IOT AND MACHINE LEARNING BASED EFFECTIVE AGRICULTURE WITH REAL TIME PREDICTION

Abstract

This paper presents the design and implementation of an AI-based smart sprinkler system for automated irrigation and fertilization, integrated with plant disease prediction capabilities. The system utilizes deep learning algorithms for the early detection of plant diseases through analysis of leaf images. Upon detecting a disease, the system blocks fertilization to prevent exacerbation of the issue. Additionally, soil moisture sensors are employed to trigger irrigation when the soil is dry, ensuring optimal moisture levels for plant growth. The hardware components, including sprinklers, fertilizer dispensers, and sensors, are controlled by a microcontroller interfaced with the decision-making algorithm. The system operates by continuously monitoring soil moisture and plant health, making informed decisions to maintain plant vitality. Integration with a user-friendly interface enables real-time monitoring and adjustment of system settings. Extensive testing validates the system's reliability and accuracy under various environmental conditions. This AI-driven approach to irrigation and fertilization not only promotes efficient resource utilization but also facilitates proactive management of plant health, contributing to sustainable agriculture practices.

Keywords: IoT-Enabled Smart Greenhouse, Arduino-Based Environmental Monitoring, Soil Moisture and Climate Control, IoT Cloud Data Logging, Automated Greenhouse System

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I. INTRODUCTION

Modern agriculture uses modern technology such as AI and IoT to increase crop management efficiency and sustainability. AI-powered systems automate irrigation and fertilizing, and sensors monitor soil conditions. This precision saves resource waste and prevents plant diseases, increasing agricultural output. Self-powered sensors in smart irrigation systems allow for independent operation, which optimizes water utilization. Traditional farming is labor-intensive and inefficient, but incorporating technology can help address water scarcity and environmental concerns, supporting sustainable agricultural practices.

1. Problem Statement

Water is required for life, yet pollution from science and negligent waste management contaminates water bodies, endangering aquatic and dependant organisms. Manual cleaning is time-consuming and expensive.

2. Objective

Create a system to improve farm yield, predict ecological conditions for higher productivity, and maintain crop quality by monitoring soil moisture, temperature, and humidity levels. The system will have both automatic and manual modes, with irrigation monitored and controlled via a wireless sensor network.

3. Scope of the Project

Create a prototype for wireless remote control of home appliances using an Android app that includes switch-mode control, voice commands, and status monitoring. It is suitable for use in homes, offices, and shopping malls and allows for intra-network or internet control. The system uses technology to provide smart recommendations and optimize environmental conditions for increased productivity

4. Components

a. **DHT11 (Temperature and Humidity Sensor):** DHT11 is a low-cost digital sensor that measures temperature and humidity. This sensor connects to microcontrollers like Arduino and Raspberry Pi to measure humidity and temperature in real-time. The DHT11 humidity and temperature sensor is offered as both a sensor and a module. The pull-up resistor and the power-on LED distinguish this sensor from the module. DHT11 is a relative humidity sensor. This sensor makes use of a thermistor and a capacitive humidity sensor to measure the air around it.

Figure 1: DHT11

b. **HI-Link AC-DC Converter:** As a result, power supplies are sometimes known as electric power converters. The Hi-Link Power Supply Module is an isolated switching power supply module installed on a PCB with a plastic enclosure. It is widely utilized in the smart home, automation and control, communication equipment, instrumentation, and other fields.

Figure 2: HI-LINK AC-DC CONVERTER

c. **Soil Moisture Sensor:** The soil moisture sensor is one type of sensor that measures the volumetric content of water in the soil. As the direct gravimetric dimension of soil moisture requires elimination, drying, and sample weighting. These sensors assess volumetric water content indirectly, using soil properties such as dielectric constant, electrical resistance, interaction with neutrons, and moisture content replacement.

Figure 3: SOIL MOISTURE SENSOR

d. **Voltage Regulator 7805:** A voltage regulator is a system that uses an electromechanical mechanism or electronic components to regulate one or more alternating current (AC) or direct current (DC) voltages. It can use a simple feed-forward design or a negative feedback system.

Figure 4: VOLTAGE REGULATOR 7805

e. **Toggle Power SPDT Switches:** SPDT Toggle Switch is a three-terminal switch, only one is used as input other two are as output. Therefore, we get two outputs, one from COM and A and second is from COM and B, but only one at a time. Mainly it is used in three-way circuit to turn ON/OFF an electrical appliance from two location.

Figure 5: TOGGLE POWER SPDT SWITCHES

f. **Ardunio Uno Board:** The Arduino Uno R3 is a microcontroller board that uses the ATmega328 AVR microcontroller, which is detachable and dual-inline-packaged (DIP). It features 20 digital input/output pins (6 PWM outputs and 6 analog inputs). It may be programmed using the simple Arduino software. The Arduino has a large support network, making it a simple method to start working with embedded electronics. The R3 is the third and most recent revision of the Arduino.

Figure 6: ARDUNIO UNO BOARD

II. LITERATURE SURVEY

The following shows a survey done for dual home automation for with and without internet on Realtime which includes an instant feedback mechanism that drives the appliances. This system is reliable to integrate on multiple platforms with the help of ESP32 master which serves as standard firmware. Further, the study was extended to multiple operation platforms like Linux, Windows, and IOS are discussed as follows. In this detailed survey, we have learned a lot in stabilizing our concepts from the existing feedback mechanisms that were designed in the previous study,

Mohamed A. Ragab, Abdelrhman Sedhom "IoT BASED SMART IRRIGATION SYS-TEM", International Journal of Industry and Sustainable Development (IJISD) 2021.

This paper describes the development of a smart home automation controller that uses IoT to convert household items into smart devices. The system uses Node MCU, IFTTT for voice commands, Adafruit for MQTT, and the Arduino IDE for coding. It connects to a 24-hour Wi-Fi network that includes automatic reconnection and power backup.

