Development and design of fully automated Indoor Farm/Gardening With IOT and Machine Learning

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Abstract - *Smart farming techniques using the Internet Of Things(IOT) are arising concepts because electronic sensors are capable of providing information about humidity, ph, temperature, soil moisture, water level, etc, and other necessities for farming then act upon based on the sensor's input. This paper focuses on the development of a system that can monitor temperature, level of water, moisture, ph, and even weather conditions so that we can prepare for precautions when necessary through sensors using Arduino UNO microcontroller and a Machine Learning Algorithm. This project aims at making use of evolving technology i.e. Internet Of Things and Machine Learning. Once the hardware has been developed depending on the change in requirements and technology the software and hardware need to be updated. This new version requires relentless testing to ensure changes are done in the old version so that it works correctly without any bugs in other parts of the system. This is necessary because updating one part of the hardware may bring some icky effects on other parts of the hardware.*

Key Words: **Internet of Things (IOT), Machine Learning, Smart Faming, Indoor Farming, Arduino UNO, Soil Moisture Sensor, Water level Sensor, Temperature Sensor.**

1.INTRODUCTION

The Smart Farming System is an Internet Of Things and Machine Learning-based device which is capable of automating the irrigation process by analyzing the moisture of soil and the climate condition (like rain). Soil Parameters like soil moisture, pH, and Humidity are measured and the Pressure sensor and the sensed values are displayed on an OLED panel and also on a mobile application.

The need for an automated farming system is to overcome over-irrigation and under irrigation. The purpose of a smart farming system is to defeat the conventional methods of farming done by farmers. The conventional methods were the ones in which the farmer did everything manually by user interaction with the motors, pump, etc. This was time-consuming and had unpredictable output. Conditions such as unexpected weather, under irrigation, and over-irrigation impacted traditional methods as well .The farmer was not able to complete everything at a particular time and usually, this led to decreased output and poor management.

The goal of smart farming is to ground a decision-making support system for farm management. Smart farming deems it necessary to address the issues of population growth, climate change, and labor that have gained a lot of technological attention, from planting and watering of crops to health and harvesting

Thus there came the need to automate it and make a Smart system so that all the processes can be improved.

Hence we are re-engineering the system as Advanced Irrigation System which would be very accurate in nature due to the various machine learning techniques which have been applied to it to make the system possibly efficient in nature.

Thus, we aim to achieve an Advance farming system that offers complete automation by taking in parameters like temperature, water content, humidity, light, etc, and then predicting the future values and according to these predictions controlling the entire process on its own and hence making the process fully automated in nature.

The following techniques are among the current trends in the smart irrigation market:

1. **Drip Irrigation:** This enables exact control of water and fertiliser application, resulting in a significant reduction in the amount of water required for agricultural irrigation.

2. **Water Flow Measuring:** Using water flow meters to precisely measure water usage can help farmers avoid overwatering and save money.

3. **Data Analytics:** New software solutions that crunch vast volumes of data can supply farmers with critical knowledge they didn't have before.

4. **Drilling More Wells:** As the water table drops due to unsustainable pumping levels, farmers are relying more on groundwater supplies for irrigation.

1.1 Problem Definition

Collecting Information related to the farm environment viz soil moisture, humidity, etc , and providing adequate support to the system with the use of Machine Learning Algorithm and putting the farmer at ease.

It can be monitored using an application that will be designed on the Machine Learning Platform and creating a network between the sensors, and a microprocessor, Hence overcoming the manual operations required to monitor and maintain the agricultural farms and saving a lot of time for the farmer.

2. LITERATURE REVIEW

Balaji Banu [1] designed a wireless sensor network to observe the conditions of farming and increase crop yield and quality. Sensors are used to monitor different conditions of the environment like water level, humidity, temperature, etc., The processors ATMEGA8535 and IC�S8817 BS, analog to digital conversion, and wireless sensor nodes with wireless transceiver module based on Zig bee protocol are used in the designing the system. Database and web application is used to retrieve and store data. In this Experiment, the sensor node failure and energy efficiency are managed.

Liu Dan [2], Joseph Haule, Kisangiri Michael [3] and WangWeihong, Cao Shuntian carried out experiments on intelligent agriculture greenhouse monitoring system based on Zig Bee technology. The system performs data acquisition, processing, transmission, and reception functions. Their experiments aim to realize a greenhouse environment system, where the system efficiency to manage the environment are a and reduce the money and farming cost and also save energy. IoT technology here is based on the B-S structure andcc2530 used like a processing chip to work for wireless sensor node and coordinator. The gateway has Linux operating system ana d cortex A8 processor actthe as core. Overall the design realizes remote intelligent monitoring and controlgreenhouseen house and also replaces the traditional wired technology twithwireless, also reduces manpower cost.

Joseph haule [3], Dragoş Mihai Ofrim, Bogdan AlexandruOfrim, and Dragoş Ioan Săcăleanu have proposed an experiment that explains the use of wsn used in automatic irrigation. Irrigation control and rescheduling based on wsn are powerful solutions for optimum water management through automatic communication to know the soil moisture conditions of irrigation design. The process used here is to determine the proper frequency and time of watering are important to ensure the efficient use of water, high-quality crop detection delay throughput, and load. Simulation is donefor agriculture by OPNET. Another design of wsn is deployed for irrigation systems using Zig bee protocol which will impact battery life. There are some drawbacks as wsn is still under development stage with unreliable communication times, fragile, power consumption and communication can be lost in the agricultural field. so automated irrigation systems and scheduling based on wireless sensor networks are used. WSN uses low power and a low data rate and hence energy-efficienttechnology. All the devices and machines are controlled with the help of inputs received via sensors that are mixed with soil. Farmers can analyze whether the system performs in normally or some actions need to be performed.

Vijay Kumar [4], Lin Zhang, Min yuan, Deyi Tai, Xia Oweixu, Xiang Zhan, Yuanyuan Zhang studied the work of rural farming communities that replaces some of the traditional techniques. The sensor nodes have several external sensors namely leaf wetness, soil moisture sensor, soil pH, atmospheric pressure sensors attached to it. Based on the soil moisture sensor the mote triggers the water sprinkling during the period of water scarcity and switches off after adequate water is sprinkled. This results in water conservation and soil pH is sent to the base station and in turn base station intimates the farmer about soil pH via SMS using GSM model. This information helps the farmers to reduce quantity of fertilizers used.

A development of rice crop monitoring using WSN is proposed to provide a helping hand to farmers in real time monitoring and increasing the rice production. The automated control of water sprinkling and ultimate supply of information is implemented using wireless sensor network.

G. Nisha [5], Chun-ling Fan, Yuan Guo proposed a wireless sensor-based automated irrigation system to optimize water use for agricultural purpose. The system consists of distributed wireless sensor network of soil moisture, and temperature sensors mounted in the crop field. Zigbee protocol is used to handle the sensor information and water quantity programming using algorithm with threshold values of the sensors sent to a micro controller for irrigation system. Data inspection is done using by using solar panel and cellular internet interface. A wireless camera is fixed in crop field to monitor the disease area using image processing technique.

