SMART FARMING WITH AUTOMATION

Jadhav Eshaan Sagar
Dept of Electrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India
E-mail : Jadhaveshaan4@gmail.com

Jadhav Rohit Arjun
DeptofElectrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India
E-mail : shubhamgosavi766613@gmail.com

Joshi Ashutosh Hemant
Dept of Electrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India
E-mail : Jadhaveshaan4@gmail.com

Ingle Sahil Devidas
Dept of Electrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India
E-mail : Jadhaveshaan4@gmail.com

Ithape Balasaheb Devram
Dept of Electrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India
E-mail : Jadhaveshaan4@gmail.com

D. R. Narkhede
Dept of Electrical Engineering,
Sanjivani K. B. P. Polytechnic,
Kopargaon, India E-mail :
pathoratee@sanjivani.org.in

ABSTRACT—Modern agriculture faces several challenges such as unpredictable weather conditions, inefficient water management, plant disease detection, and the need for continuous monitoring of crops. This paper presents a Smart Farming with Automation system designed to improve agricultural productivity using Internet of Things (IoT) technologies and intelligent sensing. The proposed system utilizes a microcontroller-based platform using the ESP32 to monitor and control various environmental parameters inside a farming environment such as a polyhouse. Multiple sensors including temperature and humidity sensors, soil moisture sensors, rain sensors, gas sensors, and flame sensors are integrated to continuously monitor the crop conditions. Additionally, an image-based monitoring system using the ESP32-CAM and a color sensor is employed to observe plant health and detect variations in crop conditions.

The system also incorporates an automated irrigation mechanism, a shed control mechanism driven by servo motors for weather protection, and real-time data display through an OLED interface. When abnormal conditions such as gas leakage, excessive temperature, fire hazards, or rainfall are detected, the system automatically activates preventive actions such as irrigation control, alert mechanisms, and protective shed movement. The proposed solution aims to reduce manual effort, optimize resource utilization, and enhance crop monitoring through intelligent automation. The implementation demonstrates a low-cost and scalable solution suitable for small and medium-scale farmers to improve crop management and agricultural efficiency.

KEYWORDS—Smart Farming, Precision Agriculture, Internet of Things (loT), Automated Irrigation System, Plant Health Monitoring, Environmental Monitoring, Polyhouse Automation, Soil Moisture Sensor, Image-Based Crop Monitoring, Smart Agriculture Systems.

INTRODUCTION

Agriculture plays a crucial role in the economic development and food security of many countries. However, traditional farming methods often rely heavily on manual monitoring and decision-making, which can lead to inefficient use of resources such as water, fertilizers, and energy. Factors such as unpredictable weather conditions, pest attacks, plant diseases, and lack of real-time monitoring significantly affect crop productivity. Therefore, there is an increasing need for intelligent farming solutions that can enhance efficiency and reduce human intervention.

With the advancement of modern technologies such as the Internet of Things (IoT), sensors, and embedded systems, agriculture is gradually transforming into a more automated and data-driven process. Smart farming systems enable continuous monitoring of environmental parameters such as soil moisture, temperature, humidity, air quality, and rainfall, allowing farmers to make better decisions regarding irrigation, crop protection, and resource management.

In this project, a smart farming automation system is developed using the ESP32 as the main controller. The system integrates multiple sensors including soil moisture sensors, rain sensors, gas sensors, flame sensors, and temperature–humidity sensors to monitor the agricultural environment in real time. Additionally, a visual monitoring system using the ESP32-CAM along with a color sensor is incorporated to analyze plant conditions and detect possible health issues.

The proposed system also includes automated irrigation control, shed control using a servo mechanism to protect crops from rain or extreme weather conditions, and an OLED display to show real-time data. By integrating sensing, monitoring, and automation, the system aims to improve crop productivity.

