IoT Based Smart Irrigation System Using ESP32

an automated solution for efficient Iot-Based Smart Irrigation System using ESP32

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Abstract

Efficient water management is a critical requirement in modern agriculture due to increasing water scarcity and the need for sustainable farming practices. Traditional irrigation systems rely on manual operation and fixed schedules, which often result in over-irrigation, water wastage, and reduced crop productivity.

This paper presents an **IoT-Based Smart Irrigation System using ESP32**, designed to automate irrigation based on real-time environmental conditions. The system utilizes a soil moisture sensor, temperature sensor, and water level sensor to continuously monitor field parameters. The ESP32 microcontroller processes the sensor data and controls a water pump through a relay module, ensuring that water is supplied only when required.

The proposed system also incorporates IoT technology to enable wireless monitoring and control through a mobile or web interface. This allows users to access real-time data and manage irrigation remotely. The system is low-cost, energy-efficient, and easy to implement, making it suitable for small-scale farms, gardens, and greenhouse applications.

The results demonstrate that the system effectively reduces water wastage, minimizes human intervention, and improves irrigation efficiency, thereby contributing to smart and sustainable agricultural practices.

Keywords: IoT, Smart Irrigation System, ESP32, Soil Moisture Sensor, Temperature Monitoring, Water Level Sensor, Automated Irrigation, Wireless Monitoring, Precision Agriculture, Sustainable Water Management.

1. Introduction

In Agriculture plays a vital role in the global economy, and efficient water management is essential for improving crop productivity. Traditional irrigation methods are mostly manual and operate on fixed schedules, which often leads to over-irrigation, water wastage, and inefficient utilization of resources.

With increasing water scarcity and the need for sustainable farming, there is a growing demand for intelligent irrigation systems.

The advancement of the Internet of Things (IoT) and embedded systems has enabled the development of smart irrigation solutions. By integrating sensors and microcontrollers, it is possible to monitor soil and environmental conditions in real time and automate irrigation processes. This reduces human intervention and ensures that crops receive water only when required.

This paper presents an **IoT-Based Smart Irrigation System using ESP32**, which uses soil moisture, temperature, and water level sensors to monitor field conditions. The ESP32 microcontroller processes the sensor data and controls a water pump through a relay module. The system also enables wireless monitoring and control through a mobile or web interface using Wi-Fi connectivity.

The proposed system aims to reduce water wastage, improve irrigation efficiency, and provide a low-cost, reliable solution for modern agriculture, making it suitable for farms, gardens, and greenhouse applications.

2. Abbreviations and Acronyms

The following abbreviations and acronyms are used in this research paper:

IoT – Internet of Things
ESP32 – Espressif 32-bit Microcontroller
ADC – Analog to Digital Converter
GPIO – General Purpose Input Output
DHT – Digital Humidity and Temperature Sensor
DC – Direct Current
Wi-Fi – Wireless Fidelity
GUI – Graphical User Interface
VCC – Voltage Common Collector
GND – Ground
PWM – Pulse Width Modulation

3. Units

The proposed IoT-based smart irrigation system utilizes standard units for measuring various physical and electrical parameters to ensure accuracy, consistency, and easy interpretation of data.

- Soil moisture is measured using analog signals from the sensor, which are represented in the **ADC range (0–4095)** in the ESP32. These values can also be converted into **percentage (%)** to indicate the level of soil wetness or dryness.
- Temperature is measured using a sensor and expressed in **degrees Celsius (°C)**, which helps in understanding environmental conditions affecting irrigation.
- Electrical voltage supplied to the system components is measured in **Volts (V)**, ensuring proper operation of the ESP32, sensors, and relay module.
- Electrical current consumed by the system is measured in **Amperes (A)**, which is important for evaluating power requirements and efficiency.
- Time intervals for sensor readings and system operations are measured in **seconds (s)**.
- Frequency of signals (if applicable in control systems) is measured in **Hertz (Hz)**.
- Distance or physical placement of components (if considered) is measured in **meters (m)**.

All the above parameters follow the **International System of Units (SI Units)**, which ensures uniformity, reliability, and standardization in data measurement and system performance.

4. Equations

The smart irrigation system uses basic mathematical relationships to interpret sensor data and control irrigation effectively.

