RESEARCH ARTICLE OPEN ACCESS

Smart Irrigation System

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ABSTRACT

The food shortage and the population growth are the most challenges facing sustainable development worldwide. Countries are collaborating to make agriculture more efficient by combining new technologies to improve its procedure. The automation of agricultural processes has the potential to transform farming from a traditional, labor-intensive practice into smart, efficient and dynamic system. The Smart Irrigation System in agriculture is an advanced technology that integrates Internet of Thing(IoT) , Artificial Intelligence(Ai) and Sensor Based automation to optimize water usage and improve the crop productivity.

Keywords — Agriculture, Irrigation, IOT , Automations , Soli Moisture.

1. INTRODUCTION

The goal of this project is to design an IoT enabled smart irrigation system that automates and monitors water usage effectively. Smart irrigation are reduced the water consumption and it is improve the quantity and quality the crop.

As climate changes intensifies droughts and water scarcity , these systems are increasingly vital for food security , enabling farmers to adapt to unpredictable conditions while supporting eco-friendly agriculture [1]-[3]. Agriculture remains the backbone of India's economy, serving as the primary source of income for a significant portion of the population [4]. However, the rising demand for food driven by an ever-growing population has necessitated increased agricultural output, which, in turn, places a heavy reliance on fresh water resources for irrigation System [5].

Currently, agriculture accounts for approximately 83%of India's total water consumption. Unfortunately, inefficient and unregulated water usage often leads to significant wastage, underscoring the urgent need for innovative techniques that minimize water loss without adding to the burdens of farmers [6]. The Internet of Things (IoT) is a global network of smart objects capable of self-organization, information exchange, and responding to environmental changes [1]. These elements, also known as ‘‘smart things’’, range from sensors and devices to machinery and household appliances.

This data is enables the system to regulate water usage efficiently, preventing issues and such as over-irrigation or insufficient watering. The incorporation of IoT technology ensures that farmers remain informed about the status of the irrigation pump. Real time updates from the sensors and water data are uploaded to a web form via Firebase.

2. LITERATURE REVIEW

2.1. Sensors Used in the Smart Irrigation System

Soil and Nutrient Monitoring Sensors

1. Soil Moisture Sensor

- Measures the water content of soil
- Helps farmers schedule irrigation efficiently and avoid overwatering or underwatering

2. Temperature Sensor

- Records the soil and air temperature
- Help determine the best planting and harvesting times for different crops

3. Humidity Sensor

- Monitors the amount of water vapor in the air
- Important of controlling greenhouse environments and predicting disease risks

4. pH Sensor

- Measures the acidity or alkalinity of soil
- Ensures the soil is suitable for specific crops and guides fertilizer application

Crop & Plant Health Sensors 5 Light Intensity Sensor

- Measures sunlight exposure and intensity
- Ensures crops receive optimal light for photosynthesis and growth

5. Leaf Wetness Sensor

- Detects water or dew on leaves
- Helps predict fungal infections and other plant diseases

6. Camera Sensors(AI Vision-Based)

- Captures high-resolution crop images.
- AI analyses images to detects diseases, pests, nutrient deficiency and growth stages.

Weather & Environmental Sensors

7. Weather Sensors(Rain, Wind, Solar Radiation)

. Track weather parameters like rainfall, wind speed and sunlight .

8. IoT Based Environmental Sensors

- Combine multiple sensors connected via IoT networks
- Send real- time environmental data to AI system for decision making.

Advanced AI & Smart Tech Sensors

9. Drone-Based Imaging Sensors

- Mounted on drones to scan large fields
- Capture real time data for AI analysis of crop health and irrigation needs

10. Proximity Sensor

- Detects nearby objects or obstacles
- Helps in autonomous tractors and robotics farming machines

11. Machine Learning- Enabled Predictive Sensors

- Combine multiple sensor inputs with AI models
- Predicts crop diseases , yields and optimal irrigation or fertilizer timing

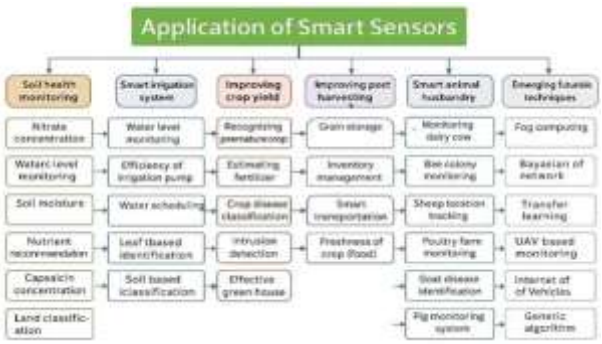

Figure 1: Applications of Sensors

2.2. Devices of Smart Irrigation System

1. Node Mcu ESP8266

Node Mcu is an open- source firmware , hardware and software development environment project developed initially for the ESP8266 Wifi Soc chip based on LUA.

