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Research Paper

An economical sensor-based automated plant watering system for smart irrigation

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ABSTRACT

Lack of water reduces photosynthesis in plants and crops, and depletion of soil water lowers agricultural production and can reduce the food supply, making water supply and management essential for effective plant growth. Over the past century, global water use has grown faster than the population, and an increasing number of regions, particularly dry ones, now use more water than they can sustainably provide. Traditional watering techniques such as sprinklers and flood irrigation are inefficient and do not match plants' actual needs, since many plants do not require excess water; this wastes water, and spillage and stagnant water can provide habitats for disease vectors such as mosquitoes. Watering should therefore be controlled intelligently, according to plants' needs and the moisture content of the soil. In this study, an automated plant watering system that monitors soil moisture to determine when watering is necessary was developed using an Arduino Uno microcontroller, a soil moisture sensor, a pump, relays, wiring, and a sprinkler, together with software to drive the hardware. The economical system was tested and can be used in small gardens and, with scaling, in larger crop fields.

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1. INTRODUCTION

Most significant losses in agriculture, whether material or monetary, are related to the health and quality of crops, which must be kept in good condition and adequately moist to avoid losses in produce [1]. Global demand for water has grown faster than the population, and agriculture is the largest user of freshwater, so efficient irrigation is essential [2]. For a farmer with large fields, it is difficult to supervise and maintain the soil moisture at a desirable level using manual methods [3], and relying on manual labour is risky because many workers prefer white-collar jobs, leaving a significant labour shortage. Farm automation, such as automated irrigation, is therefore essential for good farm output. Apart from natural calamities, improper irrigation is the main factor contributing to crop underperformance, and most such problems can be remedied by improving irrigation through technology. This study designs a sensor-based plant watering system that measures soil moisture and determines plants' water needs, controlled by an Arduino microcontroller. The aim is an automatic plant watering device using a soil moisture sensor that helps farmers by continuously monitoring soil moisture, reducing manual intervention, and ensuring adequate moisture for plant growth.

2. RELATED WORK

Kim and Evans [4] designed wireless in-field sensing and control software that provides real-time monitoring and control of inputs (field data) and outputs (sprinkler controls) through a simple graphical user interface, optimized to adapt to changes in crop, irrigation pattern, and field location, with remote access to in-field micrometeorological information from a distributed wireless sensor network and variable-rate irrigation control. Putjaikal et al. [5] designed a control system for intelligent farming using Arduino technology, focusing on the watering and roofing systems of an outdoor farm based on data from temperature, humidity, moisture, and light-intensity sensors. Because sensed data are noisy, they applied Kalman filtering before decision-making, and they combined the sensed data with weather conditions predicted by a decision-tree model in a set of rules that automatically switched the watering and roofing systems on or off.

Taneja and Bhatia [6] developed a method to convert manual irrigation into automated irrigation, switching the pump motor on and off using a soil moisture sensor and an 8051-family microcontroller, with a water-level sensor to ensure that the tank holds enough water to irrigate the fields. Other low-cost Arduino-based irrigation systems have been developed with soil moisture sensing [7], [8], GSM-based remote control and notification [9], and solar power supply [10], while Internet of Things (IoT) and fuzzy-logic approaches have been applied to smart irrigation at larger scales [1], [3].

3. METHODOLOGY

The system comprises hardware and software components. The hardware components are an Arduino Uno microcontroller, a soil moisture sensor, a pump, a relay, jumper wires, and a battery, as described below.

3.1 Hardware Components

3.1.1 Arduino Uno

The Arduino Uno (Figure 1) is one of the most popular boards in the Arduino series. It is an open-source electronics platform built on the ATmega microcontroller that can control buttons, LEDs, motors, speakers, GPS devices, cameras, and network connections. Its software is based on the C programming language, can be extended with C++ libraries, and runs on Windows, macOS, and Linux. All other hardware in the system is connected to the Arduino, which receives signals from the sensor and sends signals to drive the pump.



Figure 1. Arduino Uno Board

3.1.2 Pump

A DC motor converts direct-current electrical power into mechanical power using magnetic forces. A DC motor pump (Figure 2) uses the motor shaft to drive an impeller that circulates water and is housed in a waterproof plastic casing; the 5 V supply needed by the pump can be provided by batteries or an AC adapter.



Figure 2. DC Water Pump

3.1.3 Relay

A relay module is an electrically operated switch that allows or blocks current flow. In the proposed system, a relay is placed between the Arduino board and the water pump; it runs on 5 V DC and can switch loads of up to 220 V AC when triggered by the Arduino, so the Arduino's I/O pins can control the water pump through the relay.

