**NATURALISTA CAMPANO**
**ISSN: 1827-7160**
**Volume 28 Issue 1, 2024**

# IoT Based Soil, Water and Air Quality Monitoring System for Pomegranate Farming

**Sandeep Kedar[1*], Dr. Altaf Mulani[2]**
[1]PG Student. Electronics Engineering, S.K.N.Sinhgad College of Engineering, Korti, Pandharpur, Maharashtra, India.
Email: [1*]kedarsandeep20@gmail.com
[2]Professor, Electronics Engineering, S.K.N.Sinhgad College of Engineering, Korti, Pandharpur, Maharashtra, India.
Email: [2]aksaltaaf@gmail.com

**Abstract**: The coming of Web of Things (IoT) innovation has changed each part of daily existence for the typical individual by empowering knowledge and insight in all things. An organization of things that self-designs is alluded to as the Web of Things. Horticulture creation is changing day to day because of the advancement of Astute Shrewd Cultivating, or IoT-based devices that further develop farming as well as make it more productive and squander free. The purpose of this project is to propose an IoT-based framework for checking the nature of the soil, water, and air for pomegranate cultivating. This framework will help ranchers by giving them constant information on soil dampness and temperature for viable ecological observing, which will expand their general yield and item quality.

**Keywords:** IoT, Monitoring System, Pomegranate Farming, Blynk web dashboard.

## 1. Introduction

As the global population is growing. It will need more food, and people's changing lifestyles will put more pressure on farming needs. Additionally, as time goes on, farming grounds get smaller due to a variety of industrial and commercial needs. Because of this, engineers are under pressure to create systems that maximize crop productivity while using the fewest resources possible. Water and natural fertilizers are among the known natural resources. Additionally, workers in agriculture have been redirected to other businesses. This also resulted in the automation of all that farming is capable of producing.
IoT arrangements are intended to give astounding yields, benefit, and ecological protection, all of which will help ranchers in shutting the stockpile request hole. Accuracy horticulture is the utilization of IoT innovation to ensure ideal asset application to create high agrarian yields and lower working expenses. IoT advances for agribusiness incorporate programming, IT services, specialized equipment, and wireless connectivity.

IoT-based shrewd cultivating assists ranchers and makers with amplifying yield by improving everything from how much compost used to the quantity of homestead vehicle trips, as well as by taking advantage of assets like water and power. A Web of Things (IoT) brilliant cultivating arrangement is a framework intended to robotize the water system framework and screen the yield field utilizing sensors (light, stickiness, temperature, soil dampness, crop wellbeing, and so on.). Ranchers can watch out for field conditions from any area. Also, in light of this information, they can pick either manual and robotized options for going to the important lengths. For example, the rancher can utilize sensors to start watering assuming the dirt dampness content drops. By correlation, savvy cultivating is significantly more proficient than conventional cultivating techniques. These are the foremost ways that IoT can possibly change horticulture. In this sort of ranch the executives, sensors, control frameworks, robots, independent vehicles, computerized equipment, variable rate advances, movement identifiers, button cameras, and wearable contraptions are fundamental parts that accumulate information from brilliant agrarian sensors. This data can be used to screen worker execution, hardware proficiency, and the general soundness of the organization. It is feasible to sort out for better item circulation when one can anticipate the result of creation. Horticultural Robots, both airborne and ground-based, are being used in farming to work on a scope of rural cycles, including planting, water system, crop wellbeing assessment, crop splashing, checking, and soil and field examination.

## 2. Related Work

[1Work on the Programmed Savvy Water system Framework is recommended. India's population, which is estimated to be 1.2 billion and expanding every day, uses IOT. Because of this, there will be a serious food scarcity in 25 to 30 years, which will force agriculture to expand. Farmers are now dealing with a shortage of water as a result of the lack of rain. [2]. demonstrating work on Internet of Things-based soil testing; effective farming today depends heavily on soil analysis. Soil testing is being done in a variety of ways. The findings from previous soil testing, which was carried out in laboratories and research centers, took a lot of time and effort. A range of portable sensors can now be used for soil testing, thanks to recent developments in digital and electronic technologies. Thanks to IoT, it is now possible to connect sensors to the internet. Involving these sensors in mix with the Web of Things, we plan to do soil testing anyplace, whenever. [3]. Finish the work on the Internet of Things soil monitoring system. Effective farming is a high-tech, capital-intensive approach to providing the people with healthy, sustainable food. The Web of Things (IoT), man-made brainpower (artificial intelligence), and mechanical interaction computerization (RPA) advances are the principal subjects of this review. These innovations make it conceivable to construct a framework that utilizes sensors —, for example, those estimating light, mugginess, temperature, and soil dampness — to screen the harvest field and mechanize the water system framework. Ranchers can watch out for the condition of their homesteads from a good ways. [4]. The development of a soil moisture monitoring system based on LoRaWAN. A Web of Things (IoT) contraption that investigates soil dampness is utilized and conveyed by civil workers who are worried about water system exercises. The Web of Things gadget is a functioning model that requires three AAA batteries and the LoPy4 expansion board 3.1 from Pycom. The model isn't suitable for enormous scope testing because of its size, cost, and power utilization. [5]. concentrates on soil testing made conceivable by means of IoT. Horticulture is the fundamental business in our nation and an imperative one at that. An exorbitant measure of compost could prompt lower-quality harvest yield. Estimating the supplements in the dirt is in this manner fundamental to improving plant development. Deciding how much supplements present in the dirt is the primary obligation. The pH esteem, which is assessed to gauge soil ripeness, is one of the most significant and useful soil factors.[6]. Arranged improvement on an imaginative Web of Things-based constant pH checking and control framework for metropolitan wastewater for cultivation and horticultural This examination presents an original web of-things (IoT) based continuous pH observing and control framework for civil waste water that can be utilized in farming and planting. Following India's green unrest, how much water expected for all businesses — including farming, cultivating, and industry — has expanded emphatically in the past couple of many years.[7], work on the Web of Things (IoT)- based water quality observing framework. In Bangladesh's seaside areas, consumable water is scant because of complex hydro-topographical arrangements. Besides, the arrangement of safe water is more troublesome around here of the country than in others on account of transboundary stream issues and regular catastrophes. Worries about furnishing beach front networks with equivalent and fair admittance to safe drinking water might emerge because of modern poisons. One could fight that admittance to consumable water in one's area is a principal common freedom and is expected for saving one's wellbeing.[8], proposed investigation of a Web of Things-based stream water quality observing framework continuously. The ebb and flow strategy for evaluating water quality includes a work concentrated, tedious manual cycle. This paper proposes a sensor-based water quality observing framework. The essential parts of a remote sensor organization (WSN) are a few sensors, a correspondence framework for intra-and between hub correspondence, and a microcontroller for framework handling. Ongoing information access is conceivable with the utilization of remote checking and Web of Things (IoT) innovation. [9], suggested advancement of an IoT-basedpH peruser. The microcontroller-based pH peruser is an electrical gadget that actions an example's pH. In this undertaking, we look at the corrosiveness of an example paper strip utilizing the modest ATMEGA328 microcontroller. A low voltage power supply drives the cradle circuit, variety sensor, and chip. The result of the variety sensor can give a sign to the microcontroller.[10], suggested examinations on IoT-based savvy cultivating temperature checking and dampness control. The Web of Things (IoT) has made work more brilliant and more useful, reforming each area of human life. Brilliant cultivating, which raises rural efficiency while diminishing waste, depends intensely on Web of Things (IoT) innovations, including sensors, regulators, Wi-Fi modules, and distributed computing. [11], prescribed work on savvy farming to quantify the pH, dampness content, temperature, stickiness, and supplement upsides of the dirt utilizing the Web of Things. Nowadays, many cultivating related issues are moderated by shrewd horticulture. Ranchers can associate various sensors, actuators, and other implanted gadgets to the "Web OF THINGS (IOT)" to screen plant development, giving them admittance to significant information and data. to protect the pH, dampness content, and supplement

level of the dirt to yield harvests of prevalent quality. [12], Proposed improvement of a brilliant temperature and moistness screen in light of the Web of Things. During the Coronavirus pandemic, the Covid spreads quickly in cool temperatures and weighty stickiness. Many individuals are aware of the climate where they dwell. To help those people, a shrewd climate checking framework is required. A shrewd temperature and mugginess constant observing and revealing framework in view of the Web of Things (IoT) can profit from the expansion of temperature and relative dampness sensors.[13], work on The Pomegranate Farming Ultimate Guide is recommended. Pomegranate farming requires dry, semi-arid climates, with cold winters and scorching summers helping to promote fruit output. It is possible to think of pomegranate plants as drought-tolerant and frost-tolerant.The optimal temperature for fruit development is between 35 and 38 °C. 500 meters above sea level is the ideal elevation for pomegranate production. [14], research on the pomegranate creation innovation suggested for dry regions. The pomegranate (Punica granatum L.), a significant natural product crop for dry and semi-bone-dry areas, began in Iran. Parched locales are described by high temperatures, whimsical, low precipitation, and regular dry seasons. The dirts here are additionally lacking in supplements and water-holding limit. Since the natural conditions in a dry locale are not helpful for plant supportability, the decision of organic product crop is basic for financial creation.[15] Tentative arrangements for improving the dirt dampness observing framework The interfacing of numerous gadgets through the web is known as the Web of Things (IoT). Each item is associated with each and every using exceptional identifiers, permitting information to be communicated between them without the requirement for human contribution.