A NodeMCU works by using a microcontroller based on the ESP8266 Wi-Fi chip to connect to the internet and other devices. It is programmed using software like the Arduino IDE, allowing it to execute code that reads sensors, controls digital outputs, and communicates via Wi-Fi, serial protocols like UART, SPI, and I2C. It is powered via a micro-USB port or a VIN pin and features various input/output pins for connecting external components.

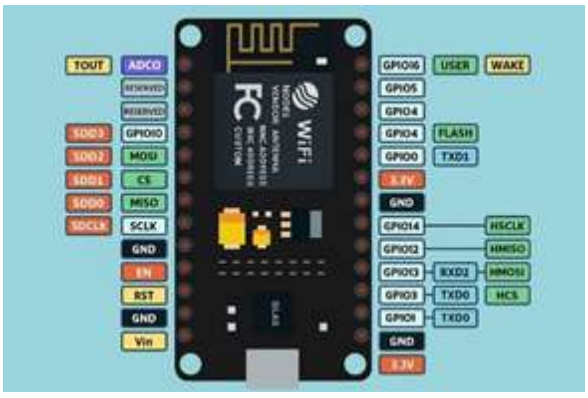

Figure 2: Node Mcu ESP8266

2. ESP 32 Cam

ESP 32 Cam is a low-cost and it is a display pictures in Firebase Web App. It is store the picture in the firebase storage. ESP32 Cam Qr Code Reder User Management System.

Figure 3: ESP 32-CAM

3. Relay Driver

A "relay driver" is a circuit that acts as a buffer between a low-power control signal, like one from a microcontroller, and a high-power relay. It uses a transistor to switch the relay on and off safely, as the control signal typically lacks the voltage and current needed to energize the relay coil directly and is vulnerable to voltage spikes produced by the coil.

Figure 4: Timer Relay

4. Arduino Uno

The Arduino Uno is used for building interactive electronics projects, serving as the "brain" for everything from simple LED lights to complex systems like home automation, robotics, and IoT devices. It interacts with

sensors (like temperature or distance sensors) and controls outputs (such as motors, LEDs, and speakers) through user-written code, making it a popular tool for hobbyists, students, and professionals alike.

Figure 6: Arduino Uno

3. Methodology

3.1. Work Flow

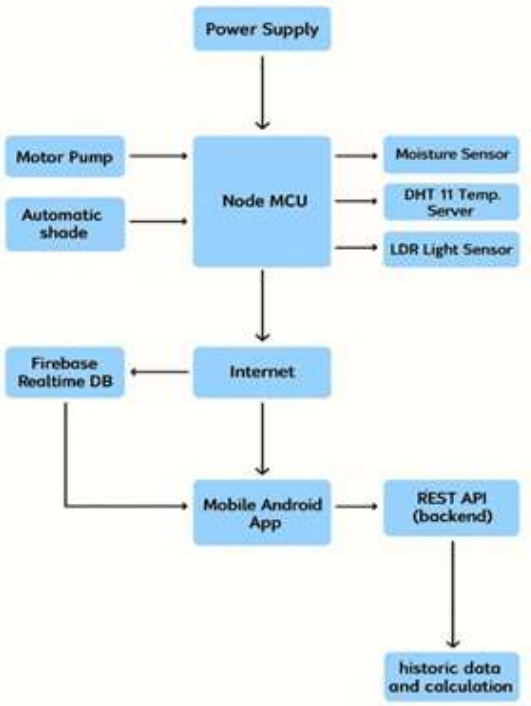

Figure 6: Flow Chart

The smart irrigation system based on ioT and cloud. The driving force behind our system is the Node MCU, which collects data from moisture sensor and platinum resistance thermometer, DHT11 temperature sensor, LDR light sensor, etc. Depending on the sensor information, it controls the motor pump for irrigation and controlling the automatic shade. The Node MCU is connected to Internet which sends data in real-time to Firebase Realtime Database and Google Cloud. Farmers can remotely monitor and control the system through a mobile android app. The backend REST API pulls and processes data from the past to make decisions and predictions. This system can automate irrigation, optimize water usage, and enhance efficiency in crop growth through intelligent control. It shows how IoT and AI can impact agriculture.

3.2. Partial Least Squares Regression Algorithm

Partial least squares regression (PLS regression) is a statistical technique that shares similarities with principal components regression. Instead of identifying hyperplanes of maximum variance between the response and independent variables, PLS regression constructs a linear regression model by projecting both the predicted and observable variables into a new space. This characteristic of projecting data to new spaces classifies PLS methods as bilinear factor models. Partial least squares discriminant analysis (PLS-DA) is a specific variant used when the response variable (Y) is categorical.

