engineering proceedings

MDPI

Proceeding Paper

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

Dhiya Sabu [1], Paramasivam A [1,*], Vijayalakshmi S [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, productivity and minimize resource wastage. One of the crucial challenges faced by farmers is the uneven distribution of soil humidity and pH across their agricultural land. 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 is 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 are placed across the farm and these units work independently as they have their own controller and battery unit. The developed device is integrated with a solar cell which charges the battery. Further, the data acquired from these sensors are wirelessly transmitted to the base station and it gathers the information of each unit including humidity levels, pH values, signal strength and energy supply. This information is processed in the base station and a graphical overview of the farm with acquired information is represented which provides farmers with a real view insight to identify the areas with poor humidity and pH conditions. The data is transmitted to IoT cloud offering the farmer to monitor their farm from a remote location and in cases where humidity levels drop drastically and remains unchecked for more than two hours, the system triggers an alert. This mechanism makes sure that farmers are notified of potential issues, allowing them to prevent crop damage and optimize resource usage.

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

Citation: Sabu, D.; A, P.; S, V.; Pittu, P.S.K.R. Design and Development of Internet of Things Based Smart Sensors for Monitoring of Agricultural Lands. *Eng. Proc.* **2023**, *56*, x. https://doi.org/10.3390/xxxxx

Academic Editor(s): Name

Published: 15 November 2023

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 it did not have a negative impact on the environment. Agriculture in many developing countries 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 put by the farmers go in complete vain which in turn affect their livelihood badly as it becomes a more expensive fix. Abnormalities of pH in the soil also can 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. IoT continues to play a major role in this journey [4].

State-of-the-art technology, specifically the Internet of Things (IoT), has 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 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 get updates on their smartphones and other similar devices.

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 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, pests, 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].

Recent years, sensor technology came 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 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, the 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 were also 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 is to develop an advanced IoT based smart sensor system which is customized for agricultural practices. This research aims to enhance the decision making in order to improve crop yields and resource utilization 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 for the proposed approach. The proposed IoT based smart sensor system consists of more than two smart sensor modules which is represented as device 1, device2, device n. Furthermore, these devices are displaced randomly on the agriculture land as shown in the Figure 1.

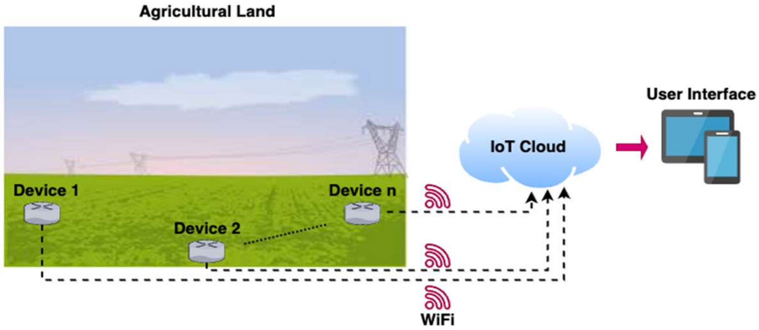


Figure 1. Proposed IoT based smart sensor system.

2.1. Proposed System

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

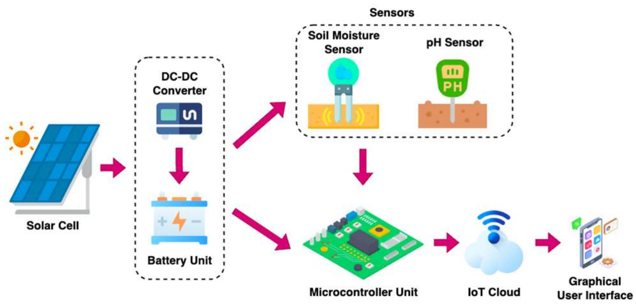


Figure 2. Overall hardware block diagram for proposed device.

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

2.1.1. Solar Cell

The proposed device is a made as a standalone device in which the electrical energy is generated with the help of solar cell. In general, a solar cell is a device which converts light energy due to solar irradiance into electricity. In this work, a compact solar cell with a dimension of not more than 14cm is used which generates output voltage of 12 V and current of 200 mA. Also, the adopted solar cell is capable to generate the 2.4 Watts of power.

2.1.2. DC-DC Converter

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

2.1.3. Battery

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

Further, a Lithium Polymer (LiPo) battery with 3.7 volts, 1000 mAh is used. Also, the LiPo battery can be charged using LiPo battery charger circuit.

2.1.4. Sensors

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

2.1.5. Microcontroller Unit

A ESP8266 Microcontroller Unit is otherwise known as Node MCU is utilized in this work to collect sensor data. Further, the Node MCU operates on 5 Volts power supply which can be powered by LiPo battery through Pololu U3V70F5 board. The Node MCU has in-built WiFi module which helps the user to feed sensor data to the IoT cloud. In general, the ESP8266 has one analog pin in which one sensor can be connected. So, the external Analog to Digital converter namely ADS1115 is connected to the utilized Node MCU. Further, the sensor data are converted into digital and these digital data are fed to Node MCU through Inter-Integrated Circuit (I2C) protocol.

