INTEGRATION OF ARDUINO-BASED AUTOMATED IRRIGATION SYSTEM WITH MOISTURE DETECTOR: INTERACTIVE SMARTPHONE APPLICATION

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In Partial Fulfillment
of the Requirements for the Subject
Inquiries, Investigations, and Immersion – INVEST080

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ABSTRACT

Withered crops seen on irrigation systems has always been a major problem in the agricultural field due to loss of moisture content prior to lack of monitoring. To address the said problem, this study aims to construct a model of an automated irrigation system controlled by an interactive smartphone application with the help of Arduino programming to manipulate the water flow, rate, and timing of water application to align with soil absorption and water holding capabilities. The researchers utilized Arduino UNO R3 as the central controller unit of the system, three (3) capacitive soil moisture sensors, solenoid valve, and invented smartphone application to set up the irrigation system and applying the subsurface drip-irrigation technique. During the experimentation, the data was obtained by the information printed on the UI and performance of the system. Then, using the moisture percentage formula, the moisture values were converted into rates with respect to the calibrated threshold values. By utilizing one-way ANOVA, the result showed that there was no significant difference on the deviated values of moisture sensors. The use of Pearson Product Moment Correlation accepted the null hypothesis as there was a strong significant relationship between the distance of the user from the HC-05 Bluetooth module and the response time of the system. As a result, the researchers successfully constructed the Arduino-based irrigation system to address the problem concerning plant deaths due to lack of monitoring.

Keywords: *Arduino-based irrigation system, Smartphone application, Arduino programming, Arduino UNO R3, Capacitive soil moisture sensors, Solenoid valve, Threshold values, and HC-05 Bluetooth module*

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Chapter 1

INTRODUCTION

Background of the Study

Agriculture, which blends the imagination, skill, and creativity required to grow crops with contemporary production techniques and cutting-edge technologies, is cultivating natural resources to sustain human life and generate economic gain (Allen, 2022). Paunlagui (2020) claims that the economy of the Philippines is heavily reliant on agriculture, which employs roughly 40% of all Filipino workers and generates 20% of the GDP on average in the country. This output is primarily the result of agribusiness, which generates roughly 70% of all agricultural sectors. According to Marcelo et al. (2020), it is most commonly about plants and irrigation, wherein by manual planting and watering, farmers spend much time checking and watering their fields. This traditional process makes it hard for the farmers because it requires much effort to ensure the soil is well-moistened since dehydration can be fatal for plants – withered (Petruzzello, 2016).

As the rampant evolution of technology increases, modern farming innovations and plant science technologies arouse global competition ("What is Agriculture? Ask a Farmer," 2021). There are many approaches to maximize the capabilities of technology in the agricultural sector. Oliver et al. (2015) proposed that wireless sensor networks can identify subtle, dynamic changes in variables being monitored in an outdoor landscape. The newest agricultural methods use automated plant irrigation via an intelligent interface; it is now operated automatically based on the needs of the soil (Lorvanleuang & Zhao, 2018). Based on the project of Bisen (2018), a system uses a soil moisture sensor to detect the moisture content, at which point the water pump is turned on automatically to give water to the plant. After that, as soon as the plant has sufficient water, the water pump will automatically shut down. The Arduino Uno operates all these in association with the relay and, of course, the sensor itself since it can make the library logging system more efficient and convenient by automating workflow processes (Morallo, 2017). To supply power, a researcher must use a USB cable to connect it to a computer and an AC-to-DC adapter or battery (Agarwal, 2020).

This study aims to construct a model of an Arduino-based automated irrigation system controlled by an interactive smartphone application with the help of a moisture detector to manipulate the water flow, rate, and timing of water application to align with soil absorption and water holding capabilities. In line with the 2020 Research Agenda with the theme: "Agenda 2030 and Sustainable Development in the Age of Global Pandemic", this study will promote the innovations of technology in the agricultural industry wherein farmers will benefit the most. This study is also beneficial to the economic growth of the country, considering the project can aid in the modernization of agricultural mechanization, lowering high production costs that depend on physical labor from planting to harvesting; farmers can be more profitable and productive ("The Role of Agriculture," 2022).

Statement of the Problem

This study aims to address the lack of monitoring of the farmers with water irrigation systems in their fields, resulting in poor soil quality that affects the production and quality of crop yields. Specifically, this study aims to construct a model of an automated irrigation system controlled by an interactive smartphone application with the help of Arduino programming to manipulate the water flow, rate, and timing of water application to align with soil absorption and water holding capabilities.

Specifically, this study seeks to answer the following questions:

1. What are the levels of water concentration in order to provoke the moisture detector and give a signal to the user of the smartphone application?
2. How long will it take for the irrigation system to respond after receiving input from the user?
3. Is there a significant difference among the readings of three (3) capacitive soil moisture sensors based on their moisture percentage values?
4. Is there a significant relationship between the response time of the model and the distance of the user from the HC-05 Bluetooth SPP (Serial Port Protocol) module?

