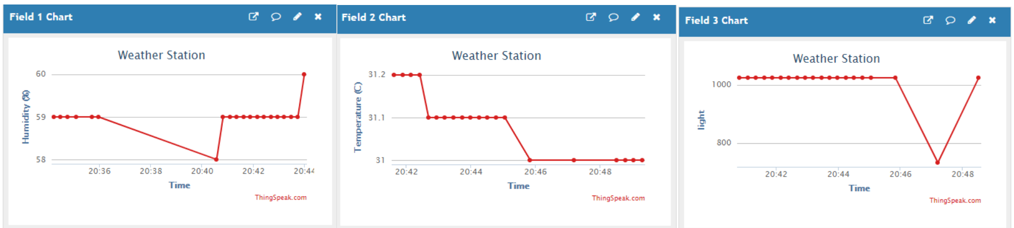


***Figure 6.*** *Graphical in real-time to represent: Humidity (Left), Temperature (Middle); Light intensity (Right).*

### *Correlation analysis*

The temperature and humidity data collected was compared with that of two notable weather forecast channels; there was the need to check the nearness to reality and correctness established by the level of correlation of data provided by the intelligent weather station system to that of existing and credible weather forecast platforms, A Pearson correlation coefficient was used due to its ability to establish the relationship between actual values. The scatter plots for the correlations are shown in *Figures 7*, *Figure 8*, *Figure 9*, *Figure 10* and *Figure 11*, while *Table 1* shows the correlation between actual data collected by the intelligent system with reputable weather channels.

***Table 1.****Correlation between actual data collected by the smart system, with reputable weather channels.*

| S/N | Variables | Correlation (r) |
|---|---|---|
| 1. | Temperature data from the smart system (X) and temperature data from the IBM Weather Channel (Y). | 0.9399 |
| 2. | Temperature data from the smart system (X) and temperature data from AccuWeather (Y). | 0.9629 |
| 3. | Humidity data from the smart system (X) and humidity data from IBM Weather Channel (Y). | 0.9473 |
| 4. | Humidity data from the smart system (X) and humidity data from AccuWeather (Y). | 0.9296 |

```
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 907.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 905.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 907.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 907.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 907.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 906.00Send to Thingspeak.
There is a very low possibility of rain
very low chanceWaiting...
Humidity = 52.00%  Temperature = 31.30C  light = 907.00Send to Thingspeak.
There is a very low possibility of rain
```

***Figure 7.*** *Humidity, temperature and light intensity with rain prediction.*

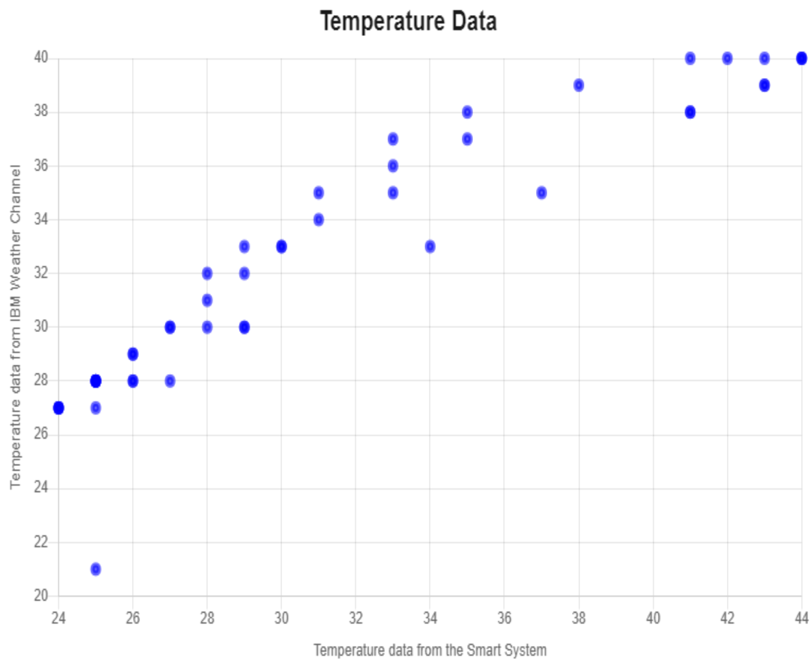

***Figure 8.*** *Scatter plot showing the correlation between temperature data from the smart system and the IBM weather channel.*

