Digital control of plant development through sensors and microcontrollers

Abstract

The plant monitoring system focuses on developing an automated solution using the Arduino Uno ATMEGA328P microcontroller module and various sensors to monitor and adjust environmental conditions for optimal plant growth. The main objective of the project is to create a comprehensive system that continuously measures parameters such as: light intensity, air humidity levels and soil moisture in real time.

The scientific paper provides a detailed description of the components used and their connections, as well as the implementation of the program code written in C++ under the Arduino Uno ATMEGA328P microcontroller environment. It also includes chapters on introduction, results, discussion and conclusion.

In conclusion, the plant development monitoring system provides an automated solution for effective and healthy plant care and development. The paper serves as a valuable resource to understand the implementation of the system, its benefits, limitations and potential for future improvements in the field of monitoring and automation for plant development surveillance.

Keywords: arduino, microcontroller, sensor, plants, system, buzzer, LCD

1. Introduction

1.1 Background

In today's fast-paced and dynamic work environments, effective project planning and monitoring are essential to their successful accomplishment. Using digital control systems, project managers and their team members can struggle to track progress, identify obstacles and make appropriate decisions.[14]

1.2 Objectives

The main objective of that paper is to create a digital and intelligent system for users that enables them a real-time monitoring of plant development. Using the Arduino Uno module, it is intended to provide managers and stakeholders valuable insights into the progress of plant development.[5]. The system will provide an intuitive interface for visualizing the main measurements, generating reports and facilitating efficient communication between monitoring team members in tracking plant development.

1.3 The purpose of the paper

This paper serves as a comprehensive documentation of the mentioned project plan monitoring system developed with Arduino Uno. It describes the entire development process, from conception and design to implementation and evaluation. The research paper aims to provide detailed knowledge on system architecture, hardware and software components, implementation methodology and performance evaluation. This paper aims to serve as a valuable resource for individuals interested in understanding the complication of our work and replicating or building upon our work.[8],[14]

By developing this plant development monitoring system and documenting our findings, we strive to contribute to the field of identical project management by providing an accessible and affordable solution for real-time plant development monitoring and tracking.

2 Methodology

2.1 System overview

The plant monitoring system developed using the Arduino Uno module is designed to provide real-time monitoring and analysis of key environmental parameters to ensure optimal plant growth. By integrating various sensors and actuators, the system provides a comprehensive solution for monitoring and managing plant health.

2.2 Main characteristics of the system

The digital plant monitoring system includes several key features that contribute to its effectiveness in supporting plant growth, development and care. These features include:

Environmental sensors: The system includes a variety of sensors to measure vital environmental parameters such as temperature, ambient humidity, light intensity and soil moisture. These sensors provide accurate information enabling users to gain insight on the plant's environment. [6], [7]

Data visualization: The system includes on-screen visualization capabilities, allowing users to analyze trends and patterns in the plant's environment. [15]

Real-time alerts and notifications: The system is equipped with an alert mechanism that notifies users of critical conditions such as excessively high or low temperatures, inappropriate ambient humidity levels, or dry soil. These real-time alerts enable immediate action to be taken to address any problems and prevent potential damage on the plant development.

2.3 Benefits of the plant monitoring system

The plant monitoring system offers numerous benefits to plant enthusiasts, gardeners and researchers. Some of the key benefits include:

Improved plant care: By constantly monitoring environmental parameters, the system enables precise control and regulation of conditions to optimize plant growth. This ensures that the plants get the ideal environment they require for healthy growth.

Resource efficiency: With the ability to monitor soil moisture, light levels and other factors, the system promotes resource efficiency by preventing over-watering, excessive energy consumption and unnecessary resource wastage. This not only benefits plant health, but also contributes to sustainable practices. [6]

Early problem detection: Real-time alerts and notifications enable immediate detection of any adverse or potential problem conditions. This allows users to take immediate action to correct problems, preventing plant damage or loss.