3.1.4 Jumper Wires and Battery

Jumper wires connect the breadboard, prototype, or circuit components, and a 9 V battery serves as the DC power source for the system.

3.1.5 Soil Moisture Sensor

A soil moisture sensor (Figure 3) measures the water content of the surrounding soil. It passes current through the soil between two probes and measures the resistance to determine the moisture level: moist soil conducts electricity more easily (lower resistance), whereas dry soil has higher resistance.

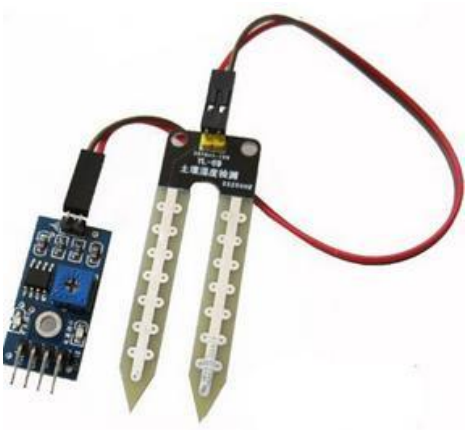

Figure 3. Soil Moisture Sensor

3.2 Software

The Arduino Uno program for the watering system was written in the Arduino IDE and uploaded to the board. The code is as follows:

```
const int waterPump = 4;       // water pump (relay) on pin 4
const int moistureSensor = A0;  // moisture sensor on analog pin A0
int threshold = 700;           // threshold for watering

void setup() {
 pinMode(waterPump, OUTPUT);    // pump pin as output
 pinMode(moistureSensor, INPUT); // sensor pin as input
 Serial.begin(9600);           // start serial communication
}

void loop() {
 int soilMoisture = analogRead(moistureSensor); // read moisture level
 Serial.println(soilMoisture);                 // print moisture level
 if (soilMoisture < threshold) {
  digitalWrite(waterPump, HIGH); // turn on the pump
  delay(1000);                  // wait 1 s
  digitalWrite(waterPump, LOW);  // turn off the pump
 }
 delay(1000);                   // wait 1 s before checking again
       }
```

3.3 System Design

The block diagram, flow chart, and circuit diagram of the system are shown in Figure *4*, Figure *5*, and Figure *6*, respectively. The 5 V pin of the Arduino is connected to the 5 V pin of the relay module and the Arduino ground to the relay GND; a digital pin of the Arduino drives the relay input; the sensor's GND is connected to the Arduino GND and its signal pin to the Arduino; and the pump is connected through the relay.