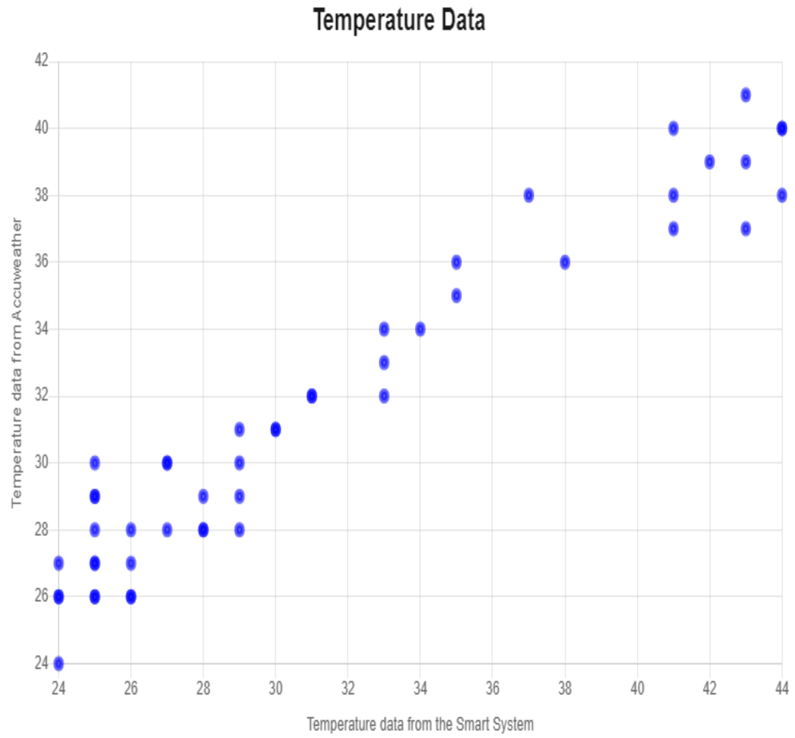


***Figure 9.*** *Scatter plot showing the correlation between temperature data from the smart system and accuweather.*

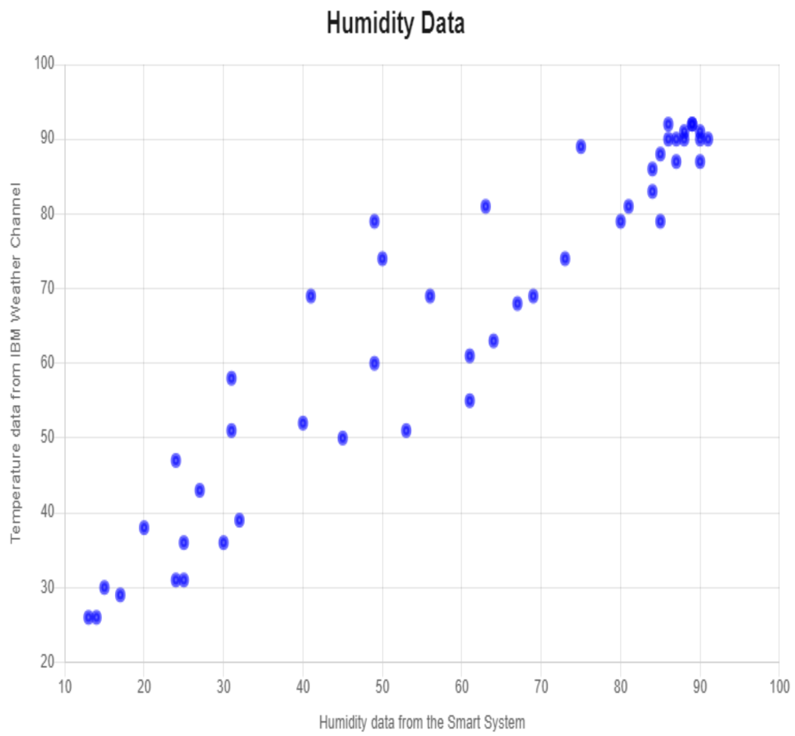

***Figure 10.*** *Scatter plot showing the correlation between humidity data from the smart system and IBM weather channel.*