## 3. Methodology

### 3.1 Block Digram

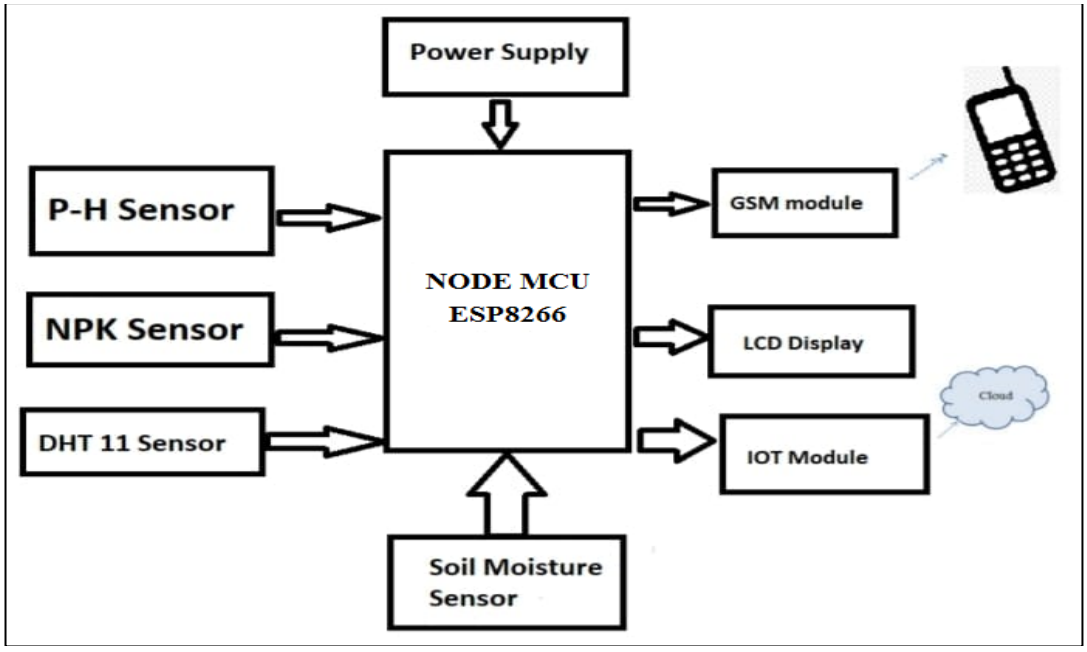



Figure: Project Block Diagram Hardware Part

As shown in above figure Numerous interface modules are attached to the Node MCU. 16x2 LCD displays are used to show various processes and statuses as well as locally variable information. In order to determine the PH of the water used for farming, a PH Sensor is connected to a Node MCU. To read the soil under test's values for nitrogen, phosphorus, and potassium, an NPK sensor is coupled to a Node MCU. To read the soil moisture value, the soil moisture test is connected to the Node MCU. The Node MCU and DHT 11 sensor are connected to read the atmosphere's humidity value. A GSM modem is used to send and receive SMS messages that include data from the NPK, soil moisture, humidity, and pH sensors. A portion of the code known as the IOT Module is internally

programmed as ESP8266 includes an integrated WiFi chip that allows it to connect to a WiFi hotspot so that Node MCU can communicate with the IOT Cloud platform.

**Hardware Setup**

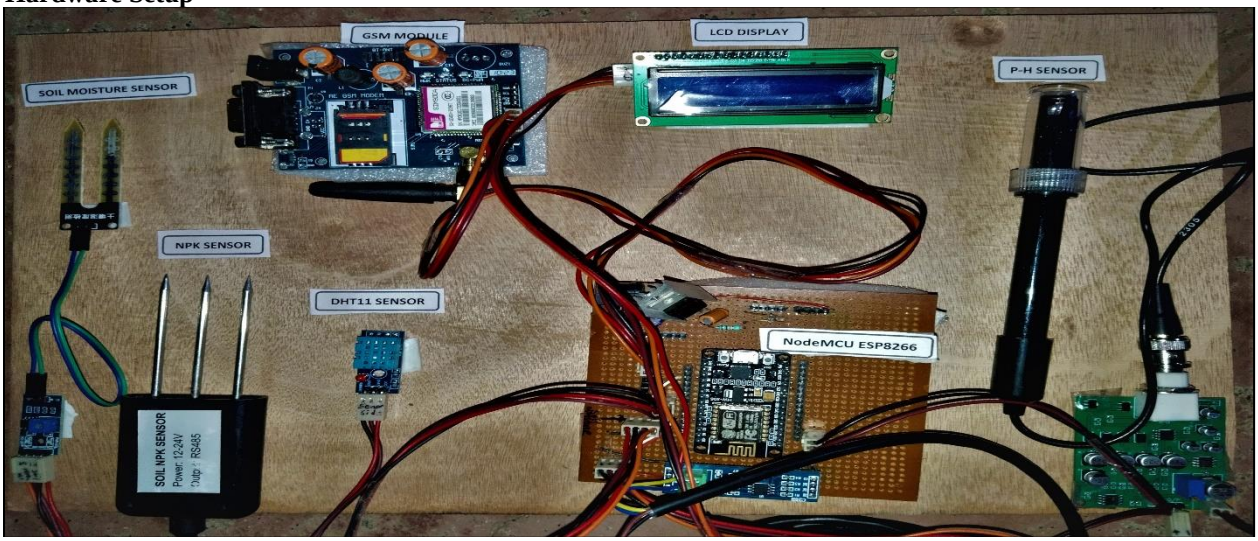
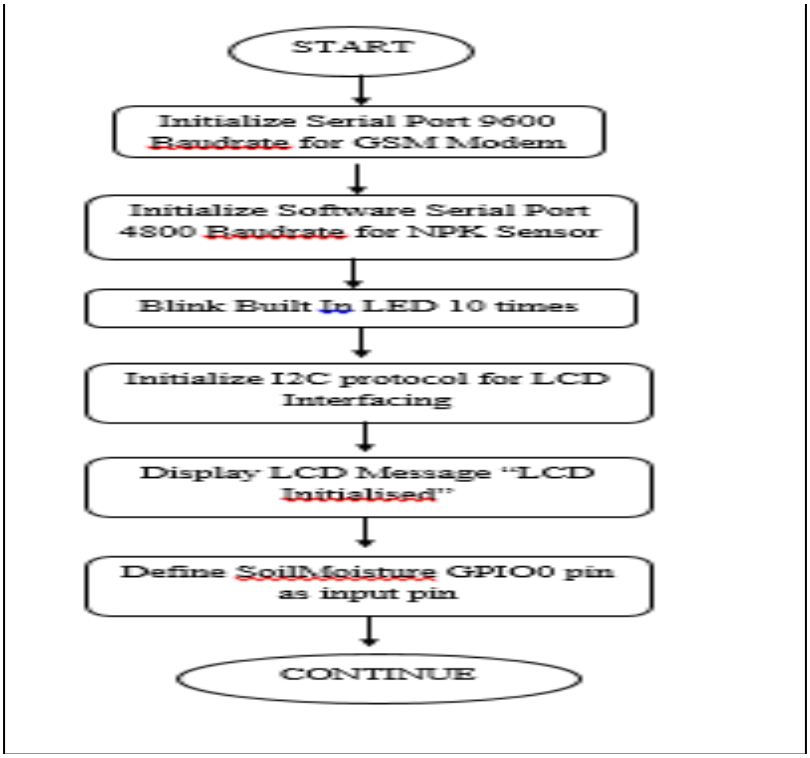
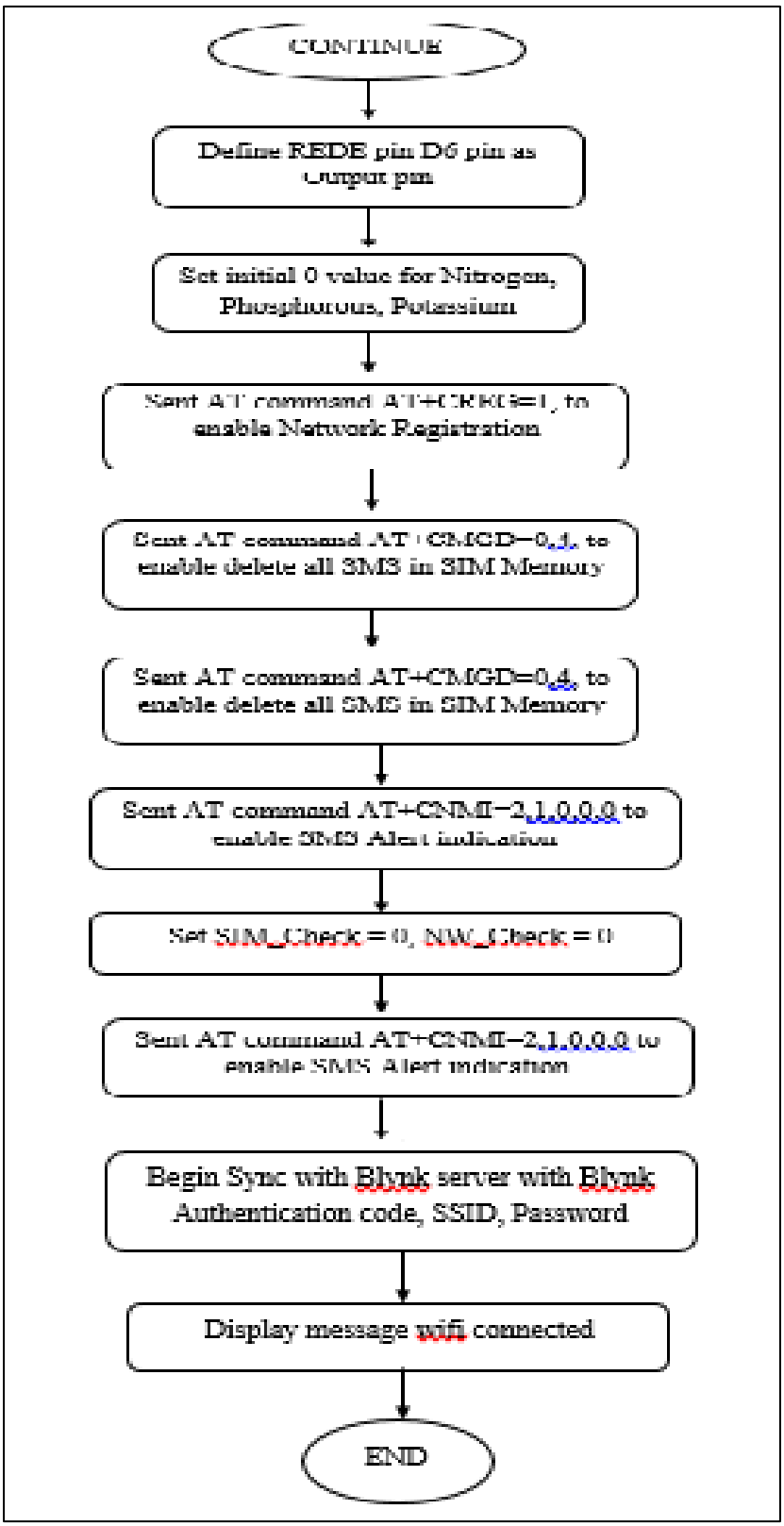