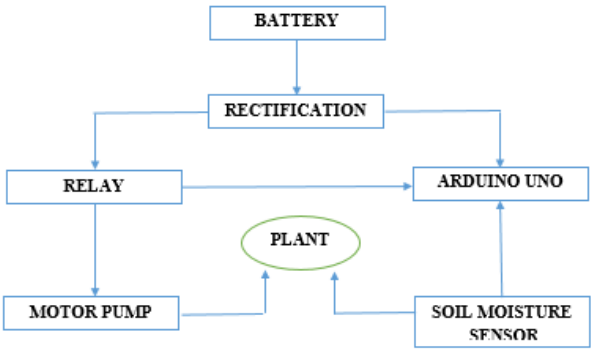

Figure 4. Block Diagram of the Designed System

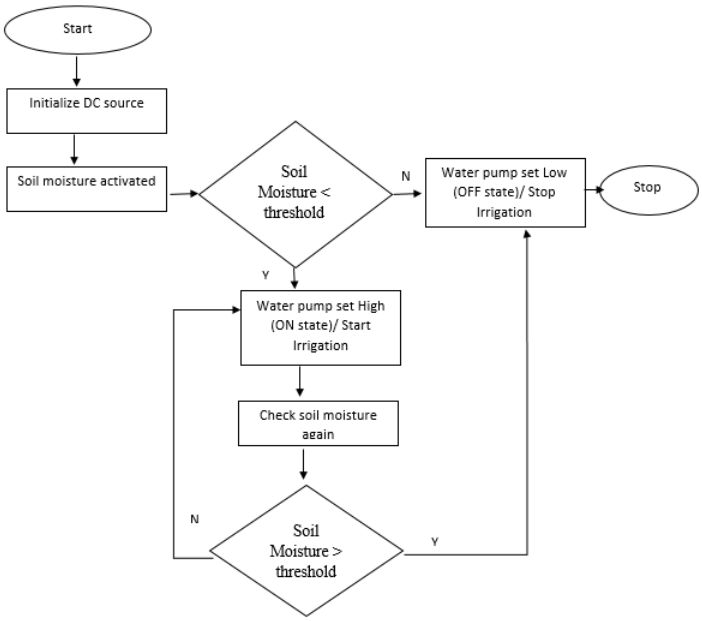

Figure 5. Flow Chart of the Designed System

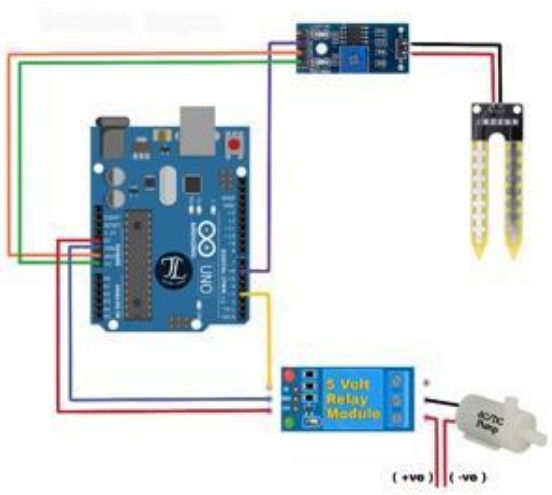

Figure 6. Circuit Diagram of the Designed System

4. RESULTS AND DISCUSSION

When the soil moisture level is low, the moisture sensor signals the Arduino, which triggers the relay, switching on the pump and watering the plant; when the soil moisture level is high, the Arduino does not trigger the relay. Figure 7 shows the prototype of the designed system. The pump is thus switched on or off automatically through the relay according to soil moisture, allowing the soil moisture content of farmland to be managed effectively, saving water, and maintaining moisture at a level favourable to the plant, which can enhance crop yields.

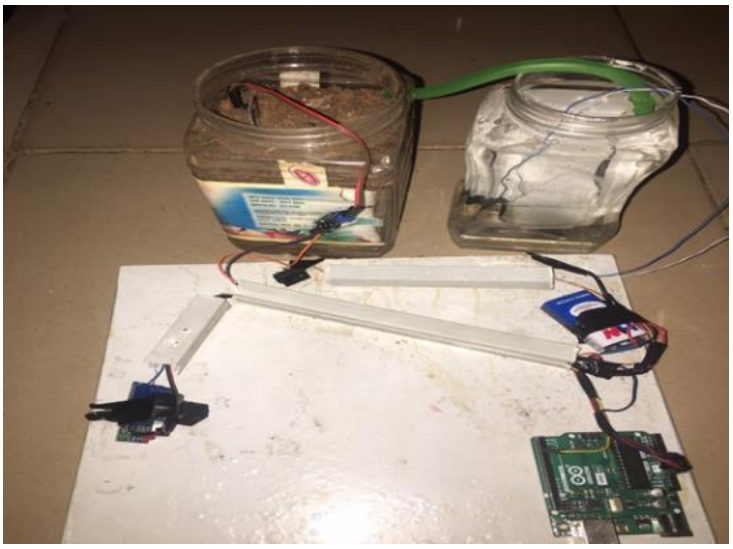

Figure 7. Prototype of the Designed System

Water is supplied only when needed, reducing waste, and the system can be adapted in software to the needs of different plants and settings, providing a scalable supporting technology that reduces the effort required for irrigation.

5. CONCLUSION

A sensor-based watering system for smart irrigation, capable of switching a water pump and sprinkler on and off, was designed, implemented, and tested. The system uses soil moisture readings to decide whether to irrigate. Testing showed that its performance is reliable, and it is economical and affordable for small-scale and large-scale farmers. Because watering occurs only when necessary, the system can reduce water use and wastage, avoid waterlogging of farmland, and support crop growth.

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Authors Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Modupe Agagu	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
I : **I**nvestigation
R : **R**esources
Vi : **Vi**sualization
Su : **Su**pervision

So : **So**ftware	D : **D**ata Curation	P : **P**roject administration
Va : **Va**lidation	O : Writing - **O**riginal Draft	Fu : **Fu**nding acquisition
Fo : **Fo**rmal analysis	E : Writing - Review & **E**diting	

Conflict of Interest Statement

No conflict of interest.

Informed Consent

Not Applicable.

Ethical Approval

Not Applicable.

Data Availability

This study draws on publicly available data. No new datasets were created.

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