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A Novel Architecture For Internet of Things in Precision Agriculture

Jisha Jayadevan
Department of Computer Science and Engineering
College of Engineering and Management Punnapra, Alappuzha, India.
(E-Mail: jishajayadevan96@gmail.com)

Smitha M Jasmine
Assistant Professor
Department of Computer Science and Engineering
College of Engineering and Management Punnapra, Alappuzha, India.
(E-Mail: smitha.cemp@gmail.com)

Suresh Kumar N
Associate Professor
Department of Computer Science and Engineering
College of Engineering and Management Punnapra, Alappuzha, India.
(E-Mail: cnsuresh2000@gmail.com)

Abstract
Internet of Things is the most evolving technology that changes the face of the world. However, the agriculture domain in India lacks technological advancements. The use of the Internet of Things in agriculture can make devices autonomous to collect data or information required to increase the yield of Agri-products in a scientific way. Precision Agriculture is an approach for farm management to make sure that the crops and fields receive whatever resources they need for maintaining optimal health and productivity through the use of information technology. In this paper, we provide a survey on various strategies and hardware components used to implement the IoT in precision agriculture. We also propose a system for precision farming using the Internet of Things and data analytics. This system aims to provide a cost-effective implementation of IoT in agriculture.
Keywords: Colorimetry, Internet Of Things (IoT) , Machine Learning, Precision Agriculture, Sensor.

I. INTRODUCTION
The Internet of Things (IoT) portrays various technological innovations and research trains that empower the Internet to connect into real-world objects. IoT [1] was characterized as the accumulation of gadgets and machines or objects that communicate with each other by utilizing the Internet. The main aim of IoT is to make the gadgets increasingly self-governing or autonomous. IoT is a new period of innovation that intends to manufacture shrewd gadgets. The Internet of things also known as the web of things consists of things, network connectivity, data, intelligence, actions, and analytics. A thing is whatever that connected or accessed using the Internet. Connectivity refers to the connection of things in a community. Data is the glue of the Internet of Things that is the information transmitted over the internet. IoT has a combination of algorithms and computations, software and hardware that makes it clever. Action refers to the choice to take primarily based on the values from the devices. Analytics is the extraction of specified data from the records generated from IoT devices.

IoT keeps the devices or things interconnected and uses in a productive way to such an extent that the information is gathered and communicated utilizing the Internet without human interaction. Smart homes and buildings, wearables, smart cities, smart grid, healthcare, smart farming, transportation, smart retail and logistics are some application domains of IoT [2]. The main components of IoT are sensors or devices, connectivity, data processing, and user interface.

The internal working of IoT is depicted in Fig. 1. Sensors or devices are deployed and programmed to collect the data from the physical environment. The collected data is passed through the gateway to store data in a cloud. Gateway is the bridge between the internal network of sensor nodes and the external internet. The data stored on the cloud can be accessed by the users through the user interface [1].

Agribusiness is one of the significant applications of IoT. As the population increases there is an extensive need for quality nourishment items to address the needs of the general population. IoT is an innovation which changes the horticulture area to self-sufficient and thereby decreasing the cost required for setting up different procedure in farming. The utilization of smart agriculture technology helps the farmers to deal with the way toward raising livestock and developing harvests, to save inadequate resources such as water, to accomplish cost-effectiveness, adaptability and so forth. Numerous difficulties in the agriculture domain can be addressed and can deliver results of high caliber and amount within the cost limitations by innovative headways. The use cases in the agriculture area are Environment Monitoring, Green House Automation, Crop Management and Cattle Monitoring and Management [3].

Applications of IoT in agriculture are precision farming, livestock monitoring, pest management, and smart greenhouse. Precision farming [4] is a methodology that utilizes the information technology for farm management to give the right things at the right spot, perfect time in the right way. The objective of precision farming is to get improved yield by safeguarding resources. The main objective of precision farming is accompanying the optimum of Cost-effectiveness, sustainability, and protection of land resources.

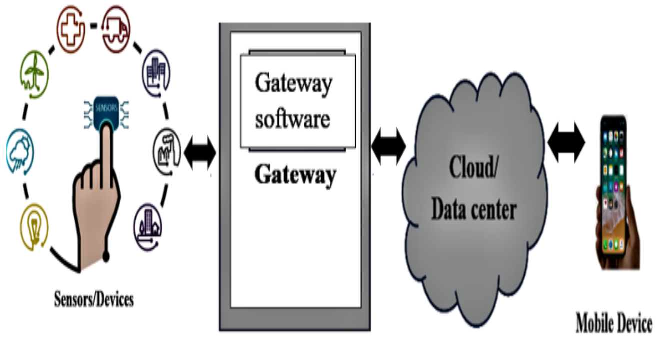

Figure 1: Working of IoT Technology

Implementation of IoT for precision farming is not only to sense data but also to analyze data to evaluate needed reactions. Implementation involves activities such as sensor integration, automatic control, information processing, and network communication capabilities. Machine learning algorithms are utilized to explore the information and to predict the required actions based on the training experience learned by the algorithm. Accurate data analysis has greater importance in accomplishing operational effectiveness [5].

