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IoT Based Smart Irrigation System using Real Time Soil Moisture Monitor

Daulat Ram
CSE
Chandigarh University
Gharuan, India

Khusi
CSE
Chandigarh University
Gharuan, India

Priyanka Kumari
CSE
Chandigarh University
Gharuan, India

Anisha
CSE
Chandigarh University
Gharuan, India

***Abstract*—One of the most urgent issues of contemporary agriculture, given growing population, climate change and water shortage, is the efficient use of water. Conventional irrigation relies on fixed time schedules and manual control, which often lead to unnecessary water usage and low crop yield. In this paper, an Internet of Things (IoT) based smart irrigation system is presented that measures soil moisture in real time and controls irrigation accordingly. The proposed system combines low-cost soil moisture, temperature and humidity sensors, a microcontroller unit, and a cloud-based monitoring system capable of making autonomous decisions. A threshold-based control algorithm ensures that irrigation is provided only when necessary. Experimental evaluation shows that the proposed system reduces water consumption by about 30–35 percent without negatively affecting optimal soil moisture. The system is affordable, scalable and suitable for precision agriculture.**

Keywords*—*Smart Irrigation, Internet of Things, Soil Moisture Sensor, Precision Agriculture, Automation.

I. INTRODUCTION

Agriculture is of paramount importance to world food security and economic development, especially in the developing world. It is, however, the biggest user of freshwater resources, accounting for almost seventy percent of the total amount of water used in the world [1]. With rising climate variability, erratic rainfall patterns and population growth, efficient irrigation has become a key issue.

Traditional irrigation methods such as flood irrigation and manual use of pumps are ineffective and rely on ad-hoc schedules instead of actual monitoring of the soil [2]. These practices often lead to over-irrigation or under-irrigation, leaching of nutrients and soil erosion, which are detrimental to crop productivity. Manual irrigation also adds to labor costs and requires constant human presence.

Recent innovations in IoT have opened the potential to create smart agricultural systems that use sensors, embedded devices and cloud computing to automate agricultural operations [3]. IoT-based irrigation systems offer real-time control and monitoring, supplying water according to the actual needs of the soil rather than assumed ones. This paper introduces a low-cost IoT based smart irrigation system that utilizes real-time soil moisture data to optimize irrigation and reduce water wastage.

II. ATED WORK

A number of researchers have developed IoT-enabled smart irrigation systems that utilize soil moisture sensors and wireless communication. Kodali and Sahu designed an IoT-based soil moisture monitoring system that offers cloud-based visualization of soil conditions, but it lacks the capability to control irrigation [4]. Mekala and Viswanathan suggested an IoT-cloud based agricultural monitoring system that optimizes environmental comfort instead of direct irrigation control through soil moisture [5].

Afzal et al. proposed an adaptive irrigation system based on predictive analytics and machine learning to predict soil moisture content [6]. Even though their system was very accurate, it needed more computational resources and more time to collect data. Ramson et al. tested a LoRaWAN-based soil monitoring system to cover large agricultural fields, but this raised cost and complexity [7].

Other works have investigated data-driven irrigation systems based on wireless sensor networks and cloud technologies [8], [9]. Although these systems enhance monitoring, only large-scale farmers can afford them. The proposed system overcomes such shortcomings by offering a user-friendly, fully automated and affordable irrigation system.

III. SYSTEM ARCHITECTURE

The proposed IoT-based smart irrigation system consists of four functional layers, as depicted below.

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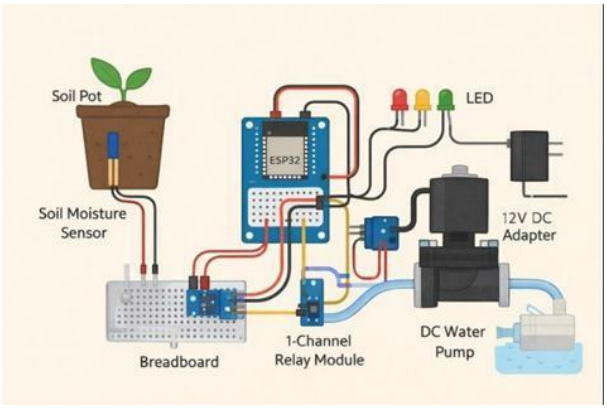


Fig. 1. Hardware architecture of proposed system

The soil moisture sensor, as depicted in Fig. 1, is installed inside the soil to continuously monitor the volumetric water content. The sensor output is connected to the ESP32 microcontroller, which serves as the main control unit of the system. According to the sensor values, the ESP32 triggers the relay module when the soil moisture is less than the set value. The DC water pump is controlled by the relay and supplies water to the plant. Visual indicators in the form of LEDs give the real-time status of the system. The system is powered by a twelve-volt DC adapter, which provides stable supply.

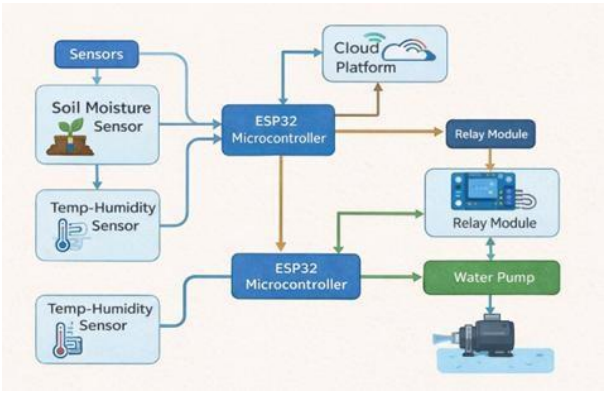


Fig. 2. Block diagram of the proposed IoT-based smart irrigation system

According to Fig. 2, the sensing layer is composed of a soil moisture sensor and a temperature-humidity sensor, which constantly obtain real-time data about the environment in the field. The sensor measurements are sent to the ESP32 microcontroller, the control centre of the system. The microcontroller processes the received data and transfers the appropriate parameters to the cloud platform, where they are stored and monitored remotely. The ESP32 compares the sensor readings against predetermined threshold values and activates the relay module to operate the water pump. The relay module switches the water pump on and off automatically whenever the soil moisture falls below the desired level. Such a closed-loop design guarantees efficient usage of water and reliability of the system.

