JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

An Internet of Things (IoT) Based Smart Agriculture Monitoring System for Enhanced Productivity in a Controlled Farm Environment

Paschal Uchenna Chinedu[1], Yusuf Isah[2] and Nkechi Blessing Chinedu[3]
[1]*Department of Computer Engineering,*
Edo State University Uzairue, Nigeria
[2]*Department of Computer Science,*
Abuja Model Centre, National Open University of Nigeria
[3]*Department of Pollution Control & Environmental Health,*
Federal Ministry of Environment, Abuja, Nigeria.

ABSTRACT

Agriculture has long been regarded as one of the most essential sectors in human history since it provides humans with necessary resources, such as food, fibre, and energy. Using modern technology, such as the Internet of Things (IoT), the agriculture industry could be further enhanced. IoT-based smart agriculture systems are increasingly transforming the way agriculture is produced, not just by making it better but also by increasing its efficiency and reducing waste. The design and implementation of a smart agriculture monitoring system based on the internet of things (IoT) are presented in this paper. This system uses sensors to capture environmental data such as temperature, humidity, soil moisture, and pH, and then transmits that data to the farmer via the internet. Farmers can use the IoT-based Smart agricultural monitoring system to obtain real-time data from sensors (Temperature, Humidity, Soil Moisture, and pH) for efficient environmental monitoring, enabling them to increase overall production and product quality. The IoT-based Smart Agriculture Monitoring System being developed combines Arduino-based microprocessor technology with various sensors and a GSM module to produce real-time data feeds that can be accessed via the internet via an IoT platform. The data gathered by the sensors is sent in real-time to an IoT platform called ThingSpeak, where it can be aggregated and visualized. The graphical representation of logged data on ThingSpeak can be analysed from anywhere in the world by a moderately knowledgeable farmer or botanist to make sensible modifications in the supplied resources (to crops) to produce a high-quality harvest.

ARTICLE INFO
Article History
Received: June, 2022
Received in revised form: August, 2022
Accepted: September, 2022
Published online: September, 2022

KEYWORDS
Internet of Things (IoT), Smart Agriculture Monitoring System Farm Environment.

INTRODUCTION

The production of food in the twenty-first century is a challenge that is becoming more urgent as the world's population continues to rise. The world's population is anticipated to reach 9.4 to 10.1 billion people by 2050, which would result in a rise in the demand for specialized food production domains, notably for livestock and plant growth (Desa, 2019). As a result of the constant digitalization brought on by the exponential growth of technology, smart goods and their associated services are progressively taking over both corporate and personal life. Traditional analogue-driven industries like agriculture are no longer exempt from the trend of digital transformation and its associated advantages (Georgakopoulos & Jayaraman, 2016). "Agriculture is an art and science of growing plants primarily for foods, human necessities, and economic gain," according to (Shomefun, Awosope, & Ebenezer, 2018).

To address concerns like increasing food production needs and labour cutbacks, smart agriculture is a modern farm management concept that makes use of techniques and technology at all levels and sizes of agricultural production (Walter et al., 2017). Smart agriculture, for instance, may use many types of sensors to collect data (e.g., temperature, humidity, light, pressure, presence, etc.), communication networks to transmit and

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.

receive data, and management information systems and data analysis solutions to manage and analyse the data (Navarro, Costa, & Pereira, 2020). The internet of things (IoT) is a term used to describe a network of interconnected gadgets (Madakam, Ramaswamy & Tripathi, 2015). The use of data in smart agriculture helps to increase productivity and decrease waste by enabling crucial tasks to be completed at the right time, amount, and place (Ayaz et al., 2019). The capabilities of smart or internet-connected devices are diverse, and they may be used for a variety of purposes, such as remote monitoring, and dynamic or adaptive decision-making (Porter & Heppelmann, 2014).

The Internet of Things, sometimes known as IoT, is a collection of networked devices that can exchange information with one another and provide meaningful data about the surroundings in which they operate. As a result, almost any piece of technology that can connect to the Internet, including household appliances, electronics, furniture, machinery for agriculture or industry, and even humans, may be referred to as a "thing" in the IoT context (Navarro, Costa & Pereira, 2020).

The Internet of Things (IoT) is made up of things that may be connected at any time and from anywhere, allowing for remote access to resources. Every object on the Internet of Things is connected by a unique identity, allowing data to be transferred over the network without the need for human contact.

IoT emphasizes process automation by eliminating human engagement. IoT collects data with sensors, processes it with controllers, and completes automation operations with actuators during the computerisation process.

In the agriculture industry, a significant amount of work has been done to build smart precision farming and greenhouse monitoring solutions using IoT technology (Stoes et al., 2016). By studying many problems and challenges in farming, the Internet of Things has brought about a major shift in the agricultural environment (Ray, 2017; Abdulrazak et al., 2019). Wireless sensor networks allow us to gather data from sensing devices and transmit it to the main servers (Ojha, Misra, & Raghuwanshi, 2015). Sensor data provides information about various environmental conditions, allowing the entire system to be adequately monitored. Monitoring environmental conditions or crop production is not the only issue in crop evaluation; several other variables influence agricultural productivity, such as field management, soil and crop monitoring, undesired item movement, wild animal assaults, and thefts, to name a few (Zhang et al. 2017; Agrawal et al., 2019; Imam et al., 2019). Additionally, IoT enables efficient scheduling of scarce resources, ensuring that IoT is used to its fullest potential to boost production.

A smart agriculture monitoring system, or simply smart farming, is a new technological advancement where a network of electronic sensors gathers information from the surroundings and a variety of agricultural fields that range in size from modest to enormous. The data is analysed by specialists and local farmers to draw both immediate and long-term conclusions regarding, among other things, weather patterns, soil fertility, crop quality now, and the amount of water required in the upcoming week to a month.

The idea is to create a cloud-based analytics system that can gather, display, and analyse live data streams. The sensor data is shown instantly by the cloud analytic system. The sensor data are sent to the distant IoT platform through a GSM module that is connected to a programmed Arduino (microcontroller). The suggested system's main goal is to compile sensor data, create visualizations, and do analytics on best agricultural practices. This system will be straightforward to use, to give farmers useful information so that they can make informed decisions about their farms, particularly irrigation.