In this paper, a broad review of IoT in precision agriculture is done, which involves a survey of technologies, hardware components used, and values measured. Also, an architecture for implementing IoT in precision agriculture is proposed in this paper.

The rest of the paper is sorted out as follows: Section II highlights the related work on IoT in precision agriculture. Section III describes the proposed architecture. Finally, Section IV concludes the paper and describes future trends and opportunities.

II. RELATED WORK

A. Research Methodology

The research technique includes three phases. In the first phase, some papers are chosen depending on the brief study about IoT and its applications. In phase 2, papers are shortlisted dependent on the significance and a chance of future advancement on the topic. This stage includes the itemized investigation of the papers. The fundamental target of this stage is to distinguish the region of research. The zone of research picked as Agriculture Domain. Finally, in stage 3, some papers were shortlisted dependent on the region chosen for the research and a detailed study has been done. The method of research is shown in Fig. 2.

B. Research contributions under agriculture domain

Manav Mehra et al. [6] developed an IoT based hydroponic system [7] by taking a tomato plant as a case study. Parameters such as temperature, pH, humidity, Lighting, and the water level taken as the input to the system and used Deep Neural Network for predicting decisions to actuate the control system to pump the water, switch the lights on, switch the fan on and so on automatically. This system uses the cloud to store the gathered information and the predicted output to give access to information from anywhere at any time.

Uélison Jean L. dos Santos et al. [8] presented a framework called the AgriPrediction model whose components based on both LoRa IoT technology and the ARIMA prediction model. AgriPrediction was useful to foresee potential problems such as the variation of certain values collected by the sensors from expected values in a particular field and notifies the farmer about the occurrence of an unusual circumstance for taking remedial actions.

Min-Sheng Liao et al. [9] developed an IoT based system consists of an environmental monitoring system and wireless imaging platform. An IoT based environmental monitoring system is used to measure Environmental parameters of an Orchid greenhouse and growth status of orchid leaves. The leaf area of Phalaenopsis orchids is estimated from an image captured by an IoT based wireless imaging platform and analyzed using an image processing algorithm.

Marti Boada et al. [10] presented a low-cost, battery-less, NFC powered device that is capable to measure soil moisture, temperature, and relative humidity. A smartphone application is used to display the measured value and upload data to the cloud to be stored or shared.

Table 1. Survey of Various Techniques for Smart Agriculture

Paper	Sensors/Devices	Board used	Measured values
Iot based hydroponics system using Deep Neural Network [6]	DHT11 [25], water level, photo resistor, pH sensor	Raspberry Pi [49], Arduino UNO [23]	pH, humidity, light intensity, temperature, water level
AgriPrediction: A proactive internet of things model to anticipate problems and improve production in agricultural crops [8]	DS18B20 [37], TSL2561 [38], DHT11 [25], SHT10 [39]	Arduino Uno [23], Arduino Mega [51], Lora shield	air temperature, soil temperature, air humidity, soil humidity, brightness, external temperature
On precisely relating the growth of phalaenopsis leaves to greenhouse environmental factors by using an IoT based monitoring system [9]	SHT11 [39], S1087-01 [40], 5 mega pixel CMOS image sensor	Raspberry Pi 1 Model B+, Octopus II (MSP430F1611 MCU, CC2420 wireless communication chip)	temperature, relative humidity, illumination, leaf area

