IJFANS INTERNATIONAL JOURNAL OF FOOD AND NUTRITIONAL SCIENCES

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 11,Iss 12, 2022

An Investigation of the Use of IOT for Agricultural Output Monitoring and Control

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Abstract:

The notion of the Internet of Things (IoT) enables physical objects equipped with computational and sensory capabilities to communicate with one another and access online services. The goal behind the Internet of Things (IoT) was to link gadgets over the Internet and make it easier for users to obtain information. IoT has many potential uses, and one area where a lot of utilisation is anticipated in the future is agriculture. Presenting the Internet of Things concept as a foundation for farm production processes' monitoring and control systems was the goal of this endeavour. IoT devices are important, and their realisation is centred on the use of suitable sensors like those made by Arduino and readily available microcontroller platforms. In addition to collecting data for monitoring systems, autonomous sensor devices also assist in control by communicating with actuators through signals. Users of such an Internet of Things-based system can remotely monitor the industrial process and environmental conditions. With the help of this technology, users can cut costs, save input costs, and track the farm's production process.

Keyterms: IOT, Agricultural, Monitoring and Control, farm's production.

Introduction

The growth of agriculture in India has become volatile over the past 10 years. The efficient deliverable of agriculture will prevent food scarcity. Being a vital occupation in our country, the annual growth rate in agriculture is 2.9% in 2019-2020 and it was observed as consistent for the past 6 years. The irregular monsoon, inadequate irrigation, overuse of soil nutrients, uneven access to modern technology across the nation, inappropriate use of fertiliser, restricted government agency procurement of food grains, and the lack of paying farmers fairly are the main factors influencing high yield. Due to the lack of adaptive technology to automate and ease the farming process (Kim et al. 2020), it turns to be challenging to improve agriculture. When the farmers are aware of the respective soil nutrients level of their land, it is possible to manage the farming process to produce a high yield (Zhiguo Li et al. 2019). Soil Nutrients are classified into two main categories namely macronutrients and micronutrients.

Macronutrients are the substances that are present in high proportion, whereas micronutrients are the substances that are present in low proportion within the soil. Potassium (K), Nitrogen (N), Magnesium (Mg), Calcium (Ca), Sulphur (S), and Phosphorus (P) belong to macronutrients of the soil. Iron (Fe),

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11,Iss 12, 2022

Chlorine (Cl), Manganese (Mn), Boron (B), Copper (Cu), Zinc (Zn), Nickel (Ni), and Molybdenum (Mo)are micronutrients present in the soil. The amount of nutrients required by the plants will vary for different types of plants.

The applications of IoT (Hatture and Yankati 2021) in various fields like smart city, smart home, smart grid, smart farming, etc., results in better livelihood for the society. [1] Thereby, the increase in the adoption of the Internet of Things (IoT) in agriculture leads to a smart way of farming. [2] IoT system collects the physical parameters such as temperature, humidity, weight, distance, pH value, speed and so on input data and process the measured physical data using a computation device that produces a result of automation or control systems. [3] The measurement of physical parameters like temperature, moisture, soil pH, etc. by the sensors and response based on sensor data results in automated decision-making in smart agriculture systems. [4] The traditional IoT system collects the data (Sujithra et al. 2017) and images from the field to support the farm monitoring system. [5] Sushmita Tapashetti and Shobha (2018) declares that an IoT based smart agriculture can provide high yield. The research work is diverted to focus on the way in which soil nutrients analysis can be executed at the farmer end using IoT as a part of smart agriculture system.

In order to adopt the dynamic changes in the procedure of farming and cultivation, prediction and decision making are desirable. [6] Machine learning (Pratyush Reddy 2020) is the recent trend used to take suitable decision in the process of agriculture. [7] Various applications of machine learning techniques in agriculture are crop management, soil management, irrigation management, disease detection, pest identification, etc. [8] Thereby, machine learning algorithms (Konstantinos et al. 2018) are integrated followed by sensing process that allow the IoT system to take the decision that pave way for high cultivation in smart agriculture.

[9] The sensor value is used to predict the desired results by using machine learning techniques like regression, Support Vector Machine (SVM), Artificial Neural Network (ANN), etc. Hence, the proposed research focuses towards the development of machine learning algorithms for IoT based smart agriculture systems. [10] The process of finding the soil macronutrients is done by embedding machine learning techniques in IoT.