2.4 Hardware Configuration

Arduino UNO ATMEGA328P is the perfect electronic module to get familiar with electronics and device coding. This versatile microcontroller is equipped with the well-known ATmega328P processor for processing the information received from the system's sensors and the memory for storing the data received from the sensors connected to the system. [1]

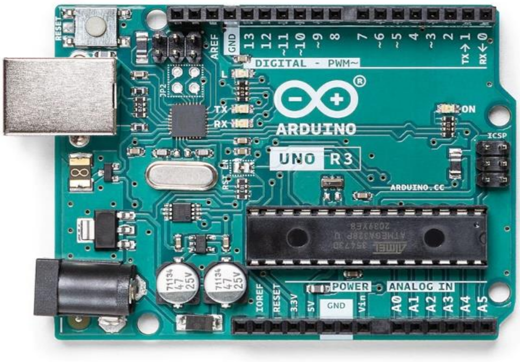

Figure 1 Arduino Uno ATMEGA328P module

2.4.1 Sensors used

The plant monitoring system uses three key sensors to measure essential environmental parameters: an ambient temperature and humidity sensor - DHT11, a soil moisture sensor - FC-28 and an LDR sensor. These sensors play a significant role in providing accurate and real-time data for optimal care of plant development.

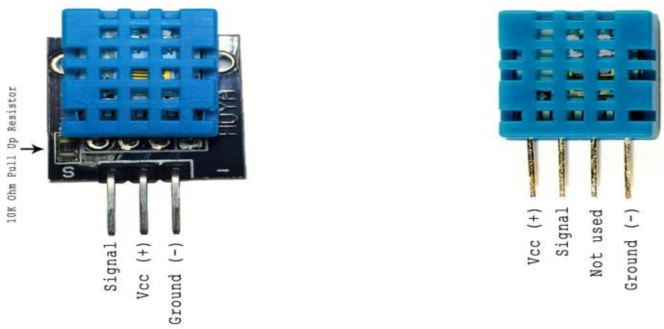

Figure 2 DHT11 temperature and humidity sensor

The DHT11 measures the relative humidity of the environment. Ambient relative humidity is the amount of water vapor in the air versus the saturation point of the water vapor in the air. At the saturation point, water vapor begins to condense and accumulate on the surface forming dew. The saturation point varies with air temperature. Cold air can hold less water vapor before it becomes saturated, and hot air can hold more water vapor before it becomes saturated. [2]

The formula for calculating relative humidity is: $RH = \left(\frac{\rho_w}{\rho_s}\right) \times 100\%$.

ρ_w - Water vapor density

ρ_s - Density of water vapor at saturation

The DHT11 detects water vapor by measuring the electrical resistance between two electrodes. The moisture-sensing component is a substrate that holds moisture with electrodes applied to the surface. When water vapor is absorbed by the substrate, ions are released from the substrate, which increases the conductivity between the electrodes. The change in resistance between the two electrodes is proportional to the relative humidity. Higher relative humidity decreases the resistance between the electrodes, while lower relative humidity increases the resistance between the electrodes. The DHT11 measures temperature with a surface-mounted NTC temperature sensor (thermistor) built into the unit. [2]

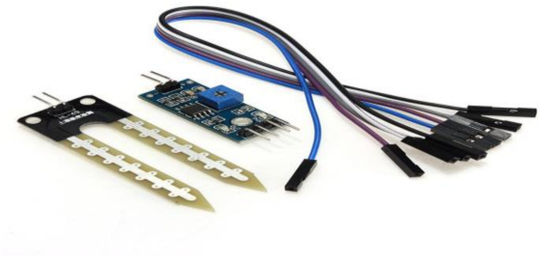

Figure 3 FC-28 soil moisture sensor

The FC-28 Soil Moisture Sensor is a soil hydrometric transducer that can read the amount of moisture present in the surrounding soil. The module uses two probes to pass current through the soil and then reads that resistance to measure the moisture level. More water makes the soil conduct electricity more easily (less resistance), while dry soil conducts electricity poorly (more resistance). The FC-28 offers enhanced protection features such as ESD protection and under voltage protection function. [3]

Figure 4 LDR sensor

LDR (Light Dependent Resistor) is a special type of photoresistor that works on the principle of photoconductivity. This means that the resistance changes according to the intensity of the light. Its resistance decreases with an increase in light intensity. It is often used as a light sensor, light meter, automatic light for street lighting, parks and public squares and in areas where we need to be sensitive to light. The same is also called as light sensor. [4]

Using these sensors, the plant development monitoring system can continuously monitor light intensity, ambient humidity levels, and soil moisture content of the soil. The data obtained from these sensors allows the system to make adequate decisions regarding watering, lighting and environmental adjustments to ensure optimal plant growth and development. [6], [7], [9]

