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Smart Irrigation System using IoT

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Abstract

This study proposes an innovative smart irrigation system designed to address the inefficiencies of traditional methods. Utilizing sensors, microcontrollers, and other integrated components, the system ensures efficient water usage, promoting a more sustainable approach to agriculture. By providing real-time soil moisture monitoring and rainfall data, the system empowers farmers to make informed irrigation decisions, thereby improving crop management. Key features, such as a soil moisture sensor and rain sensor to prevent over-watering, enhance the system's effectiveness in promoting optimal plant growth. Overall, this proposed smart irrigation system demonstrates how technology can be effectively applied to solve real-world agricultural challenges.

Keywords: Smart Irrigation, IoT, ESP32, Soil Moisture Sensors, Rain Sensors, Real Time Monitoring, Automated Watering System.

1. Introduction

Agriculture is a vital industry and the foundation of the global economy. As the global population rapidly increases, the demand for food increases, necessitating advancements in agricultural practices and technologies to meet these growing needs. Automation in agriculture has become a significant focus worldwide, aiming to enhance overall outcomes and address challenges posed by changing consumer demands and resource constraints [1][5]. The need for this study stems from the growing demand for food driven by the rising global population. Traditional agricultural practices are becoming inadequate to meet these demands efficiently.

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Moreover, factors such as land scarcity, water depletion, and environmental pollution further exacerbate the challenges faced by the agriculture industry.

This study is to develop and implement a smart irrigation system that automates irrigation processes and conserves water [2][3]. The system aims to utilize data from sensors to monitor soil and weather conditions, adjust irrigation schedules based on real-time data to optimize water use, integrate IoT devices for efficient communication and control, and contribute to environmental sustainability by reducing water waste and improving agricultural productivity. It is essential to make decisions that doesn't compromise the motive of the proposed system. In order to provide a smart irrigation system, this study uses ESP32 microcontroller in combination with a multiplexer that is placed in connection with the sensors [4]. In order to get real time data of soil moisture and rain conditions, soil moisture sensors and rain sensors are placed near the roots of the plants and around the field, respectively.

This study addresses the important need for innovative agricultural practices to meet the growing demand for food in a sustainable manner. By developing a smart irrigation system that utilizes IoT and sensory technologies, the study aims to optimize water use, enhance productivity, and reduce environmental impacts [1]. The system's advantages include water conservation, increased productivity, environmental sustainability, cost savings, and emphasize the potential to significantly benefit the agriculture industry and contribute to global sustainability efforts [6-10].

2. Proposed System

The objective of this study is to develop and implement a smart irrigation system that automates irrigation processes and conserves water. The system aims to utilize data from sensors to monitor soil and weather conditions. Adjust irrigation schedules based on real-time data to optimize water use. Integrate IoT devices for efficient communication and control. Enhance decision-making processes through data analysis. Contribute to environmental sustainability by reducing water waste and improving agricultural productivity.

2.1 Advantages of Proposed System

The smart irrigation system provides several advantages:

- Water Conservation: By adjusting irrigation based on actual soil and weather conditions, the system ensures efficient water use, reducing waste and conserving a vital resource.
- Increased Productivity: Data-driven decision making and automation enhance agricultural productivity, allowing farmers to achieve higher yields with fewer resources [5].
- Environmental Sustainability: Efficient resource use minimizes environmental impacts, such as soil degradation and water depletion, promoting sustainable agricultural practices.
- Cost Savings: Automation and optimized resource use reduce operational costs for farmers, making agriculture more economically viable [6].
- Alignment with SDGs: The system supports the United Nations' Sustainable Development Goals, particularly those related to water use efficiency and reducing environmental stress.

3. Block Diagram

This block diagram represents the working of smart irrigation system, which is shown in Figure 1.

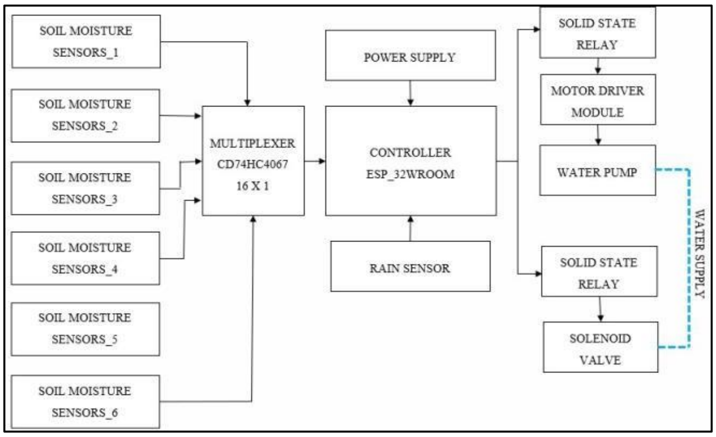

Figure 1. Block diagram

3.1 Hardware Description

The main components of Smart Irrigation System are

1. ESP32 - ESP32 is a low-cost, 32-bit microcontroller. It has built-in Bluetooth and Wi-Fi, making it useful for IoT applications. It can accommodate multiple sensors and devices with 48 general purpose input–output (GPIO) pins. It interprets sensor inputs and directs outputs to other parts. Here, the input variables like soil moisture and rain are provided to the microcontroller. It is programmed to process the input variables and control the relay module.