Paper	Sensors/Devices	Board used	Measured values
Battery-Less Soil Moisture Measurement System Based on a NFC Device with Energy Harvesting Capability [10]	LM75A [41], HIH-5030 [42], IDC sensor	PCB (NFC Antenna, ATTINY85, M24LR04E-R)	water content, temperature, relative humidity
Automated Soil Nutrient Monitoring for Improved Agriculture [11]	SEN-10972, SEN-13322 [44], Fibre optic sensors [43]	Arduino UNO [23]	soil moisture, pH, N(Nitrogen), P(Phosphorus), K(potassium)
Smart Soil Parameters Estimation System Using an Autonomous Wireless Sensor Network with Dynamic Power Management Strategy [12]	SHT10 [39], SEN0114 [45]	BQ25570 PMIC, MSP430FR5969	soil conductivity, temperature, humidity
Internet of Plants Application for Smart Agriculture [13]	DHT11 [25], Groovec soil moisture sensor	PCB (NUCLEO-L476RG, NodeMCU)	temperature, humidity, soil moisture
Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture [14]	DHT22 [47], DS18S20	4duino [46]	humidity, ambient temperature, soil temperature, soil moisture, dew point
Soil pH and Nutrient (Nitrogen, Phosphorus and Potassium) Analyzer using Colorimetry [15]	TCS3471 color sensor [53], LDR sensor	Gizduino X [50]	soil nutrients (Nitrogen, Phosphorus and Potassium), pH
IoT Based Intelligent Agriculture Field Monitoring System [16]	LM35 [48], VL95	Arduino UNO [23]	Temperature, soil moisture
AgriTalk: IoT for Precision Soil Farming of Turmeric Cultivation [17]	Weather station (CO_2, temperature, humidity, pressure, UV, wind gauge, rain gauge), soil sensors including 3-in-one sensor (soil moisture, temperature, EC), pH sensor, insect trappers.	Arduino microcontroller board	Climatic conditions, soil conditions
Iot based smart irrigation management system using machine learning and open source technologies [18]	soil temperature, UV, soil moisture, air temperature and humidity	Raspberry Pi [49], Arduino	soil temperature, UV, soil moisture, air temperature, humidity
CLUefarm: Integrated web service platform for smart farms [19]	Solar radiation, Leaf wetness, Soil moisture and temperature, soil water content, air temperature, humidity and dew point	Wireless node (Base radio)	air and soil parameter in greenhouse
Promoting Greenness with IoT-Based Plant Growth System [20]	MQ135 [52], DHT22 [47], MQ9, Grove-Gas, DS18B20, SEN-00035, TOL-00087 pH meter	Arduino	CO_2 value, temperature, humidity, CO value, O_2 value, soil pH, soil temperature, soil moisture.
Iot based Smart crop-field Monitoring and Automation Irrigation System [21]	Soil moisture, LM35 [48]	Raspberry Pi 3 Model B	Soil moisture, temperature

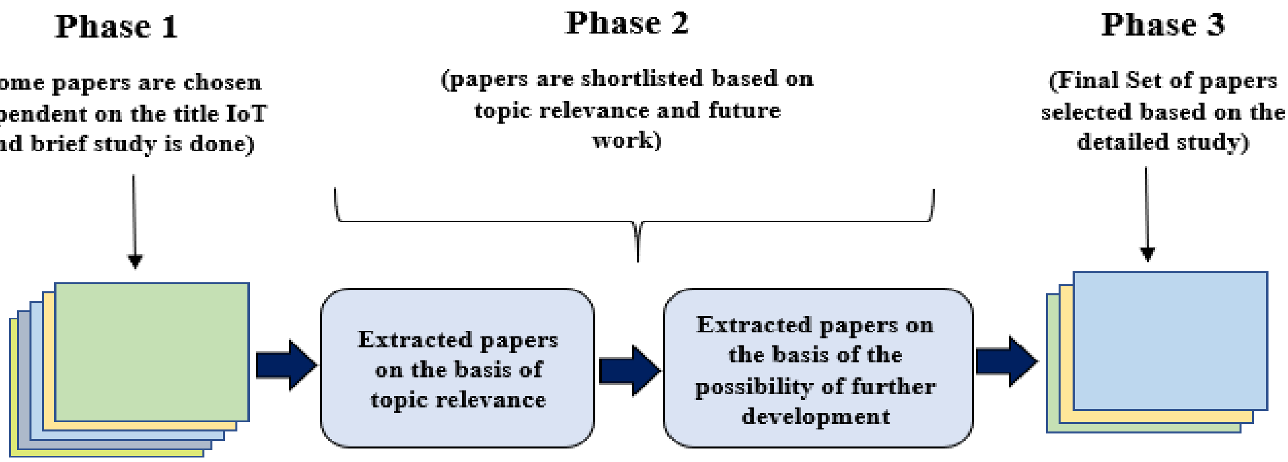

Figure 2: Research Methodology

Akhil R et al. [11] proposed a model consisting of a pH sensor, a sensor to measure dielectric permittivity of soil and a fiber optic sensor to measure NPK values are deployed to collect real-time data. A prediction algorithm is used to predict the nutrient variation in soil. Based on the prediction, a recommendation to improve the level of soil nutrient is provided to the farmer. The collected data and recommendation can be viewed by the user using a web application.

Johan J. Estrada-López et al. [12] proposed an autonomous wireless sensor network for the estimation of soil parameters such as temperature, humidity, and conductivity. An artificial neural network (ANN) is used to examine the sensed information and gauge the levels of phosphorus (P) content in the soil. To establish an adaptive balance between energy consumption and the accuracy of phosphorus estimation by the system, dynamic power management (DPM) strategy is applied.