Shweta B Saraf, Shaunak Oke, Parth "IoT Based Smart Irrigation Monitoring and Con-trolling System", International Conference on recent Trends in Electronics Information and Communication Technology (IRTEICT) 2020.

This paper describes an Internet of Things-based home automation system that includes a security camera module. An Android app turns cellphones into appliance remotes, with motion sensors sending out real-time notifications. The system is built on a Raspberry Pi server and includes modules for home automation and security.

Kiranmai Pernapati "IoT based low Cost Smart Irrigation System", International Con-ference on Inventive Communication and Computational Technologies (ICICCT), 2021.

This study suggests improving household power consumption with PLC (Power Line Communication) and a Zigbee and PLC-based renewable energy gateway for monitoring energy generation. The ACS and DDEM algorithms create intelligent power management systems to ensure a constant power supply. Power supply models divide home sensor networks into groups for effective administration, with the goal of developing a real-time processing strategy for different sensor network topologies.

Amogh Jayaraj Rau "IoT Based Smart Irrigation System and Nutrient Detection with Disease Analysis", International Journal of Innovative Research in Physics, 2021.

This research provides a technique for reducing computing overhead in smart home solutions by leveraging encryption technologies such as AES and ECHD. It automates devices using sensor-based learning, allowing for autonomous functioning without human involvement. By bypassing local gateways, the system improves security while reducing computation overhead. The real-time broker cloud handles all requests from users and devices.

K.N. Bhanu; H. S. Mahadevaswamy; H. J. Jasmine, "IoT based Smart System for Enhanced Irrigation in Agriculture", Procedia Computer Science Transactions on Mobile Device, 2022.

The Internet of Things (IoT) in agriculture connects devices to send data and control processes autonomously. IoT advances smart farming by upgrading information and communication. Sensors monitor important parameters like as soil type, moisture, nutrients, temperature, light, and oxygen, and send data to the cloud for analysis. This helps farmers to make better judgments. The proposed solution, which was built on the ThingSpeak IoT cloud platform, demonstrated superior performance for increased crop growth.

Mrs. Paul Jasmin Rani, Jason Bakthakumar, Praveen Kumar B, Praveen Kumar U. Santhosh Kumar. "Voice Controlled Home Automation System using Natural Language Processing and Internet of Things", INCC Transactions on National Security Science and Computa-tion, 2018

This article discusses a voice-based home automation system that uses IoT, AI, and NLP to operate home appliances at a reasonable cost. The prototype employs an Arduino MK1000, allowing users to interface with appliances through voice instructions. The appliances are linked to a mobile device using an Arduino Board, bringing them into the IoT framework.

Jonathan J. Hull, Berna Erol, Jamey Graham, Qifa Ke, Hidenobu Kishi, Jorge Moraleda, Daniel G. Van Olst, Research Gate "Paper-Based Augmented Reality", Research Gate Transaction on Camera and Paper documentation, 2007

This study describes study-Based Augmented Reality, a technique for augmenting paper documents with electronic information without changing their format. It applies to commercially printed and computer-generated publications. A camera phone implementation allows users to get data and links from paper documents. On a Treo 700w, recognition occurs at 4 frames per second, allowing for a variety of applications such as "clickable paper" for navigating printed web pages.

Mikko Kytö[1,2], Barrett Ens[2], Thammathip Piumsomboon[2], Gun A. Lee[2], and Mark Billinghurst[2], Research Gate "Pinpointing: Precise Head- and Eye-Based Target Selection for Augmented Reality", Research Gate Transactions on Augmented Reality in Computer Science Engineering, 2018

This project investigates using head and eye movements to improve interactions with wearable displays. While head movements are correct, eye gazing is faster but less precise due to calibration problems. The study compares speed and accuracy, highlighting the advantages of each method for augmented reality and calibration drift correction.

Subramani Roy Choudri, A. Divija, G. V V N Vijayalakshmi, P. Vamsi, JARTMS "TOUCHLESS HOME AUTOMATION USING AUGMENTED REALITY", JARTMS Transactions on Augmented Reality and Web Interface, 2021

As hectic schedules need home automation to reduce human mistake, our initiative seeks to improve efficiency, security, and dependability. Augmented reality (AR) allows for the automation of electrical appliances by incorporating virtual items into the actual world.