Hypothesis

Based on the previous statement of the problem, the following hypotheses are formulated:

1. There is no significant difference among the readings of three (3) capacitive soil moisture sensors based on their moisture percentage values.
2. There is no significant relationship between the response time of the model and the distance of the user from the HC-05 Bluetooth SPP (Serial Port Protocol) module.

Review of Related Literature

The foundation of this study is primarily based on Arduino, an open-source computer hardware and software company. According to, Banzi & Shiloh (2022), the project and user group that creates and makes use of development boards based on microcontrollers is known as the "Arduino Community." The Arduino board, the hardware component, and the Arduino IDE (Integrated Development Environment), the computer software component, make up its two main components. Arduino IDE is the standard programming approach in this set-up which uses C++ programming language, or entirely C, or mix-and-match depending on the convenience of the user (Arduino, 2022). On the other hand, there are different types of Arduino boards or hardware.

The Arduino-based system of the project is then equipped with a moisture sensor to gather data on the volumetric water content of the soil to give a signal through Bluetooth interface to the irrigation system (Mittelback et al., 2012). Based on the project of Marcelo et al. (2020), the water pump will automatically switch on once the soil moisture senses that the soil is not moist enough, run until the necessary moisture is attained, and then shut off again. It is carried out by the Arduino UNO (R3), and the power source is unimportant because it can come from any direct current voltage source. The Arduino UNO (R3), with a relay and the sensor itself, controls all of them. It can ease certain burdens and aims to make every user as comfortable as possible.

The strategic placement of moisture content is justified in the agricultural project of Amiri et al. (2022). According to the study, the efficient use of water in precision agriculture depends on determining the best location for monitoring soil water content (SWC), but the fundamental problem is the dynamic movement of water and root growth in the soil profile. While drip-tape is positioned close to the maize row, it is advised to put soil sensors, such as tensiometers and TDRs, at a depth of 10–20 cm from the soil surface and a horizontal distance of 5–20 cm from the crop.

In line with this, to maximize the capabilities of the Arduino-based irrigation system, numerous studies have shown using different controlling platforms such as SMS, IoT, and website interface. Thakare & Bhagat (2018) proposed a paper utilizing the IoT (Internet of things) platform, which gives better efficiency and is less expensive. Arduino collects the data from all the sensors and links the data with the cloud. In contrary the theory of Yasin et al. (2019), the system makes use of an Arduino mega 2560 that has been upgraded with GSM technology so that the Arduino platform may send and receive SMS to and from the mobile phones of farmers and homeowners in accordance with the amount of soil that needs watering or the user's instructions.

Morallo (2017) claims that using short-wavelength radio transmission, wireless technology enables data exchange across tiny distances, offering ease, intelligence, and controllability. The design uses the HC-05 Bluetooth SPP (Serial Port Protocol) module, which is intended to construct a transparent wireless serial connection. To remotely monitor and manage the operation of the lighting system, an Android application is downloaded to an Android smartphone. The program makes it easier to control the Arduino's working pins.

Soil is the clastic mineral or organic material found on the surface of the planet ("What Is Soil?," n.d.). Soil quality is the ability of a specific type of soil to work within the boundaries of a natural or managed ecosystem to support plant and animal productivity. United States Department of Agriculture (2020) stated that successful and sustainable agriculture is built on healthy soil. However, there are many factors to consider before presuming that the soil has good quality. In the study of Shukla et al. (2016), soil properties were categorized into five factors: water transmission, soil aeration, soil pore connection, soil texture, and moisture status.

Water is one of the most important natural resources and is vital for life. On the other hand, the water absorption capacity of the soil is sometimes referred to as the water retaining capacity of the soil (Vedantu, 2022). The study of Li (2015) proposed that soil-water relation is one of the most important factors to consider when determining whether or not remediated soils are suitable for plant growth. Water serves a variety of purposes in plants, including maintaining cell turgidity for structure and growth, transporting nutrients and organic compounds throughout the plant, making up a large portion of the living protoplasm in cells, acting as a starting point for a variety of chemical reactions, including photosynthesis, and protecting the plant from extreme temperature changes through transpiration ("Functions of Water in Plants," n.d.). Furthermore, soil water deficit hinders the ability of plant roots to absorb sufficient amounts of water and nutrients for various metabolic processes (Ahmad & Anjum, 2020).

The Centers for Disease Control and Prevention (2016) claims that irrigation is applying water to the soil in a controlled manner using various mechanical devices such as sprays, pumps, and tubes. Irrigation is common in regions with erratic rainfall or is forecast to experience dry periods or drought. Various kinds of irrigation systems deliver water in an even distribution across the whole field. In line with this, water flow plays a vital role in irrigation systems because of its impact on the continuous supply of water needed by the soil and crops (Mishra et al., 2018). Girma and Jimal (2015) claim that measurements of flow rate aid in confirming the effectiveness of the irrigation system. On the other hand, the slope of a soil absorption area should be between 2 and 15 percent in ideal conditions. A slope of between 15 and 30 percent in certain regions is considered provisionally acceptable ("Onsite Installer," 2017).