LITERATURE SURVEY

A. IoT-Based Smart Farming Systems

Recent developments in the Internet of Things (IoT) have significantly influenced modern agricultural practices. IoT-based smart farming systems enable continuous monitoring of environmental conditions such as soil moisture, temperature, humidity, and light intensity. Researchers have proposed various sensor-based monitoring systems that collect real-time agricultural data and transmit it to a central controller for analysis. These systems improve decision-making in irrigation and crop management while reducing manual labor and water wastage. However, many of these systems focus mainly on environmental monitoring without integrating automated response mechanisms for changing field conditions.

B. Automated Irrigation and Environmental Monitoring Automated

Irrigation systems have been widely studied to address water management issues in agriculture. Soil moisture sensors are commonly used to determine the water requirement of crops and activate irrigation systems accordingly. Temperature and humidity sensors are also used to monitor climatic conditions inside greenhouses or polyhouses. These automated systems help maintain optimal growing conditions for crops and reduce unnecessary water usage. Despite these advancements, many existing systems operate independently and do not combine multiple environmental parameters with intelligent decision-making for complete farm automation.

C. Image-Based Crop Monitoring Systems

Recent research has explored the use of camera-based monitoring systems to detect plant diseases and evaluate crop health. Image processing techniques are applied to analyze leaf color, texture, and shape to identify early signs of plant stress or disease. Color sensors and camera modules are also used to monitor plant growth and detect nutrient deficiencies. Such systems provide valuable information about plant health and enable early intervention. However, many image-based systems require complex computational resources or cloud processing, making them less suitable for low-cost and small-scale farming applications.

D. Integrated Smart Agriculture Platforms

Several studies have proposed integrated smart agriculture systems that combine environmental sensing, automated irrigation, and remote monitoring. These systems utilize embedded controllers and wireless communication technologies to create a connected farming environment. Actuators such as pumps, fans, and motors are used to automatically respond to changes in environmental parameters. While these systems provide improved efficiency, many of them still lack comprehensive plant health monitoring and multi-sensor integration within a single low-cost platform suitable for small-scale farmers.

RESEARCH GAP

From the above literature survey, several research gaps can be identified in existing smart farming systems. Most currently available agricultural monitoring systems focus primarily on individual parameters such as soil moisture, temperature, or humidity monitoring. While these systems provide useful information, they often lack a fully integrated approach that combines multiple environmental sensors with automated control mechanisms in a single platform.

Many IoT-based farming solutions rely mainly on environmental sensing and remote monitoring but do not incorporate intelligent automation features such as automatic irrigation, weather protection mechanisms, or hazard detection. As a result, farmers still need to manually intervene to control irrigation systems or protect crops from environmental conditions such as rainfall or extreme temperature.

Additionally, existing plant health monitoring systems often depend on complex image processing algorithms or cloud-based platforms, which increase system cost and computational requirements. This makes them less suitable for small-scale farmers who require affordable and easy-to-maintain solutions.

Furthermore, many previously proposed systems lack integration between environmental monitoring, crop protection mechanisms, and visual plant health analysis. There is limited research that combines multiple sensing technologies such as soil moisture sensors, gas sensors, rain sensors, and image-based monitoring in a single compact system.

Therefore, there is a need for a low-cost, integrated smart farming system that combines environmental monitoring, automated irrigation control, crop protection mechanisms, and plant health analysis using embedded systems and IoT technologies. The proposed system aims to address these limitations by integrating multiple sensors, automated control features, and visual monitoring using an embedded microcontroller platform to improve farming efficiency and crop productivity.