A. Sensing Layer

The sensing layer comprises soil moisture sensors and temperature-humidity sensors. The soil moisture sensor measures the volumetric water content of the soil, one of the important parameters used to determine when to irrigate. The temperature-humidity sensor gives environmental data that can be used in the analysis of crop conditions [10].

B. Control Layer

A microcontroller, e.g. ESP32 or Arduino Uno, is used in the control layer. The sensor data are sent to the microcontroller, which compares them to predefined threshold values stored in the system memory. Based on this comparison, irrigation decisions are made automatically.

C. Actuation Layer

The actuation layer consists of a relay module and a water pump. The relay is an electronic switch used to control the operation of the pump. The relay triggers the pump to sprinkle water on the soil when the soil moisture drops below the threshold level.

D. Cloud and Monitoring Layer

Sensor data is sent to a cloud system such as ThingSpeak or Blynk over Wi-Fi. This layer offers real-time visualization, storage of historical data and remote monitoring through a web or mobile interface [11].

IV. METHODOLOGY

The system is rule-based and works on an automation algorithm. First, the microcontroller measures the soil moisture values at fixed intervals. The readings are converted into percent moisture content and compared against set threshold values.

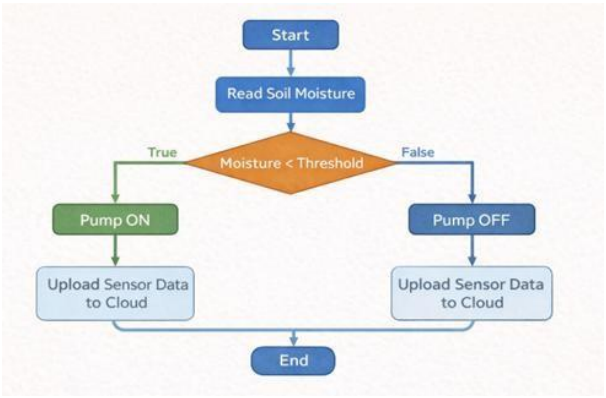


Fig. 3. Flowchart of the automated irrigation control algorithm

Fig. 3 illustrates that the algorithm starts by acquiring the soil moisture sensor reading. The obtained value is then compared with a preset value. When the soil moisture level is lower than the threshold, the controller switches on the relay module, which in turn switches on the water pump. When the moisture level is adequate, the pump remains off. In both cases, the current sensor readings are uploaded to the cloud platform for monitoring and data logging. Repetition of this cycle provides efficient and independent irrigation control.

When the soil moisture falls below the minimum value, the microcontroller transmits a control signal to the relay module to switch on the water pump. Irrigation continues until the soil moisture reaches an optimal level. When the required moisture has been attained, the pump is automatically switched off.

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At the same time, sensor data is uploaded to the cloud environment for tracking and processing. This closed-loop control system provides efficient irrigation with minimal use of water [12].

V. HARDWARE AND SOFTWARE IMPLEMENTATION

A. Hardware Components

The hardware comprises an ESP32 or Arduino Uno microcontroller, soil moisture sensor, DHT11/DHT22 temperature and humidity sensor, relay, water pump and power supply. These parts were chosen because they are low-cost, readily available and energy efficient [13].

B. Software Components

The system software is developed in embedded C/C++ using the Arduino Integrated Development Environment. Cloud communication is implemented through HTTP APIs and an IoT platform for data transmission and visualization.

VI. EXPERIMENTAL FINDINGS AND DISCUSSION

The proposed system was tested in a controlled farm setting over a period of several days. The soil moisture level was continuously monitored and irrigation was automatically controlled according to the sensor values.



Fig. 4. Real-time soil moisture monitoring dashboard on IoT cloud platform

Fig. 4 shows the real-time sensor data and system status visualization. The web-based cloud dashboard allows continuous tracking of soil moisture, temperature, humidity and irrigation activity.

The dashboard presents the real-time and past sensor data recorded in the field. Variations in soil moisture are continuously plotted, displaying the irrigation pattern and system performance to the users. The dashboard also reflects the functional state of the water pump, allowing the irrigation process to be observed remotely. This cloud-based monitoring improves decision making, transparency and effective management of water resources.

The system was found to use less water, with an experimental reduction of about 30–35% compared with conventional irrigation systems. The soil moisture level did not fall below the optimum level during the test period, so over-irrigation and under-irrigation were avoided. The cloud dashboard showed real-time and past data, making monitoring and analysis effective [14].

VII. BENEFITS AND APPLICATIONS

The proposed system has various benefits, including low cost, minimal human intervention, energy saving and scalability. It can be used in precision agriculture, greenhouse irrigation, smart agriculture, home gardening and optimization of water resources.

VIII. CONCLUSION

This paper introduced a smart irrigation system with IoT-driven real-time monitoring of soil moisture and remote control of irrigation. The system is effective in minimizing water wastage while keeping the soil in the best condition for crop growth. The proposed solution is simple, affordable and scalable, which makes it suitable for real-world application in the agricultural field.

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