engineering proceedings

MDPI

Proceeding Paper

Design and Development of Internet of Things-Based Smart Sensors for Monitoring Agricultural Lands †

Dhiya Sabu [1], Paramasivam Alagumariappan [1,*], Vijayalakshmi Sankaran [2] and Pavan Sai Kiran Reddy Pittu [1]

[1] Department of Biomedical Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai 600062, India; vtu16805@veltech.edu.in (D.S.); vtu18106@veltech.edu.in (P.S.K.R.P.)
[2] Department of Electronics and Communication Engineering, Vel Tech Rangarajan Dr. Sagunthala R&D Institute of Science and Technology, Chennai 600062, India; drvijayalakshmis@veltech.edu.in
* Correspondence: parama.ice@gmail.com or draparamasivam@veltech.edu.in; Tel.: +91-984-378-0801
† Presented at the 10th International Electronic Conference on Sensors and Applications (ECSA-10), 15–30 November 2023; Available online: https://ecsa-10.sciforum.net/.

Abstract: In recent years, the demand for efficient and sustainable agricultural practices has been leveraged, leading to smart farming practices. These practices aim to enhance agricultural processes and productivity and minimize resource waste. One of the crucial challenges faced by farmers is the uneven distribution of soil humidity and pH across their agricultural lands. Further, the irregularity in soil moisture content and pH can lead to poor crop performance, water wastage, and increased resource utilization. In this work, an Internet of Things-based smart sensor node was developed, which consists of humidity and pH sensors to ensure the efficient management of water and soil conditions across an entire farm. Also, an array of humidity and pH sensors were placed across the farm, and these units worked independently as they have their own controller and battery unit. The developed device was integrated with a solar cell, which charged the battery. Further, the data acquired from these sensors were wirelessly transmitted to the base station, and it gathered the information of each unit, including their humidity levels, pH values, signal strength, and energy supply. This information was processed at the base station, and a graphical overview of the farm with the acquired information was represented, which provides farmers with real-view insight to identify areas with poor humidity and pH conditions. These data were transmitted to an IoT cloud, offering the farmer the ability to monitor their farm from a remote location. In cases where humidity levels dropped drastically and remained unchecked for more than two hours, the system triggered an alert. This mechanism makes sure that farmers are notified of potential issues, allowing them to prevent crop damage and optimize their resource usage.

Keywords: agriculture; cloud platform; Internet of Things; smart farming; humidity; pH

check for updates

Citation: Sabu, D.; Alagumariappan, P.; Sankaran, V.; Pittu, P.S.K.R. Design and Development of Internet of Things-Based Smart Sensors for Monitoring Agricultural Lands. *Eng. Proc.* **2023**, *58*, 13. https://doi.org/10.3390/ecsa-10-16207

Academic Editor: Francisco Falcone

Published: 15 November 2023

Copyright: © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Agriculture is one of the prominent components of human civilization, supplying food, prosperity, and an integral means of survival for inhabitants worldwide. As the world continued to grow, the farming sector and the overall agricultural industry were faced with significant challenges, as they had to produce more food and supplements for the growing population with limited resources [1]. At the same time, they had to make sure that it did not have a negative impact on the environment. Agriculture in many developing countries is confronted with a lot of complications, such as nutrient deficiencies, imbalance of pH and humidity, and multiple subterranean pests, along with water scarcity [2]. Often, the hidden adverse effects of crops go unrecognized or undetected until it is too late, and these pose a hidden threat to the farmers and the foundation of the whole population that relies on agriculture for survival. All the efforts and hard work made by the farmers go in complete vain, which, in turn, affects their livelihood badly as it becomes a more expensive

fix. Abnormalities of the pH in the soil can also permanently impair crop productivity and yield and, at the same time, affect the overall quality [3]. The implementation of cutting-edge and groundbreaking technologies in agriculture is serving as a feasible solution for a lot of issues and has helped advance the fields of precision farming and pest disease management. The IoT continues to play a major role in this journey [4].

State-of-the-art technologies, specifically the Internet of Things (IoT), have helped to be an effective collaborator in the attempt to track, regulate, and evaluate in order to enhance the overall health of the crop and yield [5]. One major advantage of the IoT in agriculture is that it provides access to remote monitoring, which can be beneficial to farmers handling large areas of land [6]. They can easily receive updates on their smartphones and other similar devices.