2. Multiplexer – CD74HC4067 can select one of 16 input channels and direct the selected signal to the output. This multiplexer helps to integrate multiple soil moisture sensors to the microcontroller. Hence, multiple sensors can be used with a single microcontroller.

3. Soil moisture sensor – This sensor measures the volumetric water content in the soil. It sends this data as an electrical signal to the microcontroller. Based on the soil moisture readings, the control system can then make informed decisions about when and how much to irrigate, thereby optimizing water usage and promoting healthy plant growth [2].

4. Rain sensor – This sensor detects rainfall and signals the microcontroller to adjust irrigation schedules. By providing real-time information about precipitation, it prevents over-watering and optimizes water conservation within the automated irrigation system [3].

5. Solid state relay – G3MB-202P This module provides a reliable and efficient switching mechanism for the irrigation system. It offers electrical isolation between the control signals and the power circuits of components like the motor driver module and the solenoid valve. Here, the solid-state relay controls the power supply to the motor driver and the solenoid that manages water flow.

6. Solenoid valve – This electrically controlled valve regulates the flow of water within the irrigation system. Activated by an electromagnetic solenoid, the internal plunger moves to either open or close the water passage, allowing for automated on/off control of irrigation to specific zones

7. Motor driver module – L293D This integrated circuit is designed to drive inductive loads, specifically the DC pump used in this irrigation system. Capable of managing two motors, it controls the speed and direction of the DC pump, enabling efficient water delivery for irrigation purposes.

8. DC submersible pump – This water pump is designed to operate while submerged in a water source. Its efficient design allows it to move water without requiring priming. In this system, a small-scale DC submersible pump facilitates water distribution for irrigation, and larger pumps can be implemented for larger agricultural areas.

3.2 Software Description

The Arduino Integrated Development Environment (IDE) was utilized to write and upload code (sketches) to the Arduino Uno board. The IDE's extensive library support streamlined the implementation of complex functionalities, significantly reducing development time. Its user-friendly interface simplified code creation, and the real-time debugging tools facilitated efficient error identification and correction during testing. The Arduino IDE's compatibility with the microcontroller board was crucial for the seamless deployment and operation of our code, ultimately enhancing the practicality and reliability of our study.

