AUTOMATED PROTOTYPE ARDUINO-BASED MINI-GREENHOUSE FOR AGRICULTURAL SUSTAINABILITY

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ABSTRACT

The utilization of automated systems, controlled by the Arduino UNO microcontroller, can facilitate the efficient growth of plants in a compact greenhouse. The enclosed greenhouse structure helps in plant propagation as it optimizes the surrounding environment while it gathers sensory data. The greenhouse is structured with the corresponding sensors for specific abiotic factors mainly, the DHT11 for temperature and humidity, and The soil moisture sensor. This data from the greenhouse environment will then be processed by the system which utilizes a submersible water pump and irrigation systems, LED lights, and sensors for humidity, temperature, and moisture. The Arduino UNO controls the water resources competently as the major microcontroller, while sensors provide accurate data for managing the greenhouse environment. With automation features like the irrigation system and soil moisture sensor, water conservation, and proficiency are improved. LED light delivers reliable light sources, which promote optimal plant growth. Accurate data collection is ensured by proper sensor placement and protection. Remote monitoring and control via IoT platforms are much more practical and convenient than manually overseeing the plant environment. The Arduino UNO- Based system offers significant advantages, including decreased manual labor, cost-effectiveness, and advancements in agricultural practices to combat the damages brought by climate change to agriculture and meet the demands of a growing world population. Thus, continuous development to the prototype is necessary for the sustainability of both the agriculture and the automated greenhouse as this will further assist in the application of growing advancing technologies of the generation for agricultural development and plant care.

Keywords: Automated greenhouse, Arduino UNO, programming, automation, prototype, sensors, agriculture, sustainability

INTRODUCTION

Climate change is irreversible. The domestication of plants by mankind revolutionized agriculture by allowing desired plant propagation and protecting them from abiotic and biotic stress factors. This led to year-round production, integrated crop production, and better control over pests and diseases. A greenhouse is a covered building that creates a microclimate necessary for plant growth (Iosr et al.,2015). It provides the ideal environment for plant development and supports plants in a kind and caring manner. A greenhouse aids in stabilizing the growing conditions by insulating the surroundings from the outside temperature and safeguarding the plants from the extreme cold (Soni, 2022).

Although it provides the ideal habitat for plants, it still requires human attention to maintain optimal conditions in the house, such as humidity, temperature, and moisture. (Roldán et al.,2018) People can cultivate plants more easily when they use an automated greenhouse. When they are not at home, it is easier to keep an eye on things. Automation is a subfield of engineering that combines information technology that commands-and-control systems to boost energy efficiency and improve manufacturing processes, worker safety, product damage reduction, and increased production as well as quality. Automation is the interaction of, facilitating coordination and management of operating systems. (Bhujel et al.,2020).

Automation in the greenhouse is a method by which a farmer can automatically monitor and control the greenhouse environment from any location around the world at any time (Jiabul et al.,2020). However, research reveals that existing automation options often fall short of the expected decrease in workload, although automation is still the most common strategy for system design. It will run upon unforeseen issues, malfunctions, and failures that will damage the system itself.

With the help of Arduino UNO, this can help counter this issue. This system uses interface boards that provide a low-cost, easy-to-use technology to create microcontroller-based projects (Saha et al.,2017) . With little electronics, you can make your Arduino do all sorts of things, from controlling lights in an art installation to managing the power on a solar energy system. Its basic concept can help with operating the mechanical system needed for an automated mini-greenhouse to run. This study intends to use the Arduino UNO to help run and control the mechanical systems required for the mini-greenhouse to run automatically without an excessive amount of physical labor.

This study aims to reduce the need for manual labor by utilizing automated technologies for more effective and efficient plant growth. This will be controlled by a computer; an Arduino UNO will be used for a more practical method of managing the systems operating inside the miniature greenhouse. The study's goal is to create an automated greenhouse that is portable and accessible to farmers all over the world. This also provides a more cost-effective method of constructing the project without requiring a large investment, as well as planning to gather information for research purposes and to be used by future researchers in the field to increase agricultural productivity.

This research study, “Promoting Sustainability in Agriculture: Launching an Automated Arduino-Based Mini-Greenhouse Prototype” was subjected to extensive testing and utilization using automation controlled by the Arduino UNO system, as well as the capability and possible results of the outcome. In conclusion, applying technologically automated systems for agricultural use will greatly benefit farmers and agriculturists. The automated system has significantly enhanced the effectiveness and efficiency of the miniature greenhouse for plant development. The use of the Arduino UNO microcontroller as the control center of the automated systems within the greenhouse as well as the monitoring ones has shown positive results for its cost-effectiveness in the project. As technology advances, more potential capabilities will arise for the improvement of the agricultural system.