Theoretical Framework

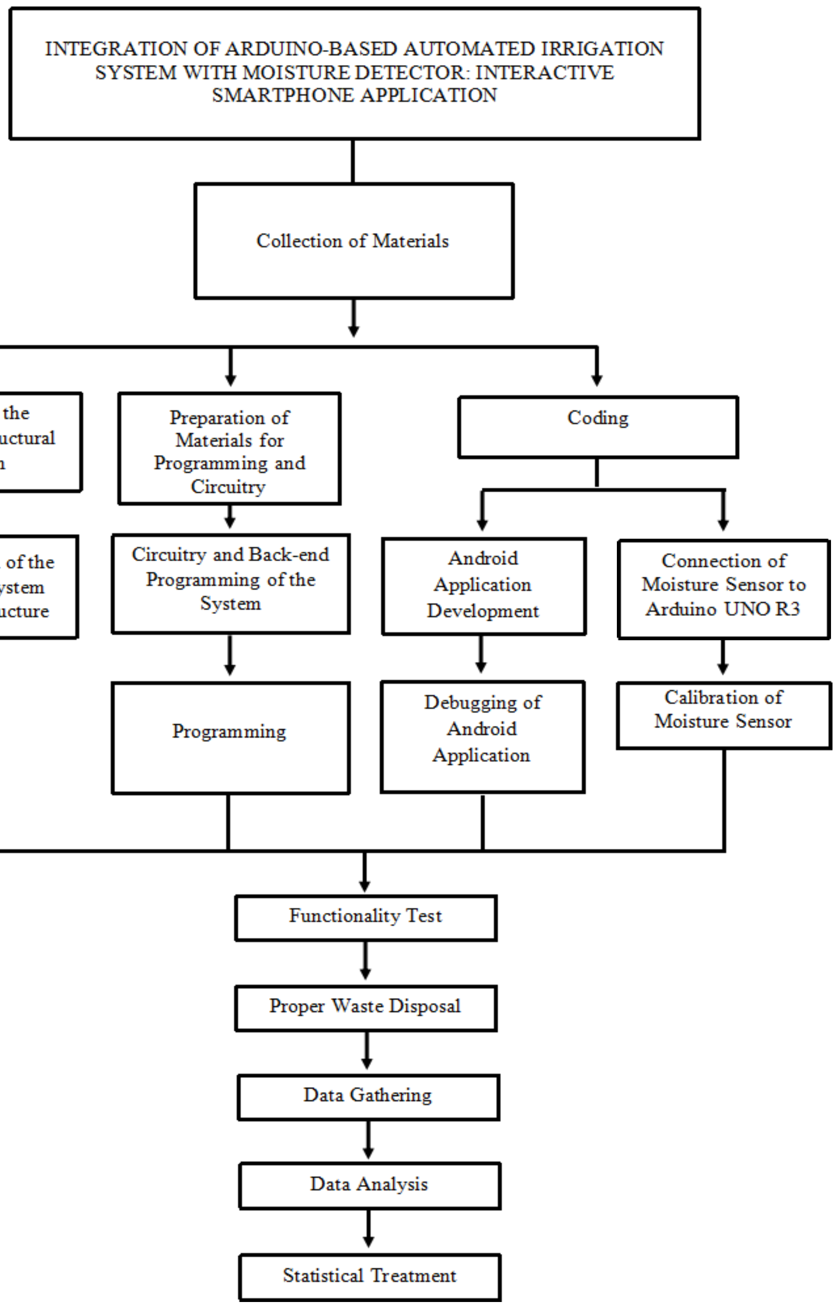
This research was based on the study of Marcelo et al. (2020), wherein it stated that "the solenoid valve will automatically switch on once the soil moisture senses that the soil is not moist enough, run until the necessary moisture is attained, and then shut off again." When inserted into the soil, the sensing unit's Sensor 1 and Sensor 2 electrode probes provided an analogue voltage proportional to the soil's moisture content. The voltage of the electrodes delivered the difference in voltage between them, which is correlated with the soil conductivity. The underlying idea is straightforward: the soil's conductivity directly relates to its moisture content. The output of the sensing unit, which is compared with the reference voltage obtained from a capacitive soil moisture sensor that has been properly calibrated (R2) and corresponds to the soil moisture threshold value, is the differential voltage between the electrodes. The water was carried out by the Arduino Uno (R3) to the solid state relay and a capacitive soil moisture sensor that controls all of them. This can improve the efficiency of the hardware and make it user-friendly.

Conceptual Framework

This study primarily focused on constructing an automated Arduino-based irrigation system with a moisture sensor using a developed android application as a platform. This study was conducted to control and manipulate the water flow; rate, and timing of water application to align with soil absorption and water-holding capabilities. This research also tackled programming and coding the devices was used in the system: (1) Arduino IDE, (2) Calibration of Moisture Sensor, and (3) Android Application. The researchers utilized C++ programming language to code the Arduino IDE and the Moisture Sensor to establish a calibrated threshold value. On the other hand, this research study used MIT App Inventor as a tool to develop the researcher's Android application.