Figure: Actual project Hardware setup

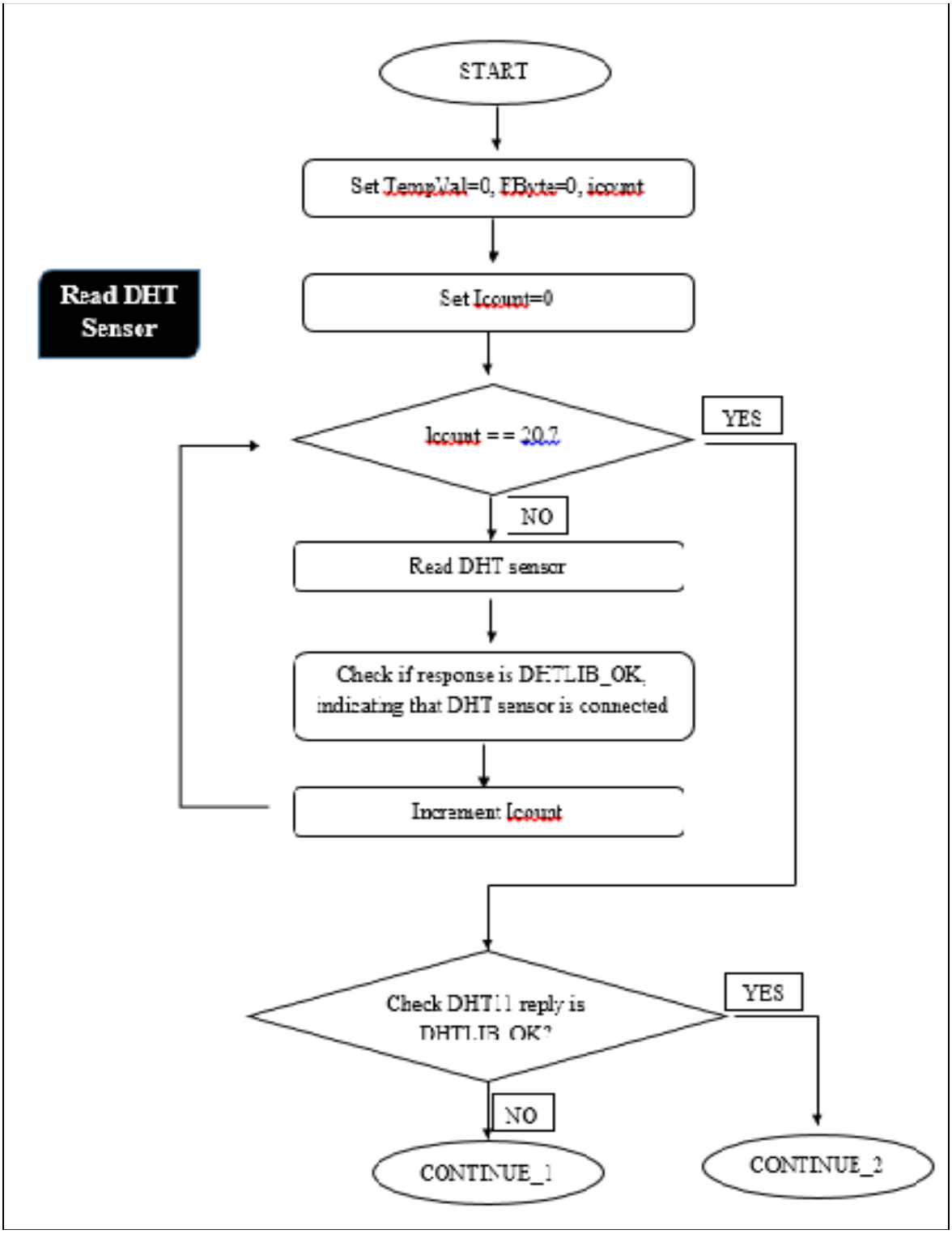
**Flowchart**

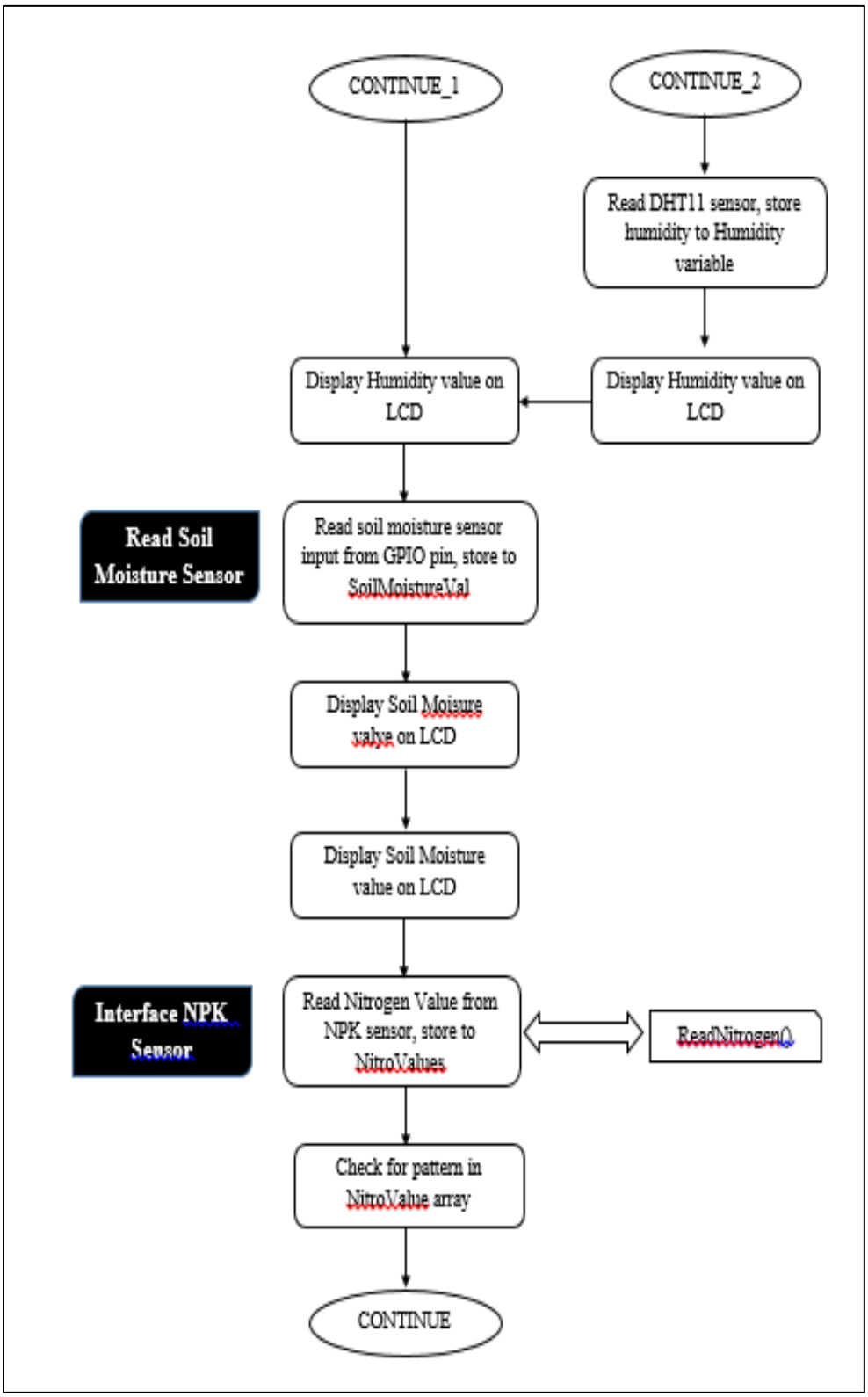
**Flowchart of Setup**

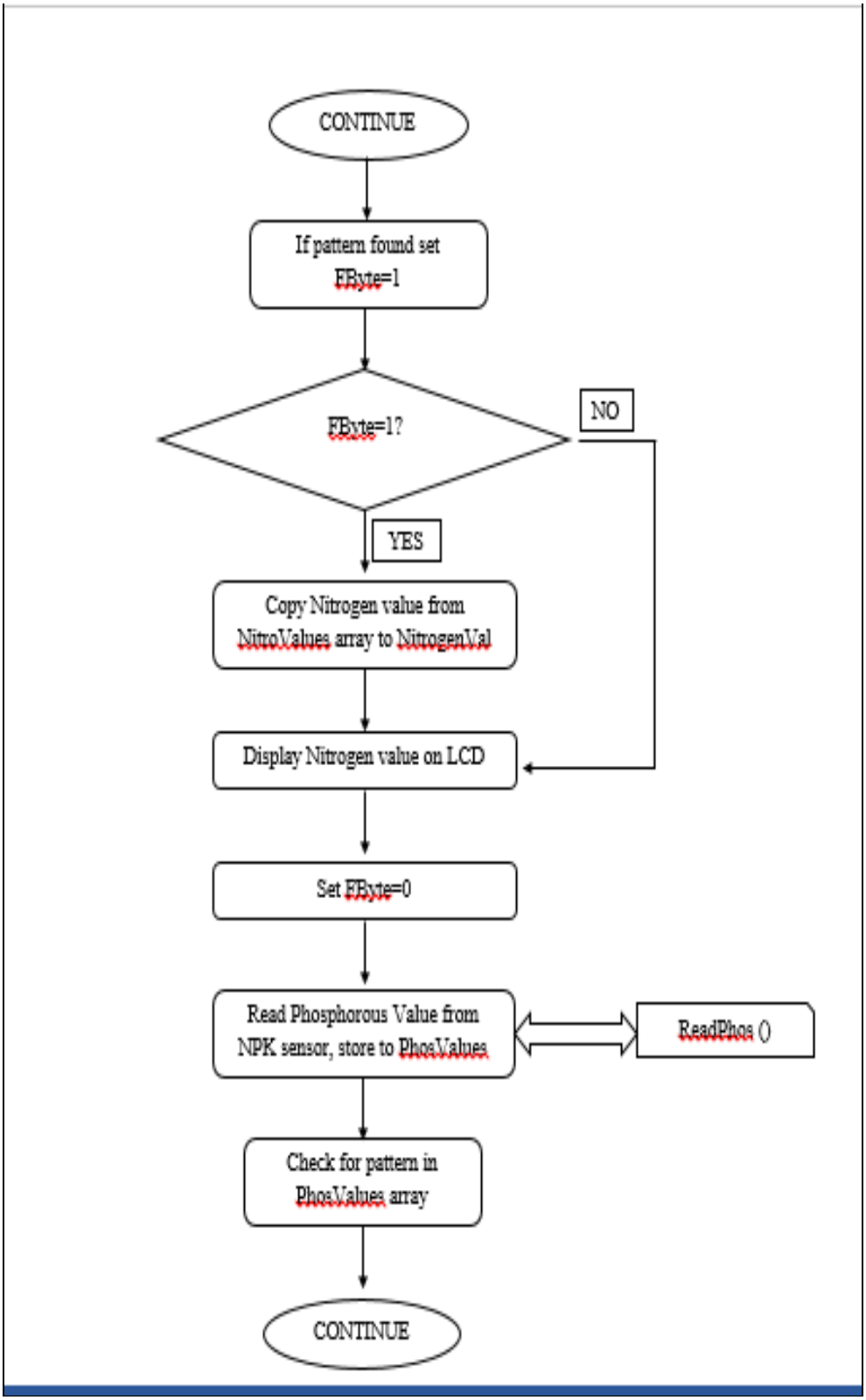


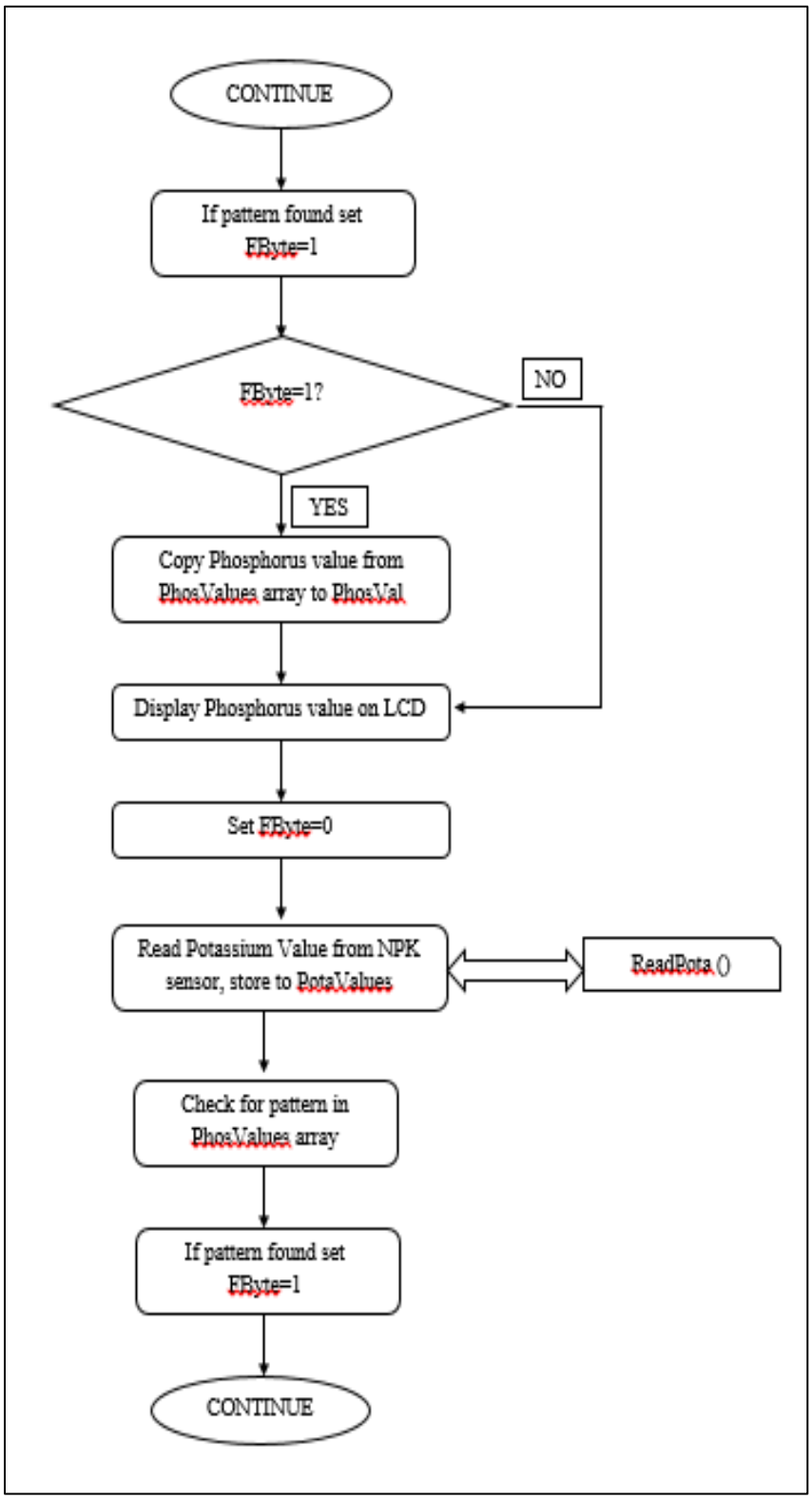

CONTINUE
Define REDE pin D6 pin as Output pin
Set initial 0 value for Nitrogen, Phosphorous, Potassium
enable Network Registration
Sent AT command AT+CMGD=0,4, to enable delete all SMS in SIM Memory
Sent AT command AT+CNMI=2,1,0,0,0 to
Set SIM_Check = 0, NW_Check = 0
Begin Sync with Blynk server with Blynk Authentication code, SSID, Password
Display message wifi connected
END