Agriculture is crucial for human survival because it is the main source of food grains and other basic materials. It is vital to the nation's economic development. Low crop yields are produced by conventional agriculture because of specific environmental conditions. Plant growth and geographic distribution are greatly influenced by the environment. Any environmental factor that is less than ideal hinders a plant's development and/or dispersal. Deserts, for instance, can only sustain plants that have adapted to scarce water sources. Environmental stress causes most plant problems, either directly or indirectly. A plant may suffer direct damage from unfavourable environmental conditions (such as a lack of water). Stress from the environment can also increase a plant's susceptibility to disease and

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.

insect attack. Environmental factors such as nutrition, water, light, temperature, and humidity influence how plants grow. It is essential to comprehend how these elements impact plant growth and development. When manual labour is used to collect crucial environmental data in agricultural sites, we must dispatch thousands of workers to different locations each day.

However, there is no assurance that the data will be accurate because we are human and may become complacent and manipulate the data, which could lead to mistakes in data analysis and poor decisions. The proposed system's goal is to assist farmers in making informed agricultural decisions. This is accomplished by installing sensors along the fields to measure pH, humidity, temperature, and soil moisture changes in the crops. In this case, data collection is automated, data integrity is ensured, and data processing is done with the aid of an analytics system. To produce the proper crops, the weather pattern in farms may be identified by the analysis of sensor data for humidity, temperature, soil moisture, and pH.

Aim and Objectives of the Study

Designing and implementing a cloud-based smart agriculture monitoring solution is the goal of this research paper, and this will enable smart monitoring of the soil content and environmental conditions. Therefore, the research is set to achieve the following objectives:

1. To implement an IoT-based real-time smart agriculture monitoring solution for smart farming with an Email alert system.
2. To implement an effective, reliable, low-cost and portable embedded system using Arduino Uno-based microcontroller.
3. To design a system that uses temperature, humidity, soil moisture, as well as pH sensor to monitor soil content and provide live reporting of the soil conditions at any location in the world and at any time of the day.
4. To design an agriculture monitoring system that allows people to directly check the environmental conditions without the need to be physically present on the farm.

REVIEW OF RELATED LITERATURE

The SmartFarmNet platform was introduced by Jayaraman et al. (2016). Smart equipment, such as sensors and cameras, may be integrated into the SmartFarmNet platform. SmartFarmNet gateway is used to connect these smart devices. Data was collected using OpenIoTX-GSN in the gateway. The incoming data is subsequently annotated and encoded using a preset ontology by the gateway. The resource description framework (RDF)-annotated data is then stored in a No SQL graph database before being transferred to the cloud platform Sensors were located using Open IoT's scheduler, service delivery, and utility management functionalities. The SmartFarmNet platform allows customers to register smart devices using this concept. Users may then utilize the web page to get statistical data about smart devices. This platform has the advantage of allowing users to access IoT services without needing to know how to program.

Cambra et al. (2018) used IoT to keep the pH of hydroponic agricultural nutrient solutions (bicarbonates, salts, and nitric acid) at a constant level. The pH sensor and pH electrode detect the pH level and hydrogen content in the nutritional solution and send the information to the NRF24L01 gateway. Data is sent through the gateway to an MYSQL database, which is then saved to cloud storage. When the pH of the nutritional solution falls below a certain level, tiny pumps provide the necessary acid. Java Drools, PHP, and HTML5 were used to create a decision-making system that determines how much acid should be added to the nutritional solution. The technique was put in place to keep lettuce and tomato plants alive in a greenhouse. The system uses less energy and can adapt to a vast region, which is one of the article's benefits.

Aliev et al. (2018) used an IoT device to track a variety of agricultural factors and used a neural network approach to forecast weather details. The DHT11 sensor was used to track temperature and humidity. Six Groovec sensors were utilized to get soil moisture information. The operation and communication of these sensors were handled by an STM32L476RG microcontroller and Wi-Fi module. A Wi-Fi connection was established using the NodeMCU Wi-Fi board. Thing Speak cloud platform was used to store the data obtained. The sensor information may be accessed using

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

an Android app. This technique's benefit was that it used a neural network to obtain great accuracy.

LoRA technology was utilized by Yim et al. (2018) to monitor environmental indicators in a tree plantation. LORA represents a low-power wide area network (LPWAN). To determine the communication range of LORA, tests were conducted among maple, pine, and oak trees in a rural tree plantation in Indiana. Several sensors, including a temperature and humidity sensor (DHT11), a flame sensor, a photosensitive sensor, and a soil humidity sensor, were used to detect the ambient parameters. The Arduino Uno board was utilized to connect all of the sensors, and the LoRA Gateway—LG01 was used as the communication portal. They evaluated the LoRA communication range among trees in this experiment by installing sensors at various distances. As a result, LoRA does not offer the desired communication range between trees.

To monitor tomato seedlings, Kalathas et al. (2016) employed IoT approaches. Tomato seeds were stored in both an IoT-monitored seedbed and a traditional seedbed.

A soil temperature and humidity sensor (SHT10), as well as air humidity and temperature sensor, were used to monitor the seedbed's environmental conditions (DHT22 and Tmp 100). The data is sent to Arduino Uno regularly by these sensors. When the seedbed climate was not favourable to tomato seeds, the measured values were utilized to activate the heating circuit. The results suggest that having an IoT-monitored seed bed saves seed growing time while also increasing seed breeding. Energy saving and security limitations are both absent from the system.

Halim et al. (2017) used the Internet of Things (IoT) to monitor mango trees grown in the UniMAP Agrotech greenhouse in Malaysia. The following sensors were employed to detect environmental parameters: a temperature sensor, a humidity sensor, a light sensor, a soil moisture sensor, and a carbon dioxide sensor. The MIB520CB Wi-Fi module was utilized to gather data from the sensor. The data was saved in an MYSQL database, and Lab View was used for programming and interfacing.

To monitor and regulate a variety of factors in the greenhouse, Kodali et al. (2016) employed an Arduino as a microcontroller. Water tanks were monitored using ultrasonic sensors, and when the level dropped below a pre-set threshold, an SMS was sent to the user, who then sent back an SMS to switch on the pump. When the temperature or humidity exceeds the threshold, a microcontroller will turn on a relay connected to the foggier, releasing small water droplets that stay suspended in the air and reduce the temperature and maintain the relative humidity. Inside the greenhouse, LED lights were installed, and when the light sensor detected less light than necessary (from the sun), the lights were turned on, promoting plant growth. An ultrasonic sensor was installed in the beehive boxes, which detects the amount of honey and sends an email when the amount exceeds a certain threshold. Finally, the goods were placed in a storage facility in containers equipped with ultrasonic sensors that relay data to a Google spreadsheet and an e-commerce website through email.