PROPOSED CONTRIBUTION

The proposed smart farming automation system introduces several important contributions aimed at improving agricultural monitoring and automation. The key contributions of this research work are summarized as follows:

- **Integrated Multi-Sensor Monitoring System**
The proposed system integrates multiple environmental sensors such as soil moisture sensors, rain sensors, gas sensors, flame sensors, and temperature–humidity sensors to continuously monitor agricultural conditions in real time.
- **Automated Irrigation Control**
An automatic irrigation mechanism is implemented based on soil moisture levels. The system activates a water pump when soil moisture drops below a defined threshold, thereby ensuring efficient water usage and reducing manual effort.
- **Automated Weather Protection Mechanism**
A servo-controlled shed system is designed to protect crops from rainfall and extreme weather conditions. The rain sensor detects rainfall and automatically triggers the closing or opening of the protective shed.
- **Plant Health Monitoring System**
A visual monitoring system using the ESP32-CAM and a color sensor is incorporated to observe plant conditions and detect variations in leaf color that may indicate plant stress or disease.
- **Real-Time Data Display**
An OLED display is used to provide real-time information about environmental parameters such as temperature, humidity, soil moisture levels, and system status.
- **Low-Cost and Scalable Smart Farming Solution**
The system is developed using the ESP32, which provides an affordable and scalable platform suitable for small and medium-scale farmers.
- **Improved Resource Management**
By integrating sensing, monitoring, and automation, the system helps optimize the use of water, energy, and other agricultural resources while improving crop productivity.

METHODOLOGY / SYSTEM DESIGN

1. BLOCK DIAGRAM
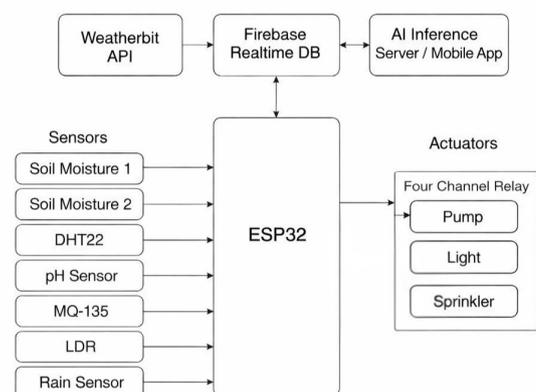
2. WORKING PRINCIPLE

The smart farming automation system operates by continuously monitoring environmental parameters and automatically controlling agricultural processes based on sensor data. The system is centered around the ESP32, which functions as the main controller responsible for collecting sensor data, processing it, and activating the appropriate actuators.

Initially, different sensors installed in the farming environment measure various parameters such as soil moisture, temperature, humidity, rainfall, gas concentration, and flame detection. The soil moisture sensors monitor the water content in the soil and send analog signals to the controller. When the soil moisture level falls below a predefined threshold, the controller activates a relay to start the irrigation pump. Once the soil reaches the required moisture level, the pump is automatically turned off, ensuring efficient water management.

The temperature and humidity sensor continuously measures atmospheric conditions within the farming area. These parameters help in maintaining suitable environmental conditions for plant growth. At the same time, the rain sensor detects rainfall. When rainfall is detected, the controller activates a servo motor that moves a protective shed mechanism to cover the crops and protect them from excessive rain. When the rain stops, the shed automatically returns to its original position.

Additionally, gas and flame sensors are used to detect harmful gases or fire hazards in the agricultural environment. If abnormal gas levels or flame conditions are detected, the system can trigger alerts or activate safety mechanisms to prevent potential damage.

For plant health monitoring, a visual monitoring system using the ESP32-CAM and a color sensor captures information about plant leaves. Variations in leaf color can indicate possible plant stress, nutrient deficiency, or disease. This information helps in early detection of plant health issues.

All the collected sensor data and system status are displayed on an OLED display in real time. By integrating environmental sensing, automated control, and visual monitoring, the system provides an efficient and intelligent solution for modern agricultural automation.