Meng Ji-hua [6] conducted a research on growth of cereal crop seedlings, as well as the status and trend of their growth. This paper introduced the design, methods used and implementation of a global crop growth monitoring system, which satisfies the need of the global crop monitoring in the world. The system uses two methods of monitoring, which are real-time crop growth monitoring and crop growing process monitoring. Real-time crop growth monitoring could get the crop growing status for certain period by comparing the remote sensed data (NDVI, for example) of the period with the data of the period in the history (last year, mostly). The differential result was classified into several categories to reflect the condition at difference level of crop growing. In this system, both real-time crop growth monitoring and crop growing process monitoring are carried out at three scales, which are state (province) scale, country scale and continent scale. Global crop growth monitoring system was found in this design and built a system that can monitor the global crop growth with remote sensing data. The system showed the characteristics of fast, effective, high credibility and operational in its run.

Alan Main-waring [7], A. Sivasankari, S. Gandhimathi have provided an in-depth study of applying wireless sensor networks to real-world habitat monitoring. A set of system design requirements are developed that cover the hardware design of the nodes, the design of the sensor network, and the capabilities for remote data access and management. To evaluate this implementation, have deployed an initial prototype network at the James San Jacinto Mountains Reserve (JMR) in Idyllwild, California. JMR is a 29-acreecological preserve, representing just one of the University of California System Natural Reserve System's 34 land holdings. JMR climate is different from GD and weather changes can exists for long time. The data collection can be made easy from previously inaccessible using a micro-measurement scale. Xiao

[8] Fiona Edwards Murphy, Emanuel Popovici, Whelan, and Michele Magno Proposed agriculture monitoring system using wireless sensor network(WSN). The conditions can be monitored in real time are temperature, light intensity, and humidity. The experiment involves the hardware and software design of the built modules, network topology and network with the challenges. Design explains how the node can achieve agricultural condition information collection and transmission. The system is compact in frame work, lightweight, good in performance and operation. It improves the agricultural production efficiency automatically.

Ling-ling LI [9], Wen-Yao Zhuang, Miguel Costa Junior, Pedro Cheong, Kam-Weng Tam [12] have proposed system uses ZigBee technology. This research deals with hardware and the software of the network coordinator node and the sensor nodes. The theoretical and practical results show that the system can efficiently capture greenhouse environmental parameters, including temperature, humidity, and carbon dioxide concentration and also clears the normal communication between nodes and the network coordinator, good network stability. The implementation explored values used in the complex greenhouse environmental monitoring.

Yunseop Kim [14], R. Balamurali, K. Kathiravan [15] have proposed the design for wireless sensor network (WSN) for a water irrigation control and monitoring that is composed of a number of sensor nodes with a networking capability that is deployed for an ad-hoc for the purpose of ongoing monitoring. The parameters used in the water reservation control are water levels and motor movement of the gate controlling the flow of water which is measured by the sensors, which will sense the condition and forward it to base station or control room. This proposed system offers a low power consumption with high reliability based on the result. The use of high power WSN is suitable for tasks in industries involving huge area monitoring like manufacturing, mining constructing, etc., The system discussed here is very easy to install and the base station can be placed at the local residence close to the area of monitoring where a person requires minimal training at the beginning of the system installation.

Giuseppe Anastasi [16] designed a WSN-based system to monitor the productive cycle of high-quality wine in a sicilian winery. This project aimed to ensure overall good quality of the production. The design incorporates accurate planning in field, the stored product preservation. Wireless Sensor Networks are deployed as the sensing infrastructure of distributed system to control prototype productive chain, nodes have been deployed both in the field and in the cellar, where wine aging is produced. The data is collected at a main unit in order to process inferences that suggest timely interventions that preserve the grapes quality.

Rwan Mahmoud [17], Chen XianYi, Jin Zhi Gang, Yang Xiong [33] describes the security issues of Internet of Things which are directly related to the wide application of the system. Beginning with the architecture and features of IOT, expands many security issues that exist in three layered architectures, and came up with solutions to the issues. The safety measures concerned with it, the ones about perception layer are particularly viewed, including algorithm and key management, security routing protocol and data fusion technology, as well as authentication and access control, etc.

Dragoş Mihai Ofrim [18], Zulhani Rasin, Hizzi Hamzah Mohd, Shahrieel Mohd Aras [24] designed an improved system for environmental monitoring and controlling in terms of efficiency, flexibility and performance. Some parameters that have been taken into consideration are resolution, accuracy, acquisition rate, energy consumption, flexibility etc., The designed system allows multi-point monitoring at any location, without any need of wired connection and have intelligent sensors. The measuring point density offers high accurate data even from the remote locations. A split is created, in terms of physical connection, between the measuring, monitoring and control parts, making the system extremely flexible. The disadvantage of this system is regarding power consumption, which is a key factor of wireless sensor networks. Therefore, the sensor nodes require a good resource management in network. This paper uses Zig bee protocol. Improvements and further developments of this system predicts: alternative energy resources, algorithms for energy saving, increased connectivity and reduced traffic. To monitor the parameters from a greater distance, this system could be

supplied with GSM or Wi-Fi transmitters, to be able to transfer the information through existing telecommunication networks.

Rachel Cardell-Oliver [19] described the design and implementation of a reactive event driven network for environmental monitoring of soil moisture and evaluates the effectiveness of this solution. A novel feature is to create a solution is its reactivity to the environment: when rain fall sand soil moisture is changing rapidly, measurements are collected frequently, whereas during dry periods between rainfall event measurements are collected much less often. allows to focus on dynamic responses and limit the amount of useless data gathered, as well as improving robustness and network lifetime. The main aim of this experiment is to demonstrate a reactive sensor network that can deliver useful data on soil moisture responses to rainfall. The Pin-jar network meets the goal of providing useful data on dynamic responses of soil moisture to rainfall. Future work will focus on addressing the limitations of the in robustness of packet delivery and network longevity, and in guaranteeing network response to events of interest. Authors plan to generalize event-condition-action framework for programming reactive sensor networks.

Duan Yan-e [20] explained that agricultural information technology (AIT) is widely applied to every part of agriculture and is going to become the most efficient means and tool for enhancing agricultural production and for making use of complete agricultural resources. Agriculture Information Management affects the range of agricultural information and the efficiency of agricultural production. In this experiment, on the count of introducing the concept of agricultural information management and analyzing some of the features of agricultural data, the design method and architecture of Intelligent Agriculture MIS were designed in detail, finally, the proposal gives an implementation illustration of the system in agricultural production.

Fiona Edwards Murphy [21] proposed system uses Wireless Sensor Network (WSN) technology to monitor a honeybee colony and collect information about the activity within a beehive as well as its surrounding area. The project uses low-power WSN technologies, including novel sensing techniques, energy-neutral operation, and multi-radio communications including cloud computing to monitor the conditions within the colony. WSN is a modern new technology, it is an important concept of the Internet of Things. A complete solution is presented including a smart hive communication with data aggregation and visualization tools. Future work will focus on improving the energy performance of the system, introducing a more specialized set of sensors, implementing a machine-learning algorithm to extract meaning from the data without136 human supervision; and securing additional deployments of the system.