III. PROPOSED SYSTEM (HARDWARE IMPLEMENTATION)

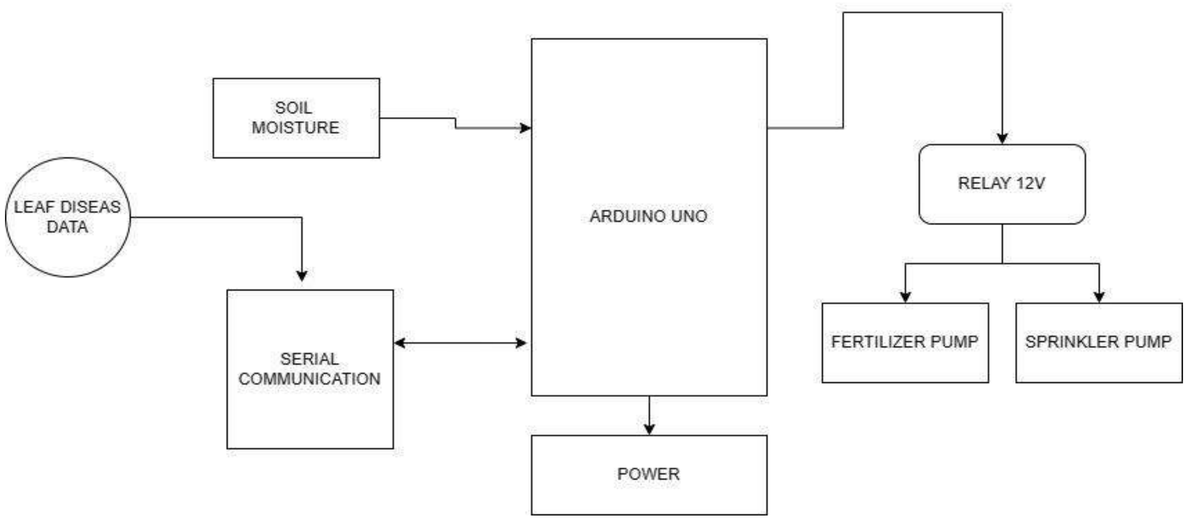

Figure 7: Workflow

1. Working

The AI-powered smart sprinkler system combines hardware and software to improve farm man-agement. It employs soil moisture sensors to monitor levels and activates the sprinkler as needed. A decision-making method uses sensor data and a deep learning model to analyze photos in order to forecast and manage plant diseases. The device performs preventive actions, stops fertilization if diseases are identified, and automatically delivers fertilizers depending on nutrient requirements. A simple interface enables farmers to monitor real-time data, receive alerts, and change settings. This method improves agricultural sustainability, production, and resilience by integrating irrigation, fertilization, and disease management.

2. Proposed Architecture

In this proposed strategy, we will employ a hybrid ensemble technique to forecast higher crop yields. pH, temperature, average rainfall, and humidity are all examined while determining the ideal crop for the soil. The study entails a comparative investigation of prominent classification methods such as Logistic Regression, Decision Tree, Random Forest Classification, SVM, and Naive Bayes Classification to determine the best crop for given soil conditions.

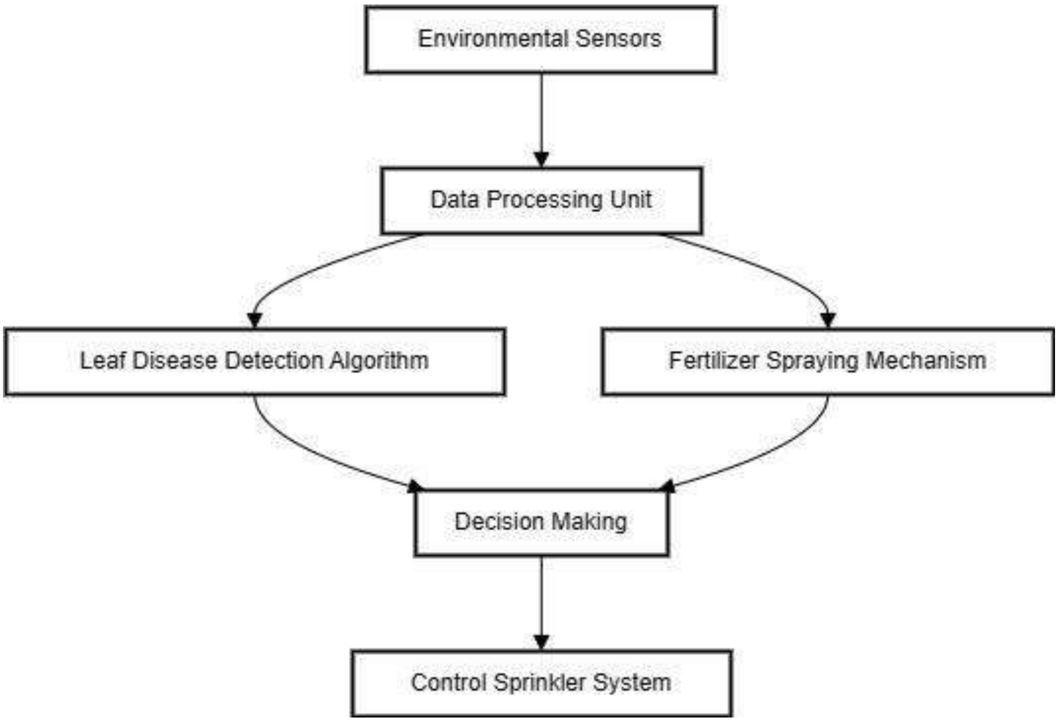

Figure 8: Proposed system architecture

3. Exploratory Data Analysis

Exploratory Data Analysis (EDA) is an important but often overlooked element in data science efforts. It entails comprehending the dataset, finding missing numbers and outliers, and revealing the underlying story using visual and quantitative tools. EDA facilitates the connection with fresh data and guides the project's subsequent phases. Identification of variables and data types, correlation analysis, simple metrics analysis, variable transformation, and missing value removal are all important phases in EDA.

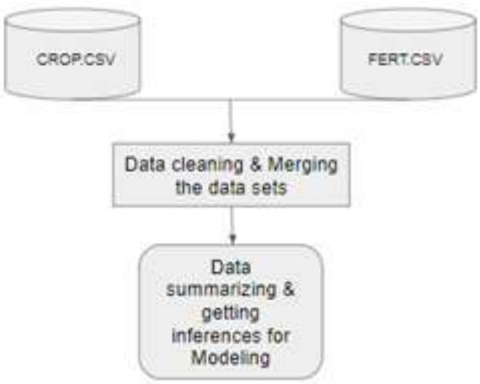

Figure 9: Diagram for EDA

4. Modules

- **a.** Hardware components include sprinkler system, fertilizer dispenser, soil moisture, and leaf diseasesensors.
  Microcontroller (Arduino or Raspberry Pi).

- **b.** Software components include a deep learning algorithm for predicting plant diseases.
  Adecision-making algorithm for irrigation and fertilization.
  Control logic for hardware components.

- **c.** **System Operation:** Check soil moisture and plant health.
  Turn on irrigation if the soil is dry; stop fertilizer if disease is discovered.
  Inform consumers about diseases and give nutrition as needed.

- **d.** **Integration and Testing:** Combine hardware and software.
  Experiment with different situations and fine-tune.
  User Interface: Mobile app or web dashboard for monitoring and configuration.

