Agri Sense: ARIMA-Based Smart Irrigation with Pesticide Detection

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Abstract: *Agriculture continues to be the backbone of many economies, yet traditional irrigation and pesticide management practices often rely on manual observation, resulting in either over-irrigation, water scarcity, or excessive pesticide use. With advancements in the Internet of Things (IoT) and predictive analytics, smart agriculture solutions have gained popularity due to their ability to automate decision- making and improve resource utilization. In this study, we propose AgriSense, an IoT-enabled smart irrigation system that combines ARIMA-based time series forecasting with real-time pesticide detection. ARIMA models are well-suited for soil moisture prediction due to their ability to capture temporal dependencies. Pesticide detection ensures safe food production and prevents harmful effects of chemical residues. Integrating these features enables farmers to monitor field conditions, automate irrigation, and ensure crop safety using a unified system.*

Key Words: *IoT, Smart Irrigation, ARIMA, Soil Moisture Prediction, Pesticide Detection, Smart Agriculture, Wireless Sensor Network, Precision Farming.*

I.INTRODUCTION

Agriculture continues to be the backbone of many economics, yet traditional irrigation and pesticide management practices often rely on manual observation, resulting in either over-irrigation, water scarcity, or excessive pesticide use. With advancements in the Internet of Things (IoT) and predictive analytics, smart agriculture solutions have gained popularity due to their ability to automate decision-making and improve resource utilization.

In this study, we propose AgriSense, an IoT-enabled smart irrigation system that combines ARIMA-based time series forecasting with real-time pesticide detection. ARIMA models are well-suited for soil moisture prediction due to their ability to capture temporal dependencies. Pesticide detection ensures safe food production and prevents harmful effects of chemical residues. Integrating these features enables farmers to monitor field conditions, automate irrigation, and ensure crop safety using a unified system.

II.SYSTEM METHODOLOGY

1. Microcontroller Unit (MCU) ESP32

The central processing module is a microcontroller responsible for collecting data from all sensors, executing ARIMA-based prediction algorithms, and controlling the irrigation system, It handles sensor data acquisition, processing and decision making, sending data to IoT cloud, relay switching for the solenoid/pump, lcd communication for displaying values. All sensors are connected to its analog/digital GPIO pins.

2. Sensor Used

The hardware setup includes the following sensors:

a) Soil Moisture Sensor

This sensor measures soil moisture content by detecting resistance/conductivity between its two probes. Determines current moisture levels. Helps trigger irrigation when the soil is dry.

b) Humidity & Temperature Sensor

A blue sensor module placed near the bottom-left. Measures real-time air temperature. Measures surrounding humidity Used to refine prediction models and understand environmental conditions.

c) Rain Sensor Module

The square copper PCB plate with black traces placed at the lower centre. Detects presence of rainfall. Helps system avoid irrigation during rainy conditions
Improves water-saving accuracy.

3. Pesticide / Water Quality Sensor

Seen as the white cylindrical sensor on the right side. Detects chemical impurities/pesticide levels. Prevents harmful

residue accumulation. Triggers alerts to the user

4. **Display Unit 16x2 LCD Display**

Mounted at the top centre of the board. Displays real-time sensor readings of temperature, humidity, soil moisture, rain status. Shows irrigation ON/OFF status. The LCD module is interfaced using I2C/SPI to reduce wiring complexity.

5. **Relay Module**

Located on the right side of the board. Controls pump/solenoid valve. Acts as a switching interface between the low-power microcontroller and high-power irrigation pump.

6. **Power Supply Module**

Positioned on the top-left of the board (green PCB with capacitors). Provides regulated 5V/12V supply to sensors and microcontroller. Ensures stable operation even with multiple modules running.

7. **Connecting Wires and PCB Arrangement**

The board includes multiple jumper wires to connect sensors to the microcontroller, provide power supply connections, and carry control signals to the relay, Link the display module for showing outputs.

8. **System Implementation Flow**

All sensors collect environmental data. The microcontroller reads sensor inputs. Moisture values are passed through ARIMA forecasting for prediction. LCD displays all real-time values. If moisture (real/predicted) < threshold → Relay switches ON → Irrigation starts. Rain detection overrides irrigation to prevent water waste. Pesticide sensor triggers alert if chemicals exceed safe levels. System continues to monitor in a loop for autonomous operation.

9. **Overall Functionality**

Automated prediction-based irrigation, real-time sensing of temp, humidity, moisture, rain avoidance for water-saving Pesticide detection for safe farming, LCD monitoring, relay-controlled smart water pump.

III.LITERATURE REVIEW

Several studies in the field of smart agriculture have demonstrated that IoT-based irrigation systems greatly enhance water efficiency when compared to traditional manual practices. Research emphasizes the use of wireless sensor networks for real-time monitoring of soil conditions and climatic parameters, enabling precise and data-driven decision-making. In parallel, ARIMA models have been widely explored for predicting environmental data due to their strong ability to model time-dependent variables. These models have shown higher accuracy in soil moisture prediction over conventional threshold-based systems, leading to more efficient irrigation scheduling.

Additionally, various studies on pesticide detection highlight the effectiveness of electrochemical and optical sensors in identifying harmful chemical residues in soil and water, thus improving crop safety and traceability. While existing literature presents numerous IoT-based predictive irrigation and sensing systems, there is limited work integrating both ARIMA-based moisture forecasting and pesticide detection into a unified platform. The *AgriSense* system addresses this gap by combining predictive analytics with real-time contamination monitoring to create a more comprehensive and sustainable smart farming solution.

