

# Implementation of an IoT-Enabled Smart Irrigation System with Web-Based Monitoring and Control

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## Abstract

This paper dives into the design and development of an IoT-enabled smart irrigation system using the Arduino Uno micro-controller. The main objective of this system is to automate the irrigation process by monitoring soil moisture levels and controlling water supply efficiently for irrigation [1]. A soil moisture sensor is used to detect the levels of water or moisture in the soil, and on the bases of sensor readings, the Arduino controls a relay module to operate the water pump [2].

The system is enhanced with a web-based interface that allows real-time monitoring and manual or automatic control over the irrigation system [3]. Users can switch between automatic and manual modes and control the pump remotely through the web application. The proposed system ensures adequate water usage by supplying water only when it is required, thereby it reduces water wastage and minimizing any human interaction [4].

This system is cost-effective, easy to implement, and suitable for applications such as home gardening, agriculture, and greenhouse irrigation [5]. The results demonstrate that the system improves irrigation efficiency and provides a reliable solution for smart water management and saving.

Conventional irrigation practices rely heavily on manual intervention, which often results in inconsistent moisture levels and significant water wastage. This lack of real-time precision makes more human labour and hinders optimal plant health.

## Keywords

Automation, Microcontroller, Arduino Uno, IOT, Web-based Interface.

## Literature Review

### 1.1 Need for IoT-Based Plant Irrigation System

There has been an increase demand for an efficient water management system and as everything is getting automated [11], IoT-based irrigation systems have become quite important. Old methods of irrigation lead to excessive watering and requiring constant human intervention. In most cases non-uniform watering of plants and crops resulted in over-irrigation or under irrigation, this terribly leads to a bad crop yield.

With the integration of IoT microcontrollers and sensors, it has enabled real-time monitoring and decision-making capability improves efficiency and reduces human effort [12]. Secure and efficient communication between devices is one of the important features of IoT systems. Recent studies have shed light on the role of advanced technology for example blockchain for enhancing the reliability of IoT communication. That's why the need for an IoT-based irrigation system for modern agricultural practices.

Recent studies have also shown that in the role of advanced technology for example blockchain for enhancing the reliability of IoT communication [13]. This technology provides a decentralized model for energy and data management which is

crucial for modern automated systems [14], ensuring that remote control applications remain secure from unauthorized access [15].

## 1.2 Existing Solutions

Until now, Irrigation was performed mostly by humans using buckets, pipes or sprays, all done on the basis of observation and experience [16]. This is quite simple but requires human effort all the times and even then, it may require a person who has good judgement of time and water requirement.

Even though these methods are globally used, they still lack the real-time monitoring and adaptability. Newer technologies have shown advancements in automated systems that use sensors and microcontrollers for irrigation purposes [17]. With the improvements in Artificial Intelligence the systems have become a lot more optimized in performance, they are able to make predictions considering environmental conditions much better [18]. Though these implementations come at a cost not everybody can afford. With the improvements in Artificial Intelligence, systems now have become a lot more optimized in performance for longer period. Basic Artificial Neural Networks (ANN) provide a foundation for this [19], while newer frameworks allow for more adaptable system designs [20]. Specific algorithms, such as the Bipolar Sigmoid and its extended versions, have significantly enhanced the learning performance of these networks and ANN in environmental monitoring [21], [22].

## 1.3 Limitations of existing solutions

Manual irrigation systems have several flaws, such as inefficient water usage, bad precision, and

dependent on human effort [23]. Over and under watering can lead to crop damage and water wastage. Timer-based systems often fail to respond real time soil conditions.

Also, many existing smart systems don't have much secure and reliable network mechanisms [24].

## 1.4 Key features of the proposed System

The proposed IoT-backed automatic irrigation system bridges the gaps and limitations left behind by traditional methods of irrigation by using sensors, actuators and microcontrollers to enable automation and web-based control. It uses a soil moisture sensor to measure moisture levels in the soil from there the data signals go to the Arduino Microcontroller for processing the data. Based on that, the relay module sends transfers the electricity to the water pump.