Khurshid Aliev et al. [13] proposed a novel WSN approach to acquire temperature, humidity, and soil moisture of plants from sensors with a predictive model for the smart agriculture sector using ANN. An android application is created to show data and cloud service is used to store acquired data.

Kayode E. Adetunji et al. [14] implemented an approach to achieve data transfer to a self-implemented cloud platform using 4duino [46] and relevant sensors. The 4duino consists of ESP8266 Wi-Fi module, Arduino Uno nomenclature, LCD, and a MicroSD slot. The main microprocessors used are the PICASSO and ATmega32U4. Soil moisture, ambient temperature, humidity, dew point, and soil temperature were used as variables for monitoring. Dew point was measured using the readings of ambient temperature and humidity.

Rigor G. Regalado et al. [15] developed a device to determine the Nitrogen, Phosphorus, Potassium content, and pH of the soil by using the chemicals of the Soil Test Kit in giving nutrient recommendations.

Md Ashifuddin Mondal et al. [16] proposed an intelligent agriculture field monitoring system to monitor soil humidity and temperature. The information gathered from sensors is used to automate the process, such as watering the field and opening the flap of polyhouse. Sensed values are stored in the ThingSpeak cloud for future data analysis.

Wen-Liang Chen et al. [17] proposed a cost-effective IoT platform called AgriTalk for precision farming. The experiments were conducted on turmeric cultivation. IoT devices for AgriTalk consist of weather stations, soil and insect sensors, and actuators. AgriGUI is a Graphical User Interface (GUI) of AgriTalk, which helps to configure the connection between sensors and actuators. A farmer can access the resources of AgriTalk through the web browser. AgriTalk automatically compares the data of the nearby sensors of the same type and monitors the power consumption of the sensors to detect the potential problems of IoT devices. AgriTalk alerts the farmer when a potential problem arises.

Amarendra Goap et al. [18] proposed an IoT based smart irrigation architecture. This architecture involves collecting real-time data from sensors and application of a hybrid machine learning-based approach to predict the soil moisture of upcoming days by using sensors' data of the recent past and weather forecasted data. The irrigation process is planned on the based on the prediction. The web-based user interface is used for monitoring the data from sensors and scheduling of irrigation process.

In paper [19], an integrated web-service platform is described. This platform uses the cloud service and allows users to locate and efficiently manage farms by providing access to different types of statistics and predictions. It acts as a community collaboration platform allowing users to interact with each other by sending private messages or posting on the forum or blog to get information from agricultural experts.

S. M. Kamruzzaman et al. [20] designed a system for monitoring air and soil parameters. The gathered data is stored in the server and then analyzed based on the autoregressive integrated moving average (ARIMA) to predict future values for analyzing the variations in air and soil quality. A prediction system to predict future data is designed to make decisions for better plant growth.

R. Nageswara Rao et al. [21] developed a Precision agriculture irrigation system. This system monitors the real-time values of soil moisture and temperature using corresponding sensors. The measured data are stored in a cloud database. The irrigation process can be activated by comparing the collected data and the threshold value. So, the implementation of this approach helps to automate the irrigation process. Using a mobile phone or PC farmer can monitor the data from sensors.

A detailed study of various applications of IoT in the agriculture sector is done by analyzing the sensors, boards, and values measured. The survey of the above specified details is shown in Table 1.

III. PROPOSED METHOD

In this paper, we propose a novel architecture for implementing the combination of IoT and machine learning in precision agriculture to improve the crop yield and its quality. Proposed Architecture is depicted in Fig. 3 consists of three main modules: Hardware development of a crop monitoring system, Data analytics, and Automation.

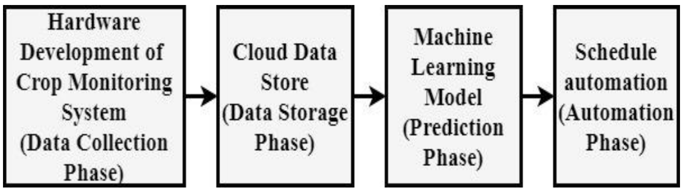

Figure 3: Block Diagram of Proposed System

A. Hardware Development of Crop Monitoring System

The proposed crop monitoring system is shown in Fig. 4. The main objective of this system is to monitor the crop metrics of a field. The detected information is transmitted by utilizing remote transmission and is stored in a cloud.