- **Soil Moisture Percentage Calculation:**

$$\text{Soil Moisture (\%)} = \left(\frac{ADC_{max} - ADC_{value}}{ADC_{max} - ADC_{min}}\right) \times 100$$

Where:

- ADC_{value}= current sensor reading
- ADC_{max}= dry soil value
- ADC_{min}= wet soil value

- **Temperature Conversion (if required):**

$$T(°C) = \frac{5}{9} \times (T(°F) - 32)$$

- **Power Consumption Equation:**

$$P = V \times I$$

Where:

- P= Power (Watts)
- V= Voltage (Volts)
- I= Current (Amperes)

- **Decision Condition for Irrigation:**

$$\text{If } M < M_{threshold} \rightarrow \text{Pump ON}$$
$$\text{If } M \geq M_{threshold} \rightarrow \text{Pump OFF}$$

Where:

- M= Soil moisture value
- $M_{threshold}$= predefined moisture threshold

These equations help in analyzing sensor data and controlling the irrigation process efficiently.

5. Headings

The headings in this paper are organized in a structured manner to ensure clarity, readability, and proper presentation of the content. Different levels of headings are used to represent the hierarchy of information.

- **Main Headings** are numbered and written in **bold capital letters** to indicate major sections of the paper (e.g., Introduction, Methodology, Results).
- **Subheadings** are used to divide sections into smaller parts and are written in **bold with title case** for better understanding.
- **Sub-subheadings** may be used if further division is required and are written in a smaller format.
- All headings are aligned properly and follow a **consistent numbering system** throughout the document.
- Adequate spacing is maintained before and after each heading to improve readability.

This structured format of headings helps in organizing the content effectively and makes the document easy to navigate.

6. Figures and Tables

The Figures and tables are used in this paper to present information clearly and effectively. They help in better understanding of the system design, working, and results.

- **Figures** include block diagrams, flowcharts, and system architecture diagrams of the smart irrigation system.
- Each figure is properly labeled and numbered (e.g., Fig. 1, Fig. 2) with a suitable caption below the figure.
- Figures are aligned properly and placed near the relevant content for easy reference.
- **Tables** are used to represent structured data such as component lists, sensor values, and system parameters.
- Each table is numbered (e.g., Table 1, Table 2) and includes a clear title above the table.
- Proper rows and columns are used to maintain readability and organization of data.
- All figures and tables are referenced in the main text to explain their purpose and significance.
- Proper formatting and spacing are maintained to ensure clarity and consistency throughout the document.

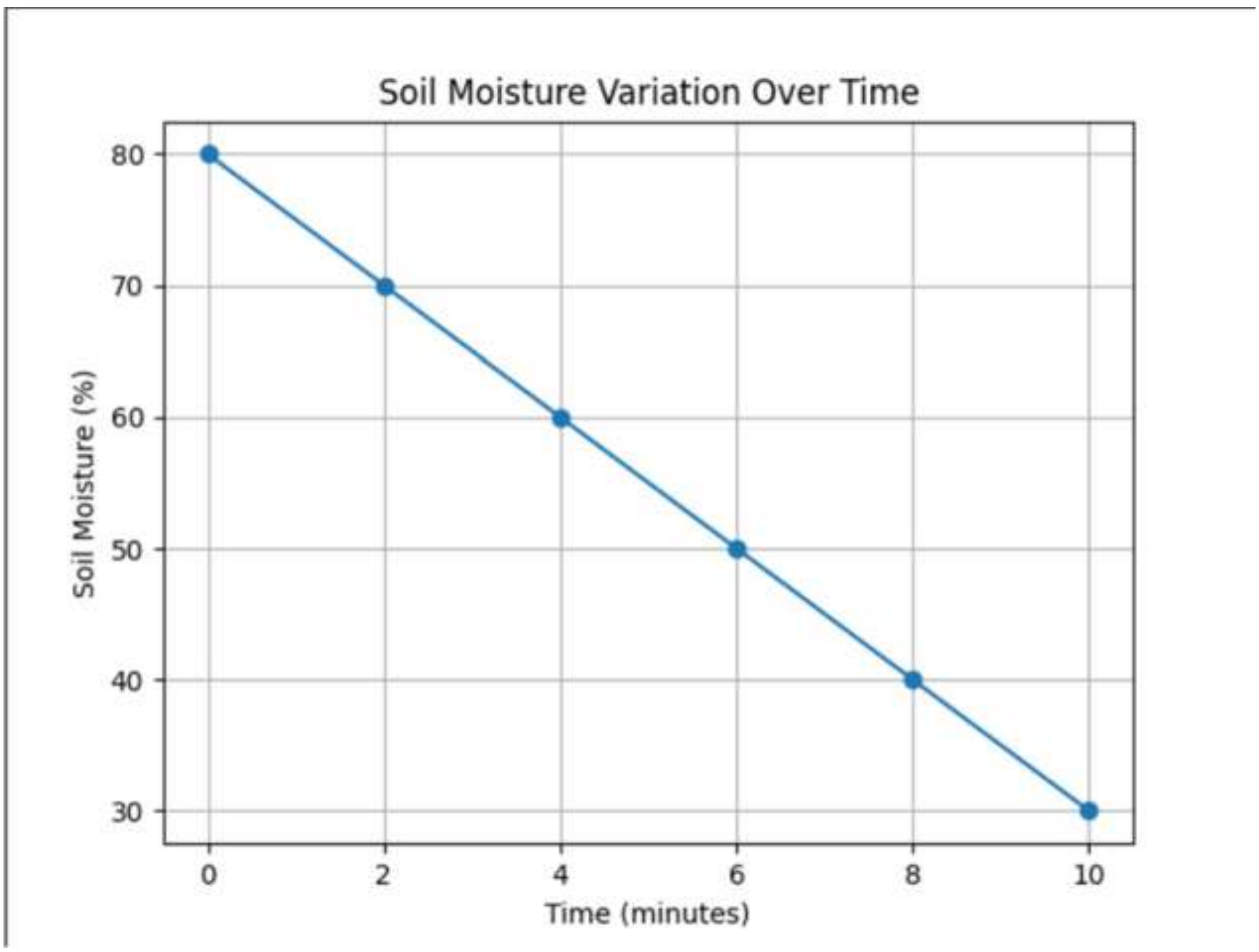
The use of figures and tables enhances the presentation of the project and improves the understanding of the system.