In the farming process, detection of macronutrients available in the soil is significant before crop plantation as well as for the addition of fertilizer during plant growth. [11] It is inattentive by most of the farmers due to high-cost manual testing in laboratories. The addition of fertilizer without knowing the soil fertility causes mutilation of crops.[12] Different principles are adopted in finding the presence of macronutrients in soil that lead to huge apparatus and complex procedure.

[13] Predominant smart agriculture systems facilitate automated irrigation systems, farm monitoring systems, plant growth monitoring systems, disease detection systems, etc. The existing smart agriculture systems lack in soil nutrient analysis to add fertilizer at right time during plant growth. [14] As the outcome of the literature survey, it is found that the soil testing is executed in laboratories with a huge experimental setup. Moreover, existing systems fail to incorporate soil nutrients analysis as an automated process.

Foundation for system development

. It contributes to the design of soil sensor using the colorimetric principle that alternates the manual and expensive soil testing procedures in laboratories. The designed IOT sensor is integrated with a developed IoT based smart agriculture system. The single value of the sensor provides the measure of all macronutrients present in the soil. [15] So the system requires an inbuilt prediction analysis to identify the proportions of N, P and K present in the soil. Initially, the analysis of sensor data is executed using a Fuzzy Rule-Based system (FRBS) with the WIFI communication interface as an edge computing process.

[16] As the soil nutrients proportion depends on the pH value of the soil, the research is extended with improving the accuracy of the prediction algorithm by fetching two sensor values from IOT sensor and pH sensor to predict the presence of N, P and K levels in the soil using fog computation. [17] Multivariate Linear Regression model is developed to respond to predict the proportions of N.P and K present in the soil. Finally, a comparative analysis is done between FRBS based smart agriculture systems and MvLR based smart agriculture system with prediction accuracy.

Figure 1. Arduino Ethernet Module ENC28J60

Figure 2. Board: Arduino Ethernet Rev. 3

A new Microchip ENC28J60 is used by the Ethernet module (Figure 1) to manage network protocol needs. The SPI interface connects the module to the majority of microcontrollers. Its maximum transfer speed is 20 MHz, and its power source is +3.3 V (ENC28J60 Ethernet).

In Figure 2, an Arduino Ethernet is seen. It has an Ethernet port integrated within the Arduino development board, which is based on the ATmega328. This board can be powered by an external power source, an add-on PoE module, or an Arduino Ethernet USB serial connector or FTDI cable.

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Figure 3. ESP8266 Wireless Module

A WiFi networking solution called ESP8266 makes it possible to link the microcontroller to the WiFi (Figure 3.). It may also execute different apps on its own. The following specifications apply to the ESP8266 Module: 3.3 volt power supply, 32K + 80K RAM, 80-160 MHz CPU speed, and 802.11 b/g/n/d/e/i/k/r compatibility. The transmitting current consumption can reach 170mA at full power, while 10uA is needed in sleep mode (Kolban, 2015). This module's battery power source could include a solar panel for battery recharge..

<u>Utilising Internet of Things devices in farming operations</u>

The collected data in the server is fetched for processing through machine learning techniques to make several decisions in the field of application. Machine learning techniques are used for either classification or prediction in agriculture (López et al. 2018). With the previous history of the data set, the data is pre-processed to transform the data to the desired form to train the data. An algorithm or a training model is designed and adapted to train the system based on collected data.

The training model can be designed using appropriate supervised or unsupervised learning techniques in order to produce accurate prediction or classification. The designed training model can be installed in the IoT based system as edge computation or fog computation or cloud computation to test the real-time data from the sensor. The data fetched by the machine learning system is tested to produce the predicted results to make decisions on soil classification, crop classification, yield prediction, irrigation management, pest detection, etc.

Smart soil parameters can be estimated through wireless sensor networks by using machine learning techniques (Estrada-López et al. 2018). (Liviu-Cristian et al. 2018) declares and prove that rule based fuzzy system using Mamdani model leads to fast and accurate results. The author states that the fuzzy system produces a prediction analysis where the data is uncertain and not well defined. Regalado et al, develop a fuzzy System (Regalado and Cruz 2016) to identify N,P, K and soil pH levels of soil. It was identified that N, P and K in soil depends on soil pH (Abubaker et al. 2015). Su et al (2012) develops a Multivariate Linear Regression (MvLR) that produces improved results in the sample linear regression

ISSN PRINT 2319 1775 Online 2320 7876
 UGC CARE Listed (Group -I) Journal Volume 11,Iss 12, 2022

(Su et al. 2012) in prediction analysis of field of application. In the article (Yang 2018), MvLR is used for prediction analysis of chemical composition that infers accurate results.