In [43], the authors have proposed an irrigation system that assists to diminish water wastage and mechanizing the water system structure for huge regions of cropland. The system evaluates the necessity of water in the crop based on the behavior of atmospheric temperature, humidity, and soil moisture. The framework utilizes a machine learning technique and contrasts sensed values acquired from sensors and limits values that have been given to machine learning for further analysis. After this procedure, the ML algorithm cross-checks the outcome acquired with the weather forecast and afterward provides a decision on whether water supply should be done or not [44]. The user gets an immediate notification on his mobile phone and he can decide to turn on the water supply with a simple click. Also, the framework has a web application and is useful if at any point the user needs to see the analytical sensor information and evaluate the changes in sensor readings all through a timeframe. Moreover, the framework can be aligned for various sorts of plants, that is, the client is given a list of plant decisions in his web application and mobile application [45]. With this, the farmer can pick the particular sort of plant that is being cultivated and get an increasingly exact threshold limit and in this manner a progressively precise irrigation prediction. In addition, an SMS alert can be coordinated by chance there is no web access. With this, the client would be informed about the predictions utilizing an SMS and he can decide to turn on or off the water supply to the crop by answering the SMS that the user received.

In [46], the authors have introduced IoT to detect the physical data and send it to the user. They also highlighted methodologies that can be utilized to provide solutions to different problems like recognizing rodents, and several risks to crops. IoT device is developed using python scripts, which can send a notification with no human interference.

In [47], the authors have discussed the concepts of web services and IoT which have a great capacity in handling the huge data regarding the cultivation field by using the concept of the internet of things and other web services. This combination of cloud services and IoT has advanced quickly and also contributed a lot to developing numerous smart solutions for the problems in agricultural fields as well as problems faced by the farmers, very productively [48]

In [49], the authors proposed an intelligent water system that will go about as a benefit by optimizing the water system while showing the issue of water deficiency by initiating optimal utilization of water through modernized IoT-based procedure. The brilliant irrigation module can be altered to the particular need of different yields. This information can be put away on the server

[50]. Given the harvest chosen by the farmer on the mobile apps, information would be retrieved from the servers and the framework would modify itself accordingly, bringing about an efficient irrigation system and expanded yields

3. RESEARCH GAP

3.1 Agricultural Automation And Robotics: (PRESENT APPLICATIONS)

In agriculture, the automation of specific operations has enabled the farmers to manage crop production efficiently with less energy and cost. Factors such as the lack of agricultural workers in addition to the aging farmer population and the increasing agricultural wage have made the farmers and researchers play interest in the development of automation systems in agriculture. The implementation and development of agricultural automation have been executed by autonomous robots and agricultural types of machinery such as tractors which are usually attached with cultivators, planters, cultipacker, and chisel plows.

Figure 1 shows several agricultural robots and types of machinery which require automation to enhance the efficiency of the agricultural operation.

Based on Figure 1, the application of automation and robotics in agriculture can be varied significantly. The execution of agricultural operations needs to be executed by different robotics and vehicle structure based on the type of land and operation requirement. Different robot and vehicle structures had its limitation that need to be solved by using other types of machinery. The robotic structure cannot execute extreme operations in agriculture due to its sensitive characteristic toward water and mud. Therefore, the tractor is being used to execute such a task due to its great ability to traverse inside the muddy structure and less protection against electronic circuits. On the other hand, tractor applications are only limited to a wide area due to their large structure. Thus, the application of the small area needs to be executed by a mobile robot. For drone application, it is only applicable to open areas and its application would be insignificant to a closed area such as the greenhouse as the probability of collision will be increased. To explore more the present application of automation and robotics in agriculture, the categorization was made based on the different agricultural operations.

Figure 1. Agriculture robot and machineries (a) BoniRob [23] (b) Shrimp robot [24](c) Chisel cultivator [25] (d) DJI AGRAS MG-1S Drone sprayer [26](e) Combined harvester [27]

3.1.1 Planting

Planting is the process of putting seeds or young plants into the ground to begin the growth phase of the plant. This procedure necessitates a higher level of precision because various plants require varied distances between them to optimize growth and output. A farmer must physically insert each seed into the soil in the traditional planting process. This method necessitates a significant amount of time and effort because the process requires a high level of consistency and precision, and it typically spans a large agricultural area. As a result, a planter machine has been invented, in which the farmer will operate the machine by controlling the machine. The machine will not be in a straight line, and there will be certain regions where the planter will be unable or miss planting the seed. As a result, an efficient autonomous system is required that ensures the production of a straight-line plant row and does not miss any seed planting. motion while simultaneously planting the seed into the soil. Figure 2 depicts the planters that have been built for the planting of various plants. As shown in Figure 2, the designed planter is normally pulled behind a tractor and used to plant seeds in a repetitive action. Because the tractor and planter are operated by humans, the row's consistency will be impacted because the row will not be in a straight line and there will be some locations where the planter is unable or misses to plant the seed. As a result, an efficient autonomous system is required that will ensure that a straight-line plant row is produced and that no seed planting is missed.

Figure 2. Planters (a) Single-seed corn planter [28], (b) Minimum-tillage planter [29], (c) Billet planter [30]

3.1.2 Inspection

In agriculture, inspection refers to the process of inspecting or observing plants for diseases or quality flaws. Plant diseases are the primary cause of reduced productivity in agriculture, which results in economic losses. Because the agricultural environment is so dynamic, plants and their products have been affected by a variety of unexpected and typical stress scenarios such as changes in temperature, humidity, water levels, disease outbreaks, and pests. Farmers have typically used their human vision system to manually inspect plant anomalies to carry out the inspection. Farmers' ages have risen in recent years, reducing the efficiency of inspection operations since the quality of the human vision system deteriorates with age. Furthermore, the adoption of agricultural inspection automation necessitates the development of a system to replace the ability of human vision to carry out the inspection process. As a result, computer vision is increasingly being used to replace human vision in agricultural plant inspection.

3.1.3 Spraying

In agriculture, spraying is a common way of administering pest-control chemicals, fertilizers, or growing media to plants in the form of a fine mist for disease treatment and plant growth management. To limit the spread of illnesses, pest control chemicals are normally administered consistently over the fields in most farming operations. Even though several pests and illnesses have an uneven spatial distribution, especially during the early phases of development, this strategy is used.

As a result, in the last two decades, selective spraying has been developed and explored to reduce the cost of pest-control chemicals used in agricultural operations. The automated selective spraying technique, which is normally carried out by highly automated equipment or mobile robots, allows pesticide application to be targeted only where and when it is needed. The major goal of this targeted operation is to reduce pesticide usage while also avoiding the development of infection and subsequent epidemics across the greenhouse.

3.1.4 Harvesting

Harvesting is the process of gathering agricultural goods to be processed or sold in agriculture. The fruits or vegetables must be collected and stored for further processing or sold directly to the buyers to run this operation. This method is recognized as a time-consuming and labor-intensive process since it necessitates extensive observation and a repeating operation.

As a result, throughout the last few decades, the development of autonomous harvesting systems has been extensively pursued.