Schematic Diagram

Figure 1. Schematic Diagram of the Methodology



Scope and Limitations of the Study

The study will revolve around the creation of an Arduino-based irrigation system. The model consists of Arduino components, electronic parts, and an HC05 Bluetooth Module, which will enable the model to be controlled by the user. In addition, the system will be incorporated with a smartphone app, which will enable the user to send and receive data and to power the system. Furthermore, the app was developed through MIT App Inventor, a block-based Programming Environment. The exchange and transfer of data will be facilitated by the UART (Universal Asynchronous Receiver – Transmitter) Connection between the HC05 Module and the smartphone app. The user can either manually power or automate the system.

The study implemented subsurface drip irrigation technology, a type of irrigation system wherein water is supplied beneath the soil to prevent water loss due to environmental factors such as drought and harsh conditions. To achieve a garden-like setup, the researchers constructed a plant box whose dimensions are: eighty cm (0.8m) in length, sixty cm (0.6 m) in width, and 20 cm (0.2 m) in height. Three (3) capacitive soil moisture sensors were distributed evenly across the plant box in order to read the moisture level equally. The researchers designed the water hose in an S-pattern to ensure that the water was distributed evenly across the plant box. In addition, the loamy soil was used as the researcher's-controlled variable. The researcher's construction of the model and data-gathering process were accomplished within a span of one (1) week at the researcher's residence.

The time it took to construct the system was affected due to the limited knowledge of the researchers in the field of electronics and programming. The lack of knowledge causes numerous errors in coding the algorithm of the system and the smartphone application. Furthermore, due to Google's latest security updates on Bluetooth, the researchers utilized an Android 5.1 cellphone to host the developed application. The change in security features caused errors in the Bluetooth connection between phones operating on Android 11 above and the application.

In addition, the researchers will only focus on the interaction between the soil and the Arduino - based system in a garden simulation. The use of actual plants during the simulation is beyond the scope of the study.

Significance of the Study

This study is of considerable value to Household Gardeners, Engineering, IT, and Agricultural Learners, and Future Researchers.

Household Gardeners. This study suggests the use of an Arduino-based automated irrigation system with a capacitive soil moisture detector: an interactive smartphone application that can provide them with efficiency in taking care of their plants and crops in a garden setting. The system extracts the physical interaction between the gardener and the garden, thus, providing an excellent degree of convenience.

Learners in the Engineering and IT Field. For engineering and IT students learning programming and coding different systems, this study would serve as source codes for their algorithm. Students would also analyze and plan for any potential modifications or alternatives for the betterment of the project.

Agricultural field. This project can help the agricultural sector to innovate various technological approaches for farmers to their plants and crops, especially in fields that suffer from withered plants due to lack of soil moisture. Lack of monitoring in the irrigation field is a major problem in agricultural perspective. Therefore, this project is highly beneficial for farmers who wish to address the said problem.

Future Researchers. As data from September 2022 to May 2023 will be found in the study, this will help future researchers who will perform a study aligned with making an Arduino-based automated irrigation system with a moisture detector: an interactive smartphone application. Researchers who intend to examine this work further will benefit from this study.

Definition of Terms

The following technical terms are defined conceptually and operationally to aid clear comprehension of the study:

Arduino. Arduino is a company that produces hardware and software components of a microcontroller and microcontroller kits used for programmed devices.

(a) **UNO R3 Arduino (hardware).** Conceptually, a detachable, dual-inline-package (DIP) ATmega328 AVR microcontroller is the foundation of the Arduino Uno R3 microcontroller board. It may be programmed using the user-friendly Arduino computer program (Balboa, 2021). Operationally, the UNO R3 Arduino acts as the heart of the system. It is where all the components, input and output, were attached for the system to be able to operate.

(b) **Arduino IDE (software).** Conceptually, a toolbar with buttons for typical functions, a text editor for writing code, a message area, a text console, and a number of menus. In order to upload programs and communicate with them, it connects to the Arduino hardware (Arduino, 2022). Operationally, the Arduino IDE acts as the brain of the system. It is an environment where the code is stored in order for the system to program, code, debug, analyze and process the syntax in order for the system to operate.

Algorithms. Conceptually, this is the programmed instruction set of the system that controls the water distribution based on the signals from the sensors. Operationally, it is a set of instructions meant to perform a specific task. Often, they are created as functions that are called on by larger programs.

Capacitive Soil Moisture Sensor. Conceptually, A fork-shaped programmable device or variable that measures the volumetric content of water within the soil. It gives input through jumper wires connected to the Arduino UNO R3. Operationally, it is a sensor that is wired to an irrigation system controller that checks the active root zone's soil moisture content prior to each planned irrigation event and skips the cycle if the moisture level is higher or lower than the calibrated threshold values.