Precision agriculture based on IoT was proposed by Ferrández-Pastor et al. (2018). In this work, edge nodes such as sensors and actuators were used to monitor various environmental parameters such as soil moisture, soil PH, soil EC, water pH, water EC, inside/outside temperature, and so on. The observed data was communicated to a fog node, which is a device with a processor, GPU, and operating system, via the MQTT protocol. Edge nodes were in charge of data collection, filtering, and connecting. Fog nodes were used for data monitoring, analysis, supervision, storage, and management. Machine learning techniques were implemented in the fog node, and a decision tree was used to manage water use and plant development. Details from the analysis were saved in cloud platforms like Ubidots and Mobile-Alerts Cloud. Finally, the farmers were able to use mobile devices to obtain data from the cloud. The suggested system is constructed in such a manner that it may be integrated with current automated systems, but the downside is that it does not contribute to security and power consumption limits.

Maia et al. (2017) created an IoT smart gadget that detects several environmental factors using humidity sensors, temperature sensors, and brightness sensors. This device used ZigBee for communication and navigation and was powered by solar energy and a battery. This device was created with a Raspberry Pi 3 and NodeJS open-source software. The gadget is known as a “monitoring

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

node" monitors the environment and sends data to the central node. A NoSQL database is used by the central node to gather and store data. The data is transferred to the cloud platform for storage. The apparatus was put to the test, and the findings were promising. The system's advantage is that it is extremely portable, allowing farmers to take it anywhere they choose to examine the soil composition and ambient circumstances. Without solar power, the system's elapsed time was 38 hours, which may be extended with more efficient energy usage.

METHODOLOGY

System Design Methodology

The conventional System Development Life Cycle (SDLC) techniques would be followed to construct the IoT-based smart agricultural monitoring system, which would include system planning and requirement analysis, system design, system implementation, and testing. The technique used included a thorough examination of the current system, as well as a study of relevant work and requirement analysis. The proposed cloud-based smart agricultural monitoring system will be built with UML tools including sequence diagrams and use case diagrams. C++ will be utilized as a programming tool for the IoT-based smart agricultural monitoring system, and ThingSpeak will be utilized as an IoT platform for storing and retrieving data from the thing over the Internet with the aid of HTTP and MQTT protocols. We can analyze and display data in MATLAB using the IoT platform. After the system has been developed, it will be evaluated to determine its efficiency and overall performance, as well as to assess its ability to check and assure the system's appropriate execution. The steps involved in the project's analysis, design, and development are as follows:

1. The problem space is defined as follows: The challenges associated in the existing traditional technique calls for automated monitoring solution. The structure and operation will be evaluated while the project's scope is considered.
2. Analysis of the existing system: This entails doing a comprehensive literature assessment of the existing system's functioning, features, advantages, and flaws.
3. Design of the system: After examining the present system and visualizing the many modules necessary to complete this project, an appropriate solution to the problem will be offered. At this point, information on the mode of operation will be obtained to help with the design.

System Design

The project's objectives call for the creation of a portable prototype of the proposed system. Different design techniques have been tested to meet these goals. An Arduino-based microcontroller is used to read data from temperature, humidity, pH, and soil moisture sensors in the proposed system. The internal TCP/IP stack of the GSM/GPRS Modem enables you to establish a GPRS connection to the internet. To transmit and receive data to and from the internet, the GSM module is interfaced with an Arduino-based microprocessor.