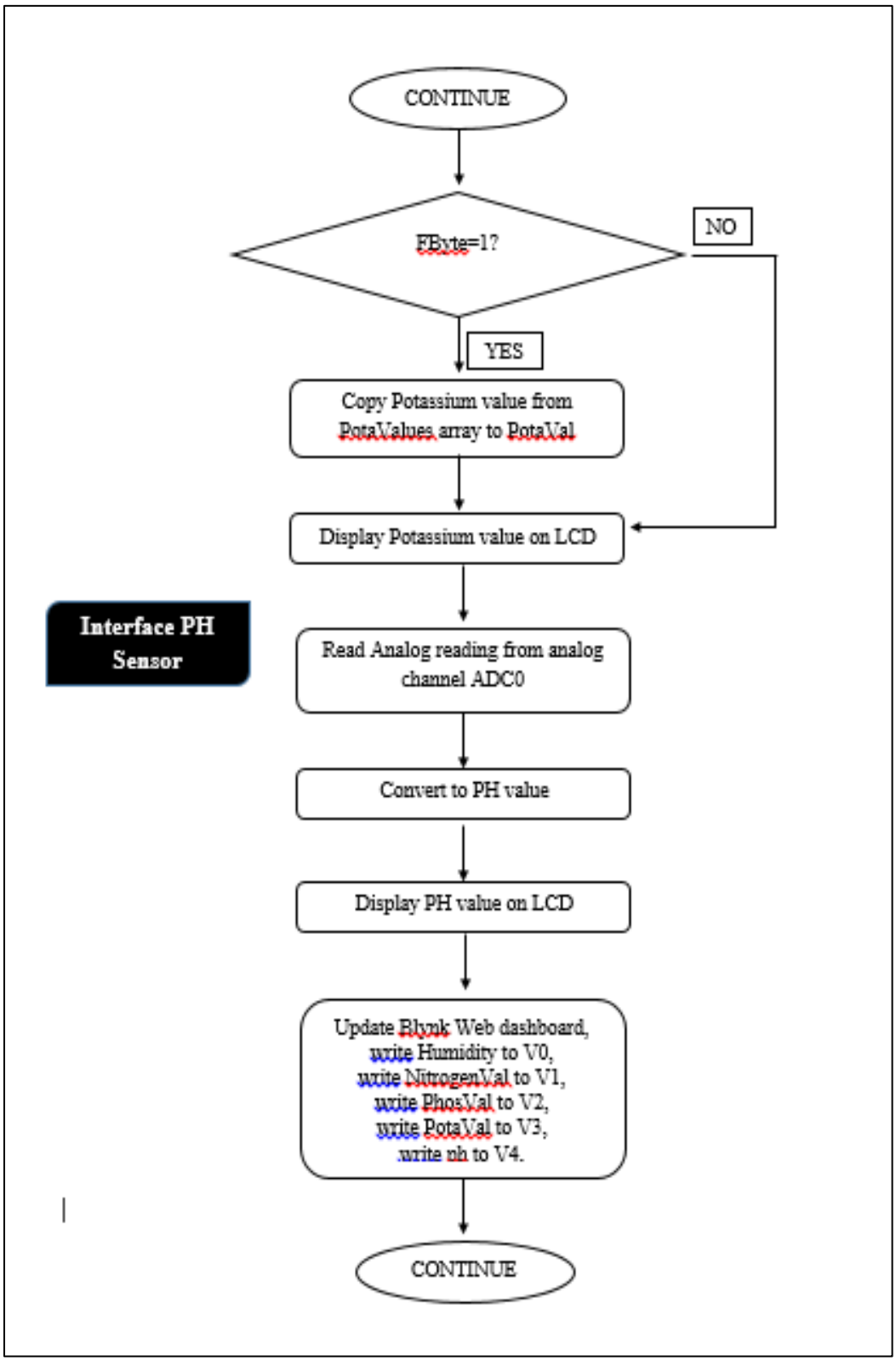
**Flowchart of Loop**

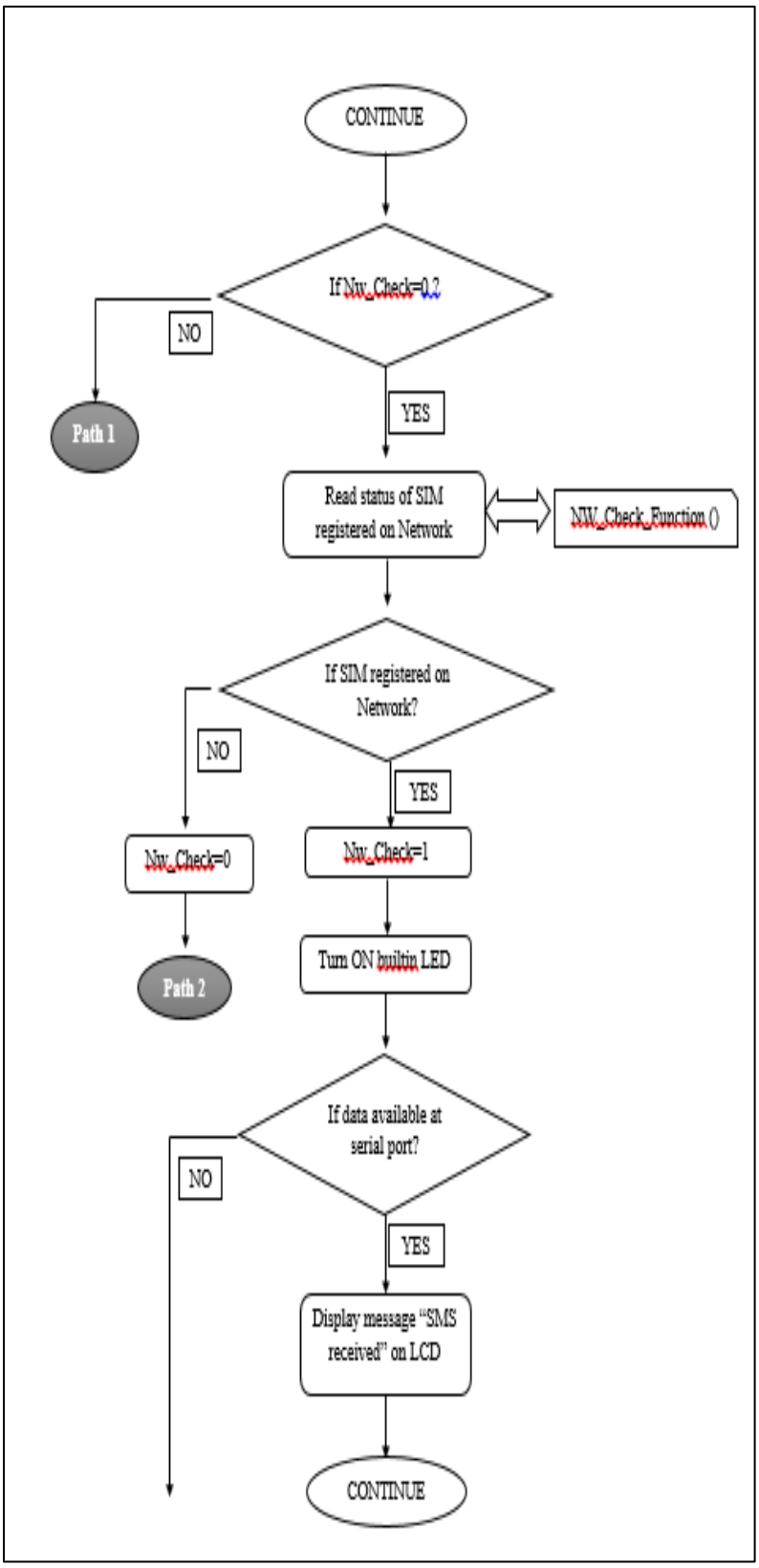


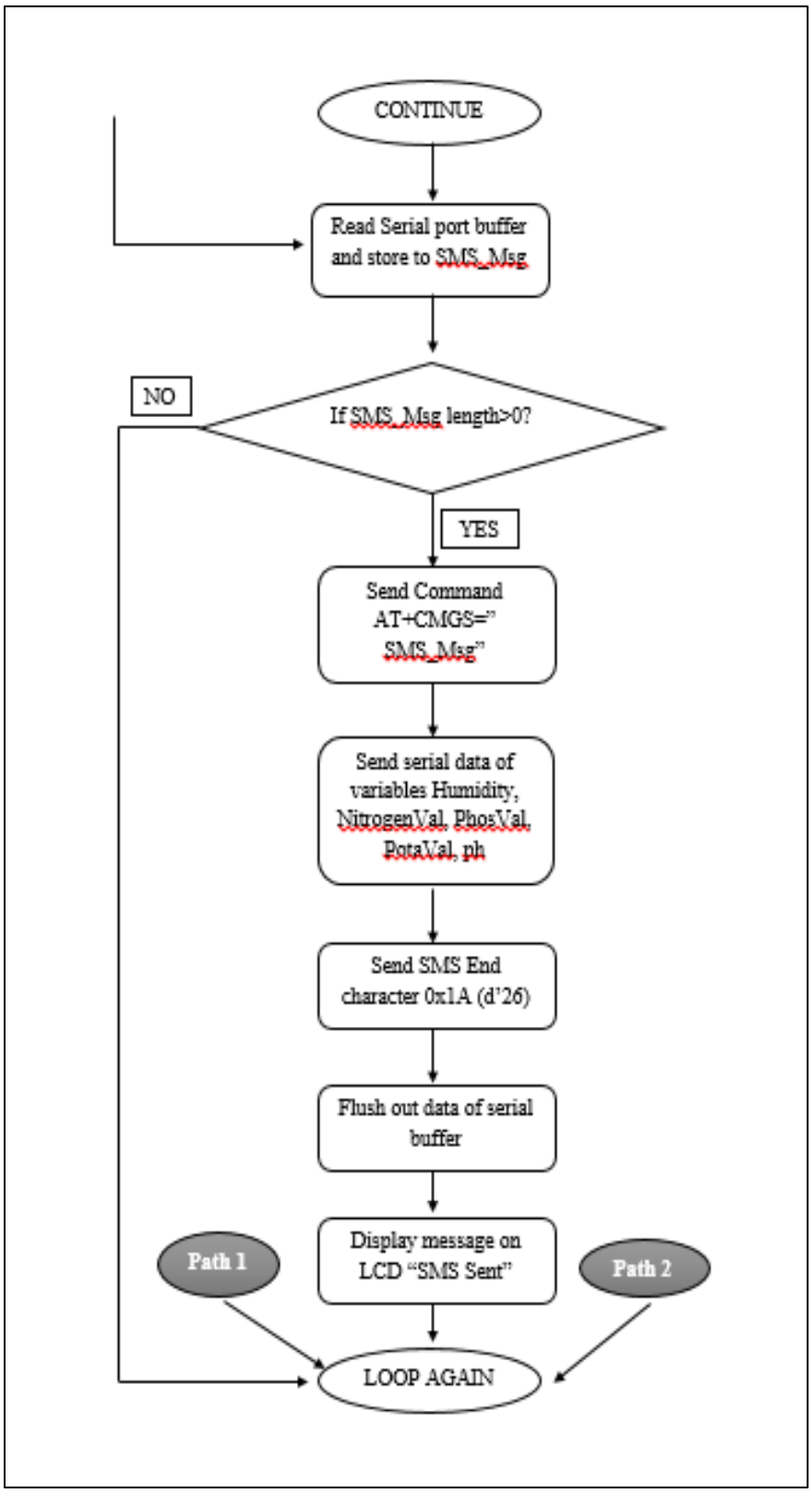

CONTINUE_1
CONTINUE_2
Read DHT11 sensor, store humidity to Humidity variable
Display Humidity value on LCD
Display Humidity value on LCD
Read Soil Moisture Sensor
Read soil moisture sensor input from GPIO pin, store to SoilMoistureVal
Display Soil Moisure valye on LCD
Display Soil Moisture value on LCD
Interface NPK Sensor
Read Nitrogen Value from NPK sensor, store to NitroValues
ReadNitrogen()
Check for pattern in NitroValue array
CONTINUE


CONTINUE
If pattern found set FByte=1
FByte=1?
NO
YES
Copy Nitrogen value from NitroValues array to NitrogenVal
Display Nitrogen value on LCD
Set FByte=0
Read Phosphorous Value from NPK sensor, store to PhosValues
ReadPhos ()
Check for pattern in PhosValues array
CONTINUE


CONTINUE
If pattern found set FByte=1
FByte=1?
NO
YES
Copy Phosphorus value from PhosValues array to PhosVal
Display Phosphorus value on LCD
Set FByte=0
Read Potassium Value from NPK sensor, store to PotaValues
ReadPota ()
Check for pattern in PhosValues array
If pattern found set FByte=1
CONTINUE


CONTINUE
FByte=1?
NO
YES
Copy Potassium value from PotaValues array to PotaVal
Display Potassium value on LCD
Interface PH Sensor
Read Analog reading from analog channel ADC0
Convert to PH value