4. Flow Chart

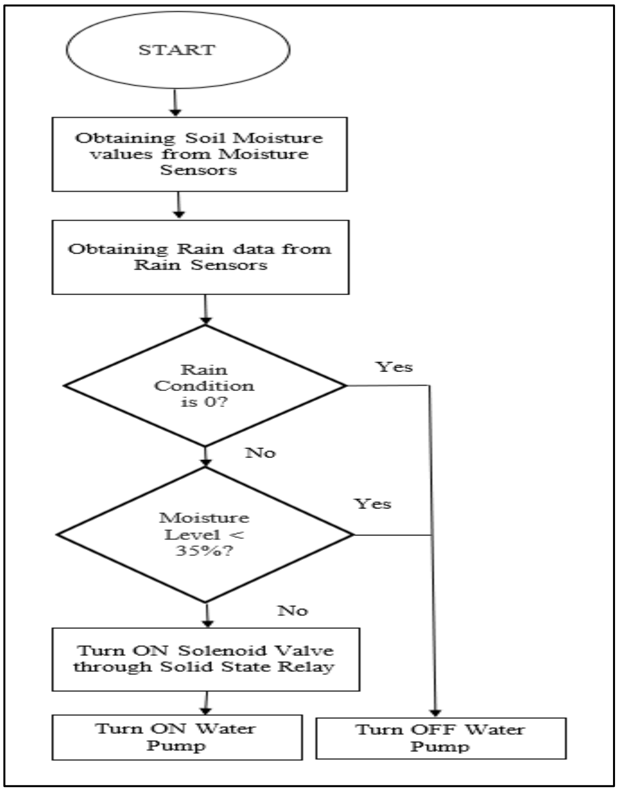

Figure 2. Flowchart

To ensure smarter water usage in farming, an intuitive control system has been developed that operates based on real-time environmental data. The system begins by collecting input from two types of sensors—one monitoring soil moisture levels and another detecting rainfall. These inputs provide essential information to determine whether irrigation is necessary. The logic starts by checking for rainfall. If it is currently raining, the system refrains from watering. If no rain is detected, it then evaluates the soil moisture. When the moisture level falls below 35%, the system recognizes that the soil is becoming too dry and initiates irrigation. At this point, the water pump is activated, and a solenoid valve is opened using a solid-state relay. The relay ensures safe and efficient switching without mechanical wear. This entire process runs continuously in a loop, constantly monitoring changes in moisture and rainfall conditions. This setup not only conserves water but also eliminates the need for constant human supervision. It's a practical solution for small-scale farms or gardens, where traditional irrigation systems may not be viable, but intelligent automation can still deliver significant benefits. By responding dynamically to actual environmental conditions, the system encourages a more sustainable and efficient approach to irrigation. The flowchart of proposed irrigation system is illustrated in Figure 2.

5. Irrigation System Techniques

Effective irrigation planning is therefore important to ensure optimal water utilization. This approach allows for precise application of water, providing just the right amount needed, reducing both yield losses and pumping costs. One key advantage of this method is improved soil health, which enhances long-term productivity and return on investment. In the future, the integration of the Internet of Things (IoT) is expected to improve the accuracy and efficiency of irrigation systems. These technologies can offer customized irrigation suggestions based on various crop types and environmental conditions. Water can be sourced in multiple ways, but the ultimate goal is uniform distribution, ensuring every plant has access to sufficient moisture. Modern irrigation systems aim to minimize waste and deliver water efficiently, guided by smart sensors. For example, sensors measuring soil tension from 0 to 239 kPa help determine the right timing and quantity of irrigation. When the soil becomes too wet, pressure readings change, indicating its water-holding capacity. Monitoring these values is essential for assessing soil conditions and making informed irrigation decisions. A reference Table 1 describing different soil types and their characteristics from the beginning of the farming process can help fine-tune irrigation strategies. Estimating the soil's ability to retain water is essential, especially since various soil types store and release moisture differently.

Table 1. Water Holding Capacity for Different Soil Types

Soil texture	Depletion in water holding capacity		
	30%	50%	70%
Sand	20	30	60
Loamy Sand	25	40	67
Sandy Loam	28	50	80
Silt Loam	80	150	250

5.1 Drip Irrigation

Drip irrigation is a important method for dealing with the world's scarcity of water. Trickle irrigation is another name for drip irrigation. Drip irrigation is a type of irrigation in which water is given drop by drop to the root region of plants. Because evaporation and runoff are reduced, this technique can be the most water-efficient type of irrigation. In modern agriculture, drip irrigation is frequently used in conjunction with organic or inorganic (plastic) protections, which provide additional benefits such as reduced evaporation, increased soil warmth, weed control, etc. The issue of drip irrigation emitter blockage, on the other hand, has a significant effect on irrigation uniformity and efficiency, even causing the system to be disabled and crop productivity to be reduced.

6. Result and Discussion

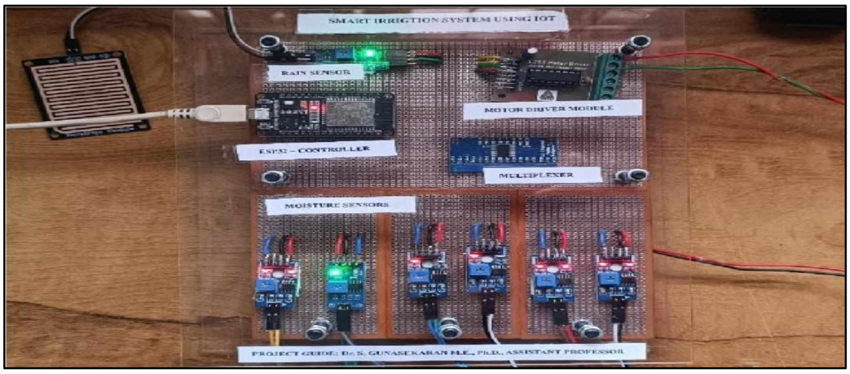

Figure 3. Prototype Model

This section gives us a brief explanation of all the hardware components used for the Smart Irrigation System using IoT. It also tells us briefly about the hardware testing along with the results of the study and the hardware development is done using the above mentioned components. The prototype model of the Smart Irrigation System using IoT is shown in Figure 3

6.1 ESP32-WROOM Microcontroller

The microcontroller is the central component of a smart irrigation system, enabling it to make intelligent decisions based on real-time sensor data and optimize water usage for efficient and sustainable agriculture. The central controller ESP-32 WROOM Microcontroller is shown in Figure 4.