Breadboard. Conceptually, a breadboard is a board for circuit prototyping or construction. It enables you to build circuits without soldering by allowing you to arrange parts and connections on the board (Crowell, 2019). Operationally, it is essentially the equipment for connecting the jumper wires from the breadboard to the Universal PCB or Arduino UNO R3 which makes it simpler and quicker to connect circuit design experiments.

Universal PCB. Conceptually, a circuit board used throughout the design phase to test theories and confirm system concepts. (Jocson, 2023). Operationally, it is the used the same as the bread board but the difference was the wirings were needed to be soldered unto the Universal PCB in order for the wirings to bee more secured and it would be stable.

HC-05 Bluetooth Module. Conceptually, a hardware component is used to communicate with the microcontroller (Arduino UNO R3) and perform outputs wirelessly with Bluetooth functionality connected to a device. Operationally, it is a technology that serves as an interface to help the Android phone and the Arduino UNO R3 to communicate wirelessly using Bluetooth Low energy. It has a built-in protocol called Universal Asynchronous Receiver- Transmitter (UART) which makes communication between the components possible.

MIT App Inventor. Conceptually, it is an integrated development environment for web applications that was first made available by Google and is currently maintained by the

Massachusetts Institute of Technology. Operationally, is was used by the researchers to develop their own app that would be connected to the HC-05 Bluetooth module and to the Arduino Uno R3 with the use of UART in order for the user to control the system.

IN4007 Diode. Conceptually, a diode is a component that only permits current to flow in one direction. An electric field that is already present helps to accomplish this (James, 2020). Operationally, a small resistor-like hardware which has a grey scale on the other side symbolizes negative polar, is attached to the solenoid valve to prevent backflow of the current that could potentially burn and destroy other components in the system.

Solenoid Valve. Conceptually, a valve is operated electromechanically. The properties of the electric current used, the intensity of the magnetic field produced, the method used to control the flow of fluid, and the kind and qualities of the fluid are all different between solenoid valves. Operationally, it is used to control the opening or closing of the valve thus, controlling the flow of the water

Chapter 2

METHODOLOGY

Research Design

Quantitative research is a type of research that is best suitable to conduct this study in answering the fundamental questions and gathering and analyzing numerical data. Quantitative methods place emphasis on precise measurements and the statistical, mathematical, or numerical analysis of data gathered through surveys, polls, and other types of research (Babbie, 2022). Specifically, true experimental research was utilized in this study to manipulate and control the variables. This particular type of experimental research is frequently regarded as the most accurate study because it helps reduce any inaccuracy in the outcome since it has complete control over the process (Vetter & Sullivan, 2021).

Variables

The independent variables in this study are the Arduino IDE System, the Smartphone Application, and the Calibration of the Capacitive Soil Moisture Sensor. On the other hand, the dependent variable is the soil moisture content and the reaction time of the designed system, which the researchers aim to test and measure. The controlled variables in this study are loam soil and tap water which will be consistently used throughout the study.

Materials and Methods

In this study, the equipment that the researchers used are as follows: For constructing the Irrigation System Model, the researchers used the following components: 24L Utility Pale, plant box for soil, one-half (½) sack of loam soil, fifteen (15) meters of Copper Wire, Soldering Iron and Lead, Wire Extensions, Plywood, Hand saw, Iron nails, and Hammer. For programming and circuitry: one (1) Multi-purpose Plastic Container, one (1) Solid State Relay 3-32VDC, three (2) sets of Jumper Wires, fifteen (15) meters of Copper Wire, one (1) Power Supply 12v 1A, one (1) Solenoid Valve, three (3) Capacitive Soil Moisture Sensor, one (1) IN5819 diode. one (1) 1K Ohm Resistor, one (1) Universal PCB, one (1) UNO-R3 Arduino, one (1) Android Phone, and (1) HC-05 Bluetooth module.

Collection of Samples

For the Structure of the Irrigation System Model

The 24L utility pale, and Multi-purpose Plastic Container was purchased at Mr. DIY at Ayala Malls 3rd floor, Bacolod City, 6100 Negros Occidental. The Wire Extensions was bought at City Hardware Tangub located at Araneta St., Brgy, Tangub, Bacolod City, 6100 Negros Occidental. The Hand Saw, one (1) kilo of twenty (20) mm iron nails, and two (2) meters of hose was purchased at Triumph Hardware located at Lot 522-B, Araneta Ave., Bacolod City, 6100 Negros Occidental. The meter stick, loam soil ang soldering iron was assigned to the designated research member. Lastly, the Solenoid Valve was ordered online via Shopee.ph.

For the Circuitry

Solid state relay 3-32V, Transistor BC547, 12V 1A Power Supply, Connecting/Jumping Wires, Copper wires, and 1k Ohms Resistor were ordered online on Shopee.ph. These components will be included in the Arduino UNO R3 Starter kits.