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

Model Diagrams

Use Case Diagram

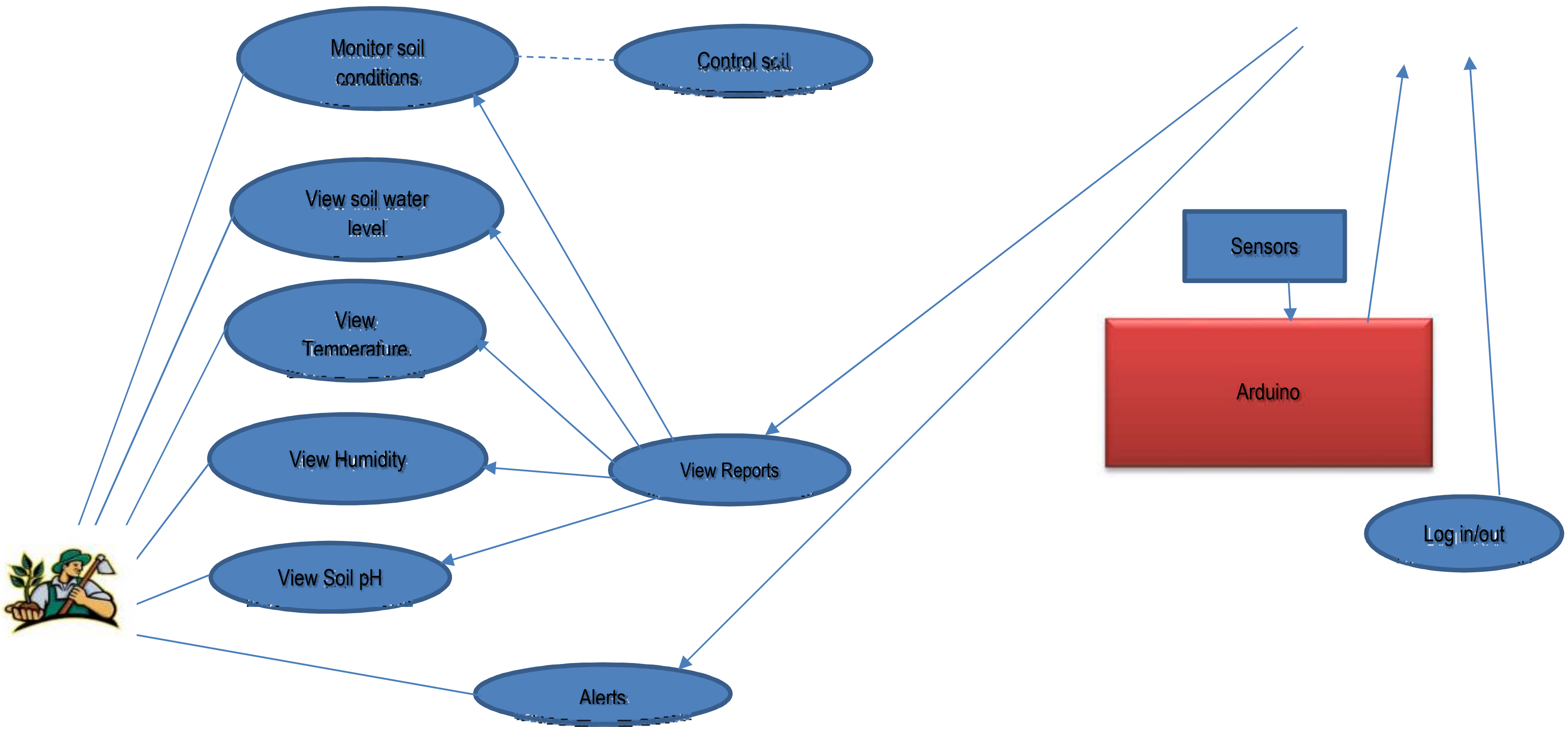

Figure 1: Use case Diagram of the System

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

Class Diagram

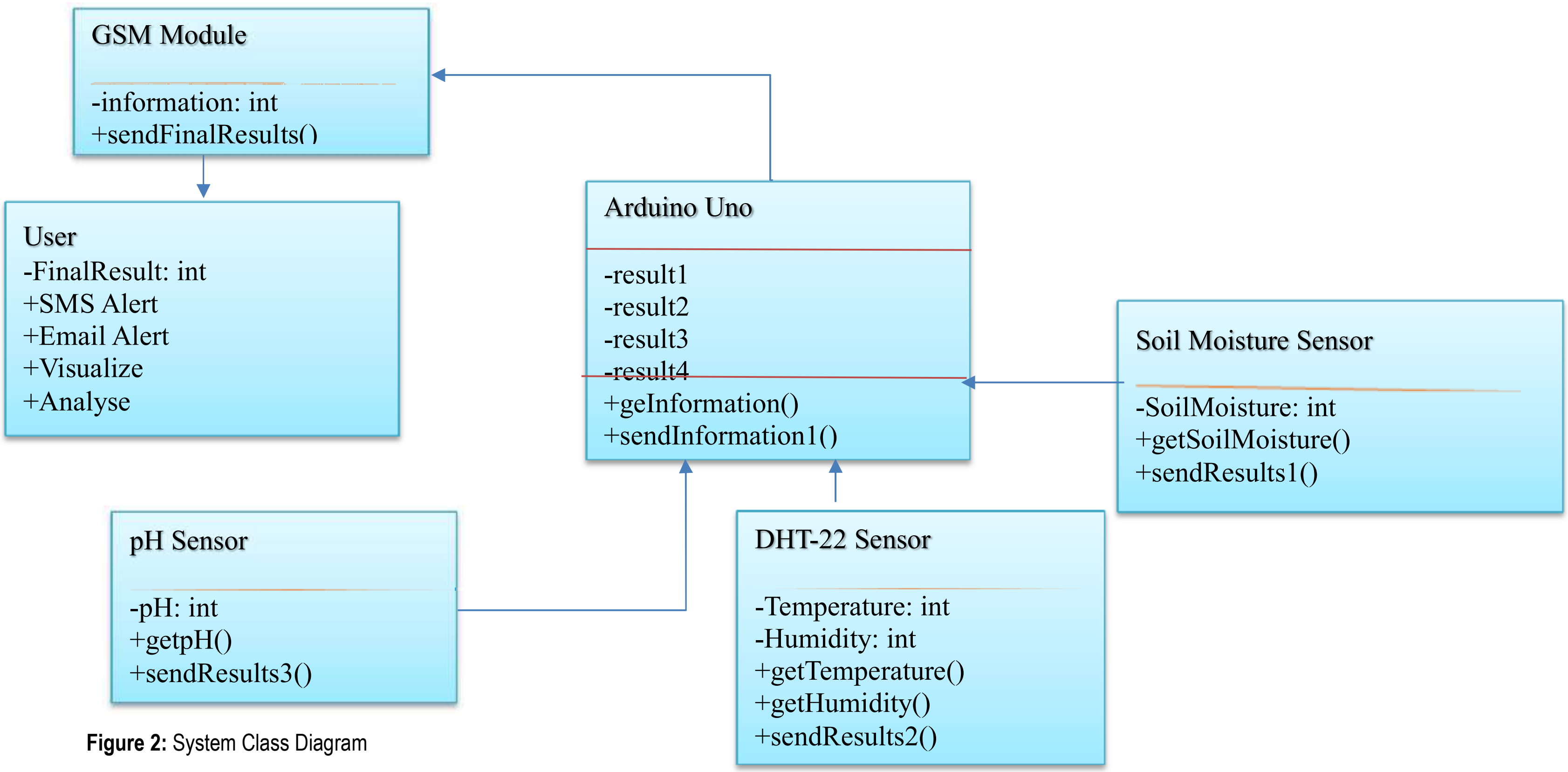

Figure 2: System Class Diagram

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

System Activity Diagram

The proposed system's block diagram

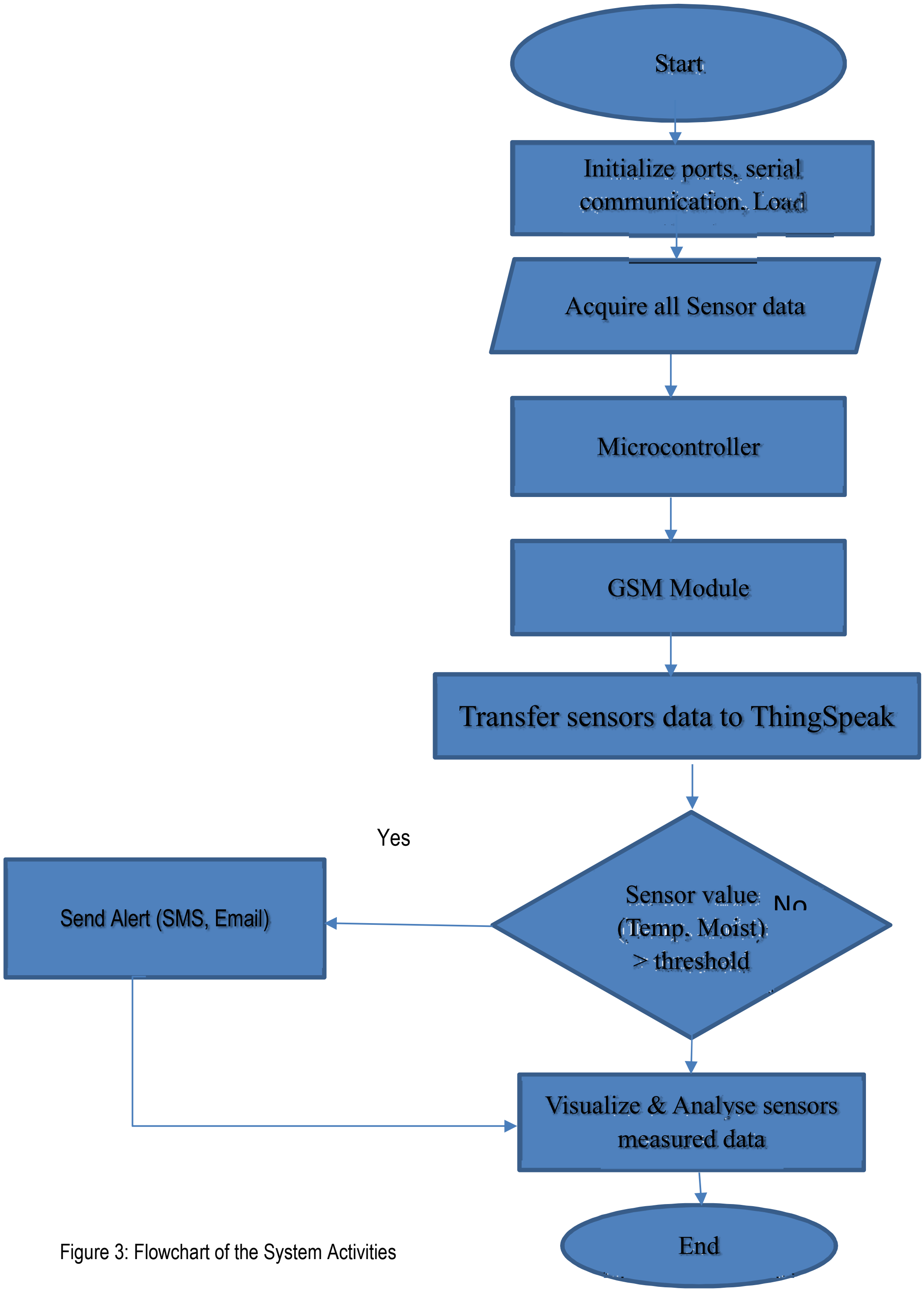

Figure 3: Flowchart of the System Activities

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

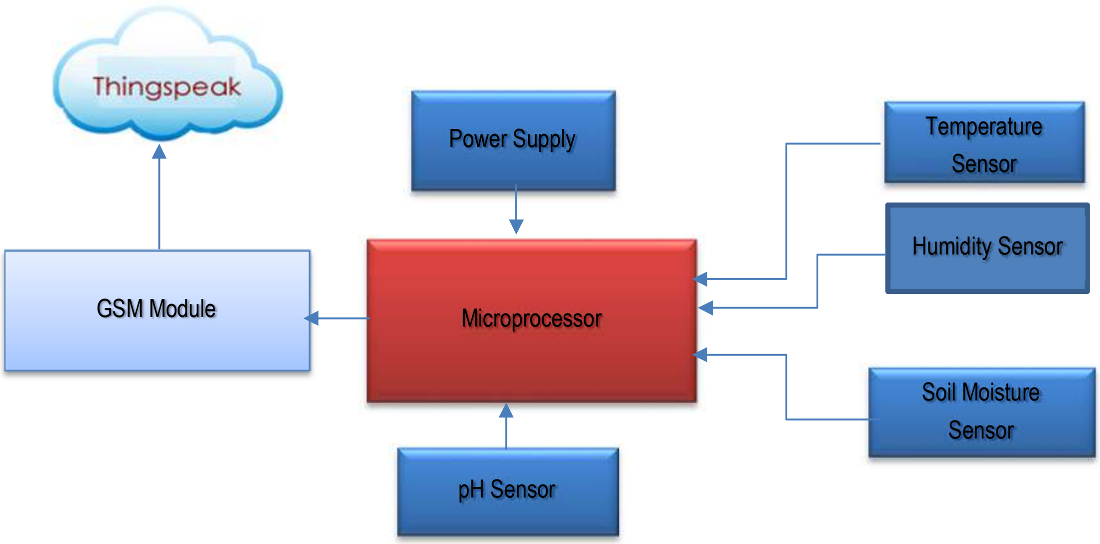

Figure 4: Proposed System Block Diagram

RESULTS AND DISCUSSION

Circuit Description

The smart agricultural monitoring system's experimental configuration is depicted in Figure 5. The setup consists of an Arduino Uno microcontroller, sensors, a GSM module, and soil moisture, humidity, temperature, and pH sensors. The sensors are plugged into a microcontroller built on the Arduino Uno platform and are powered by a 12V supply. The Arduino senses the factors in the environment by receiving data from the sensors and converting it to temperature, relative humidity, pH, and soil moisture values. The GSM module is used to deliver the data to the IoT platform. When the value of soil moisture drops below or climbs over a predetermined threshold, an email or SMS alert is delivered to the user.

