

Design and Implementation of an IoT-Enabled Smart Agriculture Irrigation System Using Arduino Uno

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Abstract

The problem of water management arises due to water scarcity and sustainable agriculture in modern agricultural production. In this paper, the design and implementation of an IoT-enabled intelligent irrigation system developed through the use of the Arduino controller and soil moisture sensor will be addressed. The proposed irrigation system operates under the principle of continuous soil moisture measurement and automatic irrigation control according to the specified threshold. The irrigation process takes place immediately when the soil dries out, which occurs through the operation of the water pump connected to the relay board. It stops when moisture reaches a certain level in the soil. This system provides efficient irrigation, reduces labor and water use, and ensures optimal plant growth.

Keywords : IoT, Smart Irrigation System, Arduino Uno, Soil Moisture Sensor, Water Management, Agriculture Automation, Embedded Systems, Relay Module

1. INTRODUCTION

Indian agriculture contributes about 18.2% to India's GDP [1]. Numerous factors influence agricultural activities, including soil moisture, temperature, pesticide pH level, soil quality, etc., which affect crop growth. Irrigation of crops at the right time and with the right amount of water is extremely necessary for plants to grow healthy and properly. With the increasing issue of water scarcity, it is very important to use water wisely and meet the needs of farming. Many times, farmers overwater their crops or sometimes provide less water than required.

To solve this issue the “development of a Smart Irrigation System Based on IoT & Soil Moisture Monitoring Using Arduino” comes into the picture. Where a sensor is attached to soil to measure the moisture, if the moisture level is lesser than the threshold value the attached water pump releases water into the soil. This makes sure that the crops never over-watered or under-watered. It also ensures that a water preservation and management

of water is maintained.

1.1 MOTIVATION

Minimising human labour and making agriculture automated inspired the need for this project. Farmers on a daily basis irrigate their lands for crop production. It takes a lot of time and human effort.

It can also lead to human error and inappropriate level of water used in watering of crops. For the elimination of this issue the proposed model is required.

With the ever growing water shortage issues it is also highly recommended to use water sustainably and not waste water by over-watering the crops.

2. LITERATURE REVIEW

Smart irrigation systems have been widely studied as an effective solution for efficient water management in agriculture. These systems use sensors, microcontrollers, and automation techniques to optimize water usage and improve crop productivity.

Recent studies have shown that the integration of Artificial Neural Networks (ANN) with IoT-based systems can significantly improve the efficiency of smart irrigation. ANN models are capable of analyzing environmental parameters such as soil moisture, temperature, and humidity to enable intelligent decision-making for optimal water usage. Kaur and Gupta proposed various ANN-based approaches, including constructive neural network frameworks and bipolar sigmoid algorithms, which enhance learning efficiency, prediction accuracy, and adaptability in dynamic agricultural conditions [2]-[5]. These advancements highlight the potential of ANN in improving water management and supporting sustainable agriculture.

2.1 Need for an IoT-Based Smart Irrigation System

It is a fact that agricultural activities demand effective water management techniques for the development of plants. It has been noticed in many

cases that plants receive either too much or too little water supply, mainly due to inadequate monitoring, which affects plant quality and leads to water wastage. Smart irrigation systems have been developed to address water scarcity issues by automating irrigation based on soil moisture and environmental conditions [6]-[9].

With the increasing need for food and the necessity to preserve water, the need for an intelligent irrigation system is critical.

It is possible to assess the soil moisture and, in turn, control the water supply to the soil by using an IoT-based irrigation system. This helps to reduce the workload in irrigation activities while providing the optimal water supply to plants, resulting in their proper development. Hence, the incorporation of IoT in irrigation systems is an effective solution for modern agricultural activities.

Recent studies suggest that blockchain technology can enhance security and transparency in agricultural IoT systems by enabling secure data storage and reliable data sharing, with potential for future implementation [10]-[12].

