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Measuring Soil Moisture in Real-Time: Arduino Uno Based Tool Innovation

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ABSTRACT

Humidity measurement is vital across various sectors, such as agriculture, meteorology, industry, and households, where accurate monitoring ensures product quality, environmental stability, and process efficiency. Over time, humidity measurement technologies have evolved significantly, transitioning from basic evaporation-based methods to advanced electronic sensors like capacitive and resistive sensors, which offer real-time accuracy. Hygrometers and moisture meters are key devices in this field, with hygrometers measuring air humidity and moisture meters assessing water content in materials like soil, wood, and grains. Their integration with automation systems further enhances operational efficiency and simplifies environmental monitoring. Despite these advancements, challenges persist, including the need for higher accuracy, adaptability to diverse environments, and cost reduction. Research and development continue to tackle these issues, driving innovation toward more reliable, user-friendly, and affordable solutions. This article reviews the latest advancements in humidity measurement technologies, highlights the challenges faced, and explores future innovations that promise to enhance the accuracy and efficiency of these devices. Such progress is crucial for sustainability and improved performance in fields dependent on precise humidity data, ultimately supporting better decision-making and resource management.

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1. INTRODUCTION

Humidity is one of the environmental parameters that has a significant impact on various fields, including agriculture, meteorology, industry, and households. Accurate humidity monitoring is essential to maintain product quality, environmental stability, and process efficiency. In the context of agriculture, measuring soil moisture is crucial to ensure that crops receive sufficient water, which in turn affects growth and yield. In the food industry, precise control of humidity levels is necessary to prevent spoilage or damage to products, thereby maintaining food quality and safety. To meet these needs, humidity measuring devices, known as hygrometers and moisture meters, have been developed with various technologies. Hygrometers are used to measure air humidity, while moisture meters are used to determine the water content in various materials, such as soil, wood, and grains. With the advancement of technology, these devices are now available in various shapes and sizes, from simple to sophisticated, allowing users to obtain humidity data more accurately and efficiently[1].

The development of humidity measurement technology has progressed rapidly, moving from simple evaporation-based methods to sophisticated systems using electronic sensors[2]. Capacitive and resistive sensors are examples of modern technologies that are widely used due to their accuracy in reading humidity levels in real time. In addition, these devices can be integrated with automation systems, allowing for more efficient and productive humidity management. This integration not only increases operational effectiveness but also makes it easier for users to monitor and control environmental conditions[3]. However, the development of humidity meters still faces several challenges. The need for higher accuracy, compatibility with various types of environments, and reduced production costs are issues that need to be addressed. Therefore, innovation continues to be carried out to produce humidity meters that are more reliable, easy to use, and affordable[4]. Research and development in this field is expected to produce solutions that not only meet user needs but also contribute to sustainability and efficiency in various sectors[5].

This article aims to explore the latest developments in humidity measurement technology, the challenges faced in its development, and the potential for innovation that can improve the accuracy and efficiency of humidity meters. With a better understanding of these tools and technologies, it is hoped that they can make a positive contribution to various fields that depend on humidity measurement[6].

2. RESEARCH METHOD

This research aims to design and implement a soil moisture detection tool utilizing the Arduino Uno and a Soil Moisture Sensor. The tool is intended to provide an efficient and accurate method for monitoring soil moisture levels, particularly in agricultural and horticultural applications. By integrating microcontroller technology with sensor-based measurements, this tool enables users to optimize irrigation management, conserve water resources, and enhance crop productivity. The study also explores the feasibility, cost-effectiveness, and scalability of this system, ensuring it can be adopted in diverse environmental and economic contexts

Additional Hardware

To create a soil moisture detector based on Arduino Uno, there are several components used in this research. The components are as follows table 1:

Table 1. Component Names

No.	Component Name
1	Arduino Uno
2	Soil Moisture Sensor
3	Resistor (10k Ohm)
4	Jumper Cable
5	Breadboard
6	LCD 16x2
7	Power Supply

Diagram of a Raspberry Pi-Based Cctv Monitoring System

This system is designed to detect soil moisture levels using a Soil Moisture Sensor. This sensor will measure soil moisture levels through varying resistance values depending on the water level in the soil[7]. The moisture data obtained will be processed by Arduino Uno, which functions as the main control unit. Moisture information will then be displayed in real-time on a 16x2 LCD, allowing users to monitor soil conditions practically and visually[8]. This system is designed to provide an energy-efficient, easy-to-use solution that can be applied to various types of soil. The system block diagram can be seen in the following figure:

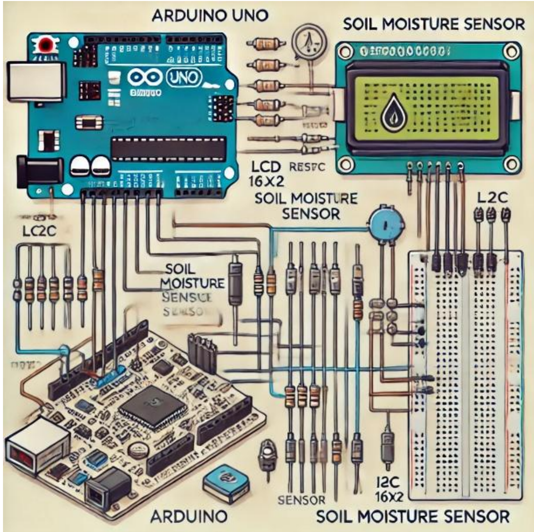

Figure 1. Connecting Soil Moisture Sensor to Arduino Uno via Breadboard

Connecting Soil Moisture Sensor to Arduino Uno via Breadboard

The first step in developing a soil moisture detector is to connect the Soil Moisture Sensor to the Arduino Uno using a breadboard[9]. Soil Moisture Sensors usually have three pins: VCC (power), GND (ground), and A0 (analog output). To get started, prepare all the necessary components, including the Arduino Uno, Soil Moisture Sensor, breadboard, and jumper wires. Connect the VCC pin of the sensor to the positive (+) line on the breadboard, and the GND pin to the negative (-) line. Next, connect the A0 pin of the sensor to one of the analog pins on the Arduino Uno, for example pin A0. Then, use a jumper wire to connect the positive (+) line on the breadboard to the 5V pin on the Arduino Uno and the negative (-) line to the GND pin on the Arduino. With this step, the Soil Moisture Sensor is ready to be used in measuring soil moisture[10].

Assembling the Electronic Circuit According to the Block Diagram

After connecting the Soil Moisture Sensor, the next step is to assemble the electronic circuit according to the block diagram that has been created. This block diagram serves as a visual guide to ensure that all components are connected correctly. In addition to the Soil Moisture Sensor, we also need to connect the LCD Display to the Arduino Uno to display the measurement results. Place all components on the breadboard neatly, and connect the pins according to the desired configuration. For example, connect the RS (Register Select) pin from the LCD to digital pin 12 on the Arduino, the E (Enable) pin to digital pin 11, and the data pins D4, D5, D6, and D7 to digital pins 5, 4, 3, and 2. Also make sure to connect the VSS pin to GND and the VDD pin to 5V[11]. After all connections are complete, double-check to ensure there are no errors in the wiring, so that the circuit can function properly.

Writing a Program on Arduino IDE to Read Data from Sensor and Display it on LCD

After the electronic circuit is assembled, the last step is to write a program on Arduino IDE to read data from the Soil Moisture Sensor and display it on the LCD. First, open Arduino IDE and create a new project. In the program code, import the necessary libraries, such as LiquidCrystal, to control the LCD. Declare the pins used for the sensor and LCD, then in the setup() function, initialize the LCD and set the initial display. In the loop() function, use the analogRead() function to read the value from the A0 pin connected to the Soil Moisture Sensor. Display the humidity value read on the LCD by setting the cursor position and printing the value. After finishing writing the code, connect the Arduino Uno to the computer and upload the program. With this step, the soil moisture detector is ready to be used to measure and display soil moisture levels in real-time[12].

3. RESULTS AND DISCUSSION

In this section, using the Internet of Things system, objects will be viewed from a smartphone or a PC, and an analysis of face detection capabilities on CCTV will be presented in this part.

3.1 How the Soil Moisture Detector Works

In developing an Arduino-based soil moisture detector, the first step that needs to be done is to activate the LCD[13]. This process begins by writing the program code using the Arduino IDE installed on the computer[14]. After the code is finished being written, the Arduino Uno is connected to the computer using a USB cable. This connection not only functions to upload the program to the Arduino, but also to provide power to the device during the testing process. In this way, we can ensure that all components are functioning properly before assembling them into a more permanent box or container. After ensuring that the LCD is functioning properly, the next step is to connect the soil moisture sensor to the Arduino. This sensor will be connected via the analog pins on the Arduino, which allows real-time reading of humidity data[15]. To connect the sensor, we first need to connect the VCC and GND pins of the sensor to the 5V and GND pins on the Arduino. This connection is important to provide the power needed for the sensor to operate properly. Next, the analog output pin of the sensor, which is usually marked as A0, is connected to one of the analog pins on the Arduino. In this way, the Arduino can read the humidity value produced by the sensor[16].