The accessibility and availability of nutrients, vitamins, minerals, activity of microbial species, etc., are vital for plant growth. The pH of the soil has a direct impact on factors such as the efficiency and yield of the crops [3]. Furthermore, the deviations from normal levels of humidity can have an undesirable impact on the intake of water, transpiration, and general crop health. These imbalances can lead to various problems, such as stunted growth, increased susceptibility to various diseases and pests, and even pollination, and photosynthesis. These humidity fluctuations are often overlooked until and unless the crop or harvest shows signs of being in distress. In the pre-technology era, farmers made use of the conventional and manual techniques to keep an eye on their crops. This consisted of making decisions based on experience, manual irrigation, and visual examination [7].

In recent years, sensor technology has come into existence, and a single sensor can very well provide the required data, but relying on just one sensor has its own limitations due to a lack of context and inefficiency. Investigations and experiments have been conducted concerning topics such as the health of the soil, tracking and surveillance of diseases, insect management, and climate-related challenges [8]. The aforementioned initiatives provided valuable insights and led to the creation of numerous monitoring systems and methodologies. To avoid the mentioned drawbacks, scientists have developed highly sophisticated sensors and data acquisition systems that can gauge moisture and humidity levels, soil wetness, and systems that can foresee potential hazards to crops. Predictive models and disease detection techniques have also been established [9].

Amidst other challenges, the major difficulty lies in making farmers from rural areas understand these datasets. The data have to be unambiguous so that the farmers can easily perceive the data and make wise judgments, as it can be a difficult task for them due to their low literacy rate and lack of access to technologies [10,11]. So, there is a need for a user-friendly interface and assistance tools. These systems should help farmers convert raw data into understandable and practical insights so that they can improve their farming approaches [11].

The objective of this paper was to develop an advanced IoT-based smart sensor system that is customized for agricultural practices. This article aims to enhance decision making in order to improve crop yields and resource utilization and, at the same time, intends to eradicate the shortcomings of wired technology and single-sensor solutions.

2. Materials and Methods

Figure 1 shows a graphical diagram of the proposed approach. The proposed IoT-based smart sensor system consists of more than two smart sensor modules, which are represented as device 1, device 2, and device n. Furthermore, these devices were displaced randomly on the agricultural land, as shown in Figure 1.

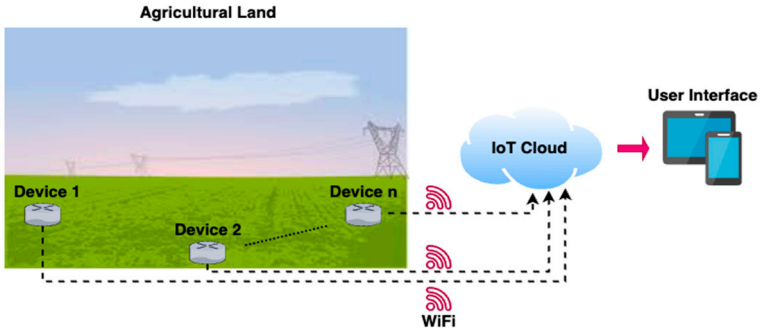


Figure 1. Proposed IoT-based smart sensor system.

2.1. The Proposed System

Figure 2 shows the overall hardware block diagram of the proposed device. Also, the proposed IoT-based smart sensor device is a standalone device, which is self-powered using a solar cell and a battery unit.

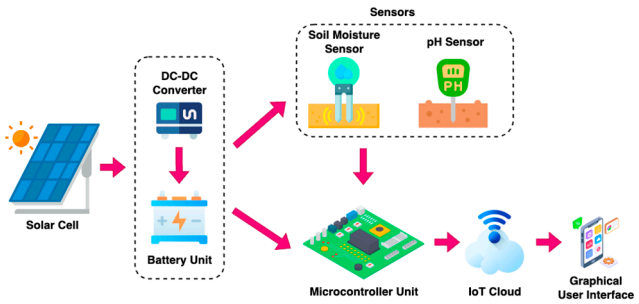


Figure 2. Overall hardware block diagram of the proposed device.

The entire device components are arranged in a three-stack structure, in which the solar cell is placed at the top stack; the battery, microcontroller unit, DC-to-DC converter, and battery charger unit are mounted on the middle stack; and the sensors, namely the pH sensor and the soil moisture sensor, are arranged on the bottom stack. Also, the foam floats were attached to the bottom stack to make the device float if the land was filled with water.