It was identified that the soil testing apparatus are not handheld devices that cannot be integrated with an IoT system. Most of the spectroscopy-based devices are installed in laboratories to perform soil testing. The color sensor used to identify the soil nutrients is tested with soil solution of chemical agents which would lead to less accuracy in the prediction. The research work aims to solve the issue of complex and manual soil testing procedures by designing the IOT sensor that can be integrated with an IoT system to automate the soil testing at regular intervals of time

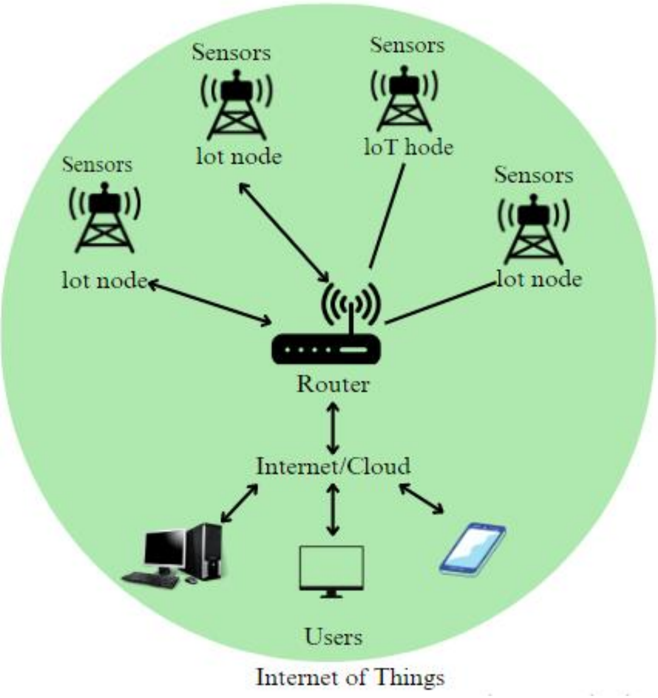

Figure 4. Internet of Things

Design of IOT Sensor

Four different coloured a Light Dependent Resistor (LDR),four resistors, and Light Emitting Diodes (LED) are intended to be used with the proposed IOT sensor. The connections between the parts that make up an IOT sensor are depicted in Figure 3.1. The input voltage (V) in Figure 3.1 is represented by Vcc, and the output voltage over the LDR in V is Vo. To prevent current overflow in LEDs, R1, R2, R3, and R4 are resistors with a 10 KΩ value. The following is how the circuit design shown in Figure 3.1 detects the nutrients in the soil. Initially, the soil solution selected for the nutrient level test is illuminated by LEDs. The colorimetric concept states that the chemical concentration of the soil determines how much light is absorbed from the soil solution.

According to the photoconductivity concept, light mirrored from the soil solution is taken in by LDR and captured in proportion to the amount of light received. The amount of light absorption (A) in LDR is provided by Beer-Lambert's law. Light reflection per unit area (Lux) is a function of LDR resistance level (RL). Figure 5 is one example of the Internet of Things idea used with Arduino platforms and suitable sensors. The Arduino Uno Board serves as the IoT node's computational foundation. Sensors are attached to this board, which is also used to pin numerous extra shields.

Among the many applications for sensors are water flow, light intensity, gas emission, temperature and relative humidity (DHT11), and motion detection. These sensors may collect data, which can then be broadcast to a remote server or saved locally on analogue and digital Arduino pins. SPI communication is used to link the main board to the Ethernet module, and HTTP protocol may be used to transmit data. In this scenario, the Internet of Things gadget serves as the web client. It can send an HTTP request to the web server on the Internet to transfer data when it receives data from sensors. IoT devices can also play the function of a recipient, accepting requests from other devices. This indicates that the device is acting as a Web server and responding to network queries. The device's associated actuators, such as the DC motor and light intensity, are controllable by the users.