Several implementations for various types of crops have been done in the last few years, including strawberry, apple, tomato, kiwi, capsicum, grape, litchi, citrus pumpkin, and heavyweight crop. The majority of implementations are aimed at improving the accuracy of harvesting systems by proposing a variety of approaches and methods, each with its software and hardware architecture.

3.2 Communication Technologies In IOT Based farms

According to a survey of IoT communication technologies [31,32], communication technologies must gradually improve the evolution of IoT devices to incorporate IoT into the smart agriculture sector. They have a significant impact on the development of IoT systems. Protocol, spectrum, and topology are the three types of extant communication systems.

Protocols: For the smart agriculture sector, several wireless communication protocols have been developed. Devices in a smart agricultural system can communicate, exchange information, and make decisions based on these protocols to monitor and control farming conditions and increase yields and production efficiency. Based on the communication range, the common low-power communication protocol numbers used in smart agriculture may be split into short-range and long-range categories.

- Short-range: NFMI (near-field magnetic induction) [33], Bluetooth [34], ZigBee [35], terahertz (Z-Wave) [36,37], and RFID [38].

- Long-range: LoRa [39], Sigfox [40], and NB-IoT (Narrowband IoT) [41]

Table 1 shows some of the most common communication technologies used in smart agriculture. Short-range communication technologies have a transmission distance of less than 20 (m), a high energy efficiency, and a low data rate, according to the values in Table 1.

Long-range communication systems, on the other hand, have transmission distances of up to many tens of kilometers, require more energy, and are installed for backhaul device-to-device connections. Sundaram et al. give a diverse assessment of low-power communication technologies for IoT that includes solutions, problems, and some outstanding topics. [42]

Table 1. Some typical communication technologies for smart agriculture.

Type	Spectrum	Transmission Distance	Type of Network	Frequency	Data Rate
802.11a/b/g/n/ac	Unlicensed	100 m	WLAN	2.4–5 GHz	2–700 Mbps
802.11ah	Unlicensed	1000 m	WLAN	Several Sub-GHz	78 Mbps
802.11p	Licensed	1 km	WLAN	5.9 GHz	3–27 Mbps
802.11af	Licensed	1 km	WLAN	54–790	25–550 Mbps
SigFox	Licensed	Rural: 50 km Urban:10 km	LPWA	Zwave	100–600 bps
LoRaWAN	Licensed	20 km	LPWA	Several Sub-GHz	0.3–100 kbps
NB-IoT	Licensed	35 km	LPWA	Zwave	250 kbps
LTE-3GPP	Licensed	5 km	WWAN	1.4 MHz	200 kbps
EC-GPRS	Licensed	5 m	WWAN	GSM bands	240 kbps
WiMAX	Hybrid	50–80 km	WWAN	Several Sub-GHz	70 Mbps
Bluetooth	Unlicensed	100 m	WPAN	2.4 GHz	2–26 Mbps
ZigBee	Unlicensed	1 km	WHAN	2.4 GHz	250 kbps
Z-Wave	Unlicensed	100 m	WHAN	900 MHz	100 kbps
6LoWPAN	Unlicensed	30 m	WHAN	Zwave	250 kbps
NFC	Unlicensed	20 cm	D2D	13.56 MHz	424 kbps

4. OBJECTIVE

Every aspect of traditional farming processes can be significantly transformed by incorporating the latest sensor and IoT technologies into agricultural practices. Currently, the seamless integration of wireless sensors and the Internet of Things in smart agriculture can take agriculture to previously imagined heights. IoT can help to enhance the answers to many traditional farming challenges, such as drought response, yield optimization, land appropriateness, irrigation, and insect management, by implementing smart agriculture methods. A hierarchy of important applications, services, and wireless sensors utilized in smart agriculture applications is shown in Figure 3. Integrating Machine Learning in this architecture will not just inform us about the stated problems but also help us monitor the crop and follow the data and predict how the crop will perform but also provide solutions when any irregularities occur.

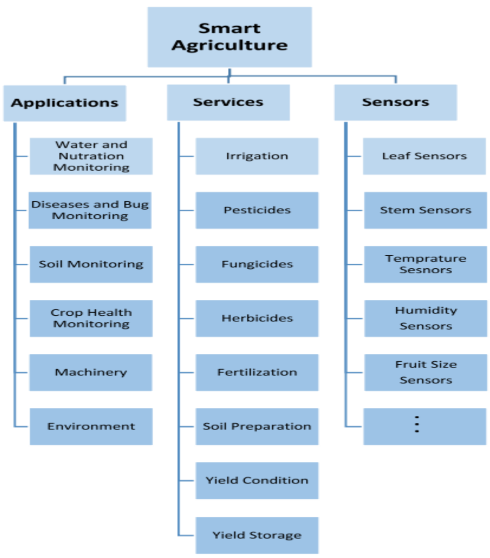


Figure 3.

5. IMPLEMENTATION

5.1 Implementation of IoT Ecosystem.

We propose a common architecture for an IoT ecosystem for smart agriculture in this part, which is made up of three key components: IoT devices, communication technologies, and data processing and storage solutions. Figure 4 shows an illustration of the IoT ecosystem for smart agriculture.

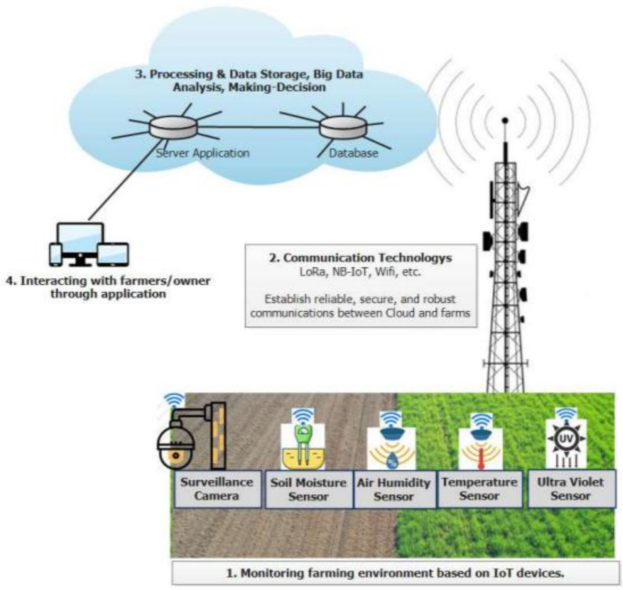


Figure 4. An illustration of IoT ecosystems' architecture for smart agriculture

Sensors to collect data from the environment, actuators with wired or wireless connections, and an embedded system with a CPU, memory, communication modules, input-output interfaces, and battery power are all standard components of an IoT device. Figure 5 depicts the common architecture of a typical IoT device for smart agriculture.