2.1.1. Solar Cell

The proposed device was a made as a standalone device, in which the electrical energy is generated with the help of a solar cell. In general, a solar cell is a device that converts light energy, due to solar irradiance, into electricity. In this work, a compact solar cell with a dimension of no more than 14 cm was used, which generated an output voltage of 12 V and a current of 200 mA. Also, the adopted solar cell was capable of generating the 2.4 watts of power.

2.1.2. DC-to-DC Converter

The output of the solar cell was 12 volts, and all the device components utilized in this work required a maximum of 5 volts. So, it was essential to step down the voltage level of the solar cell, and to achieve this operation, a DC-to-DC converter was used [12]. The XY-3606-based DC-to-DC converter was used as a step-down converter, which reduced the voltage from 12 volts to 5 volts and supplied a maximum current of 5 A.

2.1.3. Battery

In this work, a solar cell was utilized to generate electrical energy. Also, the solar irradiance may not be constant all the time, and, in turn, the electrical energy generated varies with time. To supply a constant source to all the device components, the battery was

utilized. Further, a lithium polymer (LiPo) battery with 3.7 volts (1000 mAh) was used. Also, the LiPo battery was charged using the LiPo battery charger circuit.

2.1.4. Sensors

In this work, two different sensors were used, namely the pH sensor and the soil moisture sensor. Further, the acidity and basicity of the soil were measured with the help of the pH sensor. In general, its value ranges from 1 to 14, where 1 indicates that the soil is more acidic and 14 indicates that the soil is more basic in nature. Also, a pH value of 7 indicates that the soil is neither acidic nor basic. Furthermore, the proposed pH sensor was capable of operating from 3.3 to 5.5 volts. Also, the same pH sensor module was utilized to measure the temperature of the soil. The soil moisture sensor module has a pair of electrodes and a comparator board that operates from 3.3 to 5 volts.

2.1.5. Microcontroller Unit

An ESP8266 microcontroller unit, otherwise known as the Node MCU, was utilized in this work to collect sensor data. Further, the Node MCU operates on a 5-volt power supply, which can be powered using a LiPo battery through the Pololu U3V70F5 board. The Node MCU has an in-built WiFi module that helps the user to feed their sensor data to the IoT cloud. In general, the ESP8266 has one analog pin to which one sensor can be connected. So, the external analog-to-digital converter, namely the ADS1115, was connected to the utilized Node MCU. Further, the sensor data were converted into digital data, and these digital data were fed to the Node MCU via the inter-integrated circuit (I2C) protocol.

2.1.6. IoT Cloud Platform

Two different IoT clouds, namely the ThingSpeak platform and the custom-designed IoT platform, were used in this work to log the parameters of the agricultural land. The ThingSpeak IoT cloud platform stores the data with respect to time. Also, the custom-designed IoT platform has various features to monitor the wetness, temperature, and pH of the soil.

3. Results and Discussion

Figure 3 shows the ThingSpeak IoT cloud platform. A ThingSpeak account can be created by any person for free, and the sensor data can be logged to the appropriate account.