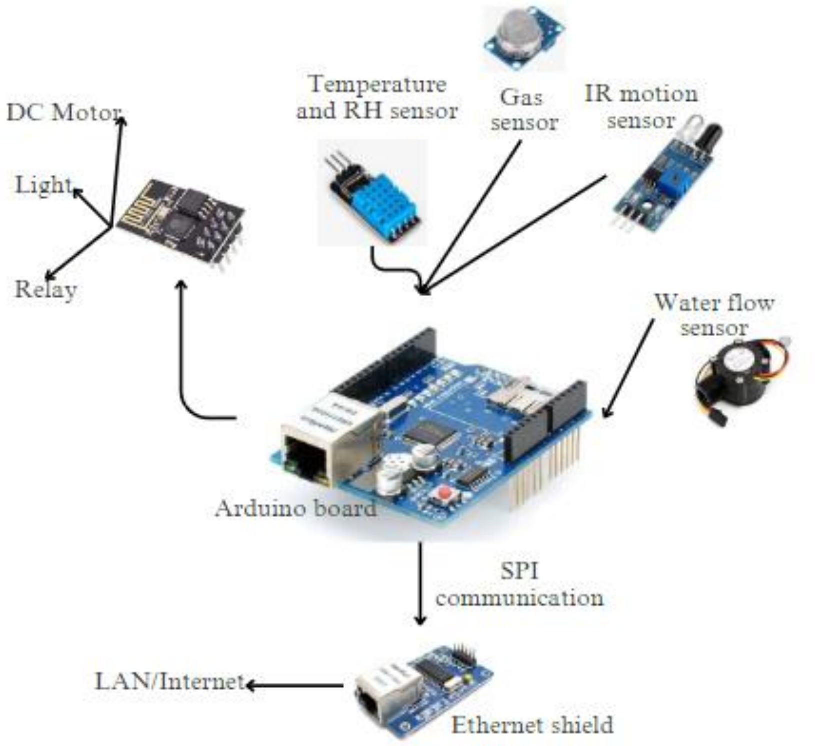

Figure 5. Node with Ethernet support

The components' arrangement permits the employment of these devices in agricultural output. The greenhouse provides information through the temperature and relative humidity sensor. This sensor offers information regarding steady circumstances, in addition to the gas and light sensors. Water consumption is tracked by the water flow sensor. Additionally, the device's output can be used to remotely alter the light or start the motor when combined with the relay module.

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 11,Iss 12, 2022

Experimental Results

The design of an IOT sensor-based single node is depicted in Figure 3.1. The voltage and soil content are the two metrics that are used to evaluate the produced IOT sensor. Three distinct types of soil— mountain soil,desert soil, and red soil—are tested in these two experiments.

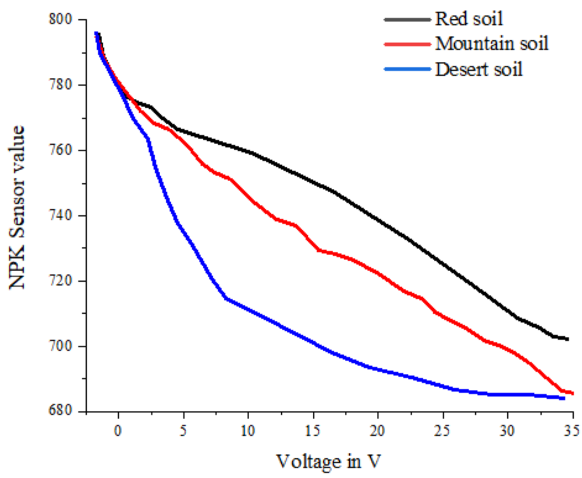

Figure 6 Output of IOT sensor with various voltage levels

The LED voltage in the IOT sensor is first changed in order to test it. For the test, a sample soil solution is prepared by combining 50 grammes of soil with 100 millilitres of water. The purpose of this test is to demonstrate that the sensor operates in accordance with above figure that are discussed in this section. The IOT sensor output varies as the voltage level is changed from 0 V to 5 V. Figure 3.2 illustrates how the sensor's value decreases proportionately to an increase in voltage. This demonstrates that the IOT sensor, as designed, fulfils its function in accordance with Beer-Lambert law.