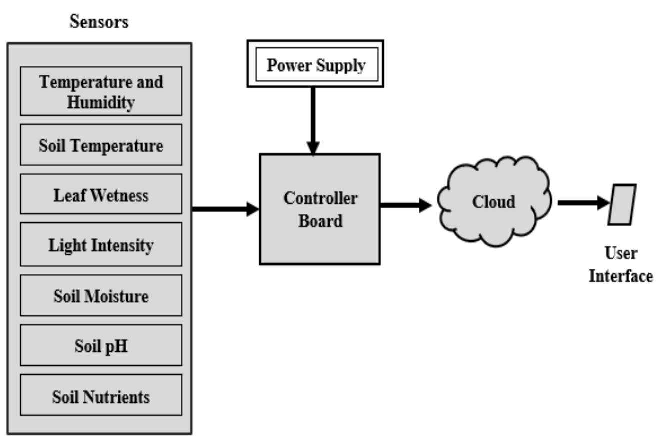

Figure 4: Diagrammatic Representation of Proposed Crop Monitoring System

Requirements for proposed crop monitoring systems involve Sensors and the Arduino board. Sensors are used to collect data from the surrounding environment [22]. The parameters such as air temperature, humidity, soil moisture, soil temperature, pH, leaf wetness and light intensity are measured using the corresponding sensors. Soil nutrients are measured by using the concept of colorimetry [15]. Arduino is an open-source electronics platform to design hardware and software, develop and test electronic components [23]. Arduino is responsible for sending information collected from sensors to the cloud by utilizing Wireless Communication Technology. The sensors that can be used in this system are specified in Table 2.

Table 2. Sensors Used

Sensors	Measured Value
DS18B20 probe [24]	Soil temperature
DHT11 [25]	Air temperature and humidity
BH1750 [26]	Light intensity
KG003 [27]	Soil moisture
LWS237 [28]	Leaf wetness
pH probe [29]	pH
TCS3200 [30] / LDR [31]	Soil nutrients

B. Cloud Data Store

Data is collected from the sensors periodically. Therefore, a large amount of data will be generated. To store such big data, the cloud data store is used since cloud computing provides storage as a service. Cloud computing helps farmers to access the information from anywhere at any time using the Internet that is it provides 24x7 availability. Amazon, Google, Salesforce, IBM, Microsoft, and Sun Microsystems provide data centers for hosting cloud computing applications [32].

C. Predictive Analytics using Machine Learning

The information collected by the Arduino is passed to Raspberry Pi [33] using serial communication. In Raspberry Pi, KNN (K Nearest Neighbor) machine learning algorithm is employed for predicting whether the crop needs water or fertilizer. KNN is the simplest machine learning technique that works on the belief that similar samples lie in close vicinity [34]. The predicted output is used to control the water and fertilizer pumps. This predicted information is also stored in the cloud along with date and time so that farmers can get to know when the field is irrigated and fertilizers are provided. Fig. 5. shows the prediction mechanism.

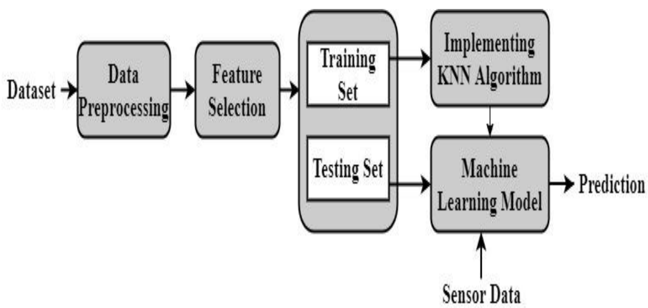

Figure 5: Machine Learning Prediction Mechanism

D. Automation

Based on the decision from the Machine Learning (ML) module, a smart irrigation system [35] or fertilizer spraying system [36] gets activated automatically on the corresponding fields. The block diagram of smart irrigation and fertilizer spraying system is shown in Fig. 6.

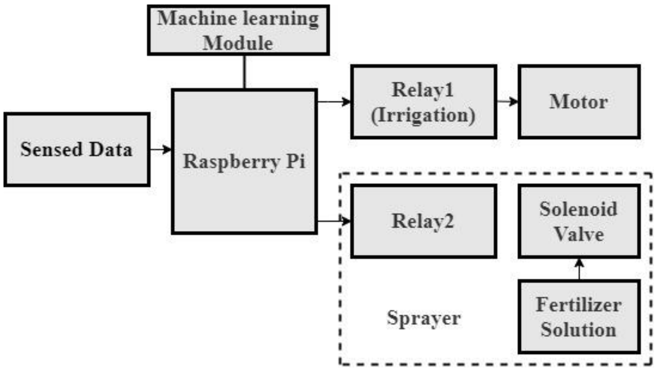

Figure 6: Block Diagram of Smart Irrigation and Fertilizer Spraying System

E. Software Requirements

An android application or web application can be created to provide a platform to monitor the real-time data collected from the sensors which will assist the farmers to take necessary action to improve the crop productivity. The farmer has to register the application by providing basic personal and field information. The farmer can view all the information regarding the farm.

The workflow of the proposed architecture for precision agriculture is shown in Fig. 7.