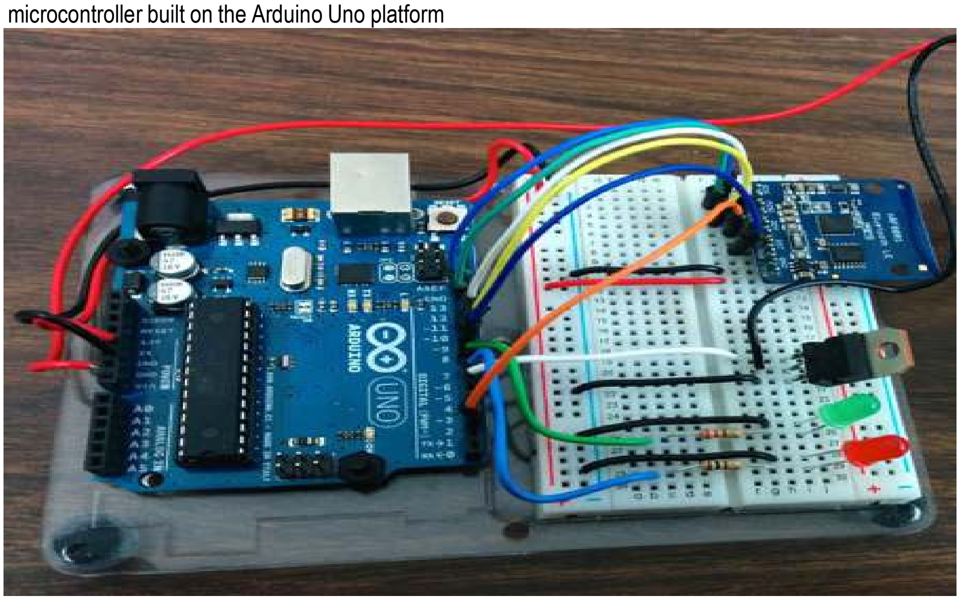

Figure 5: Hardware Setup

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

Operation of the Monitoring System

1. Insert a valid SIM card with an active mobile data plan when the hardware configuration is complete.
2. Using a USB cord and the proper APN and API key, upload the program code (without powering the circuit from the wall adapter).
3. After the program has been uploaded, take the USB out of the device, and turn on the circuit using a 9V to 12V/1 amp (or more) wall converter.
4. The circuit will start up, and you will be given one minute to wait. The GSM module is preparing to connect to the mobile network at that time.
5. The GSM module's Network LED will flicker rapidly, indicating that it has established an internet connection and is ready to transfer data to ThingSpeak.
6. Log into your ThingSpeak account and check the sensor readings.

When the sensors are turned on, the sample field will begin to take measurements. After receiving readings from the field, the Arduino Uno will process the information and convert it to the appropriate parameters for transmission. The GSM module will then be instructed by Arduino Uno to send data to ThingSpeak. When ThingSpeak receives the data, it stores it to storage and converts it to a graphical format using Iframe.

Logging into the ThingSpeak website (shown in Figure 4) allows users to see real-time data. Every 60 seconds, all parameter readings will be sent to ThingSpeak. Data cannot always be transmitted to ThingSpeak due to unreliable connectivity. As a result, until new data can be uploaded to ThingSpeak, the reading shown there will remain unchanged.
The temperature, humidity, soil moisture, and pH sensor values on the ThingSpeak website are shown in the figures below.

Sensor Readings

Table 1: Reading of the soil moisture sensor

Date	Time	Soil Moisture
10/05/2022	08:00:00	0.169
10/05/2022	08:30:00	0.164
10/05/2022	09:00:00	0.166
10/05/2022	09:30:00	0.166
10/05/2022	10:00:00	0.166
10/05/2022	10:30:00	0.165
10/05/2022	11:00:00	0.166
10/05/2022	11:30:00	0.160
10/05/2022	12:00:00	0.164
10/05/2022	12:30:00	0.161
10/05/2022	13:00:00	0.161
10/05/2022	13:30:00	0.161
10/05/2022	14:00:00	0.159
10/05/2022	14:30:00	0.158
10/05/2022	15:00:00	0.156
10/05/2022	15:30:00	0.150
10/05/2022	16:00:00	0.152

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

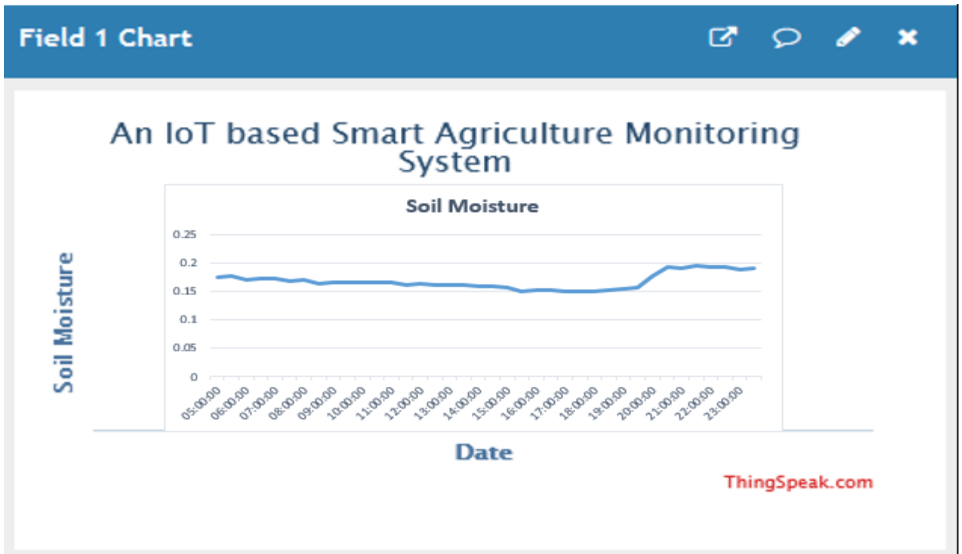

Figure 6: Graph showing soil moisture measurements on the ThingSpeak cloud server

Table 2: Reading of Humidity sensor on ThingSpeak

Date	Time	Humidity
10/05/2022	08:00:00	91
10/05/2022	08:30:00	90
10/05/2022	09:00:00	90
10/05/2022	09:30:00	89
10/05/2022	10:00:00	88
10/05/2022	10:30:00	75
10/05/2022	11:00:00	77
10/05/2022	11:30:00	80
10/05/2022	12:00:00	78
10/05/2022	12:30:00	78
10/05/2022	13:00:00	75
10/05/2022	13:30:00	72
10/05/2022	14:00:00	78
10/05/2022	14:30:00	77
10/05/2022	15:00:00	78
10/05/2022	15:30:00	82
10/05/2022	16:00:00	84