- **e.** **Maintenance and Upgrades:** Sensors and software require regular maintenance and up-grades.

IV. SOFTWARE AND HARDWARE SPECIFICATION DOCUMENT

The Arduino Uno and Arduino IDE are crucial tools for creating and managing smart systems. The Ar-duino Uno board has 20 input/output pins, including power pins (5V and 3.3V), six analog pins (A0 through A5) for reading voltage levels, and 14 digital pins (0 through 13) for controlling electronic components and reading digital information. The ATmega328 microprocessor on the board supports UART TTL (5V) serial connectivity and USB communication via the ATmega16U2.

The Arduino IDE includes a scripting language, a user interface, a text terminal, a toolbox, and menus for developing and uploading applications to Arduino hardware. It features a serial monitor for transmitting and receiving text data, as well as a Software Serial library that allows serial communication on any digital pin.

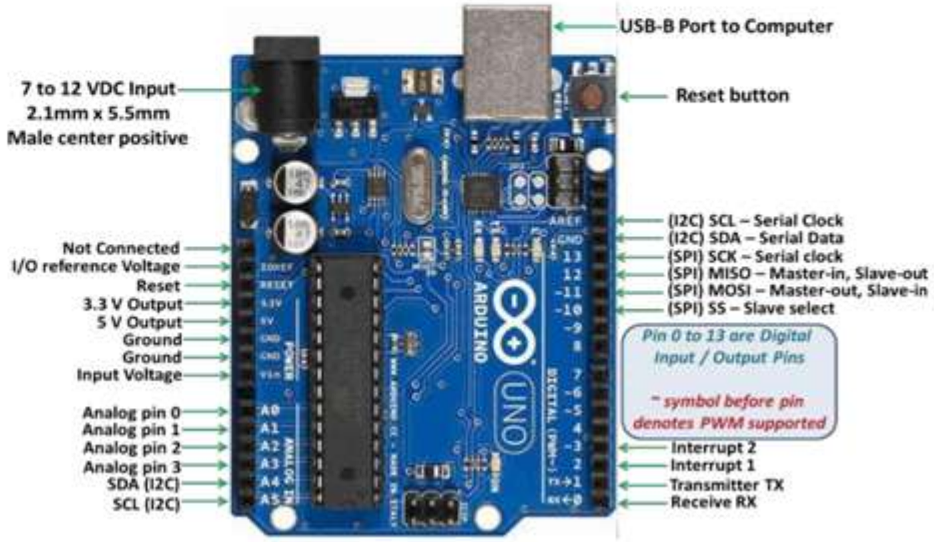

Figure 10: Arduino UNO

The Arduino Uno, which is based on the ATmega328P microcontroller, is a popular choice among hobbyists, students, and professionals due to its straightforward and user-friendly design. It includes 32KB of flash memory, 2KB of SRAM, and 1KB of EEPROM. The board has 14 digital input/output pins (6 PWM outputs) and 6 analog input pins, enabling it to communicate with a variety of sensors, actuators, and electronic devices. Digital pins can read signals and control outputs such as LEDs or motors via protocols like I2C, SPI, or UART. PWM pins provide analog voltage signals to devices such as DC motors. The analog pins, which have a built-in 10-bit ADC, read analog signals and can also function as digital pins. The Arduino Uno's USB interface allows it to communicate with a computer for code uploading and debugging using the serial monitor. It has a power supply circuit that can run on USB or external power, a voltage regulator for a stable 5V output, and a reset button for restarting the microcontroller. Overall, the Arduino Uno's simple design and open-source nature make it a fantastic platform for studying microcontrollers and electronics, with plenty of online resources and assistance. Its popularity has resulted in the development of several shields and modules to enhance its capabilities.

1. **Software Used**

   a. **Programming Language and Tools Used:** Python is a high-level, general-purpose programming language that emphasizes readability and efficiency.

      NumPy is an essential tool for scientific computing, including a multidimensional array object and various procedures. Pandas, which is built on NumPy, simplifies data chores such as cleansing, standardization, and analysis. Seaborn: Creates statistical visualizations, working closely with pandas to produce useful graphs.

      Scikit-learn provides a uniform framework for several supervised and unsupervised learning techniques.

      Pickle serializes and deserializes Python objects for storage on disk.

b. **IDEs Used:** Jupyter Notebook is a web application for creating and sharing documents containing live code, graphics, and text. Visual Studio Code: A versatile source-code editor that supports several languages and provides a configurable environment.

2. Algorithms

a. **Classification Vs Regression:** Predictive modelling problems involving classification vary from those involving regression.

Since we will be using one or more classes. So that it is coming under classification predictive model 4.2.1 Parameters involved in Measuring Accuracy:

b. **Accuracy Matrics:** Precision - The ratio of correctly predicted positive observations to total predicted positive observations is known as precision.

Precision = TP/TP+FP

Table 1: Class Prediction Table

		Predicted class	
Actual Class		Class = Yes	Class = No
	Class = Yes	True Positive	False Negative
	Class = No	False Positive	True Negative

Recall - The ratio of correctly expected positive observations to all observations in the actual class is called recall - yes.

Recall = TP/TP+FN

F1 score - The weighted average of Precision and Recall is the F1 Score.

F1 Score = 2*(Recall * Precision) / (Recall + Precision)

3. Comparison Between Different Algorithms

a. **Logistic Regression:** Logistic regression is a classification algorithm that predicts a binary outcome given a set of independent variables. It is a linear model, similar to linear regression, but is used to solve classification problems rather than regression problems. The target variable in logistic regression is categorical and may be classified into one of two groups, making it appropriate for binary classification. The algorithm separates the output into an S-shaped graph (sigmoid function), allowing predictions based on this internal network structure.