PLS is employed to uncover the underlying relationships between two matrices (X and Y). It takes a latent variable approach to model the covariance structures in these matrices. The objective of a PLS model is to identify a multidimensional direction in the X space that explains the maximum multidimensional variance direction in the Y space. PLS regression is particularly advantageous when the predictor matrix has more variables than observations and when there is multicollinearity among X values. This is in

contrast to standard regression, which may struggle in these situations unless regularization is applied.

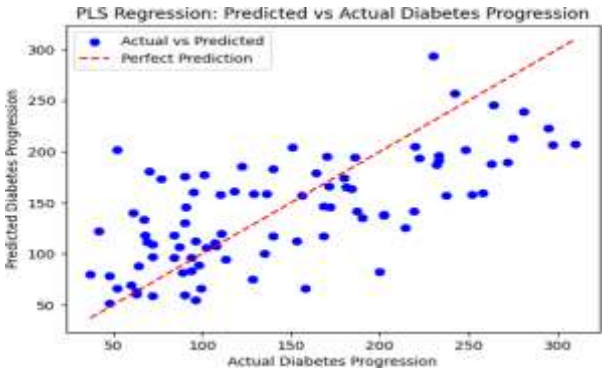

Figure 7: Flow Chart

4. Results and Experiments

4.1. Hardware Setup

In smart irrigation system includes a central microcontroller (like an Arduino or ESP32) connected to various sensors for monitoring (soil, moisture, temperature, humidity, rain) and actuators for control (a water pump or solenoid valve).

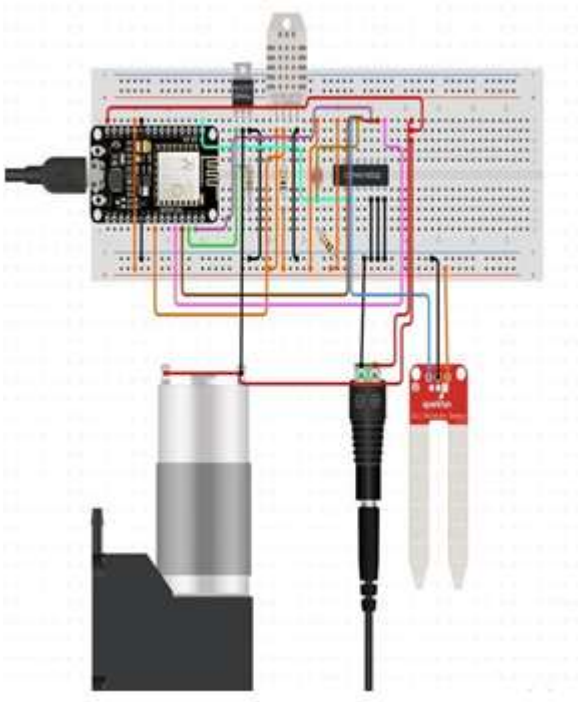

Figure 8: Block Diagram of Setup

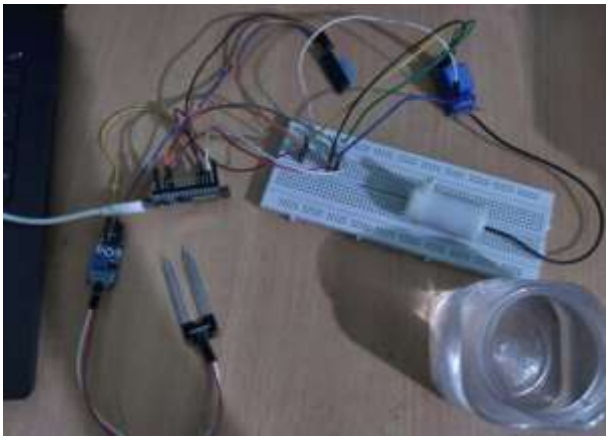

Figure 9: Hardware Setup of Smart Irrigation

4.2. Dashboard Display

Figure 10: IoT Display

5. Conclusion And Future Work

The Smart Irrigation System harnesses the advantages of IoT, AI, and sensor technology to boost the effectiveness of water and crop production. It helps reducing waste and labour through automation of irrigation from soil and

weather data. This method ensures that each ingredient is applied at the right time in the right amounts.

Future Work in Smart Irrigation

- Artificial Intelligence(AI) Integration
- Machine Learning Prediction Model
- Internet of Things(IoT) Expansion
- 5G Connectivity for Real Time Monitoring
- Drone-Assisted Irrigation and Monitoring
- Smart Sensos with High Accuracy
- Blockchain Based Water Data Manager
- Satellite-Based Weather Forecasting
- Wireless Sensor Networks
- Automated fertilizer and Nutrient Control

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