This system can work either automatic or manually, enabling users to control irrigation through a local website. All of this enhances flexibility and availability [25]. It saves a ton of water this way as the water is supplied to the plants based on their needs and not as per timings alone.

Moreover, the system is made in a way to be beginner friendly meaning anyone can use this, it's very easy to put into action and it is highly compatible for small-scale balcony pots. Combining automation with remote accessibility the proposed system gives a great solution for modern irrigation needs.

## Introduction

### 2. Introduction

The rapid advancement in technology has transformed a lot for modern agricultural practices [6]. Traditional irrigation methods now rely heavily on manual operation, which often leads to inefficient water usage or even wastage and has increased labour requirements over the time [7]. Overwatering and under-watering are common issues that directly affect plant growth and crop yield for the farmers.

#### 2.1 Objective

The main objective of this project is to build a small-scale automatic irrigation system mainly for individual households and for people who are from a non-technical background. It utilizes Arduino Microcontrollers, programming in the Arduino IDE, and a soil moisture sensor [8][9], the system's goal is to provide an automated integration based on real-time data in modern irrigation. The goal is to create a simple, portable and affordable solution rather than systems of automation for large scale agricultural environments.

#### 2.2 Motivation

The intention and motivation behind this research come from the increasing demand of automation in our day-to-day lifestyle, automated pet feeders and they've proven to be very successful. However, for plants there is not much options for individual households where traditional forms of irrigation are still practiced.

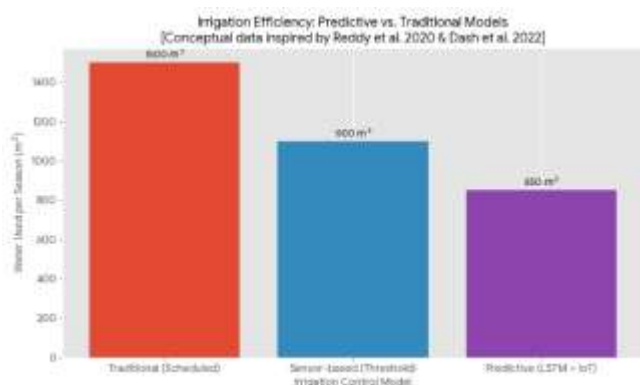
time to look after plants in their best capacity. Traditional methods of irrigation lead to the following problems:

1. Inconsistent watering: Results in damaging of plants or death.
2. Inefficiency: Often creates a mess and may waste water as well [10].

The availability of open-source devices gives opportunity to bridge this gap. The research is driven by the need to provide busy plant lovers with a reliable automated tool that makes sure plants are always given enough water at the right time of their needs without the need of constant human monitoring and effort.

### Methodology

The methodology illustrates the design, implementation and testing of IoT based automatic irrigation system. The system is equipped with sensors and microcontroller for monitoring and control; the soil moisture data is used for automation of irrigation. The research was conducted using prototype setup consisting of the modules integrated with a web-based interface for monitoring and control.



This is the case because many individuals such as students or professionals who don't have much

### 3.1 About Model



1. **Arduino Uno:** The Arduino Uno is an open-source microcontroller made by the Arduino an open source microcontroller development platform that includes both hardware and software. It is based on the ATmega328p [26]. It can also be called as the brain of the project. It includes 14 digital inputs & outputs, 6 of which can be used as PWM outputs and 6 analog inputs. All of this allows the Arduino Uno to read sensors and control actuators simultaneously. It operates at 16Mhz and can either be powered by a USB connection or an external power jack
2. **Relay Module:** A Relay Module is like a electric switch. It is the bridge between low-power microcontrollers and high-power devices [27]. An Arduino pin only outputs 5V and very low current, it cannot actually power heavy electricity requiring devices such as large water pump or a toaster. Relay Module solves this problem by using a small electromagnetic coil to physically move a metal contact, completing or breaking a separate high-voltage circuit.
3. **Soil Moisture Sensor:** Soil Moisture Sensor is one of the most important component in



our project. It is designed to measure volumetric water content in soil.