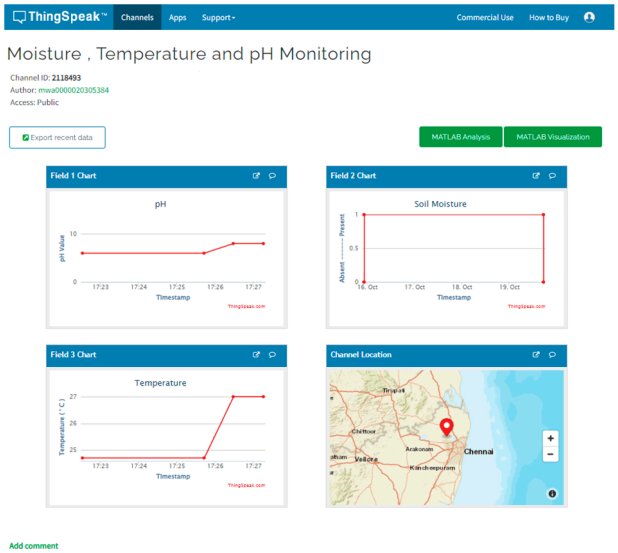
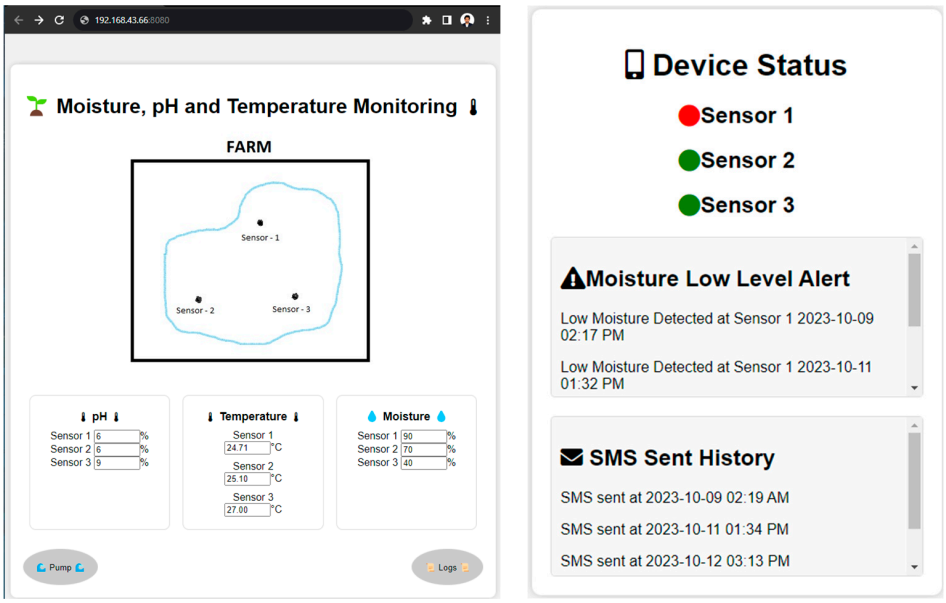


Figure 3. ThingSpeak IoT cloud platform.

Every account was created with an individual read-and-write application programmable interface (API) key. It was observed that the three different sensor values, such as the pH,

temperature, and moisture of the soil, were logged as a graph in the ThingSpeak account. Also, it was seen that the pH of the soil was logged in the field 1 chart, while soil moisture was logged in the field 2 chart. In general, the soil moisture sensor provided values in the form of analog signals especially from 0 to 5 volts, depending on the level of soil moisture. In this work, a threshold of 60% was set, and once the moisture sensor sensed beyond 60%, it produced 5 volts, which was considered one. Also, if the soil moisture sensor sensed below 60%, it produced 0 volts, which was considered 0. Both of these cases were logged in the field 2 chart of Figure 3. The field 3 chart was utilized to log the temperature of the soil. Additionally, the location of the farm is shown as a channel location. Figure 4a shows the custom-designed IoT cloud platform that was designed for smart farming. It was demonstrated that the smart sensor modules were located at distinct places, as shown in the farm layout of Figure 4a. Also, each smart sensor module was capable of measuring three different parameters, namely the pH, temperature, and moisture. It was observed that the sensor data of all the smart sensor modules were logged. Furthermore, the logged data can be visualized by pressing the logs icon, the water pump can be activated by pressing the pump button, and the pump will be switched off once all the three smart sensor modules sense soil moisture in three different places of farmland.



(**a**) (**b**)

Figure 4. (**a**) Custom-designed IoT cloud platform for smart farming. (**b**) Custom-designed IoT cloud platform to monitor the status of the smart device.

Typically, the pH of the soil changes due to factors such as rainfall, weather conditions, etc. In this regard, it is essential to monitor the pH of the soil so that the wellness of the crops can be ensured. Additionally, the biological activities of the soil depend on the soil temperature. Figure 4b shows the custom-designed IoT cloud platform to monitor the status of smart sensor modules. Further, it was observed that if the smart sensor module sensed soil moisture, it will alert the farmer with a notification, as shown in Figure 4b. Also, the short messaging service (SMS) was sent with the help of the Twilio service since the smart sensor modules were connected to the internet. It was clearly seen that the device provides the low-level moisture alert via SMS to the farmer. Also, the proposed IoT-based smart sensor module was found to be extremely efficient, which helps the farmer to take care of their agricultural parameters without any deviation.