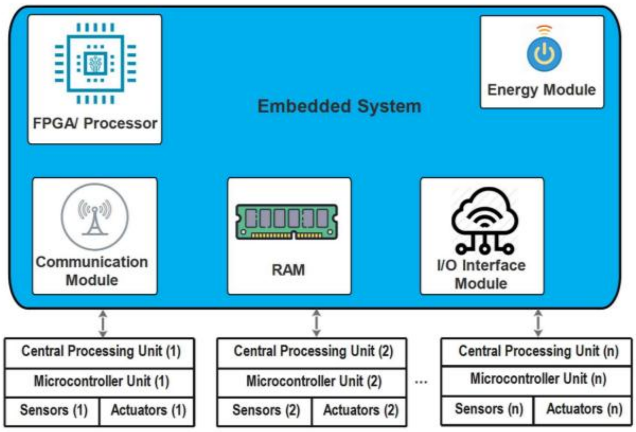


Figure 5. An illustration of the common architecture of an IoT device

5.2 Machine Learning

Using supervised Machine Learning algorithms, previously labeled data with known responses are supplied to the machine to understand the patterns involved. It examines several types of data, as well as the answers to various problems, to discover a pattern. This stage is known as data training. The more data there is, the more precise the results will be. Testing the data is the next step in supervised machine learning. In this step, the machine is given a problem to solve, and the machine, knowing the pattern of solving the problem and the various replies, provides the most appropriate answer.

The result's accuracy will be determined by the amount of the data, the algorithms employed in the data, and several other aspects such as noise and outliers in the data used as training input. The two most important steps in any classification are learning and prediction. In the learning process, the model is built using the feed training data. In the prediction step, the model should forecast the results based on the training data. A decision tree algorithm, an efficient categorization system, can be used to perceive and interpret data.

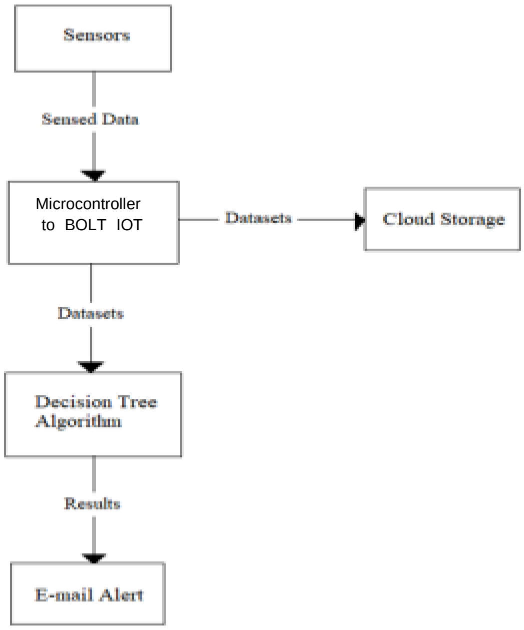


Figure 6. Data Flow Diagram

The data flow diagram represents the direction of flow of data regarding a system. It provides inputs and output of the entities present in the system. The data flow model for the proposed system is as in Figure 6.

5.2.1 Algorithm

- The decision tree algorithm is one of the most efficient and simple algorithms among the supervised learning family of algorithms.
- The decision tree algorithm is used to solve several regression and classification problems, unlike the other algorithms in supervised learning.
- The main objective of the decision tree algorithm is to train the model which can predict the value or class of the target variable by generating clear and uncomplicated decision rules derived from the previous data i.e., training data.
- To predict a class label of a record, it is required to start from the first node which is root node of the decision tree. The record's attribute should be validated with the values of every root attribute.
- Based on the validations, a path containing branches is followed with the matching value and jumps to the succeeding node as shown in figure 7.

Terminology in decision trees are:

- Root node: It is a starting node or a parent node that is divided into two or more analogous sets.

- Leaf node: These are lower-level nodes of the tree which doesn't split further.

- Decision node: It is a sub-node splitting into more sub-nodes.

- Splitting: It is the process of splitting a node into more nodes.

- Pruning: removing of sub-nodes, reverse process of splitting.

- Sub-tree/Branch: It is a part of an entire decision tree. Child node: The node evolved from the parent node by splitting.

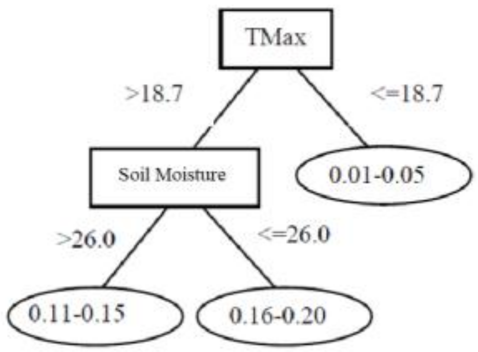


Figure 7. Sample Decision Tree

5.2.2. Architecture

The main components of the proposed system architecture are temperature, soil moisture, humidity, light, water level, rain sensors, Bolt IOT kit, and Arduino Uno microcontroller.

- BOLT IOT plays a central role in the system by providing storage to the datasets and hosting a web server.

- All the sensors are deployed in the field and are connected to Arduino UNO as shown in Figure 8.

- The data sensed through these sensors are sent to Arduino Uno and processed in it and then via Bolt IoT Wifi Module sent to the Bolt IOT cloud.

- Decision tree algorithm is applied to the datasets to predict the accurate results

. • The result is sent to the farmer through an email/Sms containing all the updates of the farm.

- All data sent from the sensors to the Arduino UNO and then to the Bolt IoT are stored in a cloud database for future use.

5.2.3. Dataset

Datasets containing values of temperature, humidity and soil moisture, water level are loaded into the decision tree algorithm. These datasets contain values of different scenarios in the fields to train the model accurately. The temperature is Celsius, and humidity and soil moisture are represented in percentages. Sample datasets areas show in Table 2.

Table 2. Sample Datasets

S.No.	Temperature (°C)	Humidity (%)	Soil Moisture (%)
1	36	76	81
2	40	85	70
3	39	73	72
4	41	79	71
5	44	73	65
6	43	75	76
7	36	73	69
8	38	62	48
9	47	67	74
10	51	69	58
11	53	67	45
12	48	93	57
13	49	90	35
14	29	76	67
15	31	74	64

5.3 Anomaly Detection

Anomaly detection is the process of locating unusual things or events in data sets that are out of the ordinary.

Anomalies in simple graph representations can be easily spotted by setting thresholds, e.g.

But what about visualizations in which thresholds aren't possible to set?

A technique for detecting anomalies is Z-score Analysis.

Essentially, the Z-score is used to compute limits, or upper and lower bounds, for plotted data.