It features two conductive probes exposed that act as a variable resistor. When soil is wet, it conducts electricity more easily, when dry, the resistance increases, this change in resistance is converted into an analog voltage that the Arduino interprets [28].

4. Jumper wires: Jumper wires is like the nervous system of the prototype. It facilitates the flow of electricity and data between components. These insulated wires come with pre-fitted connector pins or sockets. It eliminates the need for soldering during the making of the project. They are essential for connecting different modules, sensors and microcontrollers and breadboards.

- There are three main types of jumper wires used in electronics, which were utilized in this study:
- **Male-to-Male (M-M):** Used to connect two points on a breadboard or two female headers.
- **Male-to-Female (M-F):** Ideal for connecting an Arduino pin (female) to a sensor pin (male).
- **Female-to-Female (F-F):** It bridges the gap between two components that both have male header pins.

5. 5V DC Motor: A 5V DC Motor is a fundamental actuator that converts electrical energy into mechanical rotation. These motors are typically small in size, high speed, and low-torque, making them perfect for driving miniature fans, light wheeled robots, or vibrating alerts [29].

### 3.2 Circuit and Arduino Code

The system's circuit is designed by connecting components in the following ways:

Soil moisture sensor → connected to digital pin 6

Relay module → connected to digital pin 3

Pump → connected through relay (COM and NO terminals)

Power supply → provided via USB and external source

```

1 // water
2
3 int manualMode = 0; // 0 = Auto, 1 = Manual
4 int manualState = 0; // 0 = OFF, 1 = ON
5
6 void setup() {
7   pinMode(3, OUTPUT); // Relay
8   pinMode(6, INPUT); // Sensor
9
10  Serial.begin(9600); // Serial
11 }
12
13 void loop() {
14
15   water = digitalRead(6);
16
17   // Receive command from serial
18   if (Serial.available()) {
19     char cmd = Serial.read();
20
21     if (cmd == 'A') manualMode = 0;
22     if (cmd == 'M') manualMode = 1;
23     if (cmd == '1') manualState = 1;
24     if (cmd == '0') manualState = 0;
25   }
26
27   // Control logic
28   if (manualMode == 1) {
29     digitalWrite(3, manualState);
30   }
31   else {
32     if (water == HIGH) {
33       digitalWrite(3, LOW);
34     }
35     else {
36       digitalWrite(3, HIGH);
37     }
38   }
39
40   // Send data to PC
41   Serial.print(water);
42   Serial.print(",");
43   Serial.print(manualMode);
44   Serial.print(",");
45   Serial.print(digitalRead(3));
46
47   delay(1000);
48 }

```

The Arduino program in the Arduino IDE receives data sent by the moisture sensor and controls the relay module based on predefined conditions. When the soil is low in moisture, the relay module gets activated and sends power to the 5V DC pump enabling it to function, whereas when the moisture levels are above the certain limit set the relay is turned off and the pump stops working.

The system includes serial communication for transferring data to the web-app for remote monitoring and control [30].

### 3.3 Block diagram of proposed system

The system's data and power flow is:

Soil Moisture Sensor → Arduino Uno → Relay Module → Water Pump

Sensor acts as input

Arduino processes the data

Relay controls the output device

The working of the system can be explained using the following steps:

Start the system

Read soil moisture value

Compare with threshold value

If soil is dry → Turn pump ON

If soil is wet → Turn pump OFF

Send data to web interface

Repeat continuously

### 3.5 Experiment Results

The project was tested under various soil conditions to benchmark its capability. The moisture sensor accurately produced data depending on the moisture level of the soil.

For dry soil, the sensor perceives low moisture in the soil therefore sends signals to the microcontroller for the activation of the pump.

In wet soil, the sensor perceives high moisture in the soil therefore it only sends the soil moisture value to the microcontroller.

The project system also actively transfers data to the web-app where moisture levels and current status of pump is put on display. Moreover, Integrated visual charts provides a visualized insight of water usage for upto 24 hours.