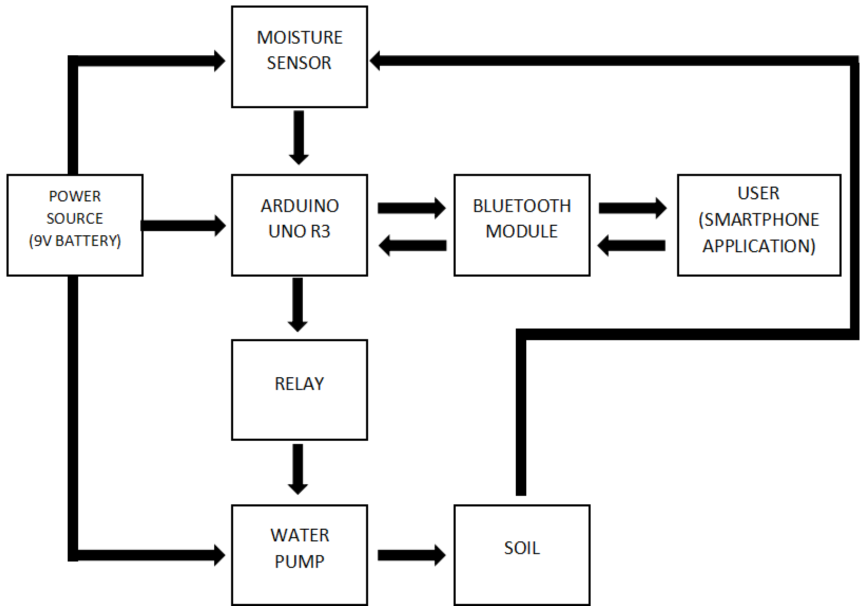
For the Electronic Components (Programming)

The HC-05 Bluetooth module, three (3) Capacitive Soil Moisture Sensors, Universal PCB, and Arduino UNO R3 kit was purchased via an online store, Shopee.ph. One (1) ampere IN5819 diode was bought at Digitone Electro Depot located at Luzuriaga Street, Purok Paghidaet, Barangay 29, Bacolod, 6100. The Universal PCB was bought at City Radio and Electric Supply located at 2697, Door 5, Capitol Shopping Center, Narra Avenue, 6100, Bacolod, 6100 Negros Occidental. The two (2) meters of Copper Wires and two (2) meters of soldering lead was bought at Bacolod Electric Supply located at Gonzaga corner, Lacson St., Bacolod City, 6100 Negros Occidental.

Proposed Structure of Smart Irrigation System Model

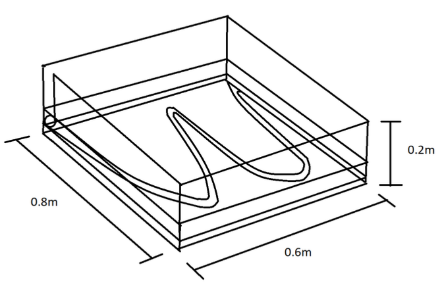
All equipment was attached to the Arduino UNO R3 using jumper wires. The three (3) capacitive soil moisture sensors were attached to the (1) Arduino UNO R3 to forward the analog data. Then, the HC-05 Bluetooth Module was put into play by connecting to the Android phone and acting as a bridge to relay the information. When the data was relayed, it was seen through the user interface wherein the user accessed the system remotely. Afterwards, once the user controlled the system, it sent the command back to the Arduino via HC-05 Bluetooth Module. Lastly, the command from the user manually or automatically turns on the solenoid valve to produce the desired amount of water in line with the soil moisture content.

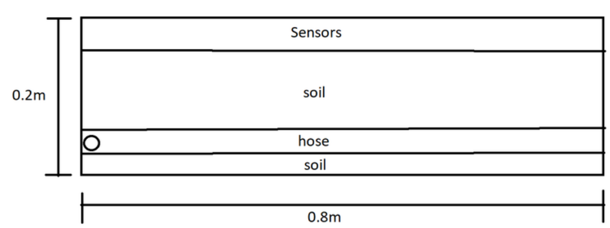
Figure 2. Schematic Diagram of the System's Proposed Structural Design



Plant Box and Hardware Storage Construction, and Water Distribution Mechanism

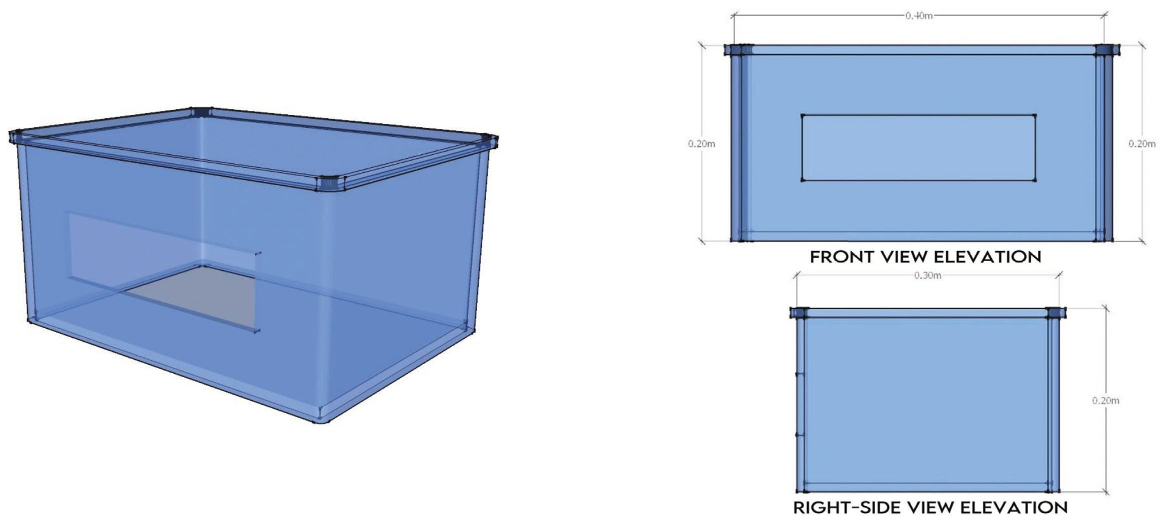
Figure 3.1. 3D Model and the construction of the plant box