2.2 EXISTING IRRIGATION METHODS

Before this system was developed and implemented, there were many more techniques for irrigation that was commonly used. Few are :

- **Manual plant watering** : In this method, plants are watered using watering cans, buckets, or pipes. This method is simple but requires constant human attention and effort.
- **Traditional irrigation systems** : The traditional irrigation systems include flood irrigation, drip irrigation, sprinkler irrigation, etc. These systems are used in the irrigation of agricultural fields. This method is used on a large scale but requires manual attention.
- **Timer-based irrigation systems** : In this method, plants are watered at a particular time of the day. This method also provides a degree of automation but does not take into consideration the moisture content in the soil, resulting in over- or under-watering.

2.3 Limitations and Challenges of Existing Systems

Even though this method is commonly used in irrigation, there are certain limitations associated with it, and this in turn affects its efficiency and

performance.

- The first limitation is that there is a lot of wastage of water in this method because it is not checked how much moisture is present in the soil.
- The second limitation is that there is no automated system in this traditional method of manual irrigation. This is the responsibility of the person concerned, i.e., the farmer or gardener.
- The third limitation is that this traditional method of irrigation is irregular in nature because it sometimes over-irrigates or under-irrigates the plants.
- Finally, this traditional method of irrigation requires a lot of manpower, especially when the soil is to be irrigated over a large scale because it is difficult to monitor it.

2.4 Key Features of the Proposed System

The proposed IoT enabled smart irrigation system has various advantages compared to other irrigation systems.

- The first advantage of the proposed smart irrigation system is that it uses an automated irrigation system. This implies that the irrigation process is done automatically without any manual intervention.
- Another advantage of the proposed smart irrigation system is the soil moisture measurement. In this regard, the soil moisture sensor is used to continuously monitor the soil's moisture level.
- Another advantage of the proposed IoT enabled smart irrigation system is the low cost. This is due to the fact that the devices used in this system, such as Arduino Uno, are readily available and not very expensive.

Similar IoT-based irrigation systems have demonstrated features such as automation, efficient water management, and real-time monitoring using Arduino platforms [13]-[17].

3. METHODOLOGY

In the agriculture sector, a smart irrigation system is very important and in this paper, we designed such a smart irrigation system. The IoT technology and

remote monitoring technology is utilized to develop a smart irrigation infrastructure. For water resources management and water supply, this is the very efficient technology. A wireless sensor network is a system that can be integrated with the Internet of Things to enable smart irrigation farming with a monitoring system for measuring farming parameters like soil moisture, temperature, and humidity.

3.1 SOIL MOISTURE DATA COLLECTION PROCESS

- First, the sensor receives power. Other sensor pins, such as the ground (GND) and analog pin (A0), must be connected to the Arduino correctly. The sensor might not work properly without these connections. Before turning on, check the entire setup for any mistakes made during the wiring process.
- A digital device is connected to the Vcc pin. to a digital pin, which ought to be designated as an output. As an alternative, the sensor can be powered by an external source. Until the power LED illuminates, it is essential to supply the sensor with full voltage.
- We can easily set the threshold voltage thanks to the sensor's integrated potentiometer. A minimum threshold voltage produces HIGH sensitivity, whereas a maximum threshold voltage produces LOW sensitivity.
- While a sensor with a high sensitivity can quickly identify slight variations in moisture content, one with a low sensitivity might take longer to detect moisture. The threshold voltage can be changed during operation to suit your requirements.



Figure 3.1(a): Soil Moisture Sensor

The system uses a **soil moisture sensor** as the primary sensing device. This sensor detects the amount of water present in the soil by measuring electrical conductivity between its probes. When the soil is dry, the conductivity is low, and when the soil is wet, conductivity increases. The sensor

converts this information into analog signals which are transmitted to the Arduino Uno microcontroller. Operating voltage: 5V (connected to Arduino 5V pin)



Figure 3.1(b): Arduino UNO

The **Arduino Uno** acts as the central processing unit of the system. It receives input data from the sensor through analog pin A0. The microcontroller processes the sensor values using programmed logic and compares them with a predefined threshold value. Based on the result, Arduino sends control signals to the relay module. Operates at 5V (via USB supply)