4. Conclusions

Generally, multi-modal farming systems consist of wired data transmission; these wires can be damaged by rodents or weather conditions, which would make it hard to

assess the fault. Also, the data visualization of the agricultural IoT devices fails when people have low literacy. In this work, a smart sensor-based agricultural land monitoring system was designed and developed in which farmers can visualize agricultural parameters, such as the pH, temperature, and moisture of the soil, through the ThingSpeak or custom-designed IoT cloud platforms. The results demonstrate that the proposed smart sensor modules are capable of monitoring agricultural parameters, such as the pH, temperature, and moisture of the soil, which helps the farmer to take the necessary actions towards the growth of their crops. This work appears to be of high societal relevance since it can be easily implemented and maintained. Also, this system is less expensive and self powered using solar-based renewable energy resources, which can be utilized to monitor all the agricultural parameters under an uneven landscape.

Author Contributions: D.S. and P.A. conceptualized the idea for this work. V.S. provided the required resources. P.S.K.R.P. designed and developed the hardware. P.S.K.R.P. and D.S. carried out the investigation and data curation. V.S. designed the visualization. P.A. validated the acquired results and prepared the original draft. D.S. and V.S. reviewed and edited the original draft. V.S. supervised, and P.A. administered the work. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Kour, V.P.; Arora, S. Recent developments of the internet of things in agriculture: A survey. *IEEE Access* **2020**, *8*, 129924–129957. [CrossRef]
2. Dhanaraju, M.; Chenniappan, P.; Ramalingam, K.; Pazhanivelan, S.; Kaliaperumal, R. Smart farming: Internet of Things (IoT)-based sustainable agriculture. *Agriculture* **2022**, *12*, 1745. [CrossRef]
3. Husnain, A.; Hussain, I.; Ijaz, A.B.; Zafar, A.; Ch, B.I.; Zafar, H.; Sohail, M.D.; Niazi, H.; Touseef, M.; Khan, A.A.; et al. Influence of soil pH and microbes on mineral solubility and plant nutrition: A review. *Int. J. Agric. Biol. Sci.* **2021**, *5*, 71–81.
4. Tzounis, A.; Katsoulas, N.; Bartzanas, T.; Kittas, C. Internet of Things in agriculture, recent advances and future challenges. *Biosyst. Eng.* **2017**, *164*, 31–48. [CrossRef]
5. Idoje, G.; Dagiuklas, T.; Iqbal, M. Survey for smart farming technologies: Challenges and issues. *Comput. Electr. Eng.* **2021**, *92*, 107104. [CrossRef]
6. Marković, D.; Koprivica, R.; Pešović, U.; Randić, S. Application of IoT in monitoring and controlling agricultural production. *Acta Agric. Serbica* **2015**, *20*, 145–153. [CrossRef]
7. Ayaz, M.; Ammad-Uddin, M.; Sharif, Z.; Mansour, A.; Aggoune, E.H. Internet-of-Things (IoT)-based smart agriculture: Toward making the fields talk. *IEEE Access* **2019**, *7*, 129551–129583. [CrossRef]
8. Devi, G.; Sowmiya, N.; Yasoda, K.; Muthulakshmi, K.; Balasubramanian, K. Review on application of drones for crop health monitoring and spraying pesticides and fertilizer. *J. Crit. Rev.* **2020**, *7*, 667–672.
9. dos Santos, U.J.; Pessin, G.; da Costa, C.A.; da Rosa Righi, R. AgriPrediction: A proactive internet of things model to anticipate problems and improve production in agricultural crops. *Comput. Electron. Agric.* **2019**, *161*, 202–213. [CrossRef]
10. Sreekantha, D.K.; Kavya, A.M. Agricultural crop monitoring using IOT–A study. In Proceedings of the 2017 11th International Conference on Intelligent Systems and Control (ISCO), Coimbatore, India, 5–6 January 2017; pp. 134–139.
11. Lova Raju, K.; Vijayaraghavan, V. IoT technologies in agricultural environment: A survey. *Wirel. Pers. Commun.* **2020**, *113*, 2415–2446. [CrossRef]
12. Paramasivam, A.; Bhaskar, K.B.; Madhanakkumar, N.; Vanchinathan, C. Analysis of an Enhanced Positive Output Super-Lift Luo Converter for Renewable Energy Applications. In *Advances in Smart Grid Technology: Select Proceedings of PECCON 2019—Volume I*; Springer: Singapore, 2020; pp. 127–136.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.