Display PH value on LCD
Update Blynk Web dashboard,
write Humidity to V0,
write NitrogenVal to V1,
write PhosVal to V2,
write PotaVal to V3,
write ph to V4.
CONTINUE


CONTINUE
If Nw_Check=0,2
NO
Path 1
YES
Read status of SIM registered on Network
NW_Check_Function ()
If SIM registered on Network?
NO
YES
Nw_Check=0
Nw_Check=1
Path 2
Turn ON builtin LED
If data available at serial port?
NO
YES
Display message "SMS received" on LCD
CONTINUE


CONTINUE
Read Serial port buffer and store to SMS_Msg
NO
If SMS_Msg length>0?
YES
Send Command AT+CMGS=" SMS_Msg"
Send serial data of variables Humidity, NitrogenVal, PhosVal, PotaVal, ph
Send SMS End character 0x1A (d'26)
Flush out data of serial buffer
Display message on LCD "SMS Sent"
Path 1
Path 2
LOOP AGAIN

## 4. Results

This technology can be used in digital farming to track various soil conditions, including moisture content, to improve crop yield. Thanks to technology, we can keep an eye on a plant's growth and resource requirements from a distance.

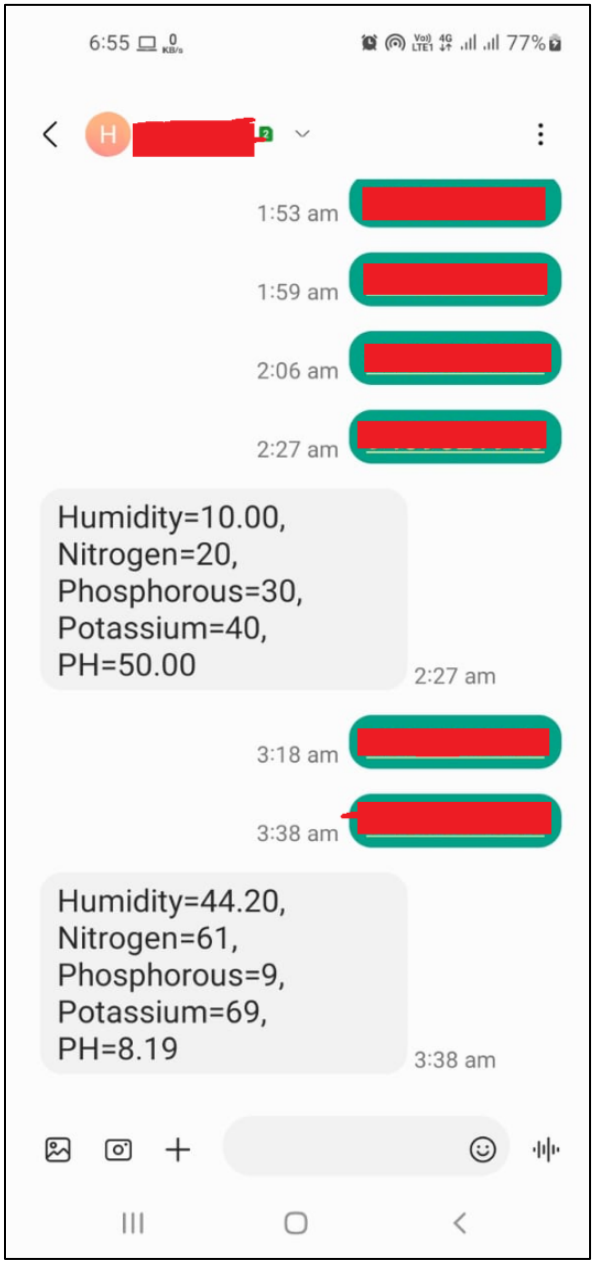



Figure: SMS Received of sensor data

As seen in the above fig, a GSM modem will reply to an SMS with all of the sensor data contained in it. When we are unable to monitor sensor data on the IOT web dashboard, it is incredibly helpful. We are able to track the soil conditions and receive sensor data via SMS.