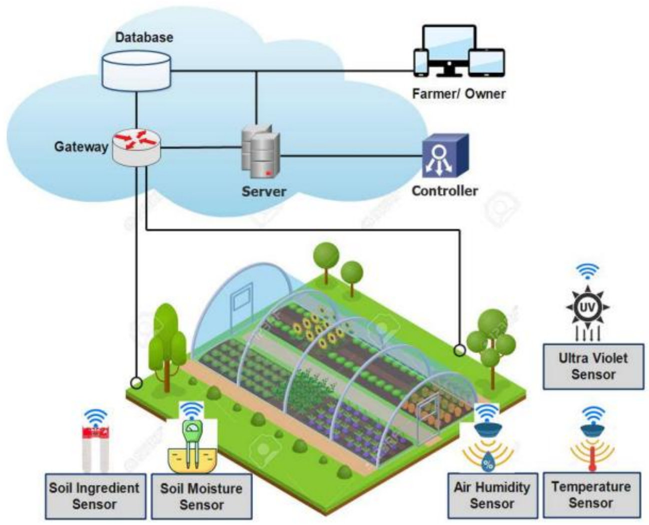


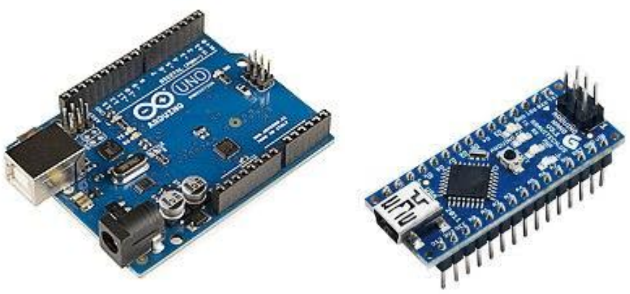
Figure 10. An illustration of a fully automated IOT-based indoor farm ecosystem.

6. DESIGN AND ARCHITECTURE

6.1 Arduino Uno

The Arduino Uno is a Microchip ATmega328P-based open-source microcontroller board created by Arduino.cc. The board has digital and analog input/output (I/O) pins that can be used to connect to different expansion boards (shields) and other circuits. The board contains 14 digital I/O pins (six of which can be used to generate PWM output) and 6 analog I/O pins, and it can be programmed using the Arduino IDE (Integrated Development Environment) and a type B USB connector. It can be powered by a USB cable or an external 9-volt battery, and it can handle voltages ranging from 7 to 20 volts. It resembles the Arduino Nano and Leonardo in appearance.

The hardware reference design is available on the Arduino website under a Creative Commons Attribution-Share-Alike 2.5 license. Some versions of the hardware have layout and production files available.



6.2 BOLTIOT kit

For the Bolt Devices connected to your account, the Bolt Cloud API provides an interface for connection between the Bolt devices and any 3rd party system control, monitoring, communication, and utility services. The Bolt Cloud API makes use of mobile apps, web servers, and Python programmes, among other things. The API employs the HTTP GET and HTTP POST methods to communicate and uses a very user-friendly HTTP protocol. As a result, users can programmatically execute operations and obtain data from Bolt devices using standard HTTP requests.

Here are a few examples of how the API can be used:

To control and monitor Bolt devices over the Internet, use the API in native iOS and Android apps.

To execute your unique AI algorithms and analytics, pull sensor data and connect it to a Bolt device or any other cloud.

Use Bolt Cloud to connect to any VPS (Virtual Private Server) and run your code in any language. Refer to the code examples.

Remote Operating System: Using the API, Bolt devices can function similarly to a board with an operating system, such as the Raspberry Pi or Beagle Bone, with the exception that the operating system will be hosted on a remote VPS (Virtual Private Server). The Bolt will collect data from the sensors and send it to a Linux-based VPS. The processing will take place on the VPS, which will send commands to the Bolt device to control motors, LEDs, and actuators. In this type of system, you can use all of the capabilities of a Linux OS.

6.3 LM35 Temperature Sensor

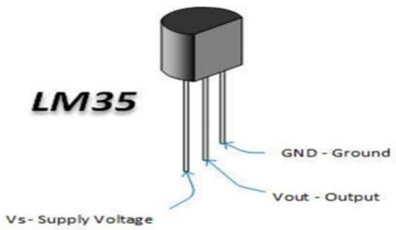
The system's functioning premise is straightforward. Allow me to explain.

The LM35 sensor in our system detects the temperature of its surroundings and creates an analogue output voltage based on its value. The LM35's analogue voltage is then fed into the Bolt A0 pin as an input. The Bolt then converts the analogue value to a ten-bit digital number between 0 and 1023. The Bolt device sends this digital data to the cloud.

As a result, while plotting the temperature, the raw sensor results must be converted into the real temperature value, which is done using the following formula:

*temp = (analog_value*100)/1023*

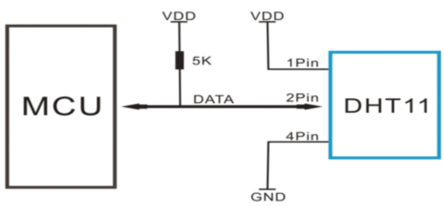
The converted digital data is then plotted for visual representation.



LM35 Pin	Corresponding Bolt WiFi Module Pin	Comment
Vs Supply Voltage	5V	LM35 sensor operates at 5V
Vout - Output	A0	Since the output is analog and A0 is the only pin on Bolt WiFi module that can read an analog input.
GND Ground	GND Ground	The ground pin of the LM35 to be connected to the ground pin of Bolt WiFi module.

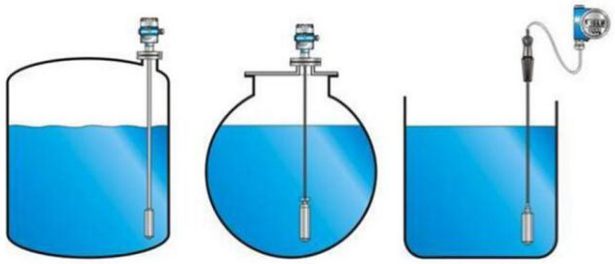
6.3 DHT11 Sensor

Parameters	Conditions	Minimum	Typical	Maximum
Humidity				
Resolution		1%RH	1%RH	1%RH
			8 Bit	
Repeatability			±1%RH	
Accuracy	25℃		±4%RH	
	0-50℃			±5%RH
Interchangeability	Fully Interchangeable			
Measurement Range	0℃	30%RH		90%RH
	25℃	20%RH		90%RH
	50℃	20%RH		80%RH
Response Time (Seconds)	1/e(63%)25℃, 1m/s Air	6 S	10 S	15 S
Hysteresis			±1%RH	
Long-Term Stability	Typical		±1%RH/year	
Temperature				
Resolution		1℃	1℃	1℃
		8 Bit	8 Bit	8 Bit
Repeatability			±1℃	
Accuracy		±1℃		±2℃
Measurement Range		0℃		50℃
Response Time (Seconds)	1/e(63%)	6 S		30 S



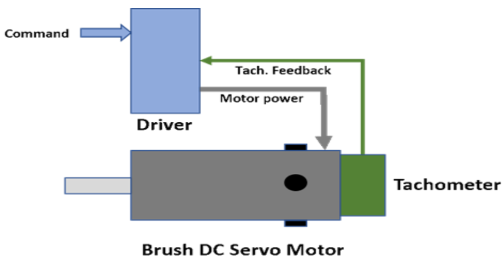
6.4 Water Level Sensor

The water level sensor is a device that detects an excessively high or low liquid level in a stationary container. It can be classified into two sorts based on how the liquid level is measured: contact type and non-contact type. A contact measurement is an input type water level transmitter that turns the height of the liquid level into an electrical signal for output. It's a frequently utilised water level transmitter right now.



