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IoT-Based Smart Irrigation System with Remote and Voice Control

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Abstract.

Conventional irrigation relies on human intuition, causing over/under-irrigation, resource wastage, and low crop yields in small farms and residential gardens. This paper proposes an IoT-based smart irrigation system using ESP32 microcontroller, soil moisture sensor, temperature sensor, and humidity sensor with event-driven architecture. A React Native mobile app integrates voice recognition (Google Speech API) and manual pump control via MQTT/HTTP protocols. Experimental validation across five moisture levels and diverse soil types (loamy, sandy, clay) demonstrates response times of 1.2–1.8 seconds—significantly faster than cloud-based systems (3–8 s)—and achieves up to 30 percent water savings. The system addresses UN SDGs 6 (Clean Water and Sanitation) and 12 (Responsible Consumption), offering low-cost, cloud-optional solutions for small farms, household gardens, and plant management.

Keywords. IoT, Smart Irrigation, ESP32, Soil Moisture Sensor, Voice Control, Google Speech API, React Native, Water Conservation, Threshold-Based Control, Sustainable Agriculture

1. INTRODUCTION

Agriculture remains a critical economic activity worldwide, particularly for communities dependent on farming. Water is essential for soil fertility and plant growth; effective irrigation directly impacts productivity, ecological state, and soil quality. Traditional irrigation relies on human judgment rather than real-time data interpretation, leading to over-irrigation or under-irrigation, plant loss, resource wastage, and reduced yields. Internet of Things (IoT) technology offers groundbreaking solutions for smart agricultural management. IoT systems combine sensor data to monitor soil moisture, temperature, and humidity in real-time, enabling automated irrigation, limiting human interaction, improving water-use efficiency, and reducing manpower requirements. This paper proposes an event-driven architecture tailored for small farms and residential gardens, eliminating expensive hardware and continuous cloud computing while offering voice-activated and manual smartphone app control.

2. RELATED WORK

IoT-based smart irrigation systems commonly use ESP32, soil moisture and DHT11 sensors, threshold-based pump control, and cloud-based remote monitoring. Recent studies also explore WSNs, weather forecasting, AI prediction, and voice control. However, limited attention is given to usability and accessibility for non-technical users. This study addresses these gaps through a low-power ESP32 architecture, voice-enabled control, fast 1.2–1.8 s response, and automated irrigation achieving 30% water savings across diverse soil types.

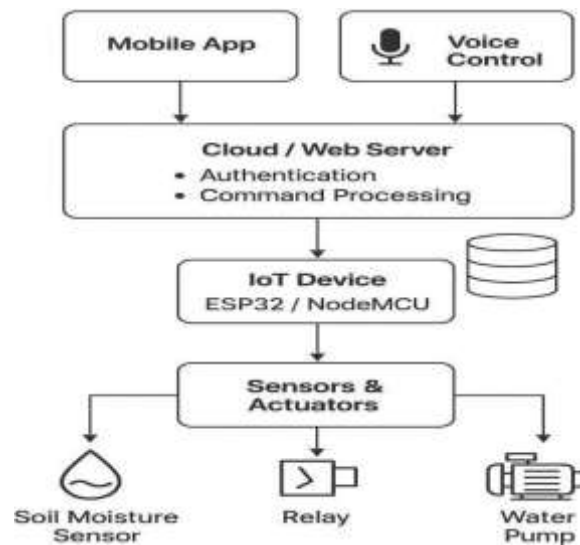


Fig 2.1: IoT-Based Smart Plant Watering System Architecture

3. SYSTEM DESIGN

A. System Architecture:

The system comprises three key components: (1) User Interface—accepts voice commands via Google Speech API and manual button presses; (2) ESP32 Microcontroller Unit—central processing unit handling wireless commands, control logic, and relay capability; (3) Relay Module and Water Pump—provides electrical isolation of low-voltage control to high-voltage pump for safe operation. Hardware includes ESP32 microcontroller, capacitive soil moisture sensor, DHT11 temperature-humidity sensor, 5V relay module, 12V DC water pump, 5V/3.3V voltage regulator, connecting circuitry, and LED indicators. Software: Arduino IDE creates firmware; React Native mobile app provides voice activation (Google Speech API) and manual pump control. Lightweight wireless command transmission uses MQTT or HTTP protocols. ThingSpeak and Blynk cloud platforms offer optional data visualization dashboards.

B. Operation Principle

The system triggers via valid user commands or sensor threshold events, eliminating constant cloud polling. The process: (1) setup ESP32 and Wi-Fi; (2) periodical soil moisture measurement; (3) pump switches on when moisture falls below 400 on sensor scale; (4) pump switches off when moisture rises above threshold; (5) mobile app allows user override.

Speech recognition converts voice inputs to digital commands; ESP32 receives signals via HTTP/MQTT and updates relay state with LED and app-based feedback. Experimental setup used ESP32, relay module, and capacitive soil moisture sensor tested across different soil types (loamy, sandy, clay) under varying environmental conditions with definite closed-loop control.

4. RESULTS AND PERFORMANCE EVALUATION

Threshold-based pump control was successfully validated, with 1.2–1.8 s response latency. The system reduced water consumption by approximately 30%, while its event-based and cloud-optional design improves energy efficiency, reliability, privacy, and usability in remote farming environments.

5. CONCLUSION AND FUTURE WORK

This paper presents an IoT-based smart irrigation system using ESP32, soil moisture and environmental sensors, and voice/manual control. Testing achieved 1.2–1.8 s response time and up to 30% water reduction. Future work includes predictive irrigation, solar integration, and weather-based automation.

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Biographies



Rutika Dhembare

is a B.Tech IT student at VIT Pune specializing in frontend development and responsive UI design. She designed and implemented the React-based dashboard providing real-time monitoring and alert visualization.



Dhanshree Dhindale

is a B.Tech IT student at VIT Pune specializing in backend development, database architecture, and RESTful APIs. She led the MongoDB schema design and Flask API implementation for SentinelX alert management.



Saloni Tanmor

is a B.Tech student in Information Technology at VIT Pune. Her research focuses on deep learning, computer vision, and real-time detection systems. She developed and optimized YOLOv8-based threat detection models for the SentinelX platform.



Shaheen Khan

is a B.Tech IT student at VIT Pune with expertise in machine learning pipelines and model optimization. She contributed to YOLOv8 training, dataset management, and comprehensive performance evaluation frameworks.



Shraddha Jagtap

is a B.Tech IT student at VIT Pune. She contributed to system integration testing, technical documentation, and multi-channel alert implementation using Twilio SMS and email services.



Mrs. Supriya Jagtap

is an Assistant Professor at the Department of Information Technology, VIT Pune. She holds an M.Tech degree with extensive expertise in artificial intelligence, deep learning applications, and embedded systems. She mentored the SentinelX project from conception through implementation and evaluation.