The following results lead to the conclusion that this system works well in both automatic and manual modes and enables a modern day smart irrigation control system.

## Result

### 1.1 System Component Integration

The implementation of the project required the following essential components:

- 1) Arduino Uno (ATmega328p): Microcontroller operating at 16MHz.
- 2) Moisture Sensor: Sensing Unit YL-69 for measuring soil moisture.
- 3) 5V Relay module: Actuation Unit connected to a 5v DC motor.
- 4) Jumper Wires: Wires for providing data and power flow (M-M, M-F, F-F).

### 1.2 Sensor Calibration and Operational Thresholds

The system utilizes a 5V DC power supply to power it and uses various modules to make the system perform all its intended functions:

| Parameter                           | Value/Status                                 |
|-------------------------------------|----------------------------------------------|
| Local Moisture Activation Threshold | < 20%                                        |
| Regional Supply Adjustment          | Variable (based on user-input state/region)  |
| Outside Temperature Monitoring      | Real-time fetching via web API               |
| Relay Signal                        | High (triggers pump when conditions are met) |

### 1.3 Advanced Web App Functionality



1. **Geographical Calibration:** User can input the specific region they're currently in, this lets the system adjust water supply based on the regional climate patterns.
2. **Historical Data Visualization:** An implemented chart shows the total duration the pump has supplied water in a 24 hours duration.
3. **Control Modes:** The system enables switching between automatic, manual and climate-aware modes.

### 1.4 Functional Performance and Observations

1. **Automated Logic:** Arduino Uno activates the pump when the soil moisture sensor signals moisture levels below 20%.
2. **Regional Optimization:** Water supply was supplied based on the user's selected region.
3. **Logging accuracy:** the 24-hour active time shown on the integrated chart provides a visual representation of water usage.
4. **Remote Access:** The internet-based UI provides features of remotely monitoring of the system.

### Discussion

This proposed system demonstrates improves efficiency and accuracy compared to traditional manual irrigation methods. By using the soil moisture sensor, the system ensures that water is supplied only when it is required, which reduces water wastage and maintains soil's optimal condition. The use of relay module also helps in safe control of the water pump through the Arduino, making the system safe and reliable.

The integration of a web-based interface enhances the features and functionality of the system both automatic and manual control. Users can monitor system status and operate the pump remotely. In addition, the system includes features such as region-based configuration and real-time weather data through the internet connectivity. This makes irrigation behavior to be adjusted based on the environment conditions, improving overall efficiency for the device and its function.

The system also provides data in form of chart that how much the pump been used under the 24-hour time period. This allows for the analysis of water usage and optimize the irrigation schedules. Compared to more complex systems using artificial intelligence or blockchain (Dargan & Gupta, 2024; Kaur & Gupta, 2019), the proposed model remains cost-effective while still offering essential smart features.

However, the system has some limitations, including dependency on sensor accuracy and internet connectivity for further advanced features. Future improvements can include the use of machine learning for predicting irrigation and integration of additional sensors for more better performance.

Overall, the system provides a simple, efficient, and scalable solution for smart

irrigation with added benefits of remote monitoring and data-driven control over the usage.

## Conclusion

Although it seems to be more demanding and difficult than this, there are a range of more different options, such as the so-called "Internet of Plants" which consists of complicated linkages of different plants of related types. Using a large number of sensors is also an experimental attempt, but there are many more experimental and challenge-like notions, such as using solar power and battery or a timer to set up an irrigation system more automated and so on for energy efficiency too. Regardless of the specific construction, there is no doubt that this system may be quite useful in a variety of situations to solve problems without human intervention. Tampering a wide range of issues, from seemingly harmless issues to those that are among the most important and damaging to the human population. Using this approach, it is practical to regulate the amount of water used in the process of watering the plant. This system automation is designed to help or assist farmers, Terrace-farming and small Vegetation farms. Although it has the potential to benefit mankind as a whole, agriculturists, craftspeople, and botanists may profit the most from it and in the end also in conserving water.

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