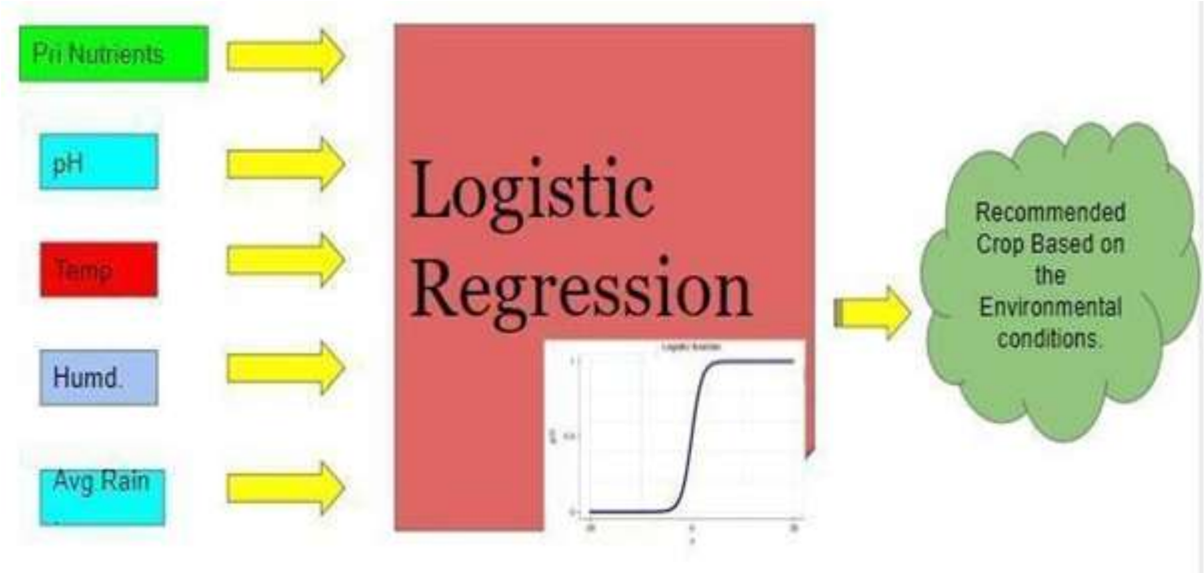

Figure 11: Logistic Regression Model

Using a Logistic Regression Model, we predicted crop names based on primary nutrients, pH, temperature, humidity, and average rainfall. The logistic regression model developed on previous data was 97.00% accurate.

b. The Decision Tree Model: Provides excellent accuracy and straightforward knowledge representation. They include two processes:

- **Induction:** Creating the tree by separating data based on the best features.
- **Pruning:** Reducing complexity by removing unneeded structure to prevent overfitting.

Evaluate each node's impact on the cost function and delete those with negligible impact.

- Accuracy achieved was 97.33%.

By comparing these models, we can determine the best technique for forecasting crop kinds based on the available information.

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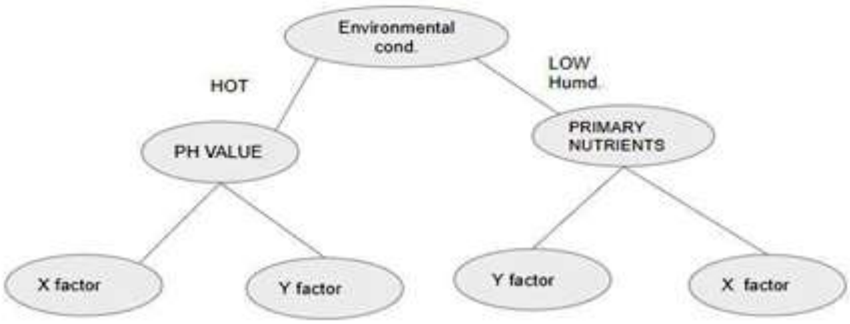