6.5 Servo Motor

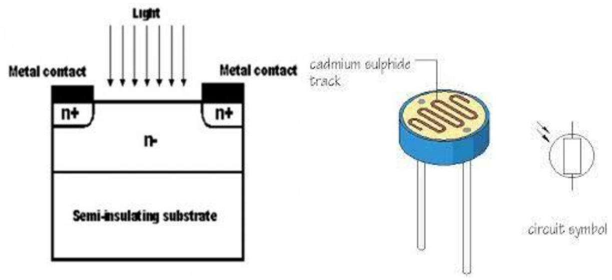
A servo motor is an electromechanical device that uses current and voltage to produce torque and velocity. A servo motor is part of a closed loop system that provides torque and velocity as directed by a servo controller and is closed by a feedback device. The feedback device provides information to the servo controller, which modifies the motor action based on the commanded parameters, such as current, velocity, or position.



6.6 LDR Sensor

An LDR's operating principle is photoconductivity, which is nothing more than an optical phenomena. When light is absorbed by the substance, the material's conductivity improves. When light shines on the LDR, the electrons in the material's valence band rush to the conduction band. However, the photons in the incident light must have more energy than the material's bandgap in order for the electrons to jump from one band to the next (valance to conduction).

As a result, when light has a lot of energy, more electrons are stimulated to the conduction band, resulting in a lot of charge carriers. The resistance of the device diminishes as the effect of this process becomes more apparent and the current flow increases.

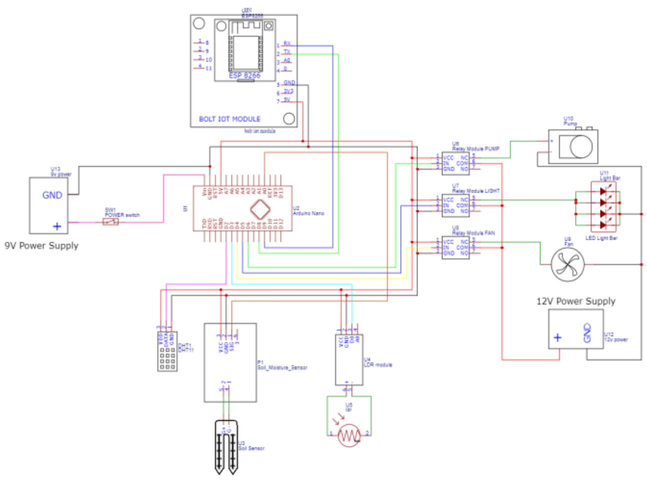


6.7 Software Implemented

Arduino ide – it is an open source development environment which helps us with using Arduino uno/ nano/ mega and many other types of Arduino for different projects. It provides us with a coding environment and it comes with pre loaded libraries and other libraries can also be installed. It has a very user friendly environment.

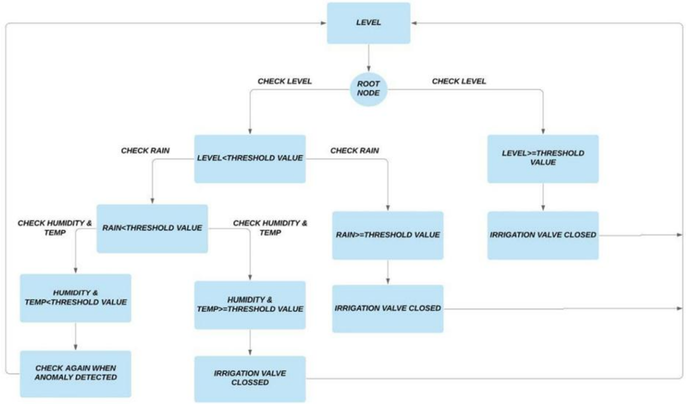
6.8 BoltIOT Cloud

It helps us with managing different projects at the same time and also comes with real-time data monitoring system. It also provides us with a coding environment that helps us in visualizing the data.



6.9 Decision Tree

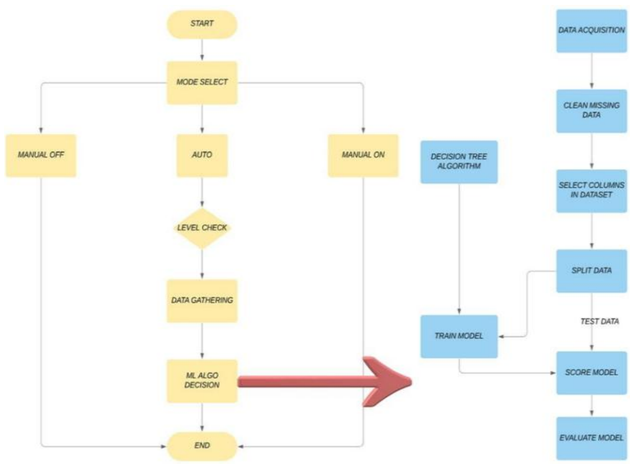
The Decision Tree algorithm is part of the supervised learning algorithms family. The decision tree approach, unlike other supervised learning algorithms, may also be utilized to solve regression and classification issues. The purpose of employing a Decision Tree is to develop a training model that can be used to forecast the class or value of the target variable by learning basic decision rules inferred from prior data (training data). We start at the root of the tree when predicting a class label for a record. The values of the root attribute and the record's attribute are compared.



The examples are classified using decision trees by sorting them down the tree from the root to a leaf/terminal node, with the leaf/terminal node providing the classification.

Each node in the tree represents a test case for some property, with each edge descending from the node corresponding to the test case's possible solutions. This is a cyclical procedure that occurs for each subtree rooted at the new node.

6.10 Data Flow



6.11 Polynomial Regression

Polynomial Visualizer is a popular data analytics/machine learning algorithm for fitting a non-linear curve to a given data collection. The trend can then be utilized to figure out where further data points may be found. The Visualizer is designed to assist you in determining whether Polynomial Visualizer is the best option for your ML system, and if it is, the Visualizer will assist you in determining the best potential parameters to utilize with the Visualizer model.

Data (t) = (Cn*tn) + (Cn-1*tn-1) + (Cn-2*tn-2) + …………. (C1*t1) + C0

which most closely resembles the trend in the input data. This number tells the Visualizer how many elements should be present in the function i.e. the value of n.