IV.SYSTEM IMPLEMENTATION AND HARDWARE DESCRIPTION

Figure4. Block Diagram: Smart Irrigation System (Agri Sense Model)
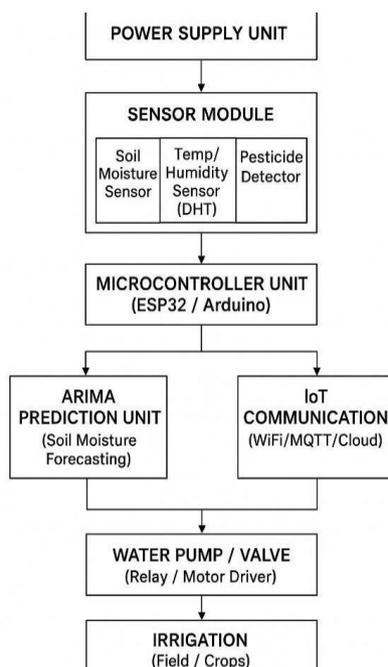
A. Power Supply Unit

The Power Supply Unit (PSU) is a critical component of the smart irrigation system, responsible for providing stable and regulated electrical power to all sensors, modules, and the microcontroller. Since most electronic components in IoT systems operate at 5V, the PSU ensures a safe and consistent voltage supply from an external power source.

Figure 4.1 Power Supply

B. LCD Display

The LCD Display is an essential output component of the smart irrigation system, used to provide real-time visual feedback to the user. Typically, a 16×2 alphanumeric LCD is used, which can display up to 32 characters across two rows. This display helps monitor sensor readings, system status, and irrigation actions without needing a mobile device or computer.

Figure 4.2 LCD Display

C. Realy

The *Relay* Module is a key component of the smart irrigation system, acting as an electrically controlled switch that enables the microcontroller to operate high-power devices such as the water pump. Since microcontrollers like the ESP32 or Arduino can only output low-voltage, low-current signals (3.3V/5V), they cannot directly drive AC motors or high- power loads. The relay serves as an interface that safely isolates the low-power control circuit from the high-voltage pump circuit.
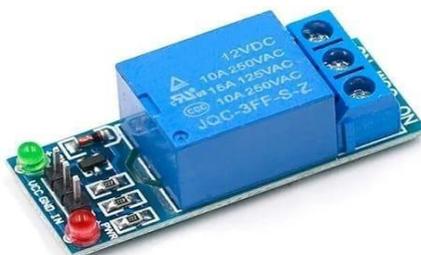

Figure 4.3 Relay

D. ESP32

The ESP32 is a powerful, low-cost microcontroller widely used in IoT-based smart agriculture systems due to its built-in Wi-Fi, Bluetooth, and high processing capability. It features a dual-core 32-bit processor, large memory, and multiple GPIO pins, making it suitable for real-time monitoring, data processing, and wireless communication
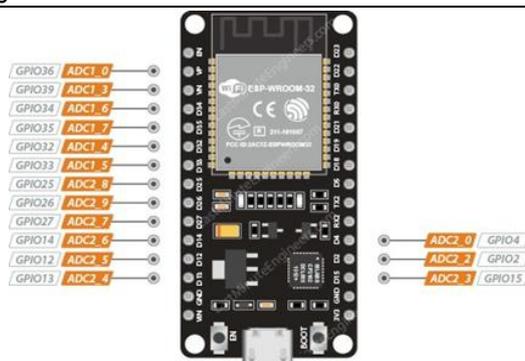
Figure 4.3 ESP32

E. Rain Module Sensor

The Rain Module Sensor is used to detect the presence and intensity of rainfall, enabling the smart irrigation system to make more accurate and water-efficient decisions. The module typically consists of two parts: a rain detection board with conductive traces and a signal processing module. When raindrops fall on the board, they create a conductive path that changes the sensor's resistance, allowing the system to determine whether it is raining and how heavily.

Figure 4.4 Rain Module Sensor

F. Soil Moisture Sensor

The Soil Moisture Sensor is one of the most essential components in the AgriSense Smart Irrigation System. It is used to measure the volumetric water content in the soil, allowing the microcontroller to determine whether irrigation is required. The sensor typically consists of two conductive probes that are inserted into the soil. As moisture increases, the conductivity between the probes also increases, producing corresponding analog voltage values.

Soil moisture sensors are lightweight, low-cost, and easy to interface with microcontrollers. Many versions include an amplifier or comparator module for stable readings. When deployed in agricultural fields, they provide accurate real-time monitoring that significantly enhances the performance and reliability of smart irrigation systems.
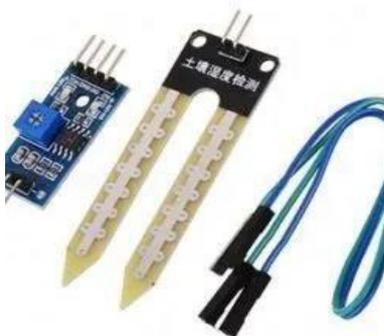

Figure 4.5 Soil Moisture Sensor

G. DHT11 Temperature & Humidity Sensor

The DHT11 sensor is a low-cost digital sensor used to measure temperature and relative humidity, making it ideal for environmental monitoring in smart agriculture systems. It uses a capacitive humidity sensing element and a thermistor to detect atmospheric conditions and outputs the data as a calibrated digital signal, which ensures stable and accurate readings.

Figure4.6 Temperature & Humidity Sensor

H. Water Flow Sensor

Figure4.7 Water Flow Sensor

The Water Flow Sensor is used to measure the rate of water flowing through the irrigation pipeline. It plays a crucial role in monitoring and regulating the amount of water supplied to crops, ensuring efficient water usage in the AgriSense Smart Irrigation System. The sensor typically contains a small turbine or impeller inside a sealed plastic body. When water flows, the turbine rotates, generating electrical pulses that correspond to the flow rate.

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