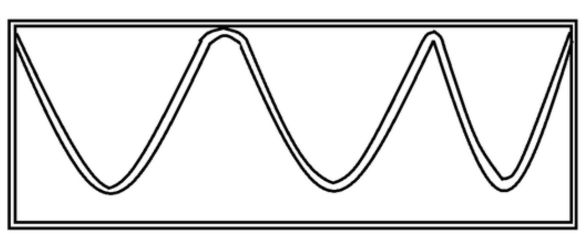
The garden-like model, a plant box, was constructed at one of the researchers' backyard. The construction was done with the use of Plywood, Iron Nails, Hand Saw, and hardware materials. The plant box had a dimension of 0.6m (width) x 0.8m (length) x 0.2m (height) respectively. For the first and bottom most layer, approximately 2 inches of loam soil was added. Next, the second layer was where the garden hose can be located. Moreover, the third layer consisted of three (3) inches of loam soil. Lastly, above the third layer was where three (3) Capacitive Soil Moisture Sensors were plugged accordingly.

Figure 3.2. Storage for Electronic Components



The storage box was where the electrical components were placed for organization and to prevent external factors that may affect them. In addition, the box was made out of plastic which provided water resistant capabilities that helped protect the electrical components during the experimentation.

Figure 3.3. Water Distribution Mechanism

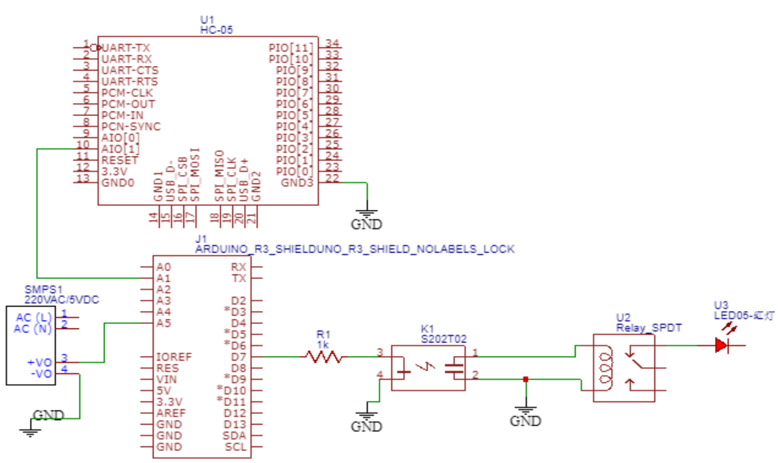


Subsurface drip irrigation system was the specific type of irrigation system that was implemented by the researchers for an automated Arduino-based irrigation system. The water supply was provided by the 24L utility pail that was connected to the hose on the 2nd layer. This irrigation technique helps prevent evaporation of water and lowers the prevalence of weeds and diseases on the surface of the soil.

Circuitry

All components were directly and indirectly attached to a power supply 12v 1A to have enough power to operate the system. The following are the designations of the jumper wire on the hardware itself:

Figure 4. Schematic Diagram of the Model's Circuitry



Note: The LED Bulb is the alternative component of the Solenoid Valve due to its unavailability in the software.

Backend Programming of the System

The researchers installed the Arduino IDE programming application to set up the codes using the C++ programming language used in the system. The set of codes used in the study of Bisen (2018) entitled "Automatic Plant Watering System Using Arduino UNO" were utilized as source code. In comparison, this study used an interactive smartphone application; therefore, there were major changes in the programming of this study as the researchers used a different set of variables, pinMode, void and loop setup, speed, and duration of the serial monitoring.