Table 1: Smart Irrigation Components and Specifications

Component Name	Function	Specification
ESP32 Development Board	Main controller for processing data and IoT communication	32-bit MCU, Wi-Fi & Bluetooth, 240 MHz
Soil Moisture Sensor	Measures soil moisture level	Analog output, 3.3V/5V operation
DHT22 Sensor	Measures temperature and humidity	Range: -40°C to 80°C, Accuracy: ±0.5°C
Water Level Sensor	Detects water availability in tank	Digital/Analog output, 3.3V/5V
Relay Module	Controls ON/OFF switching of water pump	5V relay, Single channel
DC Water Pump	Supplies water for irrigation	6V–12V DC pump
Power Supply / Adapter	Provides power to system components	5V/9V DC supply
Jumper Wires	Connects components electrically	Male-to-male / female wires
Pipes / Tubes	Carries water from pump to plants	Plastic tubing

The above data is pictured in the next graph.

Graph 1: Smart irrigation system



7. Some Common Mistakes

The following are some common mistakes that may occur during the design, implementation, and testing of the Smart irrigation System:

- **Incorrect wiring of sensors and ESP32 pins, leading to wrong or no readings.**
- **Not calibrating the soil moisture sensor properly, resulting in inaccurate moisture values.**
- **Using incorrect power supply voltage, which may damage components or affect performance.**
- **Not using proper relay connections, causing the water pump to malfunction.**
- **Ignoring the use of pull-up resistors (for sensors like DHT or DS18B20), leading to sensor errors.**
- **Incorrect pin configuration in the program code.**
- **Lack of proper grounding between all components.**
- **Not testing individual components before integrating the full system.**
- **Poor connection quality (loose wires or bad jumper wires).**
- **Not handling sensor errors or invalid readings in the code.**

8. Appendix

- The appendix provides additional supporting information related to the development and implementation of the IoT-Based Smart Irrigation System.
- Detailed circuit connections and wiring configurations of all components.
- Sample Arduino (Embedded C) code used for sensor reading and pump control.
- Calibration values for the soil moisture sensor (dry and wet conditions).
- Experimental readings of soil moisture and temperature during testing.
- Additional diagrams such as block diagram, flowchart, and system architecture.
- Datasheets of components like ESP32, DHT22, soil moisture sensor, and relay module.
- These supplementary details help in better understanding, replication, and validation of the proposed system

9. Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper. The project has been carried out as a part of academic work, and no financial or personal relationships have influenced the outcomes of this study..

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11. Authors' Biography

The **Ranju Kondapgorla** is a diploma student in the field of Engineering with an interest in embedded systems, IoT, and robotics. The author has worked on projects related to automation and smart systems and is keen to explore innovative technological solutions.

Vaishnavi Wani is pursuing a diploma in Engineering and has a strong interest in electronics and communication systems. She has actively participated in academic projects involving microcontrollers and IoT-based applications.

Shruti Sakhare is a diploma engineering student with an interest in embedded systems and hardware design. She has contributed to the development and implementation of various technical projects focusing on real-time applications.

Manju Kondagorla is a diploma student specializing in engineering studies with a keen interest in IoT and automation technologies. She has been involved in project development and enjoys working on practical problem-solving solutions.

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