Figure 3.1(c): 5V Relay Module

The **5v relay module** is integrated as a switching device that allows the low-power Arduino circuit to control a higher-power device such as the water pump. When the soil moisture value indicates dry soil, the Arduino activates the relay, which completes the electrical circuit of the water pump and allows water to flow to the plant. Operating voltage: 5V (triggered by Arduino digital pin)



Figure 3.1(d): Water Pump

The **water pump** functions as the actuator in the system. It is connected through an external power

supply to ensure sufficient current for operation. The relay ensures safe isolation between the microcontroller and the pump circuit. Operating voltage: 5V DC (since used with relay + Arduino setup)



Figure 3.1(e): Jumper Wires

All hardware components are connected using **jumper wires** and powered appropriately to maintain stable operation. The sensor continuously sends real-time data to the Arduino, forming a small sensor network that automates irrigation decisions without human intervention.

Recent studies have highlighted that IoT-based irrigation systems utilize sensors and real-time data to improve water efficiency and precision in agricultural practices [7]. These systems enable continuous monitoring of soil and environmental conditions, supporting optimized irrigation and sustainable farming[7].

This integration of sensor and actuator devices demonstrates an efficient implementation of IoT-based automation in agriculture. The hardware network ensures accurate monitoring, timely response, and optimal water usage, improving overall plant health and reducing manual effort.

3.2 BLOCK DIAGRAM OF PROPOSED MODEL



Figure 3.2(a): Block diagram of the IoT based smart irrigation system

The soil moisture sensor sends data to the Arduino Uno, which processes the information and controls the relay module. The relay then activates the water pump to supply water to the plant.

3.3 FLOWCHART OF SYSTEM OPERATION

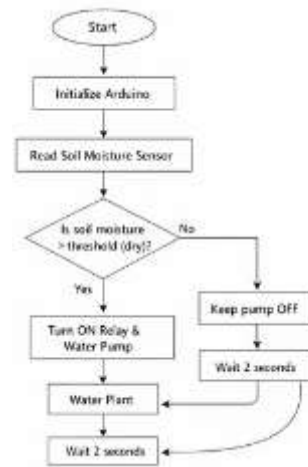


Figure 3.3(a): Flowchart of Smart Irrigation System

The system starts by reading soil moisture values. If the soil is dry, the pump turns on; otherwise, it remains off. This process continues continuously to maintain proper soil moisture levels.

3.4 CIRCUIT IMPLEMENTATION AND ARDUINO PROGRAMMING



Figure 3.4(a): Implemented Circuit of the Smart Irrigation System



Figure 3.4(b): Arduino programming of the Smart Irrigation System



Figure 3.4(c): Arduino programming of the Smart Irrigation System

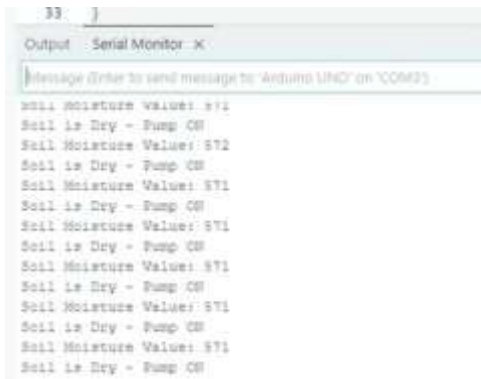


Figure 3.4(d): Arduino programming of the Smart Irrigation System

4. OBSERVATIONS

This developed IoT-based smart irrigation system was tested using different levels of moisture content in soil to analyze its performance characteristics. Soil moisture sensors were measured using Arduino Serial Monitor, and the operation of the pump response was observed.

It was observed from the experimental analysis that the output from sensors varied depending upon the moisture content in the soil. Low readings of the output from sensors indicated that soil was moist, whereas high outputs indicated that soil was dry. The threshold value was set at 500 in the Arduino code to differentiate between wet and dry soils.

If soil moisture values exceeded the threshold, Arduino switched on the relay that started the water pump. If soil moisture was below the threshold, the water pump remained off.