3. HARDWARE USED

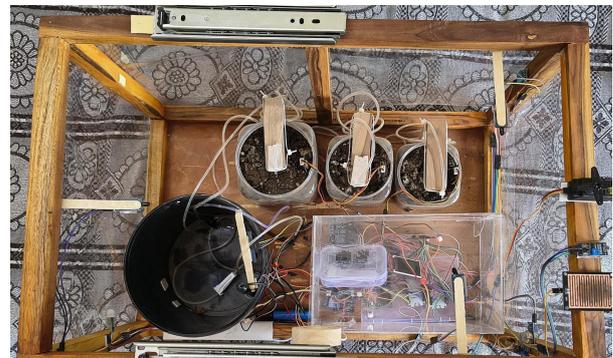| Sr. No.	Component Name
1	ESP32 DevKit V1
2	ESP32-CAM
3	Soil Moisture Sensor
4	Rain Sensor
5	MQ-135 Gas Sensor
6	Flame Sensor
7	DHT11 Sensor
8	Color Sensor
9	Water Pump
10	Relay Module
11	0.96-inch OLED Display
12	Power Supply Module
13	Connecting Wires and Breadboard
14	Used for circuit design and prototyping

EXPERIMENTAL SETUP

Fig. 1.1 View of the Experimental Setup

The setup represents a miniature smart farming system designed to automate irrigation and monitor environmental conditions inside a controlled structure (polyhouse).

Plant Section:
Multiple pots contain soil with soil moisture sensors inserted to monitor water levels in real time.

Irrigation System:
A water reservoir (black tank) is connected to the pots through pipes. Water flow is controlled automatically using a pump and relay system based on soil moisture readings.

Control Unit:
An ESP32 microcontroller (placed inside the transparent box) processes sensor data and controls actuators like the water pump and servo motors.

Environmental Sensors:
Sensors such as rain sensor, temperature (DHT22), and possibly pH sensor are used to monitor environmental conditions.
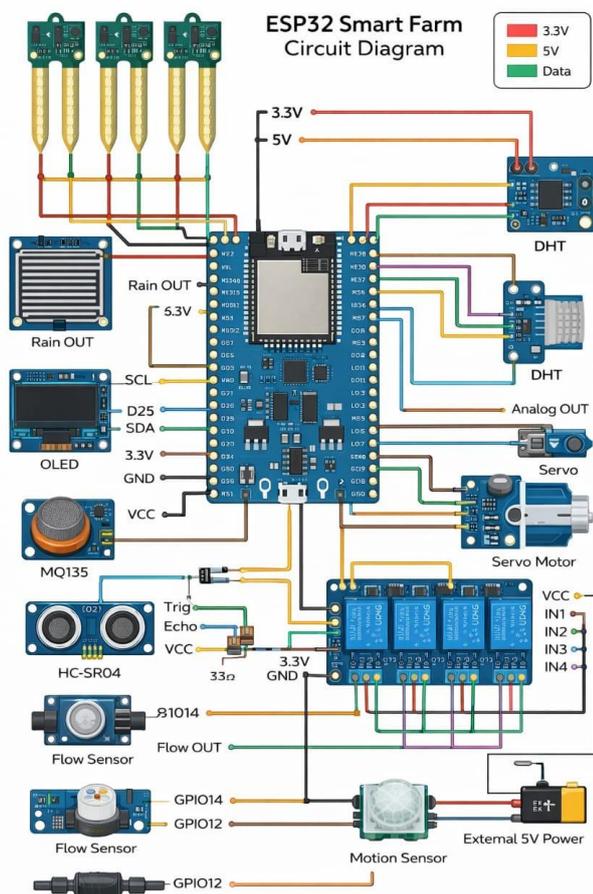
Automation Mechanism:
A servo motor with sliding rail mechanism is used to control the polyhouse shed/cover, which can open or close depending on weather conditions like rain.

Wiring & Circuit:
All components are interconnected through wiring inside the enclosure, forming a complete IoT-based smart farming system.

Circuit Diagram

Circuit Diagram Description

The circuit diagram of the smart farming automation system illustrates the interconnection between the sensors, actuators, and the main controller. The central unit of the system is the ESP32 DevKit V1, which collects data from multiple sensors and controls the actuators accordingly.