2.4.2 Other components

In addition to the previously mentioned sensors, the plant monitoring system includes two essential components: an LCD screen (20x4) and an audible alarm siren-horn. These components play specific roles in providing visual and audible feedback to the user, improving system functionality and real-time user response. [15]

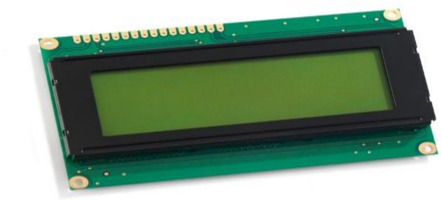

Figure 5 LCD Screeni (20x4)

- Description: LCD The screen used in the system is an electronic model with a number of characters of 20x4. It consists of 20 columns and 4 lines, allowing the presentation of alphanumeric characters and symbols that constitute an adequate message according to the monitoring situation of the system.

- Function: LCD screen serves as an output interface, providing real-time information about the plant environment and system status. It provides a clear and easily readable display of messages, ensuring convenient monitoring and interaction with the system.

• Implementation: The LCD screen is connected to the Arduino Uno via the corresponding digital input/output pins. The system communicates with the screen using the LiquidCrystal library, which enables control of the screen's content, such as printing sensor information, system messages, and prompts.

Figure 6 Sound alarm horn

- Description: The siren used in the plant monitoring system is a small electronic audio transducer that generates signals or sound tones when activated.

- Function: The siren serves as an audio indicator, providing audible feedback to alert users to specific events or conditions. It enhances the system's ability to notify users of critical situations, such as low humidity levels or system malfunctions, even when they are not actively monitoring the visual display.

- Implementation: The siren is connected to a digital output pin of the Arduino Uno. By controlling the voltage levels applied to the pin, the system can trigger the buzzer to produce different tones or sequences based on specific events or conditions. [7]

These components, when combined with sensors and the Arduino Uno ATMEGA328P module, form a comprehensive digital plant development control system that provides timely feedback to the users, facilitating effective care and management of plant development.

Table 1 provides a simple and organized overview of the main components used in the digital plant development control system. It lists the components, their descriptions and their functions in a tabular format, where Figure 7 refers to these components. The table allows the reader to quickly understand the essential components of the system.

Name	Components	Functions
U1	Arduino Uno R3	Control unit for system, processing and I/O
U2	Temperature and humidity sensor - DHT11	Monitors ambient humidity levels for optimal plant growth
R1	Photoresistor	Monitors light intensity for plant photosynthesis
SEN1	Soil moisture sensor FC-28	Monitors soil moisture levels of soil for proper irrigation
U3	LCD 20 x 4	Displays real-time data and system information
R2	1 kΩ Resistor	Limits or regulates the flow of electric current in an electronic circuit to protect other devices
R3	5 kΩ Resistor	Limits or regulates the flow of electric current in an electronic circuit to protect other devices
PIEZO1	Sound alarm horn	Provides audio alerts and voice notifications
R4	100 Ω Resistor	Limits or regulates the flow of electric current in an electronic circuit to protect other devices