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

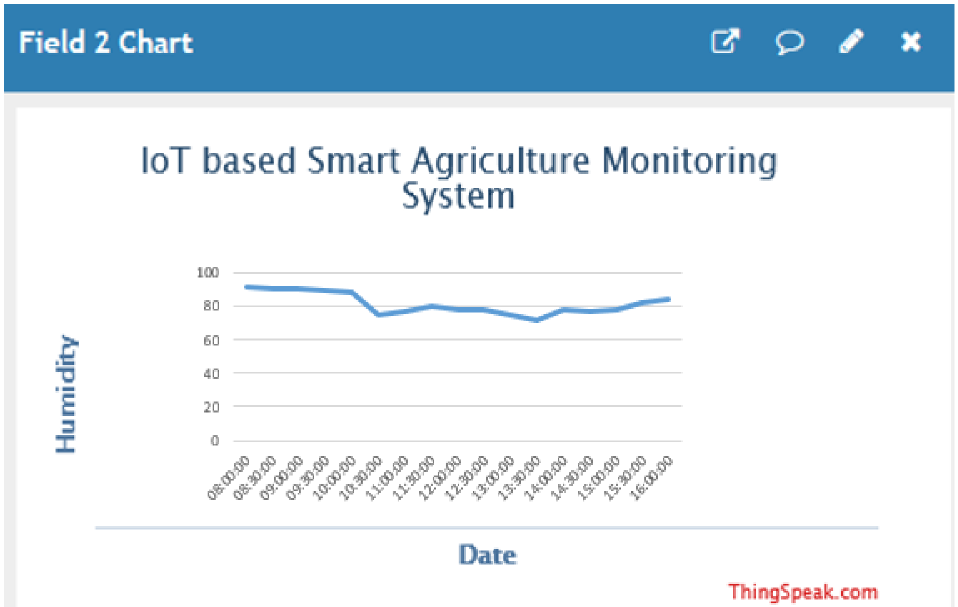

Figure 7: Graph of Humidity sensor readings on the ThingSpeak cloud server

Table 3: Reading of Temperature Sensor on ThingSpeak

Date	Time	Temperature (Degree Celsius)
10/05/2022	08:00:00	28.00
10/05/2022	08:30:00	28.30
10/05/2022	09:00:00	28.70
10/05/2022	09:30:00	28.80
10/05/2022	10:00:00	29.90
10/05/2022	10:30:00	29.00
10/05/2022	11:00:00	29.50
10/05/2022	11:30:00	29.80
10/05/2022	12:00:00	29.40
10/05/2022	12:30:00	29.50
10/05/2022	13:00:00	29.70
10/05/2022	13:30:00	31.40
10/05/2022	14:00:00	32.30
10/05/2022	14:30:00	32.10
10/05/2022	15:00:00	31.90
10/05/2022	15:30:00	30.00
10/05/2022	16:00:00	30.30
10/05/2022	16:00:00	30.60

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 10(3), SEPTEMBER, 2022
ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com

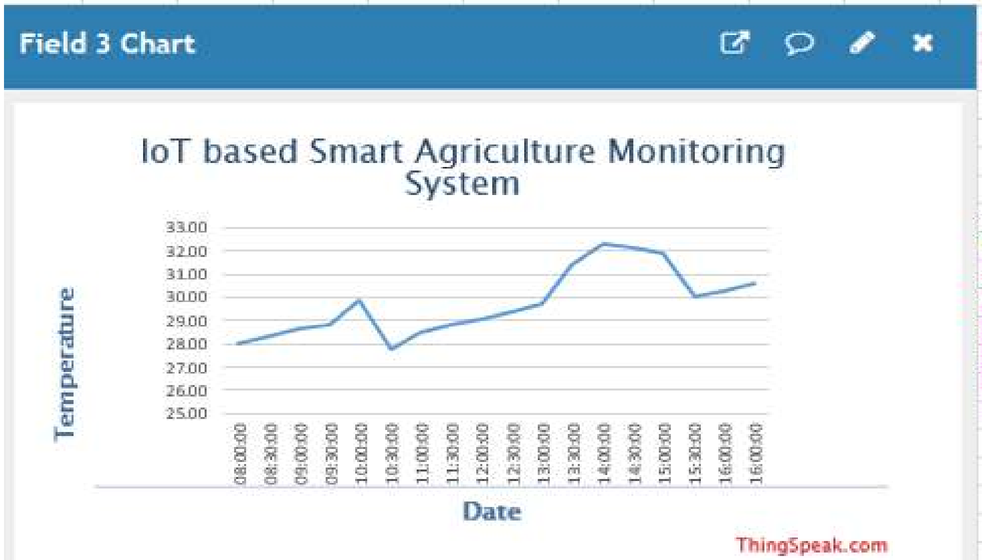

Figure 8: Graph of Temperature Sensor readings on ThingSpeak cloud server

Table 4: Reading of pH Sensor on ThingSpeak

Date	Time	Soil pH
10/05/2022	08:00:00	5.44
10/05/2022	08:30:00	5.21
10/05/2022	09:00:00	4.93
10/05/2022	09:30:00	4.98
10/05/2022	10:00:00	5.11
10/05/2022	10:30:00	4.84
10/05/2022	11:00:00	5.38
10/05/2022	11:30:00	5.55

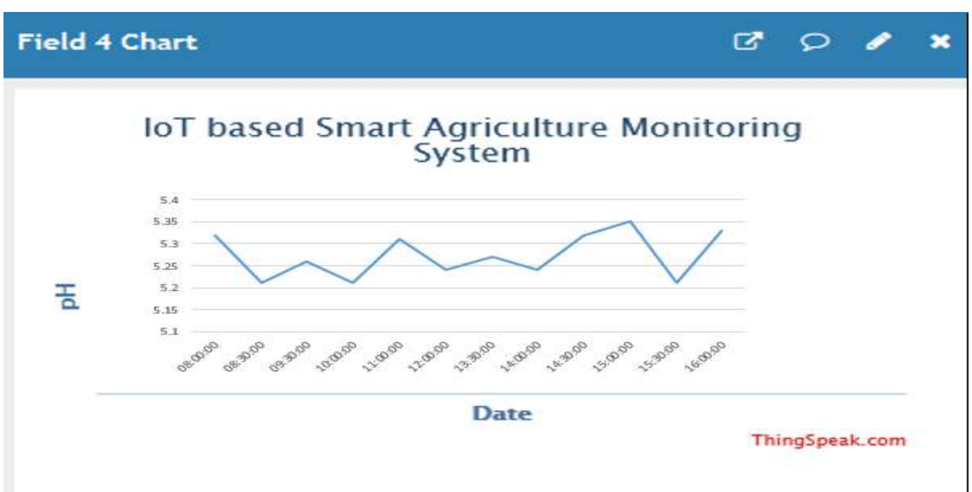

Figure 9: pH Sensor readings on ThingSpeak

Corresponding author: Paschal, U. C. ✉ puchinedu@yahoo.com ✉ Department of Computer Engineering, Edo State University, Uzairue.

The readings of the soil moisture, humidity, temperature, and pH sensors over time are depicted in Figures 6, 7, 8, and 9, respectively. The data collected on ThingSpeak in real time is shown in the graphs above.

CONCLUSION

The management of time, water, crops, soil, insecticide and pesticide control, and other areas of agriculture are all improved through the Internet of Things. Additionally, it minimises the need for human labour, streamlines agricultural procedures, and supports the creation of smart farming techniques. Smart agriculture, in addition to these qualities, may assist farmers in expanding their market with a single touch and minimum work.