2.1.6. IoT Cloud Platform

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

3. Results and Discussion

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

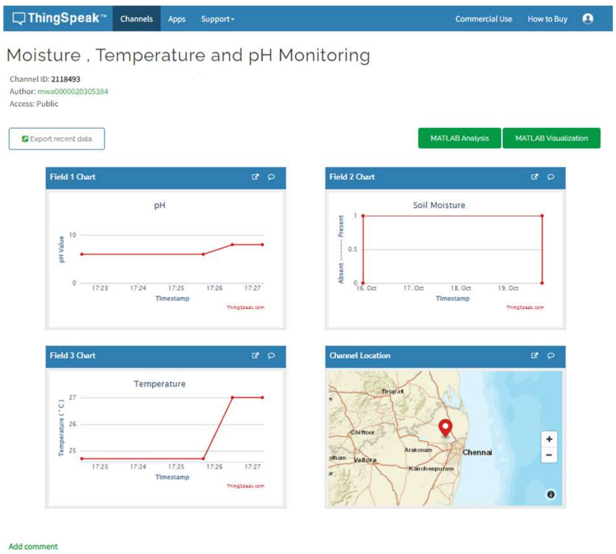
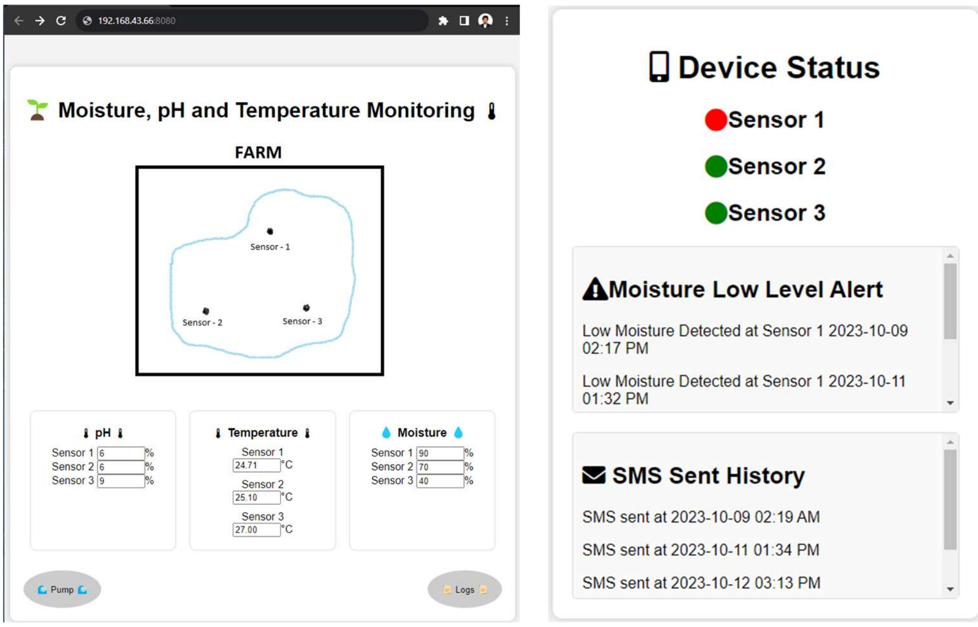


Figure 3. ThingSpeak IoT Cloud Platform.

Every account is created with an individual read and write Application Programmable Interface (API) key. It is observed that the three different sensor values such as pH, temperature and moisture of the soil were logged as a graph in the ThingSpeak account. Also, it is seen that the pH of the soil was logged in field 1 chart and soil moisture was logged in the field 2 chart. In general, the soil moisture sensor gives values in the form of analog signal especially 0 to 5 Volts depends on the level of soil moisture. In this work, the threshold of 60% is set and once the moisture sensor senses beyond 60% produces 5 volts which is considered as 1. Also, if the soil moisture sensor senses below 60% produces 0 volts which is considered as 0. Both the cases were logged at the field 2 chart of Figure 3. The field 3 chart was utilized to log temperature of the soil. Additionally, the location of the farm is shown as channel location. Figure 4a shows the custom designed IoT cloud platform designed for smart farming. It is demonstrated that the smart sensor modules were located on the distinct places as shown in the farm layout of Figure 4a. Also, each smart sensor module is capable of measuring three different parameters namely pH, temperature and moisture. It is observed that the sensor data of all the smart sensor modules were logged. Furthermore, the logged data can be visualized by pressing logs icon and 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 senses soil moisture in three different places of farm land.



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

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

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

4. Conclusions

Generally, Multi modal farming systems consist of a wired data transmission, these wires can be damaged by rodents or weather conditions which would be hard to assess the fault, and also the data visualization of the Agricultural IoT Devices fail when people with low literacy. In this work, a smart sensor based agricultural land monitoring system was designed and developed in which farmer can visualize agricultural parameters such as pH, temperature and moisture of the soil through ThingSpeak or custom designed IoT cloud platform. Results demonstrate that the proposed smart sensor modules are capable of monitoring agricultural parameters such as pH, temperature and moisture of the soil which helps the farmer to take necessary actions towards the growth of crops. This work appears to be of high societal relevance since it can be implemented and maintained easily. Also, the system is less expensive and self-powered using solar based renewable energy resource which can be utilized to monitor all the agricultural parameters in 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 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.

Conflicts of Interest: The authors declare no conflict 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.
2. Dhanaraju, M.; Chenniappan, P.; Ramalingam, K.; Pazhanivelan, S.; Kaliaperumal, R. Smart farming: Internet of Things (IoT)-based sustainable agriculture. *Agriculture* **2022**, *12*, 1745.
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.
5. Idoje, G.; Dagiuklas, T.; Iqbal, M. Survey for smart farming technologies: Challenges and issues. *Comput. Electr. Eng.* **2021**, *92*, 107104.
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.
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.
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.
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.
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.