Table 1 Components used in the digital control system of plant development

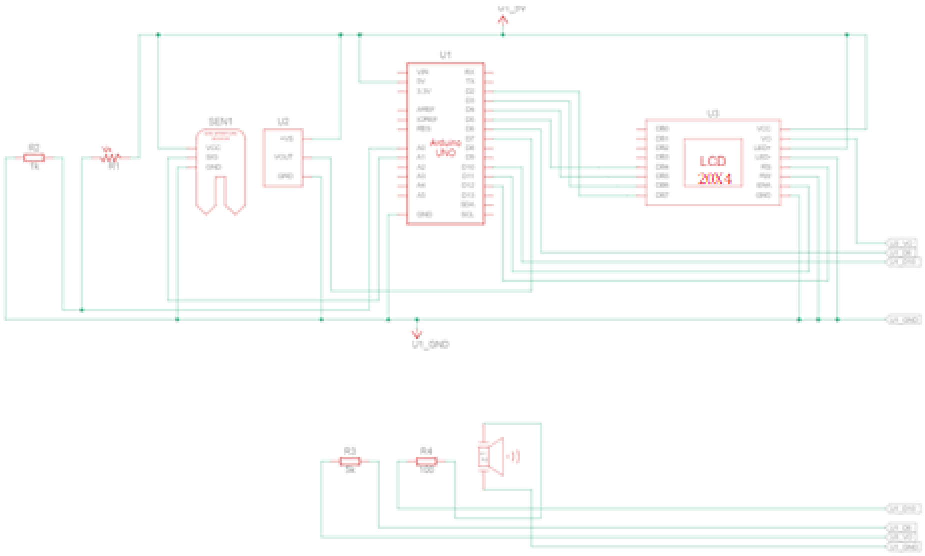

Figura 7 Component connection diagram

2.5 Code Implementation

The Software Code implementation chapter provides a detailed explanation of the responsible code for the operation of the digital plant development control system. This chapter is based on the Arduino UNO ATMEGA 328P sketch that controls the various components and processes the data provided by the sensors.

The provided code starts by including the libraries needed for the project, such as the LiquidCrystal library for controlling the LCD display and the dht11 library for reading data from the DHT11 ambient temperature and humidity sensor. It defines the pins used for various components, including the LDR (Light Dependent Resistor), buzzer and humidity sensor. Additionally, it places the pins for the LCD display.

In the setup() function, the code initializes the necessary pins and components. It sets pinMode for buzzer as output, LDR pin as input and humidity sensor pin as input. The LCD screen is also initialized with the specified number of columns and rows. Additionally, the code sets an analog output pin to a specific value. [10], [11], [12]

The loop() function is the place where the main functionality of the system resides. It starts by reading data from the DHT11 sensor, the LDR and the soil moisture sensor. Ambient humidity, temperature and soil moisture percentage are processed based on sensor information.

The code then checks various conditions to determine the state of the digital electronics and display the relevant information on the LCD screen. If the moisture percentage falls below a certain threshold, indicating low soil moisture, a warning message is displayed along with the percentage value. The horn is activated for a short period to give an audible alert. Similarly, if the humidity is below a specific level or the temperature exceeds a certain value, appropriate warning messages are displayed and the alarm is activated accordingly.

If none of the warning conditions are met, the code displays normal sensor readings on the LCD, including LDR value, percent humidity, humidity, and temperature. The display is updated every 500 milliseconds.

The code demonstrates the integration of various components and the use of sensor data to provide real-time information about plant conditions. It effectively controls the LCD screen and activates the buzzer for real-time notifications.

3 Results

The implementation of the system in plant development monitoring using Arduino Uno involves the successful integration of various electronic components, including sensors, actuators and supporting devices. This section provides an overview of the hardware configuration, including electrical connections and configurations made to ensure proper system operation.

3.1.1 Hardware Configuration

The hardware configuration of the plant development monitoring system includes the following main components: Arduino Uno ATMEGA328P Microcontroller Module: The Arduino Uno module serves as the central control unit for the digital plant development control system. It provides the processing capability, digital and analog input/output pins, and communication interfaces needed to connect and control various electronic components.

Sensors:

• Light Dependent Resistor (LDR): The LDR is connected to an analog input pin on the Arduino Uno module to measure light intensity. [11], [13]

• Ambient humidity sensor: The ambient humidity sensor is connected to a digital or analog input pin on the Arduino Uno module, depending on the specific sensor model used. [6]

• Soil Moisture Sensor: The soil moisture sensor connects to an analog input pin on the Arduino Uno module to measure soil moisture levels of the soil. [8],[14]

Activators:

Audible Alarm Horn: Connects to a digital output pin on the Arduino Uno to provide audible alerts and notifications. [7]

LCD Display (20x4): The LCD Display is connected to the Arduino Uno using digital I/O pins and also interfaces through the LiquidCrystal library.

3.1.2 Connections and Configurations

The following connections and configurations are made to ensure proper operation of the digital plant development monitoring and control system:

Arduino Uno Connections:

• The LDR is connected to an analog input pin on the Arduino Uno module. A voltage divider circuit or suitable electrical circuit is used to convert the variable resistance of the LDR into an analog voltage.

• The ambient humidity sensor is connected to a digital or analog input pin on the Arduino Uno, following the manufacturer's specifications and pin configurations.

• The soil moisture sensor is connected to an analog input pin on the Arduino Uno. The output voltage of the sensor is measured and calibrated to correspond to the soil moisture level.Lidhja me sirenën-borinë:

The siren or horn is connected to a digital output pin on the Arduino Uno. The appropriate voltage level is applied to the pin to activate the buzzer and produce audible tones or sequences.