Figure 12: Decision tree node

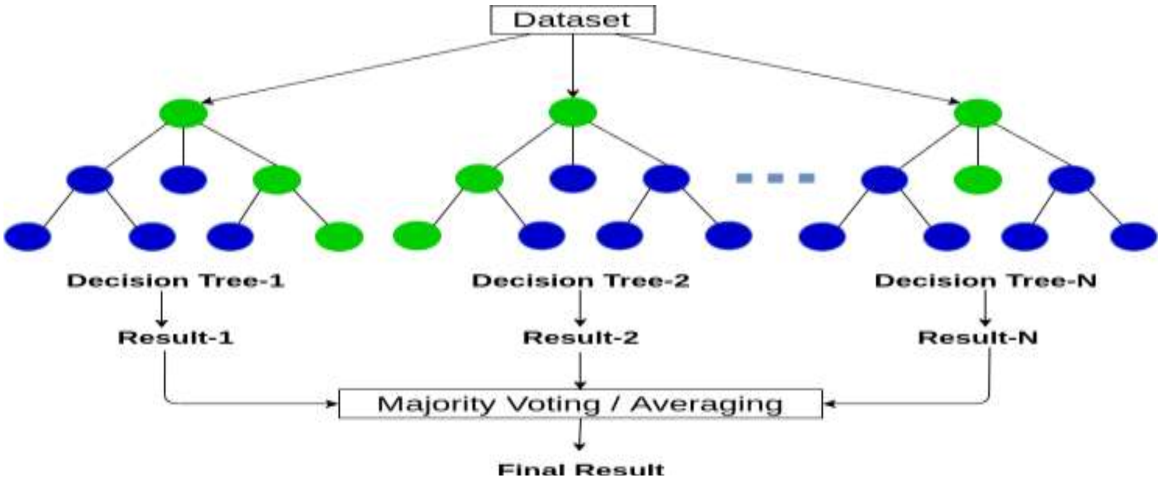

Figure 13: Random Forest tree model

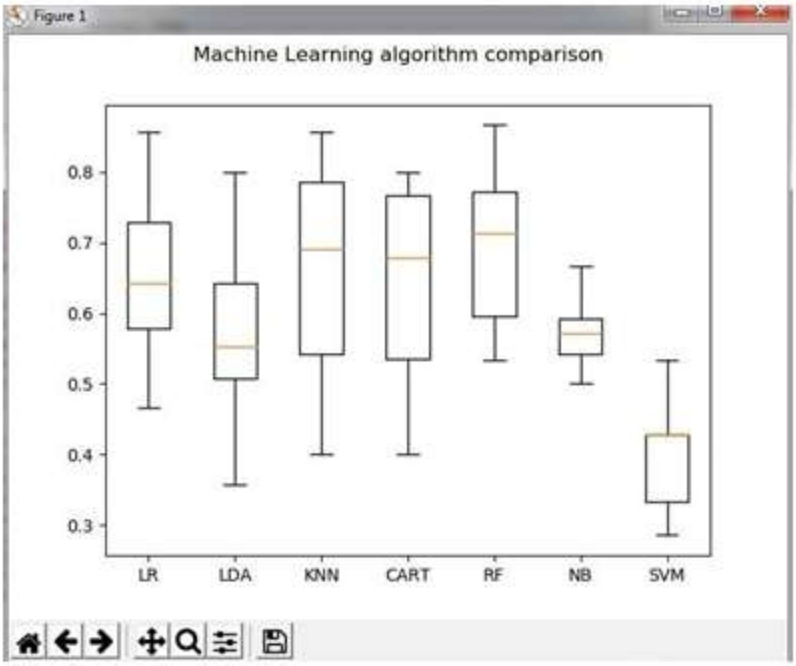

Figure 14: Accuracy for Random Forest tree mode

4. Support Vector Machine

The support vector machine algorithm's goal is to find a hyperplane in an N- dimensional space (N — the number of features) that categorizes data points clearly.

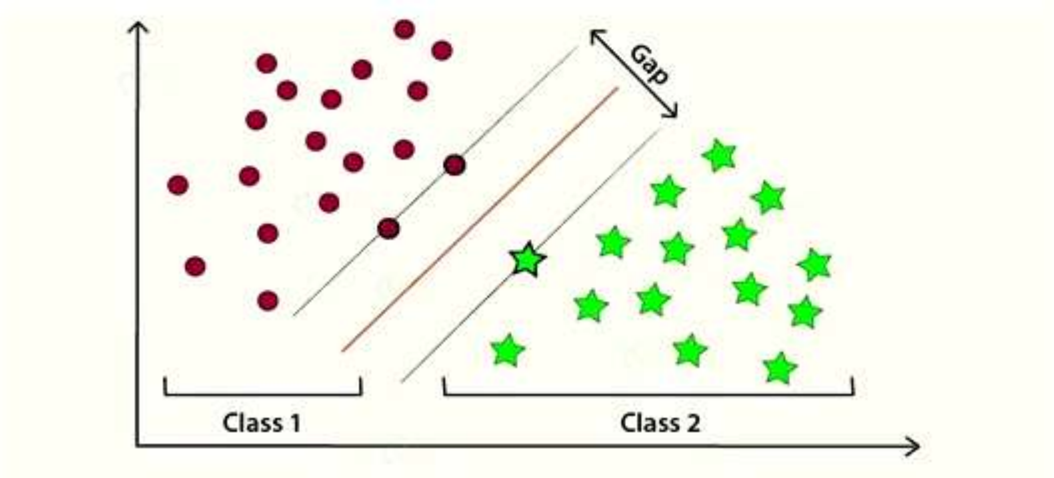

Figure 15: SVM MODEL

There are several different hyperplanes that could be used to distinguish the two types of data points (as seen in fig 4.9). Our aim is to find a plane with the greatest margin, or the greatest distance between data points from both groups. Maximizing the margin gap provides some reinforcement, making it easier to classify potential data points. Hyperplanes are decision boundaries that aid in data classification. Different groups may be assigned to data points on either side of the hyperplane. The hyperplane's dimension is also determined by the number of functions. If there are only two input features, the hyperplane is just a line. The hyperplane becomes a two-dimensional plane when the number of input features reaches three. When the number of features reaches three, it becomes impossible to picture.

5. Naïve Bayes Classification

A probabilistic machine learning model called a Naive Bayes classifier is used for classification tasks.

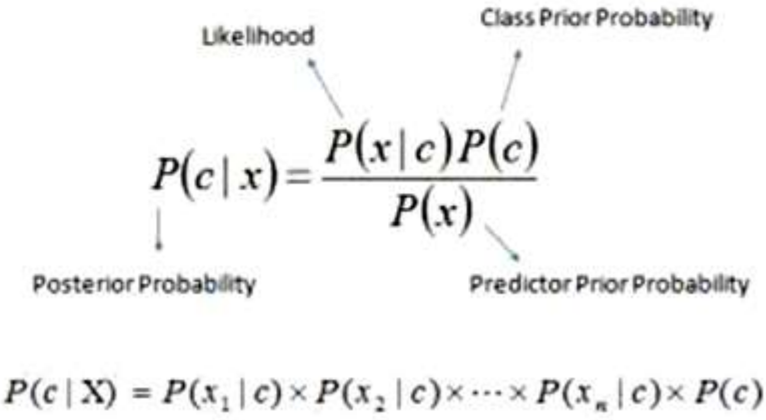

Figure 16: Naïve bayes

Provided that X has occurred, we can calculate the likelihood of C occurring using Bayes theorem. The proof is C, and the hypothesis is X. The predictors/features are assumed to be independent in this case. That is, the existence of one feature has no effect on the other. As a result, it is referred to as naive.

Types of Naive Bayes Classifier

Multinomial Naive Bayes: This is most often used to solve document classification issues, such as determining if a document falls in the sports, politics, or technology categories. The frequency of the terms present in the text is one of the features/predictors used by the classifier.