If we use an LCD to display the measurement results, the next step is to connect the LCD to the Arduino. LCDs usually have several pins that need to be connected to digital pins on the Arduino. Make sure to connect the pins according to a compatible configuration, such as the RS (Register Select), E (Enable), and data pins (D4, D5, D6, D7). The correct connection between the LCD and Arduino is very important to ensure that the data read from the sensor can be displayed clearly and accurately on the LCD screen. After all the components are connected correctly, the last step is to assemble all the devices into the box or container that has been prepared. This box not only functions to protect the components from physical damage, but also provides a neater and more professional appearance to the soil moisture detector. With all these steps, the Arduino-based soil moisture detector is ready to use, and we can start measuring soil moisture accurately and efficiently as shown in figure 2

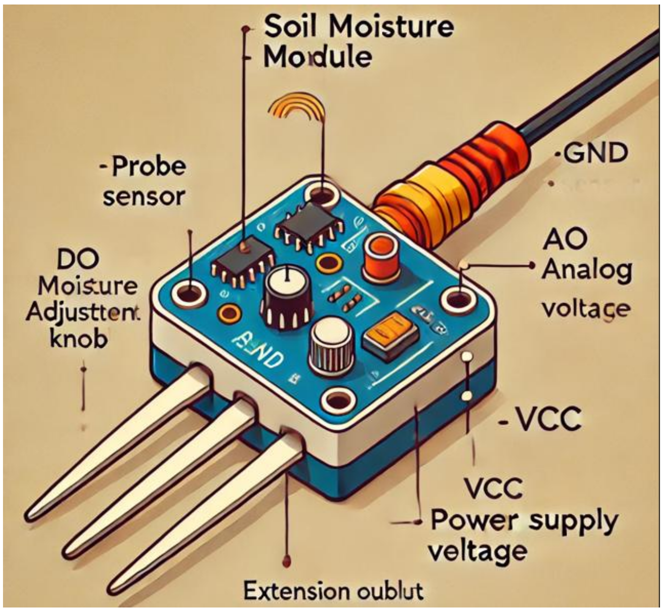

Figure 2. How the Soil Moisture Detector Works

Through this process, we not only learn about how each component works, but also understand the importance of integration between hardware and software in creating a functional tool. With this tool, it is expected to help in real-time monitoring of soil moisture, which is very useful in various applications, especially in agriculture.

3.2 Performance of software

Arduino programming is a crucial step in developing a soil moisture detector, which is done using the Arduino Integrated Development Environment (IDE) software. The Arduino IDE provides a user-friendly interface for writing, editing, and uploading code to the Arduino board. In the context of this tool, the code written aims to read humidity data from the sensor and display it in real-time on the LCD screen, so that users can easily monitor soil moisture conditions. The first step in programming is to open the Arduino IDE and create a new project. In this project, we start by importing the necessary libraries, such as LiquidCrystal.h, which allows us to control the LCD more easily. This library provides the functions needed to initialize the LCD, set the cursor position, and display the desired data. By using this library, we can ensure that the information displayed on the LCD is accurate and easy to read. After importing the libraries, the next step is to write the code to read the values from the moisture sensor. This sensor provides an output in the form of an analog signal ranging from 0 to 1023, where a value of 0 indicates very dry soil conditions and a value of 1023 indicates very wet soil conditions. In the code, we use the analogRead() function to read the value from the analog pin connected to the sensor. This value then needs to be converted into a humidity percentage to provide more intuitive information to the user.