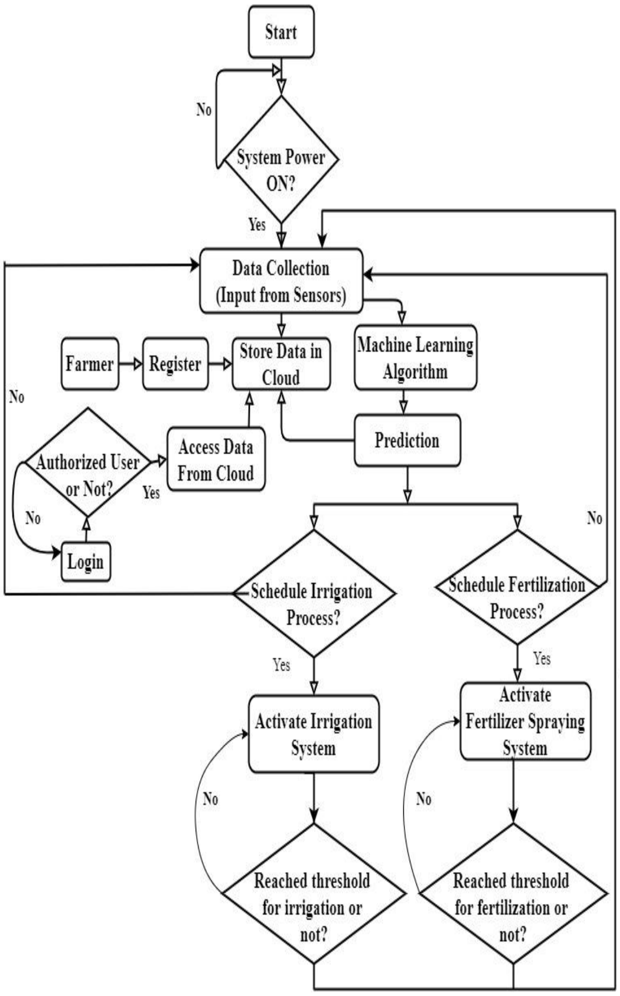

Figure 7: Flow Chart

IV. CONCLUSION AND FUTURE WORK

In this paper, we have presented an overview of various techniques used in the agriculture sector and an architecture for IoT precision agriculture applications. Major challenges faced by the agriculture domain are the excess use of water and fertilizers in harvests, which will diminish the quality and quantity of the products. This problem can be tackled by the utilization of the proposed system. Hence, the proposed framework can be implemented in a real-time farming environment to get revolutionary results. This can be extended by including disease prediction, and a recommendation system to provide instructions to farmers regarding pesticides and cultivation. We can also include a web service platform for collaborative group communication between farmers and agricultural experts as future work. A system has to be developed to measure pesticide levels in crops. Sustainable energy can be used for operating the system rather than using electricity.

REFERENCES

[1] Keyur K Patel and Sunil M Patel, "*Internet of Things-IOT: Definition, Characteristics, Architecture, Enabling Technologies, Application & Future Challenges*," In IJESC, 2016.

[2] Luigi Atzori, Antonio Iera, and Giacomo Morabito, "*The Internet of Things: A survey*," In Computer Networks Journal, ELSEVIER, 2010.

[3] Kandula Syamu, Bhupendra Pratap Singh, T. Ravi, and Vaishali Maheshkar, "*A survey on precision agriculture using effective crop monitoring with enhanced farming*," In IJARIIT, *vol. 5*, 2019.

[4] Abhishek Khanna and Sanmeet Kaur, "*Evolution of Internet of Things (IoT) and its significant impact in the field of Precision Agriculture*," In Computers and Electronics in Agriculture Journal, ELSEVIER, *vol. 157*, pp. 218-231, 2019.

[5] Olakunle Elijah, Tharek Abdul Rahman, Igbafe Orikumhi et al., "*An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges*," In IEEE INTERNET OF THINGS Journal, 2018.

[6] Manav Mehra, Sameer Saxena, Suresh Sankaranarayanan et al., "*IoT based hydroponics system using Deep Neural Networks*," In Compuers and Electronics in Agriculture Journal, ELSEVIER, *vol. 155*, pp. 473–486, 2018.

[7] Arjina Shrestha and Bruce Dunn, "*Hydroponics*" (Oklahoma Cooperative Extension Service, 2013).

[8] Uélison Jean L. dos Santos, Gustavo Pessin, Cristiano André da Costa, and Rodrigo da Rosa Righi, "*AgriPrediction: A proactive internet of things model to anticipate problems and improve production in agricultural crops*," In Computers and Electronics in Agriculture Journal, ELSEVIER, 2019.