OBJECTIVES OF THE STUDY

The main objective of this study was to propose an automated mini-greenhouse in the province of Quirino. In accordance, it aimed to:

1. Construct an affordable and portable automated mini-greenhouse;
2. Program codes for humidity, temperature, soil moisture, and LCD linked to sensors; and
3. Test the functionality of the humidity, temperature, soil moisture sensors, and Liquid Crystal Display (LCD).

METHODOLOGY

This study uses a Type I Developmental Research design. Type I Developmental Research is used in the construction of models and prototypes as a basis for developing a study. Evaluation research techniques are commonly used in Type 1 studies to assess the effectiveness of products or design and development projects. Data collection methods can vary, as seen in Fischer, Savenye, and Sullivan's (2002) and Klein et al. (2000) Type 1 studies.

This study focuses only on building and developing a mini-greenhouse prototype that is automated and controlled by an Arduino UNO. This research generally concentrates on the automated systems controlled by Arduino UNO as a whole. To determine the efficiency of the length of time, sensors are monitored per given interval to determine the accuracy of the sensors. Descriptive statistics is used to analyze the input on Soil moisture, humidity and temperature.

Instruments

1. Circuit Diagram

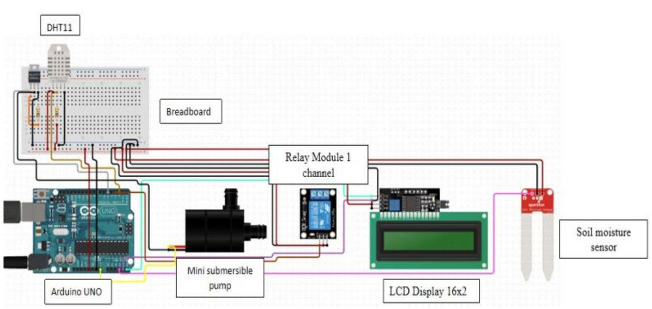

Figure 1. Greenhouse automation circuit diagram

This study used Arduino UNO as the main component of automation together with different sensors for different abiotic factors to be monitored inside the greenhouse. The Arduino UNO will act as the brain of the whole system by sending instructions to different components depending on the given data by the sensors. Soil moisture is important in agriculture and gardening. A soil moisture sensor will be used to keep track of moisture content in the soil to ensure efficient water management and water conservation. Another factor to consider are temperature and humidity, a DHT11 sensor will be used to monitor these factors to ensure better environmental control and management. A relay module will also be used and will act as a switch to activate and deactivate components based on certain conditions of the greenhouse. A relay module also makes it easier to manage and coordinate the functions of the components. Since this prototype will use a sprinkler system, a mini submersible pump will be used to provide the necessary water pressure for an effective watering operation. An LCD 16x2 is used to present real-time information for easier monitoring and management.

2. Code

```
//SOIL MOISTURE TEST

int Moisture_Level = A0;

void setup() {
  Serial.begin(9600);

}

void loop() {
  int Moisture = analogRead(Moisture_Level);
  Serial.print("Moisture: ");
  Serial.println(Moisture);
  delay(200);

}
```

Figure 2.Shows an example of soil moisture sensor code

The code shown above is written in C, which is a common programming language used for Arduino projects. The first line of code "int Moisture_Level = A0" declares an integer variable and assigns it the value of A0 which is an analog pin of the Arduino. The code "void setup()"

is executed when the Arduino board starts up and will only run once. The value 9600 is the baud rate which refers to the speed at which information is sent and received between the computer and the Arduino board. The code "void loop()" executes the code repeatedly after the setup function, this part of the code contains the main code that is to be executed repeatedly. The code "analogRead" reads the analog input values from the specified pin, which in this case is A0. The Arduino then converts the analog values into digital values. The code "Serial.print" displays the data from the soil moisture sensor to the serial monitor in real-time. The last code "delay(200)" pauses the execution of the code before starting the loop again, in this case, the delay is 200 milliseconds.

3. Early Version 3D Model

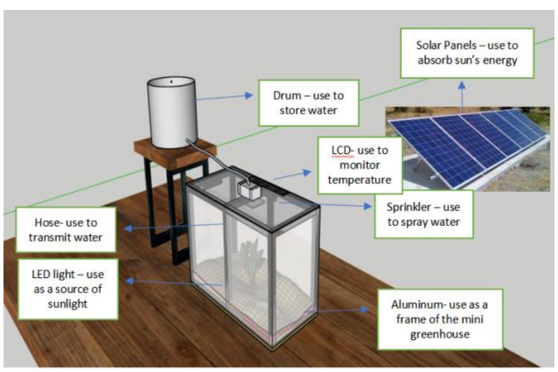

Figure 3. Early Version 3D Model of the Proposed Automated Greenhouse

The prototype used affordable materials to ensure that it is budget-friendly for local farmers. Solar panels were intended to be used to power the greenhouse as it is an efficient and reliable source of energy. A sprinkler system is used to ensure that water is dispersed throughout the greenhouse. A container is used to harvest rainwater that will run to the submersible water pump that will pump the necessary water pressure and delivered to the mini-greenhouse sprinkler system.