LCD screen configuration:

• LCD Display is connected to Arduino Uno using digital input/output pins. Specific pin connections for data and control signals are made according to the main point of the display module.

• The LiquidCrystal library is used to configure the display and control its content. This includes initializing the library, setting the appropriate parameters such as the number of columns and rows (20x4) and defining custom characters if required.

After the hardware connections and configurations are completed, the Arduino Uno module is programmed using the Arduino IDE software namely the C++ programming language under the Arduino Uno ATMEGA328P environment. Programming code includes reading data from sensors, controlling actuators, and displaying information on the LCD screen based on specific conditions and thresholds.

The results chapter highlights the successful implementation and performance of the plant development monitoring and control system using Arduino Uno. Based on the obtained results and analysis, the following main conclusions can be drawn:

• Accurate sensor readings: Sensors, including light-dependent resistance, ambient humidity sensor and soil moisture sensor, ensure consistently accurate and reliable readings. This ensures accurate monitoring of environmental parameters essential for plant health and growth and development.

• Real-time data monitoring: The plant monitoring system facilitates real-time data monitoring, allowing users to access up-to-date information about light intensity, ambient humidity levels and soil moisture content . This enables real-time decision making and proactive adjustments to ensure optimal plant development care.

• Alarms and notifications: The alarm system for plant surveillance plays a crucial role in notifying users of critical conditions. Whether it was low humidity levels, excessive light intensity or deviations from desired parameters, real-time alerts and notifications allow users to take immediate action and prevent potential plant damage.

The results obtained from the plant monitoring system highlight its effectiveness in providing accurate data, automated control and real-time alerts. By leveraging information technology to optimize plant care, the system offers significant advantages over traditional manual monitoring approaches, ultimately leading to improved plant health, resource efficiency and increased productivity.

4 Discussion

The discussion chapter explores the benefits, limitations and potential for future improvements of the plant monitoring system using the Arduino Uno. It provides an analysis of the system's strengths and weaknesses, along with suggestions for further improvements. Here are the main points to cover:

4.1 Benefits of the system

The plant monitoring system offers several important benefits, including:

1. Efficient resource management: The system optimizes resource management by providing real-time data on environmental parameters such as light intensity, air humidity and soil moisture levels. This allows precise control of water use, energy consumption and overall resource efficiency.

2. Improved plant care: By constantly monitoring and adjusting plant conditions, the system ensures optimal growth and health. It eliminates the guesswork and provides accurate information for effective decision-making regarding watering, lighting and other factors crucial to plant well-being.

3. Early detection of problems: The system's alarm mechanism immediately notifies users of critical conditions such as low humidity levels or excessive light intensity. This enables timely intervention and preventive measures to mitigate potential plant damage or stress.

4.2 Limitations and challanges

While the plant surveillance system offers significant benefits, it also has some limitations and challenges that must be considered:

1. Reliance on sensor accuracy: Accuracy of sensor readings is essential for accurate decision making. However, sensor calibration and possible variations in sensor performance can affect the reliability of the data collected. Regular maintenance and calibration of the sensor is necessary to ensure accurate readings.

2. System complexity: System implementation may require a certain level of technical expertise and familiarity with electronics and programming. Users with limited technical knowledge may face challenges in configuring and troubleshooting the system.

3. Environmental Variability: Environmental factors, such as weather conditions and seasonal variations, can introduce additional complexities into plant care. The effectiveness of the system may vary in different environmental conditions, requiring adaptation and periodic adjustments.

4.3 Potential for future improvements

To further improve the plant monitoring system, several potential areas of improvement can be explored:

1. Automated irrigation: Integrating an automated irrigation system based on soil moisture readings can provide more accurate and efficient irrigation control. This feature would

eliminate the need for manual intervention and ensure that plants receive the right amount of water at the right time.

2. Plant-Specific Recommendations: Incorporating a plant database or machine learning algorithms can enable the system to provide personalized recommendations and care instructions based on the specific plant species being monitored. This would increase the adaptability of the system to different plant requirements.

3. Remote monitoring and control: Adding remote monitoring and control capabilities would allow users to access the system and get real-time updates from anywhere. This feature would enable remote management, making it convenient for users to monitor and take care of their plants even when they are away.

4. Data visualization and analysis: Improving the system's data visualization and analysis capabilities would enable users to gain deeper insights into plant growth patterns, trends, and correlations. Visualizing data through charts, graphs or interactive interfaces would facilitate better decision making and long-term planning.