The moisture sensor detects that the soil moisture is low, and the rain sensor indicates the rain status. The microcontroller reads the digital output from this sensor and an analog voltage from the moisture sensor that varies with the moisture level. The microcontroller's Analog-to-Digital Converter (ADC) converts this voltage into a digital value that it can understand. The microcontroller, based on its programming, decides to turn on the water pump for a specific row to irrigate the field. Once the soil moisture reaches the desired level, the microcontroller turns off the pump.

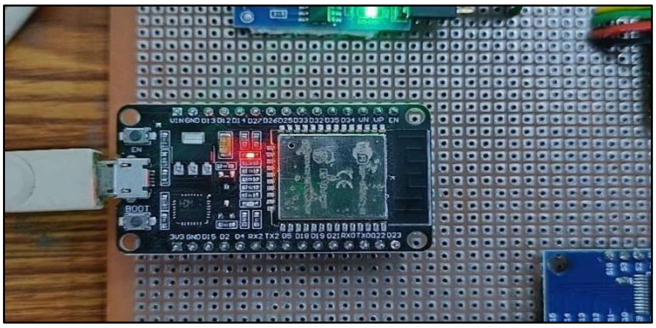

Figure 4. ESP32-WROOM Microcontroller

6.2 Soil Moisture Sensor

The soil moisture sensors shown in Figure 5, generate an analog voltage or current signal that corresponds to the measured moisture level. The analog signals may undergo signal conditioning to filter noise and amplify the signal strength for accurate readings.

Each row of crops in the farming land is equipped with several soil moisture sensors. These sensors are strategically placed within the row to capture variations in soil moisture levels across the area. Each sensor in a row transmits its moisture reading to the central controller. The controller is programmed to calculate the average moisture level for each row. This is done to account for localized variations in soil moisture and provide a representative value for the entire row.

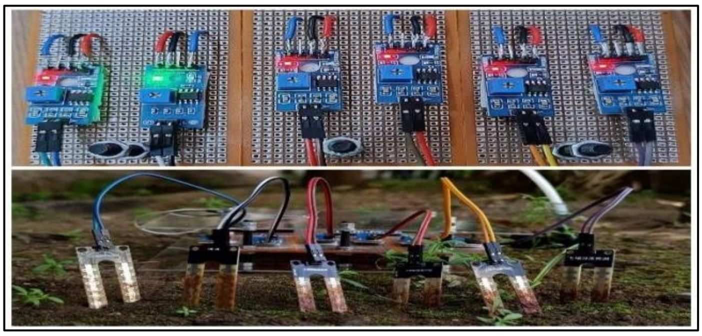

Figure 5. Soil Moisture Sensors

6.3 Rain Sensor

The Rain sensor shown in Figure 6, is typically placed in an open area where it can directly receive rainfall. It utilizes a mechanism to detect the presence and amount of rain Once the rain sensor detects rainfall, it transmits a signal to the central control unit of the smart irrigation system. The microcontroller can directly read this digital signal through a digital input pin.

Upon receiving the signal, the controller either suspends the scheduled watering cycle or prevents a new cycle from starting. This ensures that the system doesn't water the lawn or plants when it's already raining. Once the rain stops and the sensor dries out (depending on the type), it signals the controller again. The controller then resumes the normal watering schedule.

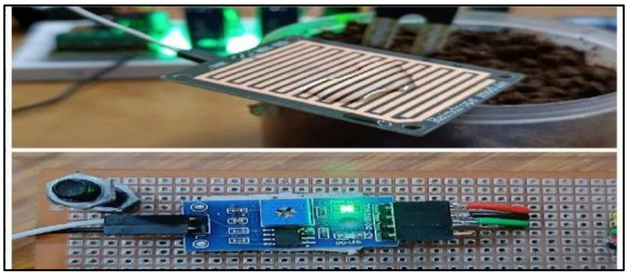

Figure 6. Rain Sensors

6.4 Solid State Relay

A solid-state relay (SSR) shown in Figure 7, is an electronic switching device that uses semiconductors to switch current on or off. Unlike mechanical relays, SSRs have no moving parts, making them more reliable and longer-lasting. The SSR receives a control signal from the central controller. This signal is a low-voltage DC signal (e.g., 5V). The light from the LED glows on a photosensitive semiconductor device (often a TRIAC or MOSFET) within the SSR.