4. Arduino UNO

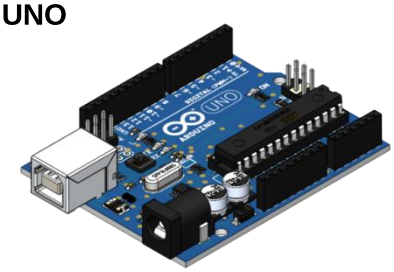

Figure 4. Shows the Arduino UNO

The researchers used Arduino UNO as a microcontroller to run all the necessary automations based from the sensory data of the greenhouse environment. C and C++ are used to program Arduino. Thus, it defaults to promote the object-oriented programming approach, that is, it endorses the use of classes, objects, members of data, and member functions. The technology in use today deals with typical C programming, which has top-to-bottom execution and public variable accessibility (Kagane and Shaji, 2021).

5. Soil Moisture Sensor

The growth of crops is influenced by soil moisture, which is exactly correlated with irrigation volume in agriculture. Therefore, one of the essential tools for determining the moisture level is a soil moisture sensor (Yu et al.,2021).

Figure 5. Shows the Soil Moisture Sensor

6. **DHT11 Humidity/Temperature Sensor**

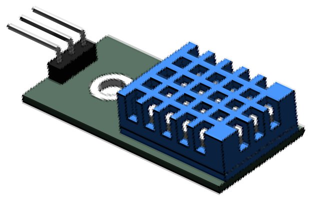

Figure 6. Shows the DHT11 Temperature and Humidity Sensor

There is a temperature and humidity complex in this module, meaning a DHT11 sensor, with a calibrated digital signal output module combines the functionality of a humidity sensor with temperature, from which a digital output signal is calibrated. DHT11 provides us with incredibly accurate humidity and temperature and guarantees long-term dependability steadiness. This humidity sensor is of the resistive type measuring element and temperature of an NTC type component for measuring using an 8-bit microcontroller built-in, which is economical, responsive, and accessible in a single row, 4-pin package (Srivastava 2018).

7. **Submersible Water Pump**

The purpose of the water pump was to artificially supply water for a certain task. It can be managed electronically by connecting a microcontroller to it. Signals can be sent to turn it on or off as needed. The procedure for pumping is the process of providing water artificially.

Figure 7.Shows the Submersible Water Pump for Irrigation

The types of water pumps that are employed are numerous. This endeavor uses a submersible water pump that is connected to a power source via a relay (Bansod, 2018).

8. **LED Lights System**

Figure 8. Shows the LED lights as a substitution for sunlight

An LED is an instance of a solid-state semiconductor diode that, within a specific voltage range, permits continuous current flow from the anode to the cathode. As an additional or primary source of lighting for agricultural production, light-emitting diodes (LED's) offer enormous potential for use both on and off Earth. These revolutionary solid-state light sources are perfect for use in plant lighting systems because of their small size, robustness, long working lifetime, wavelength specificity, relatively cold emitting surfaces, and linear photon output with electrical input current (Hannan, 2018).

RESULTS AND DISCUSSION

1. **Construction of the prototype**

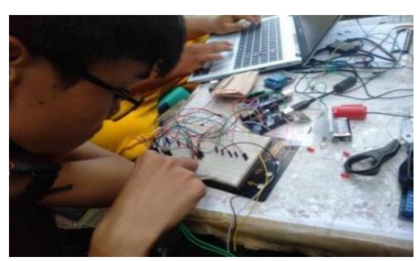

Figure 9. Shows the siring of sensors

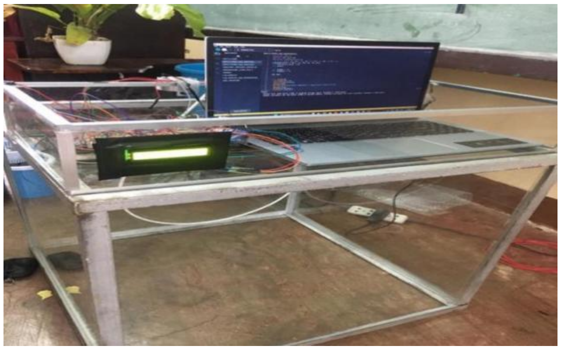

Figure 10.Shows the Structure of the Automated Mini-Greenhouse

The Arduino UNO microcontroller was utilized by the researchers to execute all automation that was required depending on sensory data collected from the greenhouse environment. An Arduino board is programmed using C and C++. As a result, by default, it supports the object-oriented programming methodology, which includes the use of classes, objects, data members, and member functions. Today's technology works with standard C programming, which offers public variable accessibility and top-to-bottom execution.