.

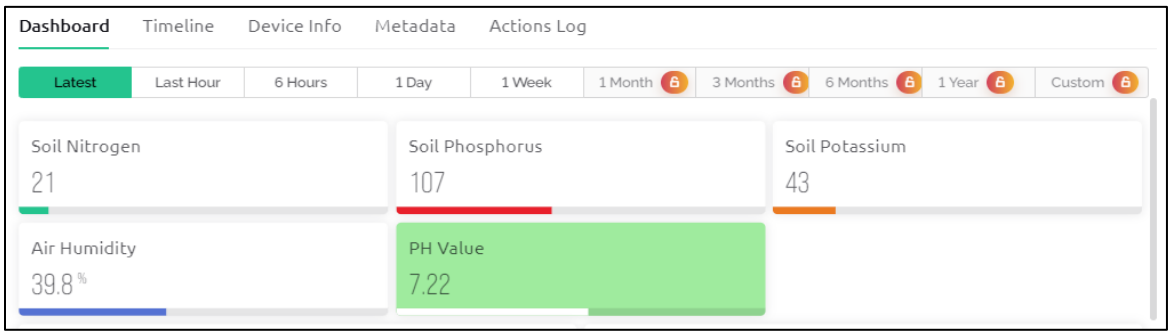



Figure: web dash board of sensor output

As seen in the above graphic, we can watch sensor data on the web dashboard when the Node MCU is connected to wifi. We are able to monitor and verify the value change.

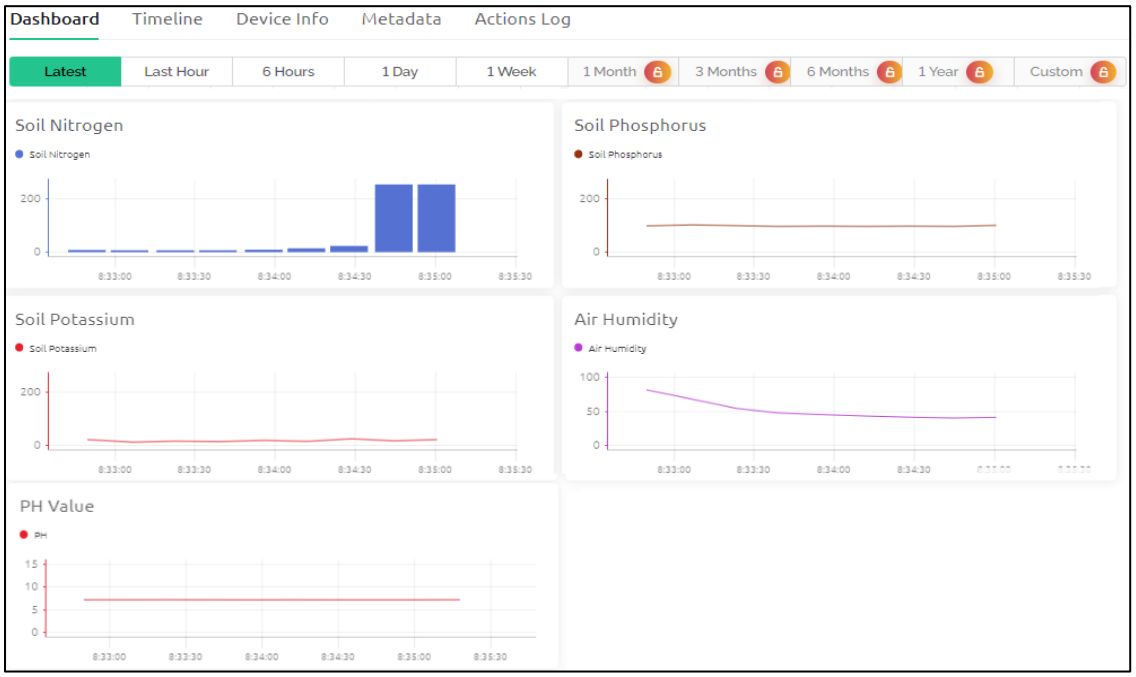



Figure: sensor data graphs

We may see a graph or chart of the different sensor outputs in the preceding figure. We are able to observe how the graph is changing and track how the values of the sensor data are changing in response to various air conditions. We can monitor farming conditions much more easily with the use of this mathematical data and historical chart, and by combining traditional farming methods with modern technology, we may increase crop yields.

## 5. Conclusion

"IoT-Based Soil, Water, and Air Quality Monitoring System for Pomegranate Farming" is a groundbreaking advance in pomegranate cultivation. This solution helps farmers protect their crops, make educated decisions, and eventually thrive in the dynamic world of modern agriculture by combining IoT technology with precision farming techniques.

## 6. References

1. C. Premalatha Department of Information Technology, Sri Ramakrishna engineering College, Coimbatore, India "Automatic Smart Irrigation System Using IOT" International Journal of Scientific Research in Computer Science and Engineering Vol.7, Issue.1, pp.1-5, February (2019),E-ISSN: 2320-7639.
2. Hridesh Shah, Dhruv Shah, Jeet Shah, Akshat Shah, Karan Shah and Krupal Vora. "IOT BASED SOIL TESTING" , Research Article, Received: 12 September 2018Final Accepted: 14 October 2018 Published: November 2018.
3. MS Shivani Sapkale, Prof. Rasika Patil MCA, Bharti Vidyapeeth, Mumbai University "SOIL MONITORING USING IOT TECHNOLOGY" , Cikitusi Journal For Multidisciplinary Research, August 2022.
4. Marcus Johansson Lnu Supervisor: Daniel Toll Semester: Spring 2021 Subject: Computer Science "Soil moisture monitoring system using LoRaWAN technology".
5. P. Sindhu and G. Indirani , "IoT Enabled Soil Testing" Asian Journal of Computer Science and Technology ISSN: 2249-0701 Vol.7 No.S1, 2018, pp. 54-57 © The Research Publication, www.trp.org.in.AJCST Vol.7 No.S1 November 2018.
6. Narendra Khatri, Dr. Abhishek Sharma, "An IoT based Innovative Real Time pH Monitoring and Control of Municipal Waste Water for Agriculture and Gardening" See discussions, stats, and author profiles for this publicationat:https://www.researchgate.net/publication/318233978, September 2017.
7. Narendra Khatri, Dr. Abhishek Sharma, "An IoT based Innovative Real Time pH Monitoring and Control of Municipal Waste Water for Agriculture and Gardening" See discussions, stats, and author profiles for this publicationat:https://www.researchgate.net/publication/318233978, September 2017.
8. Mohammad Salah Uddin Chowdurya, Talha Bin Emranb, Subhasish Ghosha, Abhijit Pathaka, Mohd. Manjur Alama, Nurul Absara, Karl Anderssonc, Mohammad Shahadat Hossain, "IoT Based Real-time River Water Quality Monitoring System" The 16th International Conference on Mobile Systems and Pervasive Computing (MobiSPC) August 19-21, 2019, Halifax, Canada.
9. Ajit P. Gosavi , Suraj A. Parab , Akshata G. Parulekar, Rohit S. Patade, Prashant L. Raorane, "IoT Based pH Reader" International Journal of Advanced Research in Science, Communication and Technology (IJARSCT) Volume 5, Issue 1, May 2021. 15.
10. P R Karthikeyan , Gokul Chandrasekaran, Neelam Sanjeev Kumar, Elango Sengottaiyan , Prabu Mani , D T Kalavathi , and V Gowrishankar, "IoT Based Moisture Control and Temperature Monitoring In Smart Farming" Journal of Physics: Conference Series 1964 (2021) 062056 IOP Publishing doi:10.1088/1742-6596/1964/6/062056.
11. Asadi Venkata Mutyalamma, Gopisetty Yoshitha, Althi Dakshyani, Bachala Venkata Padmavath, "Smart Agriculture to Measure Humidity, Temperature, Moisture, Ph. and Nutrient Values of the Soil using IoT" International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958 (Online), Volume-9 Issue-5, June 2020.
12. Akash Devade , Vaibhav Mare , Shubham Shinde , Abhishek Jori , Vishakha Dilpak, "IoT Based Smart Humidity and Temperature Monitoring System", Vol-8 Issue-3 2022 IJARIIE-ISSN(O)-2395-4396.Issue-3 2022 IJARIIE-ISSN(O)-2395-4396.
13. Amar Sawant, "The Ultimate Guide for Pomegranate Farming", https://agriculturegurui.com/pomegranate farming/August 19, 2023.
14. Ramesh Kumar Ramkesh Meena B. D. Sharma P. L. Saroj, "Production Technology of Pomegranate in Arid Region", ICAR-Central Institute for Arid Horticulture, Sriganganagar Road, NH-15, Beechwal, Bikaner-334 006, (Rajasthan), May, 2018.
15. E. Raghuveera, N. Pavan Kumar, A. Sai Yeswanth, L. Satya Mani Pavan, "Soil Moisture Monitoring System Using IOT", International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue-7 May.
16. Takale, S., & Mulani, A. (2022). DWT-PCA Based Video Watermarking. Journal of Electronics, Computer Networking and Applied Mathematics (JECNAM) ISSN: 2799-1156, 2(06), 1-7.
17. Takale, S., & Mulani, D. A. Video Watermarking System. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 10.