6. Bernoulli Naïve Bayes

The predictors are Boolean variables, close to the multinomial naive bayes. The parameters we use to predict the class variable only accept yes or no answers, such as whether a word appears in the text or not.

Gaussian Naive Bayes: We assume these values are sampled from a gaussian distribution when the predictors take up a continuous value and are not discrete.

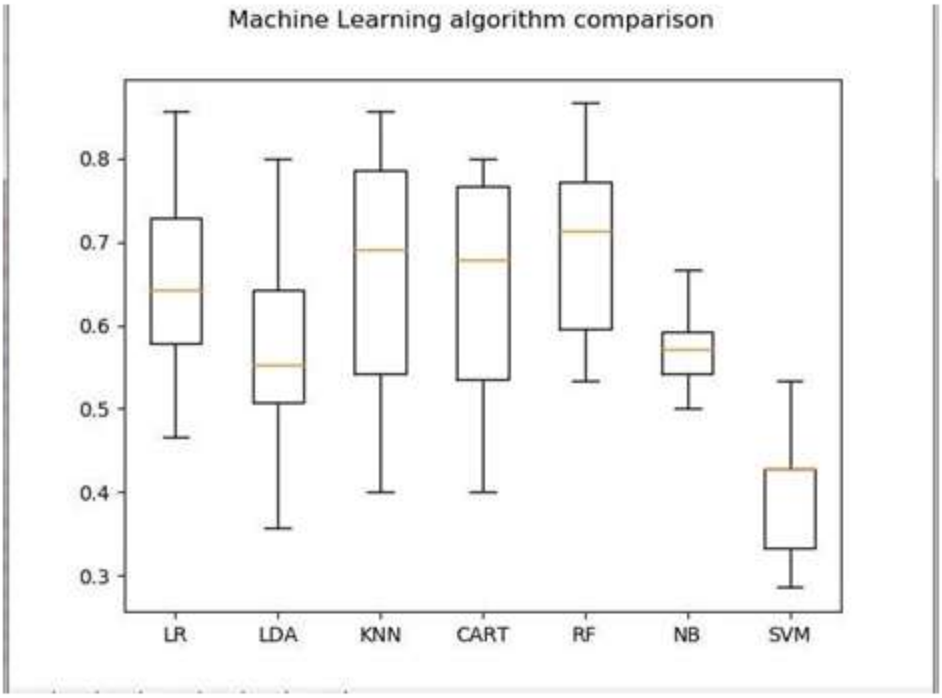

Figure 17: NAIVE BAYES ACCURACY

Since our dataset was normally distributed. so that we have used Gaussian Naive Bayes Classifier as our classifier. Basically, the Naive bayes classifier are well efficient in predicting or recommending systems. So that we have obtained 99% (as shown in fig 4.11) as our accuracy.

We have obtained 99.20% (as shown in fig 4.13) accuracy for our Hybrid Ensemble model for better plant diseaseprediction.

```
  n_iter_i = _check_optimize_result(

Accuarcy of ensemble hybrid model: 99.2 %

In [18]: new_input=[[115,40,28,27.309018,55.196224,6.348316,141.483164]]

In [19]: ensemble.fit(X,Y)
         new_output=ensemble.predict([[115,40,28,27.309018,55.196224,6.348316,141.483164]])
         print(new_input,new_output)

C:\Users\ELCOT\anaconda3\lib\site-packages\sklearn\linear_model\_logistic.py:762: ConvergenceWarning: lbfgs failed to converge
(status=1):
STOP: TOTAL NO. of ITERATIONS REACHED LIMIT.

Increase the number of iterations (max_iter) or scale the data as shown in:
    https://scikit-learn.org/stable/modules/preprocessing.html
Please also refer to the documentation for alternative solver options:
    https://scikit-learn.org/stable/modules/linear_model.html#logistic-regression
  n_iter_i = _check_optimize_result(

[[115, 40, 28, 27.309018, 55.196224, 6.348316, 141.483164]] ['coffee']
```

Figure 18: Accuracy for Hybrid Ensemble Model

System Requirements

Operating system: Windows/mac
RAM: 4GB
Processor: 64x1.0Ghz
Processor ROM: 8GB

V. RESULTS AND DISCUSSIONS

Simulation:

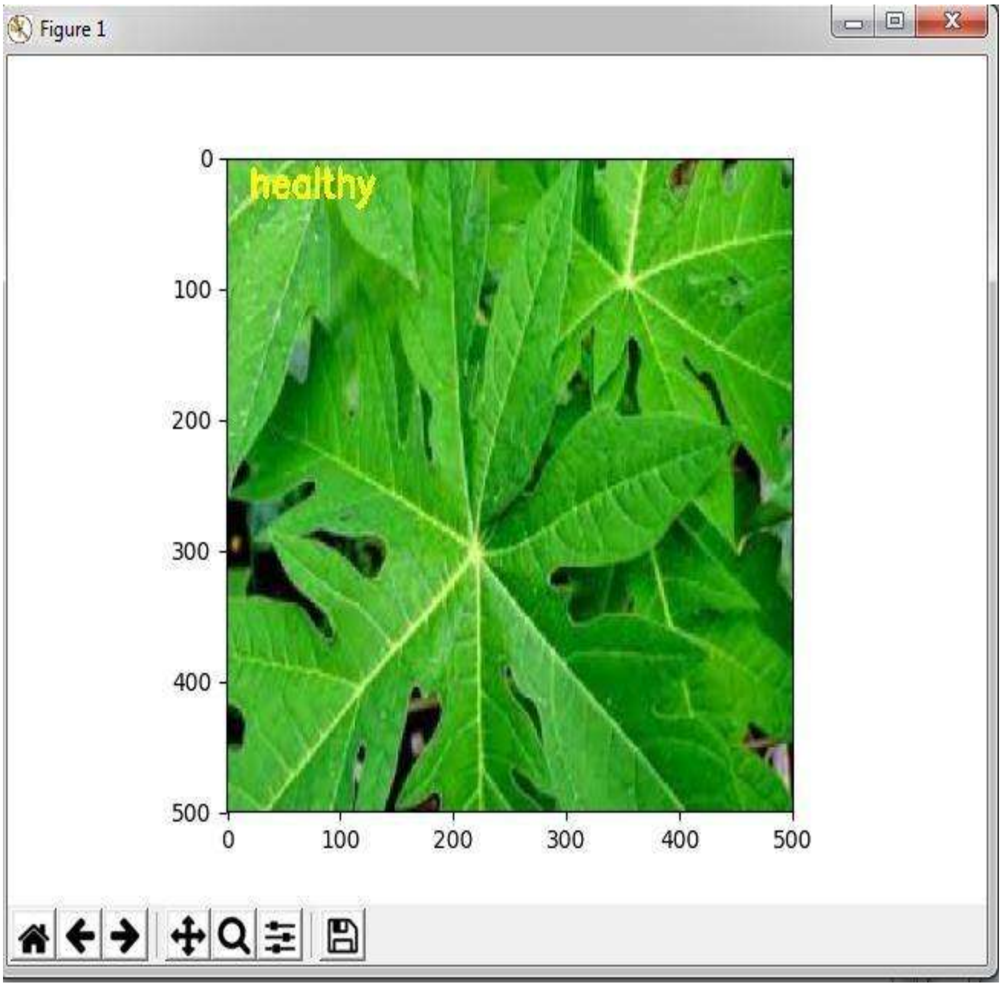

Figure 19: OUTPUT

Results Kit Image: The above figure depicts the values or results obtained from various sensors such as DHT 11(Temperature and Humidity), Soil moisture sensor and Light sensor which indicates the photosynthesis level of the plant.

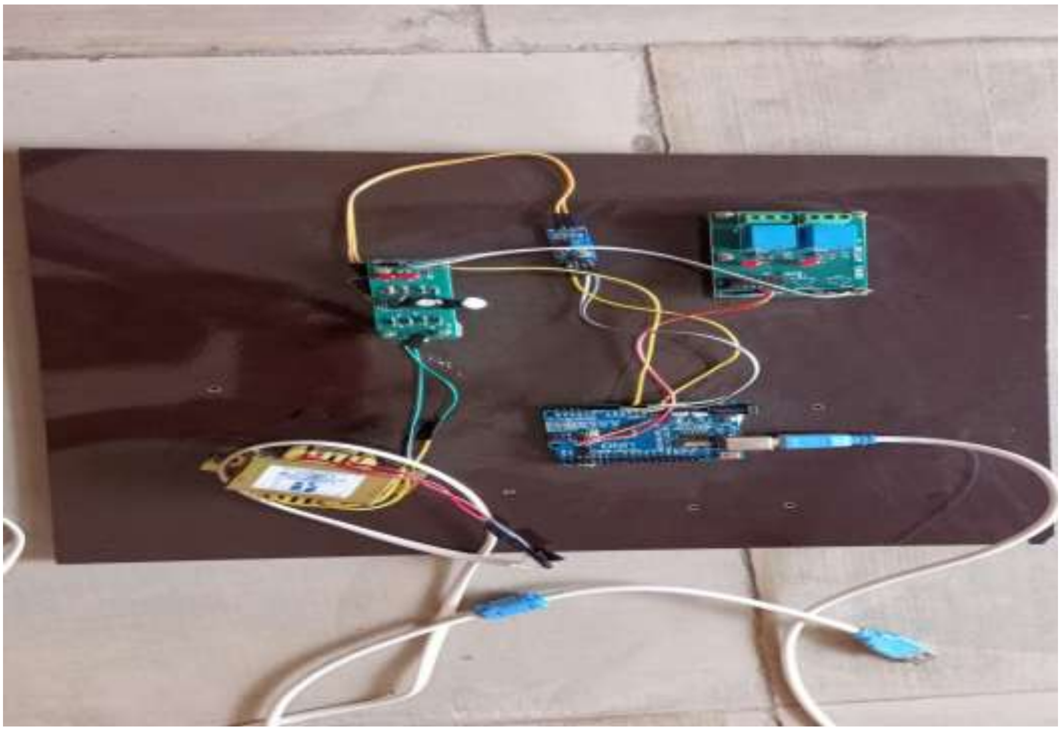

Figure 20: OUTPUT FOR ADAPTIVE FARMING

VI. CONCLUSION

Traditional irrigation systems require farmers to manually control the irrigation of their land, which is time-consuming and frequently results in water waste. Automatic irrigation systems give plants with a continuous flow of water, ensuring healthy development and effective water use. Implementing such technologies saves farmers both time and water. The ESP8266 Node MCU Microcontroller chip and wireless sensors use less power and provide these benefits at a reasonable cost.

Future Work: Smart irrigation is the use of advanced technologies to optimize the irrigation process, including the monitoring of environmental factors such as soil moisture, weather conditions, and plant water needs. Smart irrigation systems can improve water use efficiency, reduce water waste, and lower irrigation costs.

1. **Integration with IoT:** Real-time data gathering and analysis using soil moisture, temperature, and humidity sensors.
   Adjusts irrigation schedules and identifies leaks to save water waste.

2. **Artificial Intelligence:** Analyzes data to determine crop growth patterns, soil moisture, and weather trends.
   Develops predictive models to improve irrigation and resource management decisions.

3. **Precision Agriculture:** Utilizes data-driven technologies to optimize crop output. Controls water application according on crop requirements, minimizing water consumption while increasing yields.

4. **Autonomous Irrigation Systems:** Uses AI and machine learning to make automated irrigation decisions .Connects to weather sensors and data sources to make real-time modifications, saving both time and money.

5. **Water Management:** Improves water quality by optimizing water use and reducing waste .Encourages sustainable agriculture and the conservation of water resources.

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