[9] Min-Sheng Liao, Shih-Fang Chen, Cheng-Ying Chou et al., "*On precisely relating the growth of phalaenopsis leaves to greenhouse environmental factors by using an IoT-based monitoring system*," In Computers and

Electronics in Agriculture Journal, ELSEVIER, *vol. 136*, pp. 125-139, 2017.

[10] Martí Boada, Antonio Lazaro, Ramon Villarino, and David Girbau, "*Battery-Less Soil Moisture Measurement System Based on a NFC Device with Energy Harvesting Capability*," In IEEE Sensors Journal, *vol. 18*, pp. 5541-5549, 2018.

[11] Akhil R, Gokul M S, Sruthi Menon, and Lekshmi S Nair, "*Automated Soil Nutrient Monitoring for Improved Agriculture*," In ICCSP, IEEE, 2018.

[12] Johan J. Estrada-L´opez, Alejandro A. Castillo-Atoche et al., "*Smart Soil Parameters Estimation System Using an Autonomous Wireless Sensor Network with Dynamic Power Management Strategy*," In IEEE Sensors Journal, 2018.

[13] Khurshid Aliev, Eros Pasero et al., "*Internet of Plants Application for Smart Agriculture*," In IJACSA, *vol. 9*, 2018.

[14] Kayode E. Adetunji and Meera K Joseph, "*Development of a Cloud-based Monitoring System using 4duino: Applications in Agriculture*," In icABCD, IEEE, 2018.

[15] Rigor G. Regalado and Jennifer C. Dela Cruz, "*Soil pH and Nutrient (Nitrogen, Phosphorus and Potassium) Analyzer using Colorimetry*," IEEE, 2016.

[16] Md Ashifuddin Mondal and Zeenat Rehena, "*IoT Based Intelligent Agriculture Field Monitoring System*," IEEE, 2018.

[17] Wen-Liang Chen, Yi-Bing Lin et al., "*AgriTalk: IoT for Precision Soil Farming of Turmeric Cultivation*," In IEEE Internet Of Things Journal, 2019.

[18] Amarendra Goap, Deepak Sharma, A. K. Shukla, and C. Rama Krishna, "*An IoT based smart irrigation management system using Machine learning and open source technologies*," In Computers and Electronics in Agriculture Journal, ELSEVIER, *vol. 155*, pp. 41–49, 2018.

[19] Madalin Colezea, George Musat, Florin Pop, Catalin Negru, Alexandru Dumitrascu, and Mariana Mocanu, "*CLUeFARM: Integrated web-service platform for smart farms*," In Computers and Electronics in Agriculture Journal, ELSEVIER, *vol. 154*, pp. 134–154, 2018.

[20] S. M. Kamruzzaman, M. I. Pavel, M. A. Hoque, and S. R. Sabuj, "*Promoting Greenness with IoT-Based Plant Growth System*," In Computational Intelligence and Sustainable Systems, Springer, 2018.

[21] R. Nageswara Rao and B. Sridhar, "*IoT Based Smart crop-field Monitoring and Automation Irrigation System*," In ICISC, IEEE, 2018.

[22] Aqeel-ur-Rehman, Abu Zafar Abbasi, Noman Islam, and Zubair Ahmed Shaikh, "*A review of wireless sensors and networks' applications in agriculture*," In Computer Standards & Interfaces Journal, ELSEVIER, *vol. 36*, pp. 263–270, 2014.

[23] Arduino Uno, *https://www.farnell.com/datasheets/1682209.pdf*, Accessed on 24 March 2019.

[24] Waterproof DS18B20 Digital Temperature Sensor Datasheet, *https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/DFR0198_Web.pdf*, Accessed on 24 March 2019.

[25] DHT11 Sensor, *http://robocraft.ru/files/datasheet/DHT11.pdf*, Accessed on 25 March 2019.

[26] BH1750 Sensor Datasheet, *https://www.mouser.com/datasheet/2/348/bh1750fvi-e-186247.pdf*, Accessed on 26 March 2019.

[27] Digital Soil Moisture Sensor Datasheet, *https://researchdesignlab.com/projects/soil%20moisture.pdf*, Accessed on 26 March 2019.

[28] Leaf Wetness Sensor Datasheet, *https://s.campbellsci.com/documents/us/miscellaneous/old-manuals/LWS%20Dielectric%20Leaf%20Wetness%20Sensor.pdf*, Accessed on 26 March 2019.

[29] Ph Probe Datasheet, *https://www.atlas-scientific.com/_files/_datasheets/_probe/pH_probe.pdf*, Accessed on 27 March 2019.

[30] TCS3200 Color Sensor Datasheet, *https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/SEN0101_Web.pdf*, Accessed on 27 March 2019.

[31] LDR Datasheet, *https://www.mouser.com/datasheet/2/737/photocells-932884.pdf*, Accessed on 27 March 2019.