Power Supply Connections

The system operates using a regulated 5V power supply, which is distributed to the sensors, relay module, and other peripheral devices. The ESP32 board internally regulates the voltage to 3.3V, which is required for certain sensors and communication modules.

Sensor Connections

Soil Moisture Sensors

Multiple soil moisture sensors are connected to the analog input pins of the ESP32. These sensors measure the water content present in the soil and send analog signals to the controller for irrigation control.

Rain Sensor

The rain sensor module is connected to one of the digital input pins of the ESP32. When rainwater falls on the sensor plate, the module detects the change in conductivity and sends a signal to the controller.

Temperature and Humidity Sensor

The DHT11 Sensor is connected to a digital GPIO pin of the ESP32. It measures environmental temperature and humidity and sends the data to the microcontroller for monitoring and display.

Gas Sensor

The MQ-135 Gas Sensor is connected to an analog input pin. It detects harmful gases and air pollutants present in the agricultural environment.

Ultrasonic Sensor

The HC-SR04 Ultrasonic Sensor uses two pins, Trig and Echo, which are connected to digital GPIO pins of the ESP32 to measure distance for monitoring water levels or detecting obstacles.

Flow Sensor

The water flow sensor is connected to a digital input pin. It measures the rate of water flow in the irrigation system and sends pulse signals to the controller.

Motion Sensor

A motion detection sensor is connected to the ESP32 to detect movement in the farming area, which can be useful for security monitoring.

Output Devices

OLED Display

The 0.96-inch OLED Display is connected using I2C communication pins (SDA and SCL). It displays real-time data such as soil moisture, temperature, humidity, and system status.

Servo Motor

A servo motor is connected to a PWM GPIO pin of the ESP32. It is used to control the protective shed mechanism that opens or closes depending on rain conditions.

Relay Module

The relay module is connected to the ESP32 digital output pins. It controls high-power devices such as the water pump used for irrigation.

RESULTS AND DISCUSSION

The proposed smart farming automation system was designed and tested to monitor environmental parameters and automatically control agricultural operations. The system successfully integrated multiple sensors and actuators to create an efficient and intelligent farming environment.

During the testing phase, the soil moisture sensor accurately detected the moisture level of the soil. When the soil moisture level dropped below the predefined threshold value, the irrigation pump was automatically activated. Once the required moisture level was reached, the pump was turned off automatically. This helped in maintaining optimal soil conditions and reducing unnecessary water usage.

The temperature and humidity monitoring was performed using the DHT11 Sensor, which provided real-time environmental data. These parameters were continuously displayed on the OLED display, allowing users to easily monitor farm conditions.

The rain sensor successfully detected rainfall and triggered the servo motor to activate the protective shed mechanism. This feature helps in protecting crops from excessive rain and harsh weather conditions. After the rain stopped, the shed automatically returned to its original position.

Gas and flame sensors were also tested to ensure safety within the farming environment. When abnormal gas levels or flame conditions were detected, the system was able to identify the hazard and trigger alerts, improving overall safety in the agricultural field.

The visual monitoring system implemented using the ESP32-CAM and the color sensor provided additional plant monitoring capabilities. The camera captured images of plants, while the color sensor helped detect variations in leaf color, which may indicate plant health issues such as nutrient deficiency or disease.

1. Soil Moisture Sensor

Threshold Value: 50%

If soil moisture < 50% → Irrigation pump ON (via relay).

If soil moisture ≥ 50% → Irrigation pump OFF.

The soil moisture sensor continuously measures the water content in the soil. When the moisture level drops below the threshold value of 50%, the irrigation system is automatically activated to supply water to the crops. Once the soil moisture level reaches the desired range, the pump is automatically turned off to prevent over-irrigation.

2. Rain Sensor

Threshold Value: Analog value < 1500

If rain sensor value < 1500 → Rain detected, servo motor closes the shed.

If rain sensor value ≥ 1500 → Rain not detected, servo motor opens the shed.