This newly designed smart monitoring system refers to an efficient system in which sensor data is remotely monitored over the internet, eliminating the need for the farmer to be present in the field. The method is straightforward to understand and use, and it relieves farmers of some of their responsibilities. This approach aids modern farmers who face a shortage of labour in selecting suitable crops to grow while also conserving water. The farmer can water his field only if sensor values are low. Thus, this prevents the overflow of water. The system may communicate sensor data to the user's phone and issue notifications based on sensor values.

RECOMMENDATIONS

1. More sensors that can monitor the quantity of rainfall, wind direction, and speed may be added to the system to improve it even more.
2. The hardware/circuit design may be enhanced such that it can be operated by solar-powered batteries.
3. Integrating an automated watering system into the design is another option for improving the system.

REFERENCES

Abdulrazaq, A. A., Mustapha, D., Ismail, A.A., Momoh, M.O., Abdulhamid, S., Obari, J.A. and Saliu, M.S., 2018. LabVIEW Interfaced PC-Based Fishpond Monitoring System. *ATBU Journal of Science, Technology and Education*, *6*(2), pp.217-225.

Agrawal, H., Dhall, R., Iyer, K. S. S., & Chetlapalli, V. (2019). An improved energy efficient system for IoT enabled precision agriculture. *Journal of Ambient Intelligence and Humanized Computing,* (6), 2337-2348.

Aliev, K., Jawaid, M. M., Narejo, S., Pasero, E., & Pulatov, A. (2018). Internet of plants application for smart agriculture. *International Journal of Advanced Computer Science and Applications, 9*(4).

Ayaz, M., Ammad-Uddin, M., Sharif, Z., Mansour, A., & Aggoune, E. H. M. (2019). Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. IEEE Access, 7, 129551-129583.

Cambra, C., Sendra, S., Lloret, J., & Lacuesta, R. (2018). Smart system for bicarbonate control in irrigation for hydroponic precision farming. Sensors, 18(5), 1333.

Desa, U. N. (2019). World population prospects 2019: Highlights. New York, NY: United Nations Department for Economic and Social Affairs.

Ferrández-Pastor, F. J., García-Chamizo, J. M., Nieto-Hidalgo, M., & Mora-Martínez, J. (2018). Precision agriculture design method using a distributed computing architecture on internet of things context. Sensors, 18(6), 1731.

Georgakopoulos, D., & Jayaraman, P. P. (2016). Internet of things: from internet scale sensing to smart services. Computing, 98(10), 1041-1058

Halim, A. A. A., Hassan, N. M., Zakaria, A., Kamarudin, L. M., & Bakar, A. H. A. (2017). Internet of things technology for greenhouse monitoring and management system based on wireless sensor network (Doctoral dissertation, School of Computer and Communication Engineering, Universiti Malaysia Perlis).

Imam, M. L., Adebiyi, B. H., Bello-Salau, H., Olarinoye, G.A. and Momoh, M.O., 2019, October. Cultured Artificial

Corresponding author: Paschal, U. C. puchinedu@yahoo.com *Department of Computer Engineering, Edo State University, Uzairue.*

Fish Swarm Algorithm: An Experimental Evaluation. In *2019 2nd International Conference of the IEEE Nigeria Computer Chapter (NigeriaComputConf)* (pp. 1-7). IEEE.

Jayaraman, P. P., Yavari, A., Georgakopoulos, D., Morshed, A., & Zaslavsky, A. (2016). Internet of things platform for smart farming: Experiences and lessons learnt. Sensors, 16(11), 1884.

Kalathas, J., Bandekas, D. V., Kosmidis, A., & Kanakaris, V. (2016). Seedbed based on IoT: A Case Study. *Journal of Engineering Science & Technology Review, 9*(2).

Kodali, R. K., Jain, V., & Karagwal, S. (2016, December). IoT based smart greenhouse. In 2016 IEEE region 10 humanitarian technology conference (R10-HTC) (pp. 1-6). IEEE.

Madakam, S.; Ramaswamy, R.; Tripathi, S. (2015). Internet of Things (IoT): A literature review. *Journal of Computer and Communications, 3*, 164–173.

Maia, R. F., Netto, I., & Tran, A. L. H. (2017, October). Precision agriculture using remote monitoring systems in Brazil. In 2017 IEEE Global Humanitarian Technology Conference (GHTC) (pp. 1-6). IEEE.

Navarro, E., Costa, N., & Pereira, A. (2020). A systematic review of IoT solutions for smart farming. Sensors, 20(15), 4231.

Ojha, T., Misra, S., & Raghuwanshi, N. S. (2015). Wireless sensor networks for agriculture: The state-of-the-art in practice and future challenges. Computers and electronics in agriculture, 118, 66-84.

Porter, M. E., Heppelmann, J. E.: How smart, connected products are transforming competition. Harvard business review 92, 64–88 (2014)

Ray, P. P. (2017). Internet of things for smart agriculture: Technologies, practices and future direction. *Journal of Ambient Intelligence and Smart Environments, 9*(4), 395-420.

Shomefun, T., Awosope, C. O. A., & Ebenezer, O. D. (2018). Microcontroller-based vertical farming automation system. *International Journal of Electrical and Computer Engineering (IJECE), 8*(4), 2046-2053

Stočes, M., Vaněk, J., Masner, J., & Pavlík, J. (2016). Internet of things (IoT) in agriculture-selected aspects. Agris on-line Papers in Economics and Informatics, 8(665-2016-45107), 83-88.

Walter, A., Finger, R., Huber, R., & Buchmann, N. (2017). Opinion: Smart farming is key to developing sustainable agriculture. Proceedings of the National Academy of Sciences, 114(24), 6148-6150

Yim, D., Chung, J., Cho, Y., Song, H., Jin, D., Kim, S., & Riegsecker, A. (2018, March). An experimental LoRa performance evaluation in tree farm. In 2018 IEEE sensors applications Symposium (SAS) (pp. 1-6). IEEE.

Zhang, X., Zhang, J., Li, L., Zhang, Y., & Yang, G. (2017). Monitoring citrus soil moisture and nutrients using an IoT based system. Sensors, 17(3), 447.

Corresponding author: Paschal, U. C. puchinedu@yahoo.com Department of Computer Engineering, Edo State University, Uzairue.