[32] Jiyi WU, Lingdi PING et al., "*Cloud Storage as the Infrastructure of Cloud Computing*," IEEE, 2010.

[33] M. Richardson and S. Wallace, "*Getting started with Raspberry Pi*" (O'Reilly, 2013).

[34] Sayali D. Jadhav and H. P. Channe, "*Comparative Study of K-NN, Naive Bayes and Decision Tree Classification Techniques*," In IJSR, 2016.

[35] Swapnali B.Pawar, Priti Rajput, and Asif Shaikh, "*Smart Irrigation System Using IOT And Raspberry Pi*," In IRJET, 2018.

[36] V. Gowrishankar and K. Venkatachalam, "*IoT Based Precision Agriculture using Agribot*," In Global Research and Development Journal for Engineering, 2018.

[37] DS18B20 Programmable Resolution 1-Wire Digital Thermometer, *http://ee-classes.usc.edu/ee459/library/datasheets/DS18B20.pdf*.

[38] TSL2560, TSL2561, Light to Digital Converter *https://cdn-shop.adafruit.com/datasheets/TSL2561.pdf*.

[39] Datasheet SHT1x (SHT10, SHT11, SHT15), *https://www.mouser.in/datasheet/2/682/Sensirion_Humidity_Sensors_SHT1x_Datasheet-1539071.pdf*.

[40] Si Photodiodes (S1087-01) Datasheet, *https://www.hamamatsu.com/resources/pdf/ssd/s1087_etc_kspd1039e.pdf*.

[41] LM75A Digital Temperature Sensor and Thermal Watchdog With Two-Wire Interface Datasheet, *http://www.ti.com/lit/ds/symlink/lm75a.pdf*.

[42] HIH-5030/5031 Series datasheet, *https://sensing.honeywell.com/honeywell-sensing-hih5030-5031-series-product-sheet-009050-2-en.pdf*.

[43] Deepa V. Ramane, Supriya S. Patil and A D. Shaligram, "*Detection of NPK nutrients of soil using Fiber Optic Sensor*," In International Journal of Research in Advent Technology Special Issue National Conference ACGT 2015.
[44] Soil Moisture Sensor Hookup Guide, *https://media.digikey.com/pdf/Data%20Sheets/Sparkfun%20PDFs/Soil_Moisture_Sensor_HookupGuide_Web.pdf*.
[45] Moisture Sensor (SKU:SEN0114), *https://media.digikey.com/pdf/Data%20Sheets/DFRobot%20PDFs/SEN0114_Web.pdf*.
[46] 4Duino for IoT, *https://www.robotshop.com/media/files/pdf/4duino-24-tft-lcd--iot-display-module-datasheet.pdf*.
[47] DHT22 Sensor Datasheet, *https://components101.com/sites/default/files/component_datasheet/DHT22%20Sensor%20Datasheet.pdf*.
[48] LM35 Precision Centigrade Temperature Sensors, *http://www.ti.com/lit/ds/symlink/lm35.pdf*.
[49] Raspberry Pi Datasheet, *https://www.raspberrypi.org/documentation/hardware/computemodule/datasheets/rpi_DATA_CM_1p0.pdf*.
[50] Gizduino: Arduino Compatible Kit, *https://www.e-gizmo.net/oc/kits%20documents/Gizduino/Gizduino%20manual.pdf*.
[51] Arduino Mega, *https://www.fecegypt.com/uploads/dataSheet/1522496990_arduino%20mega.pdf*.
[52] MQ-135 Gas Sensor Datasheet, *https://www.electronicoscaldas.com/datasheet/MQ-135_Hanwei.pdf*.
[53] TCS3471 Color Light-to-Digital Converter Datasheet, *https://ams.com/documents/20143/36005/TCS3471_DS000109_3-00.pdf*.

AUTHORS BIOGRAPHY

Jisha Jayadevan is M. Tech Scholar in Department of Computer Science, College of Engineering and Management Punnapra affiliated to APJ Abdul Kalam Technological University. She has completed her Bachelor degree from Jawaharlal College of Engineering and Technology in 2018. Her area of interest includes Internet of Things, Machine Learning and Protocol Verification. She can be reached at jishajayadevan96@gmail.com

Smitha M Jasmine is working as Assistant Professor in the Department of Computer Science, College of Engineering and Management Punnapra. She acquired B. Tech degree in Computer Engineering and M. Tech in Computer and Information Science from CUSAT. She is currently doing her Ph.D. in the area of IoT Protocol Verification at School of Engineering, CUSAT.

Suresh Kumar N is working as Associate Professor in the Department of Computer Science, College of Engineering and Management Punnapra. His research interests include Protocol Verification, IoT Protocols, Protocol Modelling, Machine Learning and Cyber Physical Systems. He can be reached at cnsuresh2000@gmail.com.