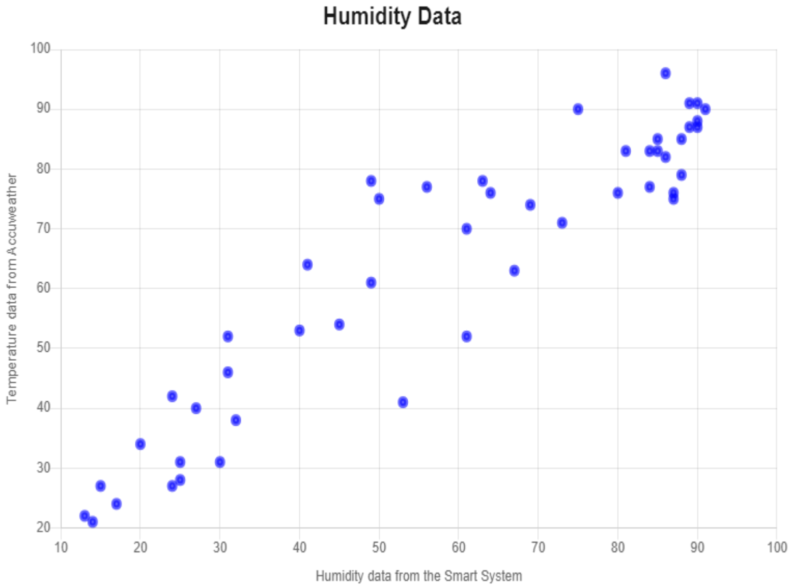


***Figure 11.*** *Scatter plot showing the correlation between humidity data from the smart system and accuweather.*

## Conclusion

The intelligent weather system provides an easy way to monitor the environment using an embedded system. It is a cost-effective and affordable way of monitoring weather parameters. It should be deployed in the environment for data collection and analysis. By this, the environment can be monitored in real-time, as data provided by this device has been validated through its positive correlation with that provided by notable weather channels. The device predicts based on data collected and will be helpful for metrologists, farmers, industry work purposes, logistics, and anyone whose works depend on the weather situation. The time for refreshing the data displayed on the monitor may vary based on the internet connectivity used in monitoring, but still, it is practical and portable enough that it can easily sit on a desk in homes or offices or hang on the wall.

## Acknowledgement

This study is self-funded.

## Conflict of interest

The authors declare that there are no conflict of interest involve with any parties in this study.

## REFERENCES

[1] Abegunde, V.O., Sibanda, M., Obi, A. (2019): The dynamics of climate change adaptation in Sub-Saharan Africa: A review of climate-smart agriculture among small-scale farmers. – Climate 7(11): 23p.

[2] Aloi, G., Caliciuri, G., Fortino, G., Gravina, R., Pace, P., Russo, W., Savaglio, C. (2017): Enabling IoT interoperability through opportunistic smartphone-based mobile gateways. – Journal of Network and Computer Applications 81: 74-84.

[3] Catsoulis, J. (2005): Designing Embedded Hardware: Create New Computers and Devices. – O'Reilly Media, Inc. 398p.

[4] Gunge, V.S., Yalagi, P.S. (2016): Smart home automation: a literature review. – International Journal of Computer Applications 10p.

[5] Himmat, M., Algazoli, G., Hammam, N., Abdalla, A. (2022): Review on the Current State of the Internet of Things and its Extension and its Challenges. – European Journal of Information Technologies and Computer Science 2(2): 1-5.

[6] Huang, Z.Q., Chen, Y.C., Wen, C.Y. (2020): Real-time weather monitoring and prediction using city buses and machine learning. – Sensors 20(18): 21p.

[7] Kodali, R.K., Mandal, S. (2016): IoT based weather station. – In 2016 international conference on control, instrumentation, communication and computational technologies (ICCICCT), IEEE 4p.

[8] Laghari, A.A., Wu, K., Laghari, R.A., Ali, M., Khan, A.A. (2021): A review and state of art of Internet of Things (IoT). – Archives of Computational Methods in Engineering: 29(2): 1-19.

[9] Ngwira, A.R., Aune, J.B., Mkwinda, S. (2012): On-farm evaluation of yield and economic benefit of short term maize legume intercropping systems under conservation agriculture in Malawi. – Field Crops Research 132: 149-157.

[10] Pinto, G.P., Prazeres, C. (2019): Web of things data visualization: from devices to web via fog and cloud computing. – In 2019 IEEE 28th International Conference on Enabling Technologies: Infrastructure for Collaborative Enterprises (WETICE), IEEE 6p.

[11] Pauzi, A.F., Hasan, M.Z. (2020): Development of IoT Based Weather Reporting System. – In IOP Conference Series: Materials Science and Engineering, IOP Publishing 917(1): 17p.

[12] Rao, J., Garfinkel, C.I., Chen, H., White, I.P. (2019): The 2019 new year stratospheric sudden warming and its real-time predictions in multiple S2S models. – Journal of Geophysical Research: Atmospheres 124(21): 11155-11174.

[13] Sharma, P., Prakash, S. (2021): Real Time Weather Monitoring System Using Iot. – In ITM Web of Conferences, EDP Sciences 40: 10p.

[14] Singh, P.Y. (2019): Internet of Things and Nodemcu A review of use of Nodemcu ESP8266 in IoT products. – Journal of Emerging Technologies and Innovative Research (JETIR) 6(6): 1085-1088.

[15] Strigaro, D., Cannata, M., Antonovic, M. (2019): Boosting a weather monitoring system in low income economies using open and non-conventional systems: Data quality analysis. – Sensors 19(5): 22p.

[16] Teymourzadeh, R., Ahmed, S.A., Chan, K.W., Hoong, M.V. (2013): Smart GSM based home automation system. – In 2013 IEEE Conference on Systems, Process & Control (ICSPC), IEEE 4p.

[17] Zhou, W., Jia, Y., Yao, Y., Zhu, L., Guan, L., Mao, Y., Liu, P., Zhang, Y. (2019): Discovering and understanding the security hazards in the interactions between {IoT} devices, mobile apps, and clouds on smart home platforms. – In 28th USENIX security symposium (USENIX security 19) 16p.