2. Codes for the sensors

2.1. Humidity and Temperature Sensor Codes

```
void loop(){
  //DHT11
  DHT.read11(dht_apin);
    lcd.setCursor(0,0);
    lcd.print("H=");
    lcd.print(DHT.humidity);
    //lcd.print("%");


    lcd.print("T=");
    lcd.print(DHT.temperature);
    lcd.print("C");

```

Figure 11.Shows the DHT11 code

The code above is responsible for the temperature and humidity readings. It obtains humidity information from a DHT11 sensor, positions the cursor on an LCD screen, and shows the humidity value along with the label "H=" and temperature value labeled as “T= C”.

2.2. Greenhouse Soil Moisture sensor

```
 int Moisture = analogRead(Moisture_Level);
 Moisture = map(Moisture,1021,220,0,100);
lcd.setCursor(0,1);
Serial.print(Moisture);
 lcd.print("Moisture:");
 lcd.print(Moisture );
 lcd.print("%");
 delay(100);
```

Figure 12.Shows the soil moisture code

The code shown is responsible for soil moisture readings. The readings from the soil moisture sensor get converted into a percentage and displayed on the LCD screen labeled as “Moisture”.

2.3. Codes for the Threshold Values

The code shown is a sample for threshold values and is responsible for the logic of the irrigation system of the mini-automated greenhouse. If the soil moisture reading is below 30, the irrigation system will start until the reading is greater than 90.

```
if(Moisture > 30 && Moisture > 90)
 { digitalWrite(ledpin, HIGH);

  }
else
  { digitalWrite(ledpin, LOW);
  }


  delay(200);

```

Figure 13.Shows a sample code for certain threshold values

3. Sensors Threshold Values

Table 1
Sensors Threshold Values

Sensor	Threshold	Indicators
Soil Moisture	(M < 30) & (M > 90)	The irrigation system starts when the reading goes below 30 and stops until the reading is 90.
Temperature	Temperature < 31 C	When the temperature reading is below 31, the LED will light up.

The following are the threshold values of the Automated-Mini Greenhouse. The threshold values are based on the optimal condition for plant growth and will automatically turn on the systems if a threshold value is reached. This ensures minimal interaction and manual monitoring of the abiotic factors.

4. Monitoring Sensors

The table shows the data on the testing of the sensors per three-minute interval with Soil moisture percentage, humidity, and temperature of the monitoring sensors.

Table 2
Monitoring Sensors per 3-minute intervals

Tests per 3-minute intervals	Soil Moisture	Humidity ($g.kg^{1}$)	Temperature
Test 1	98%	85	29 C
Test 2	96%	86	29 C
Test 3	95%	87	29 C
Test 4	92%	86	29 C
Test 5	92%	87	29 C
Mean	94.6%	86.2	29 C

From the gathered data, the gradual decrease in readings of soil moisture indicates an accurate system.the roots absorbed water nutrients from automated irrigation system, hence the soil moisture decreases overtime. The humidity fluctuates around 85-87 indicating a functional sensor due to soil moisture evaporating, and the sensor monitored it in real-time. The gathered data is aids to determine the accuracy of the sensors. The constant temperature in the 15-minute time span also indicates an operational sensor reading. It shows that the enclosed structure of the greenhouse does indeed keeps the optimal greenhouse environment as time passes.

CONCLUSIONS

The findings indicate the feasibility of employing Arduino-based automation in the mini-greenhouse prototype. Significant enhancements in plant growth were observed with the integration of sensors and controlled components, underscoring the transformative potential of this technological approach in agricultural advancement. Particularly noteworthy are the contributions to water conservation and efficient irrigation facilitated by soil moisture sensors. Additionally, the regulation of humidity and temperature proved instrumental in creating optimal growing conditions. The utilization of LED lights emerged as a cost-effective solution for lighting management. Anticipated technological strides in greenhouse farming are attributed to the versatility and efficiency of the Arduino UNO microcontroller. This pioneering strategy holds promise as a sustainable and enduring solution for agricultural challenges in the future.

RECOMMENDATIONS

Multiple ideas were implemented while theorizing the overall structure of the prototype.

This study applied a cubicle-type approach to this as a temporary solution, further research and design is needed to plan an optimal and stable structure. Additionally, Jumper cables were also experienced to be unreliable since they required minimal force to be separated from their pins, even though soldering the cables was a solution, a single-strand solid wire is much more effective.

Although it lacks a variety of factors for it to be fully operational and open for public utilization, it has the fundamental foundation covered for technological applications in agriculture.

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