The rain sensor detects rainfall on the greenhouse roof. When rain is detected, the servo motor activates the shed mechanism to protect crops from excessive rainwater.

3. Gas Sensor

Threshold Value: 60%

If gas level > 60% → Gas leakage detected → Alert triggered.

If gas level ≤ 60% → Normal condition → No action required.

The MQ-135 Gas Sensor monitors air quality and detects harmful gases in the environment. If gas concentration exceeds the safe limit, the system activates a warning alert to notify the farmer.

4. Flame Sensor

Threshold Value: Digital detection

If flame detected (HIGH signal) → Fire alert activated.

If flame not detected (LOW signal) → Normal condition.

The flame sensor detects fire or abnormal heat sources in the farming area. When a flame is detected, the system immediately triggers a safety alert to prevent potential fire hazards.

5. Temperature and Humidity Sensor

Threshold Values:

Temperature > 35°C

Humidity < 40%

If temperature > 35°C → Cooling/ventilation system activated.

If humidity < 40% → Humidifier system activated.

Otherwise → System remains normal.

The DHT11 Sensor continuously measures the environmental conditions and helps maintain an optimal climate for plant growth.

6. Color Sensor

Threshold Logic: Leaf color comparison

If leaf color matches healthy green range → Plant condition Healthy.

If leaf color deviates from green spectrum → Possible nutrient deficiency or disease detected.

The color sensor analyzes the leaf color of plants to determine their health condition. Changes in color patterns may indicate nutrient deficiencies, diseases, or environmental stress.

7. Camera Monitoring

Camera captures plant images periodically.

Images are used for visual monitoring and analysis.

The ESP32-CAM is used for real-time visual monitoring of crops, allowing farmers to observe plant growth and detect issues early.

CONCLUSION AND FUTURE SCOPE

A. Conclusion

The proposed smart farming automation system successfully demonstrates the integration of modern technologies such as IoT, sensors, and embedded systems to improve agricultural efficiency. By utilizing the ESP32 DevKit V1 as the central controller, the system effectively monitors key environmental parameters including soil moisture, temperature, humidity, rainfall, gas levels, and water availability.

The implementation of automated irrigation based on soil moisture ensures optimal water usage, reducing wastage and enhancing crop growth. The rain detection mechanism combined with a servo-controlled shed provides protection against adverse weather conditions. Additionally, safety features such as gas and flame detection improve the reliability and security of the farming environment.

The integration of real-time monitoring through an OLED display and camera-based plant observation further enhances the system's capability to support informed decision-making. Overall, the system proves to be cost-effective, efficient, and scalable, making it suitable for modern agricultural applications.

Thus, the developed smart farming system contributes towards sustainable agriculture by optimizing resource utilization, improving crop productivity, and reducing manual intervention.

B. Future Scope

The proposed smart farming automation system can be further enhanced by integrating advanced technologies to improve efficiency, accuracy, and scalability. One of the major improvements can be the incorporation of Artificial Intelligence (AI) and Machine Learning (ML) algorithms for predictive analysis. These techniques can help in forecasting soil conditions, crop health, and irrigation requirements based on historical data.

The system can also be extended by implementing cloud-based platforms for remote monitoring and control. By connecting the ESP32 to cloud services, farmers can access real-time data through mobile or web applications from anywhere.

Another significant enhancement is the integration of advanced image processing using the ESP32-CAM. This can enable automatic detection of plant diseases, pest attacks, and nutrient deficiencies by analyzing leaf color and texture.

Additionally, the system can be expanded to include automated fertigation systems, where fertilizers are supplied along with irrigation water based on soil nutrient levels. Renewable energy sources such as solar panels can also be incorporated to make the system energy-efficient and suitable for rural areas.

Further improvements may include GPS-based field monitoring, weather prediction integration, and the use of wireless sensor networks for large-scale farming. With these advancements, the system can evolve into a fully autonomous smart agriculture solution, contributing significantly to sustainable and precision farming practices.

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