18. Sarda, M., Deshpande, B., Deo, S., & Karanjkar, R. (2018). A comparative study on Maslow's theory and Indian Ashrama system.". International Journal of Innovative Technology and Exploring Engineering, 8(2), 48-50.
19. Deo, S., & Deo, S. (2019). Cybersquatting: Threat to domain name. International Journal of Innovative Technology and Exploring Engineering, 8(6), 1432-1434.
20. Deo, S., & Deo, D. S. (2019). Domain name and its protection in India. International Journal of Recent Technology and Engineering.
21. Mulani, A. O., & Mane, P. B. (2017). Watermarking and cryptography based image authentication on reconfigurable platform. Bulletin of Electrical Engineering and Informatics, 6(2), 181-187.
22. Pol, R. S., Deshmukh, A. B., Jadhav, M. M., Liyakat, K. K. S., & Mulani, A. O. (2022). iButton Based Physical access Authorization and security system. Journal of Algebraic Statistics, 13(3), 3822-3829.
23. Patale, J. P., Jagadale, A. B., Mulani, A. O., & Pise, A. (2022). Python Algorithm to Estimate Range of Electrical Vehicle. Telematique, 7046-7059.
24. Shinde, R., & Mulani, A. O. (2015). Analysis of Biomedical Image. International Journal on Recent & Innovative trend in technology (IJRITT).
25. Maske, Y., Jagadale, M. A., Mulani, A. O., & Pise, M. A. (2022). Implementation of BIOBOT System for COVID Patient and Caretakers Assistant Using IOT. International Journal of Information Technology & Computer Engineering (IJITC) ISSN: 2455-5290, 2(01), 30-43.
26. Boxey, A., Jadhav, A., Gade, P., Ghanti, P., & Mulani, A. O. (2022). Face Recognition using Raspberry Pi. Journal of Image Processing and Intelligent Remote Sensing (JIPIRS) ISSN 2815-0953, 2(04), 15-23.
27. Swapnil Takale, & Dr. Altaaf Mulani. (2022). DWT-PCA based Video Watermarking. Journal of Electronics, Computer Networking and Applied Mathematics (JECNAM) ISSN : 2799-1156, 2(06), 1–7.
28. Swapnil Takale, Dr. Altaaf Mulani, "Video Watermarking System", International Journal for Research in Applied Science & Engineering Technology (IJRASET),
29. Godase, Vaibhav, et al. "Smart Agriculture Automation Using ESP8266 Node MCU." Journal ofElectronics, Computer Networking and Applied Mathematics (JECNAM) ISSN : 2799-1156,1Aug.2023,journal.hmjournals.com/index.php/JECNAM/article/view/2417.
30. Dr. Altaf Mulani Swapnil Takale, "A video watermarking technique with video and image as watermark using DWT and PCA"Journal of Northeastern University, Vol 25 Page No. 1005-3026
31. Volume 10, Issue III, Mar-2022.
32. Ghodake, R. G., & Mulani, A. O. (2018). Microcontroller Based Automatic Drip Irrigation System. In Techno-Societal 2016: Proceedings of the International Conference on Advanced Technologies for Societal Applications (pp. 109-115). Springer International Publishing.
33. Mr. Sanket K Nagane, Mr. Prashant S Pawar, & Prof. V. V. Godase. (2022). Cinematica Sentiment Analysis. Journal of Image
34. Processing and Intelligent Remote Sensing(JIPIRS) ISSN 2815-0953, 2(03), https://doi.org/10.55529/jipirs.23.27.32
35. Mandwale, A. & Mulani, A. O. (2016). Implementation of High Speed Viterbi Decoder using FPGA. International Journal of Engineering Research & Technology (IJERT).
36. Takale, S., & Mulani, D. A. Video Watermarking System. International Journal for Research in Applied Science & Engineering Technology (IJRASET), 10.
37. Mulani, A. O., & Mane, P. B. (2017). Watermarking and cryptography based image authentication on reconfigurable platform. Bulletin of Electrical Engineering and Informatics, 6(2), 181-187.
38. Deshpande, H. S., Karande, K. J., & Mulani, A. O. (2014, April). Efficient implementation of AES algorithm on FPGA. In 2014 International Conference on Communication and Signal Processing (pp. 1895-1899). IEEE.
39. Swami, S. S., & Mulani, A. O. (2017, August). An efficient FPGA implementation of discrete wavelet transform for image compression. In 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS) (pp. 3385-3389). IEEE.
40. Kulkarni, P. R., Mulani, A. O., & Mane, P. B. (2017). Robust invisible watermarking for image authentication. In Emerging Trends in Electrical, Communications and Information Technologies: Proceedings of ICECIT-2015 (pp. 193-200). Springer Singapore.

41. Mulani, A. O., & Mane, P. B. (2016). Area efficient high speed FPGA based invisible watermarking for image authentication. Indian journal of Science and Technology.
42. Mane, P. B., & Mulani, A. O. (2018). High speed area efficient FPGA implementation of AES algorithm. International Journal of Reconfigurable and Embedded Systems, 7(3), 157-165.
43. Kashid, M. M., Karande, K. J., & Mulani, A. O. (2022, November). IoT-based environmental parameter monitoring using machine learning approach. In Proceedings of the International Conference on Cognitive and Intelligent Computing: ICCIC 2021, Volume 1 (pp. 43-51). Singapore: Springer Nature Singapore.
44. Mane, D. P., & Mulani, A. O. (2019). High throughput and area efficient FPGA implementation of AES algorithm. International Journal of Engineering and Advanced Technology, 8(4).
45. Deshpande, H. S., Karande, K. J., & Mulani, A. O. (2015, April). Area optimized implementation of AES algorithm on FPGA. In 2015 International Conference on Communications and Signal Processing (ICCSP) (pp. 0010-0014). IEEE.
46. Mulani, A. O., & Mane, D. P. (2018). Secure and area efficient implementation of digital image watermarking on reconfigurable platform. International Journal of Innovative Technology and Exploring Engineering, 8(2), 56-61.
47. Mulani, A. O., & Mane, P. B. (2019). High-Speed area-efficient implementation of AES algorithm on reconfigurable platform. Computer and Network Security, 119.
48. Mulani, A. O., & Mane, P. B. (2014, October). Area optimization of cryptographic algorithm on less dense reconfigurable platform. In 2014 International Conference on Smart Structures and Systems (ICSSS) (pp. 86-89). IEEE.
49. Mandwale, A., & Mulani, A. O. (2015, January). Different Approaches For Implementation of Viterbi decoder. In IEEE International Conference on Pervasive Computing (ICPC).
50. Jadhav, H. M., Mulani, A., & Jadhav, M. M. (2022). Design and development of chatbot based on reinforcement learning. Machine Learning Algorithms for Signal and Image Processing, 219-229.
51. Mulani, A. O., Jadhav, M. M., & Seth, M. (2022). Painless Non-invasive blood glucose concentration level estimation using PCA and machine learning. the CRC Book entitled Artificial Intelligence, Internet of Things (IoT) and Smart Materials for Energy Applications. Internet of Things (IoT) and Smart Materials for Energy Applications.
52. Mulani, A. O., Birajadar, G., Ivković, N., Salah, B., & Darlis, A. R. (2023). Deep learning based detection of dermatological diseases using convolutional neural networks and decision trees. Traitement du Signal, 40(6), 2819-2825.
53. Vikram A. Kolhe, Suyash Y. Pawar, Soheil Gohari, Altaf Osman Mulani, M. S. Sivagama Sundari, Giriraj Kiradoo, M. Sivaprakash & J. Sunil (2024) Computational and experimental analyses of pressure drop in curved tube structural sections of Coriolis mass flow metre for laminar flow region, Ships and Offshore Structures, DOI: 10.1080/17445302.2024.2317651