Soil Moisture Value	Soil Condition	Pump Status
300 – 400	Wet Soil	OFF
400 – 500	Moist Soil	OFF
500 – 600	Slightly Dry	ON
600 – 750	Dry Soil	ON
> 750	Very Dry Soil	ON

Table 4.1: Soil Moisture vs Pump Operation

Through this we understood that :

- Soil moisture readings were detected in real time using the system.
- The relay module reacted fast to the signal sent from Arduino.
- The pump only operated when required to prevent water wastage.
- Consistent soil moisture readings were obtained using the Serial Monitor.

5. RESULT

The proposed IoT-based smart irrigation system was successfully developed, deployed, and tested for various soil moisture scenarios. This IoT-based smart irrigation system constantly monitors soil moisture levels with the help of the sensor and displays the measured values on the Arduino Serial Monitor.

It can be seen from the experimentation findings that the proposed IoT-based smart irrigation system can automatically regulate the operation of the water pump according to the pre-specified threshold value.

Whenever the soil moisture value becomes greater than the threshold value (500), the relay module activates itself, and consequently, the water pump starts its operation. Similarly, if the soil moisture value is less than the threshold value, the pump stops its operations.

The results of the experiment are shown through the table 4.1 in the Observation section.

6. DISCUSSIONS

The results obtained from the irrigation system show how well the system works. This can be shown by the fact that the system is able to sense the moisture content of the soil and use it to control the function of the water pump.

This irrigation method is more efficient than other traditional methods of irrigation because the system uses soil moisture content as its input value and determines the amount of water needed at any given time.

Previous studies have demonstrated the effectiveness of IoT-based irrigation systems using Arduino and soil moisture sensors for automated plant watering and efficient water management [18]-[19].

Although the present irrigation prototype is good, some problems do exist. For instance, the sensor used to measure soil moisture is sensitive to changes in soil conditions, and thus, it measures moisture in a varying way. Moreover, the system is unable to allow remote control and monitoring.

Previous studies have also demonstrated the effectiveness of IoT-based smart irrigation systems in improving water efficiency and reducing manual intervention [20]-[23]. These systems utilize sensors and automation techniques to optimize irrigation based on real-time environmental conditions. Furthermore, low-cost and intelligent irrigation models have been developed to enhance system performance and accessibility for small-scale farmers [22]. Such advancements highlight the growing importance of smart technologies in sustainable agriculture.

Despite these demerits, the system is an efficient and cheaper way of irrigating small pieces of land or household gardens. This is because the system does not require complicated sensors but simple relay sensors and an Arduino processor, which are easily controllable.

7. FUTURE SCOPE

It should be noted that the suggested smart irrigation system, which uses IoT, successfully automates the process of watering plants depending on their soil moisture. Yet, a lot needs to be done to make this invention even more effective and productive.

In the nearest future, IoT-based smart irrigation systems can be developed into platforms that would

let one monitor and control the soil moisture levels remotely through any mobile or web application.

Machine learning algorithms and neural networks can also help improve prediction abilities regarding soil moisture trends. Also, the inclusion of the latest blockchain technology would help protect and share data related to the irrigation process.

The next step in development can involve increasing the number of sensors used and expanding the territory that can be managed using smart irrigation. Moreover, an IoT-enabled system can be used at commercial farms, while additional features like solar power may help increase its efficiency.

8. CONCLUSION

In conclusion, this paper successfully designed and implemented an IoT-based smart agriculture irrigation system using Arduino Uno and soil moisture sensor. This irrigation system will allow the users to monitor the soil situation as well as control the pump automatically without any human involvement.

The main advantage derived from this project is the development of an effective irrigation system that helps save water and boost the growth of the plants. This irrigation system highlights the application of the IoT and embedded systems in agriculture.

Concerning future work, this irrigation system could be improved by introducing different IoT devices. Moreover, some more enhancements such as temperature and humidity sensors, introduction of solar power, and capability to monitor several plants could be made.

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