6.12Code

6.12.1 Arduino code (Data Collection)

```
#include "DHT.h"
#include <boltiot.h>
#include <BoltDeviceCredentials.h>
#define DHTPIN 7
#define DHTTYPE DHT11

#include <Servo.h>
#ifndef API_KEY
#define API_KEY     "boltcloudAPI"
#endif
#ifndef DEVICE_ID
#define DEVICE_ID "boltdeviceid"
#endif

int servoPin = 3;
Servo Servo1;
DHT dht11(DHTPIN , DHTTYPE);
String getAnalogData(String *data){
    String retval="";
    retval=retval+analogRead(A1);
    return retval;
    //Serial.read();
}
String getLDR(String *data){
    String LDR="";
    LDR=LDR+analogRead(A5);
    return LDR;
}
String getRain(String *data){
    String r="";
    r=r+analogRead(A3);
    return r;
}
String getTemp(String *data){
    String value = "";
int chk = dht11.read(DHTPIN);
    value = value+ (int)dht11.readTemperature();
    return value;
    }
String getHum(String *data){
    String value = "";
int chk = dht11.read(DHTPIN);
value = value+ (int)dht11.readHumidity();
    return value;
    }
void setup () {
    Serial.begin (9600);
    Servo1.attach(servoPin);
    pinMode(A1,INPUT);
    pinMode(A5,INPUT);
    pinMode(A3,INPUT);
    Serial.setTimeout(500);
    boltiot.begin(Serial);
    boltiot.setCommandString("Level",getAnalogData);
    boltiot.setCommandString("LDR",getLDR);
    boltiot.setCommandString("Rain",getRain);
    boltiot.setCommandString("getHum",getHum);
    boltiot.setCommandString("getTemp",getTemp);
```

```
    }
void loop() {
    boltiot.handleCommand();
}
```

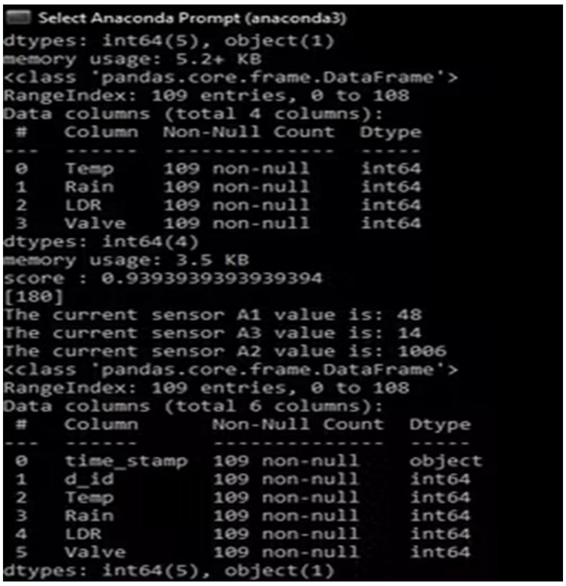
7. RESULTS AND DISCUSSION

After applying the decision tree algorithm to the sensed datasets, an output containing the decision to water the crop is made. This output containing the decision is sent to the users or farmers through an Electronic mail (E-mail) using the simple mail transfer protocol. T

The two types of decisions are named Yes and No.

a) If the algorithm predicts the result as yes, then an alert is sent to the farmer as shown in Figure 9.

b) If the algorithm predicts the result as no, then an alert is sent to the farmer as shown in Figure 10.



```
Select Anaconda Prompt (anaconda3)
dtypes: int64(5), object(1)
memory usage: 5.2+ KB
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 109 entries, 0 to 108
Data columns (total 4 columns):
 #   Column  Non-Null Count  Dtype
---  ------  --------------  -----
 0   Temp    109 non-null    int64
 1   Rain    109 non-null    int64
 2   LDR     109 non-null    int64
 3   Valve   109 non-null    int64
dtypes: int64(4)
memory usage: 3.5 KB
score : 0.9393939393939394
[180]
The current sensor A1 value is: 48
The current sensor A3 value is: 14
The current sensor A2 value is: 1006
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 109 entries, 0 to 108
Data columns (total 6 columns):
 #   Column      Non-Null Count  Dtype
---  ------      --------------  -----
 0   time_stamp  109 non-null    object
 1   d_id        109 non-null    int64
 2   Temp        109 non-null    int64
 3   Rain        109 non-null    int64
 4   LDR         109 non-null    int64
 5   Valve       109 non-null    int64
dtypes: int64(5), object(1)
```

Figure 9. E-mail alert for Water requirement

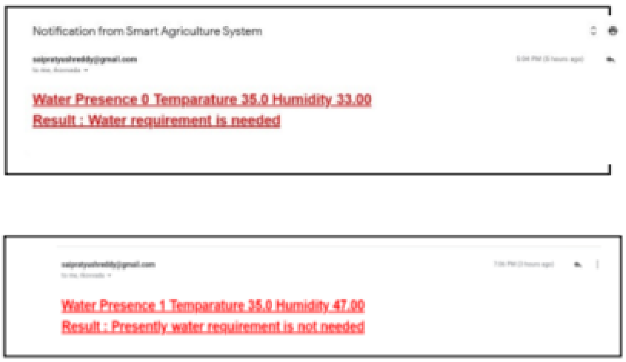


Figure 10. E-mail alert for No Water requirement

Prediction points: This number tells the Visualizer how many future data points need to be predicted.

No. Polynomial coefficients: Polynomial Visualizer processes the given input time-dependent data, and outputs the coefficients of the function of the form:

Frame Size: These are the number of previous data points the Visualizer will use to predict the trend of the data. For example, if you set this value to 5, the Visualizer will use the previous 5 points to predict the trend

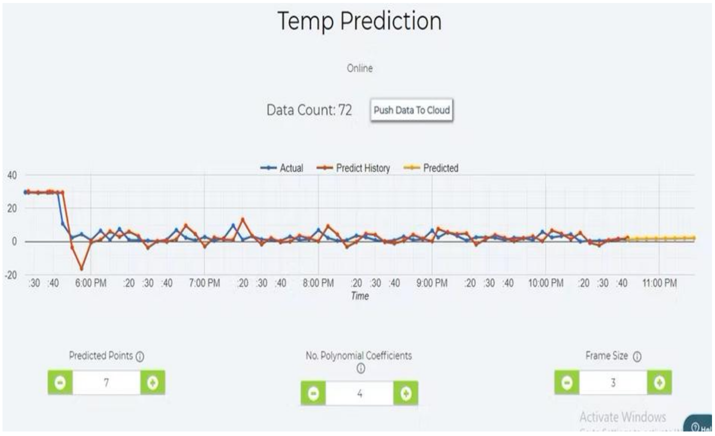


Figure 11. depicts the prediction, actual and predicted history of the input data and output of ML algorithm.

Following data will be utilized as a prediction for future anamoly and irregularities in the crop yield and thus will be helpful in taking early precautions accordingly.

Hence saving time , energy, money and labor of the farmer

8. CONCLUSION

We offered an overview of indoor farming utilizing IoT and machine learning in this paper. Several topics relevant to boosting IoT deployment in agriculture have been thoroughly examined. Many research has been conducted to utilize IoT for smart agriculture, to increase output, reduce human labor, and improve production efficiency, according to survey results. It highlighted the advantages of using IoT and big data in agriculture. We also discussed the obstacles that must be solved to expedite the use of IoT in smart agriculture. However, significant obstacles must be overcome before IoT solutions can be made cheap for the majority of farmers, especially small and medium-scale farms. Furthermore, security technologies must be upgraded regularly, but we believe that the use of IoT solutions and machine learning in smart agriculture is unavoidable and will increase productivity, supply clean and green foods, promote food traceability, minimize human labor, and improve production efficiency. On the other hand, The system was designed to learn from the data provided.

The file contains all of the data that has been sensed by the Sensors. By utilizing the decision tree learning algorithm is a member of the family of the real-world application of supervised machine learning methods.

It analyses time data and updates the farmer with the decision.

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