This conversion process can be done with a simple formula, where the analog value is divided by 10.23 to get the humidity level in percent. After getting the converted humidity value, the next step is to display the result on the LCD. By using the functions from the LiquidCrystal library, we can set the cursor position on the LCD and print the calculated humidity value. This process is done in the main loop of the program, so that the reading and display of data can be updated periodically, for example every second. In this way, users can monitor changes in soil moisture in real time, which is very useful in irrigation management and plant maintenance. Overall, Arduino programming in this project not only involves writing code to read and display data, but also includes an understanding of how the sensor works and how the data can be processed to provide useful information. With this tool, it is hoped that users can be more effective in monitoring soil moisture, which can ultimately improve agricultural yields and water use efficiency as shown in figure 3

Figure 3. Performance of software

3.3 Analysis of soil moisture measurement analysis using arduino uno with soil moisture sensor

This section explains about soil moisture analysis using the designed tool, as shown in Table 2.

Table 2. Analysis of soil moisture measurement analysis using arduino uno

No	Soil Type	Soil Condition	Moisture Level (%)	Standard Result (%)	Remarks
1	Clay Soil	Wet	85	87	Consistent
2	Sandy Soil	Dry	25	30	Minor difference
3	Humus Soil	Damp	65	67	Consistent
4	Gravel Soil	Wet	78	80	Consistent
5	Peat Soil	Dry	40	42	Consistent

Table 2 shows that the The test results provide insights into the performance of the soil moisture detection tool. Below are the key points derived from the data:

Clay Soil: The tool recorded a moisture level of 85%, closely aligning with the standard result of 87%. This indicates the tool's high accuracy in detecting moisture in clay soil.

Sandy Soil: The tool measured a moisture level of 25%, slightly below the standard result of 30%. This minor difference suggests that while the tool performs well, adjustments may improve its sensitivity for sandy soil.

Humus Soil: The tool recorded a moisture level of 65%, very close to the standard of 67%. This consistency demonstrates the tool's reliability in detecting moisture in humus soil.

Gravel Soil: A measured moisture level of 78% compared to the standard of 80% shows that the tool is effective in detecting moisture in gravel soil, with minimal variation.

Peat Soil: The tool recorded a moisture level of 40%, aligning closely with the standard result of 42%. This consistency underscores the tool's effectiveness for peat soil as well.

In this study, the soil moisture sensor was successfully tested under various conditions to evaluate its accuracy in measuring moisture content in soil. The results obtained show that the sensor is able to detect moisture changes with a high degree of reliability. The data collected showed a strong correlation between the values measured by the sensor and the actual moisture content calculated gravimetrically. In addition, the experimental results show that the sensor can respond to moisture changes in a relatively short time, with an average response time of less than 10 seconds.

The results of this study confirm that the soil moisture sensor used can provide accurate and real-time data on soil conditions. Compared to conventional methods, this sensor provides advantages in terms of efficiency and ease of use. One of the factors contributing to the measurement accuracy is the sensitivity of the sensor, which can be adjusted via the sensitivity adjustment knob. However, there are some limitations that need to be considered, such as the possibility of interference from minerals in the soil that can affect the sensor readings.In addition, compared to previous research, the method used in this study showed improvement in terms of the sensor's robustness to varying environmental conditions. However, there are still some aspects that require further improvement, such as the sensor's resistance to extreme conditions and the effect of temperature on reading accuracy.

Future Work

Based on the results of this study, there are several aspects that can be further developed:

Testing in Different SoilsConsidering that soils have different physical and chemical characteristics, the sensor needs to be tested on different types of soil to ensure its reliability in various environmental conditions.

Integration with Io SystemsTM Developing a system that allows sensor data to be accessed wirelessly through IoT networks will increase the effectiveness in real-time soil moisture monitoring.

Sensor Durability EnhancementFurther research is needed to improve the sensor's durability against external factors such as extreme temperatures, salinity, and mechanical stress so that it can be used in various agricultural conditions.

Calibration Algorithm OptimizationDevelop a more accurate calibration method for the sensor to automatically adjust its readings to different soil conditions.

With further development, the sensor is expected to make greater contributions to precision agriculture and more efficient water resource management.

4. CONCLUSION

Based on the discussion that has been presented, it can be concluded that a soil moisture meter is a device designed to measure water content in the soil by utilizing differences in resistance or electrical conductivity. This tool has a significant role in helping farmers manage irrigation efficiently, so that soil conditions can remain optimal for plant growth. The main components used in this tool include Arduino Uno R3 as a microcontroller, a soil moisture sensor to detect water content, and an LCD screen to display measurement results. The working process of this tool involves taking moisture data by the sensor, processing data through Arduino, and presenting measurement results on the LCD screen. With its practical and efficient functions, this tool provides a simple but effective solution to support modern land management.

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