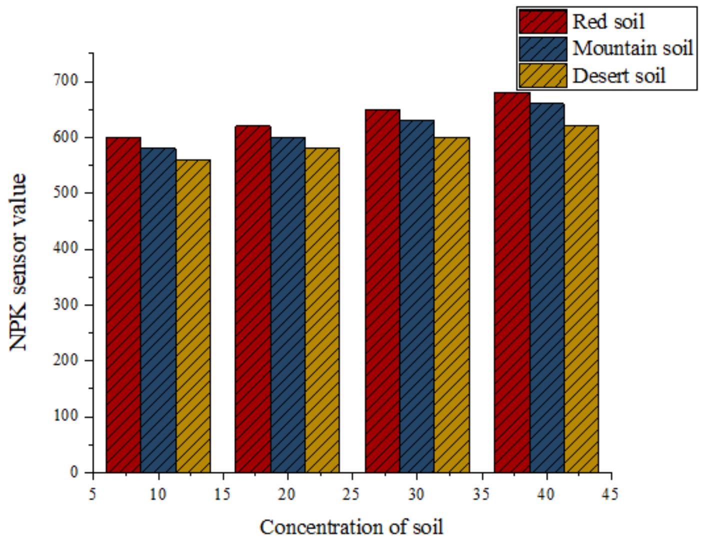

Figure 7. IOT sensor response Vs concentration of the soil solution

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 11,Iss 12, 2022

Second, the use of the colorimetric concept is demonstrated by testing the IOT sensor for the level of nutrients by altering the concentration of the soil solution. In order to conduct this test, three distinct types of soil—mountain soil, desert soil, and red soil—are given an input of 5 V DC. The IOT sensor value for each type of soil is displayed in Figure 3.3 in relation to the soil solution concentration. It has been noted that the sensor value differs for three different types of soil and increases according to the amount of soil that contains an equivalent amount of water.

Depending on the kind of soil, standard soil parameters, and the precisely determined concentration of the soil solution, the range of the IOT sensor to detect soil deficiencies will change. It is suggested that an opaque covering be placed over the developed sensor to guarantee a good response free from external light source influence. Throughout the course of a day, the created hardware IOT sensor value for a soil sample never changes. This is due to the fact that the amount of nutrients in the soil does not change over time. However, when the crops grow and absorb nutrients from the soil, it will change.

Because of this, the software's soil nutrients testing feature can be programmed to run at regular intervals (either weekly or monthly), depending on the kind of soil and crop being planted in the field. It is advised that the sensor unit be left idle aside from measurement by setting the automatic sensing to discrete measurement. When compared to manual soil testing in a laboratory, the created sensor is less expensive since the components employed in its design are less expensive.

Conclusion

Soil Testing is a significant process that contributes towards successful farming resulting in high yield. Although various types of methods available for soil testing, it is difficult to integrate with smart agriculture systems. Soil testing is not executed automatically through IoT based smart agriculture system under the unavailability of a specific sensor to measure the soil nutrients. The research task described in this chapter discusses the design of a novel sensor representing the reflection of light based on the composition of chemicals present in the soil solution. The designed sensor is referred to as an NPK sensor that provides a value that varies concerning the presence of nutrients.

The sensor is designed with electronics components and tested the functionality per the applied principle. It was observed that the sensor is designed for better results at a low cost. The sensor can be integrated with any kind of existing smart agriculture system. Soil nutrients involve more than two elements that are mentioned as macronutrients and micronutrients. All the measurement devices result in a value equivalent to the chemical reaction in the soil solution. Therefore, it requires a method of analysis (Alexander Erler 2020) to determine the proportion of each nutrient present in the soil. The analysis is possible by using the recent techniques in machine learning. The research study extended towards the machine learning techniques are used in the detection of soil nutrients. The outcome of the research study leads to the construction of two machine learning algorithms for predicting the proportions of N, P and K present in the soil from IOT sensor data.

Abbreviation

IoT	- Internet of Things
FRBS	- Fuzzy Rule-Based system
SVM	- Support Vector Machine
ANN	- Artificial Neural Network
LDR	- Light Dependent Resistor
LED	- Light Emitting Diodes

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

Funding

This research study is sponsored by the institution name. Thank you to this college for supporting this article!

Availability of data and materials

Not applicable

Authors' contribution

Author A supports to find materials and results part in this manuscript. Author B helps to develop literature part.

Acknowledgement

I offer up our fervent prayers to the omnipotent God. I want to express my sincere gratitude to my co-workers for supporting me through all of our challenges and victories to get this task done. I want to express my gratitude for our family's love and support, as well as for their encouragement. Finally, I would like to extend our sincere gratitude to everyone who has assisted us in writing this article.

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ISSN PRINT 2319 1775 Online 2320 7876

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