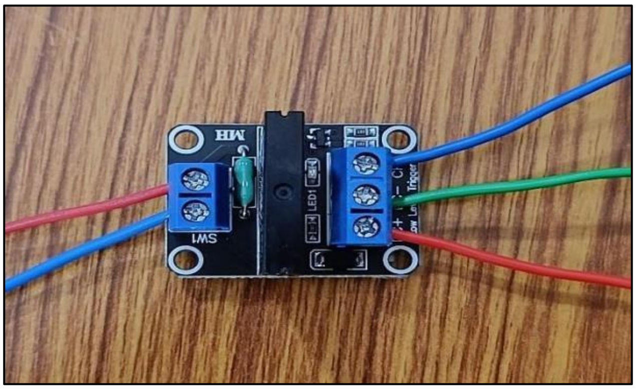

Figure 7. Solid State Relay

When the LED's light hits the semiconductor, it turns "on," allowing current to flow through the SSR. When the control signal from the microcontroller is turned off, the LED turns off, and the semiconductor switch opens, stopping the current flow. When the LED turns on, the photosensitive device also turns on, allowing current to flow through the SSR's output terminals. This completes the circuit and allows power to flow to the irrigation valve.

6.5 Solenoid Valve

When Microcontroller determines that a specific row needs watering, it sends an electrical signal (through the Solid State Relay - SSR) to the solenoid valve, which is shown in Figure 8. This signal energizes the solenoid coil. The energized coil creates a magnetic field. Inside the valve, a plunger (a small, movable metal rod) is connected to the valve's opening/closing mechanism.

The magnetic field generated by the coil attracts or repels the plunger. Once the valve is open (in the case of an NC valve), water under pressure from the main water supply flows through the valve and into the piping system that leads to the designated row or section of the irrigation system.

The controller signals the SSRs to switch the appropriate solenoid valves on and off, ensuring that each area of the farm receives the correct amount of water at the right time.

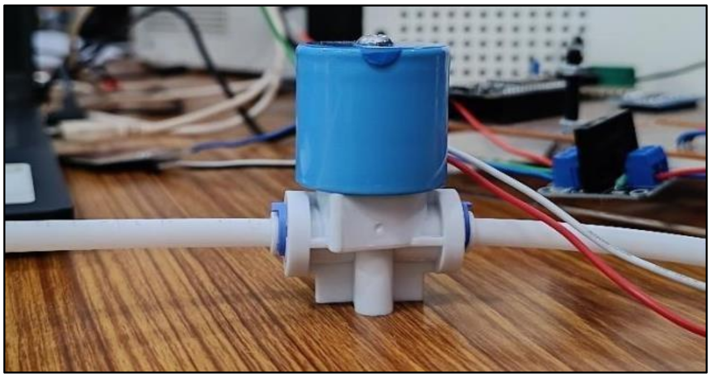

Figure 8. Solenoid Valve

6.6 Motor Driver Module

The microcontroller within the smart irrigation system sends control signals to the L293D. These signals are typically digital (HIGH/LOW, 1/0). While the L293D is often used for direction control of DC motors, in the case of a water pump. The L293D amplifies the current provided by the microcontroller. Microcontrollers can only supply very small amounts of current, not enough to drive a water pump. The L293D boosts this current, allowing it to drive the higher current demands of the water pump. The L293D which is shown in Figure 9, translates these logic signals into the appropriate switching of the H-bridge transistors to control the water pump. For simple ON/OFF control, only one input pin per motor is often needed.

Figure 9. Motor Driver Module(L293D)

6.7 DC Submersible Pump

The pump is placed inside the water source, ensuring that it is fully submerged. When the microcontroller signals the L293D to turn the pump on, the L293D supplies power to the pump's DC motor. The DC motor which is shown in Figure 10, rotates, which in turn drives an impeller or other mechanism within the pump. This creates suction, drawing water into the pump. The pump forces the water upwards through a pipe or tube, pushing it towards the main pipeline of the irrigation system. The water discharged by the submersible pump flows into the main pipeline, which then distributes the water to the various zones or sections of the farm through the network of solenoid valves and pipes.

Figure 10. DC Submersible Pump

7. Conclusion

The proposed smart irrigation system presents an innovative and smart solution to address the inefficiencies of traditional irrigation methods. By integrating sensors, microcontrollers, and real-time environmental monitoring of soil moisture, temperature, humidity, and rainfall, the system empowers farmers to make informed irrigation decisions, optimize water usage, and improve crop management. Features such as rain and ultrasonic sensors to prevent over-watering, enhance the system's efficiency and effectiveness in promoting optimal plant growth and yield. Ultimately, this smart irrigation system represents the application of technology in agriculture to enhance sustainable practices and address real-world challenges.

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