5. Integration with smart home systems: Integrating the plant monitoring system with existing smart home systems or platforms would increase its compatibility and interoperability. This integration will allow users to control and monitor their plants.

8. Conclusion

8.1 Summary

To conclude, the digital plant development monitoring and control system project successfully develops an automated solution using the Arduino Uno microcontroller module and various sensors to monitor and adjust environmental conditions for optimal plant growth and development. The system continuously measures parameters such as light intensity, ambient humidity levels and soil moisture content, providing real-time data for informed decision-making in plant care.

8.2 Implications

The implications of the plant monitoring system are important in the field of care and automation in plant development. The system provides several benefits, including efficient resource management, improved plant health and improved productivity. By precisely monitoring and adjusting environmental conditions.

Furthermore, the system's ability to continuously monitor parameters such as light, air humidity and soil moisture allows for proactive plant care. Plant owners can make data-driven decisions about watering, lighting, and other factors crucial to plant growth. This promotes healthier plant development, reduces the risk of disease or pests, and maximizes overall plant yield and quality.

The plant monitoring system also has implications beyond individual plant care. Data collected from multiple systems can be analyzed to gain insights into plant behavior, growth patterns, and environmental trends. This knowledge can contribute to scientific research, agricultural advances and the development of more effective plant care strategies.

Overall, the plant monitoring system represents a valuable tool for plant owners, researchers and the agricultural industry. Its implications extend to resource efficiency, improved plant health, and the potential for broader scientific and agricultural advances. As technology continues to evolve, further improvements and innovations in plant monitoring and automation are expected, opening up new opportunities for efficient and sustainable plant care.

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Annex

```
#include <LiquidCrystal.h>
#include <dht11.h>
#define DHT11PIN 7

const int ldr = A0;
const int buzzer = 10;
const int moistureSensor = A1;
const int rs = 12, en = 11, d4 = 5, d5 = 4, d6 = 3, d7 = 2;

int ldrValue;
int moisValue;
float moisturePercentage;
float humidity;
float temp;
dht11 DHT11;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

void setup() {
  pinMode(buzzer, OUTPUT);
  pinMode(ldr, INPUT);
  pinMode(moistureSensor, INPUT);

  lcd.begin(20, 4);
  analogWrite(6,10);
}

void loop() {
  int chk = DHT11.read(DHT11PIN);
  ldrValue = analogRead(ldr);
  moisValue = analogRead(moistureSensor);
  humidity = (float)DHT11.humidity;
  temp = (float)DHT11.temperature;
  moisturePercentage = (100 - ((moisValue/1023.00) * 100));

  if (moisturePercentage < 41)
  {
    lcd.setCursor(0, 0);
    lcd.print("Lageshtia e tokes");
    lcd.setCursor(0, 1);
    lcd.print("eshte e ulet");
    lcd.setCursor(0, 2);
    lcd.print(moisturePercentage);
    lcd.print("%");
    tone(buzzer, 220);
    delay(1000);
    lcd.clear();
  }
  else if (humidity < 40)
  {
    lcd.setCursor(0, 0);
    lcd.print("Lageshtia e ajrit");
    lcd.setCursor(0, 1);
    lcd.print("eshte e ulet");
    lcd.setCursor(0, 2);
    lcd.print(humidity);
    lcd.print("%");
    tone(buzzer, 240);
```

```
    delay(1000);
    lcd.clear();
  }
  else if (temp > 29)
  {
    lcd.setCursor(0, 0);
    lcd.print("Temperatura eshte e");
    lcd.setCursor(0, 1);
    lcd.print("larte");
    lcd.setCursor(0, 2);
    lcd.print(temp);
    lcd.print("C");
    tone(buzzer, 250);
    delay(1000);
    lcd.clear();
  }
  else
  {
    noTone(buzzer);
    lcd.setCursor(0, 0);
    lcd.print("LDR: ");
    lcd.print(ldrValue);

    lcd.setCursor(0, 1);
    lcd.print("Moisture:");
    lcd.print(moisturePercentage);
    lcd.print("%");

    lcd.setCursor(0, 2);
    lcd.print("Humidity:");
    lcd.print(humidity);
    lcd.print("%");

    lcd.setCursor(0, 3);
    lcd.print("Temp:");
    lcd.print(temp);
    lcd.print("C");
    delay(500);
    lcd.clear();
  }
}
```