Figure 5.1. System's Flowchart

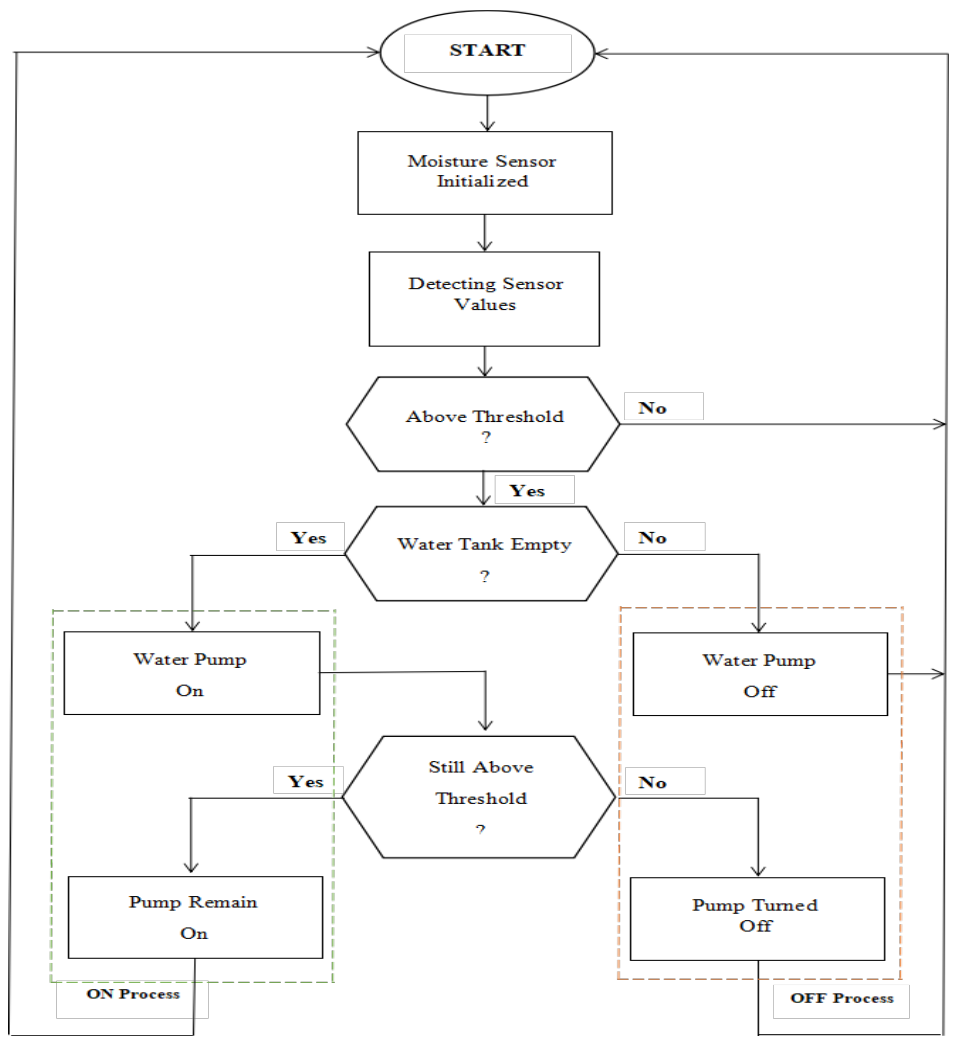


Figure 5.2. Code from the Arduino IDE

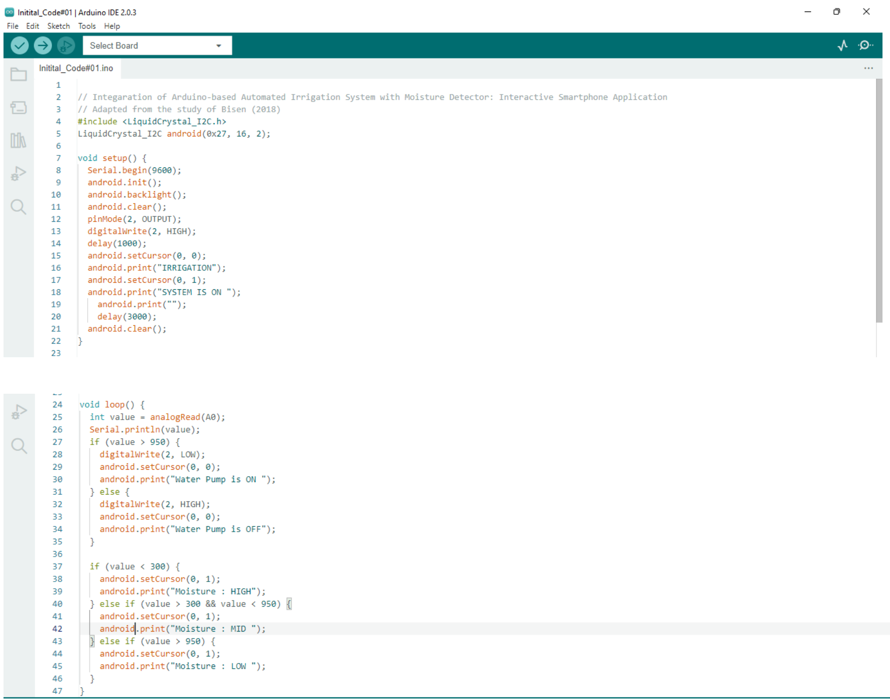
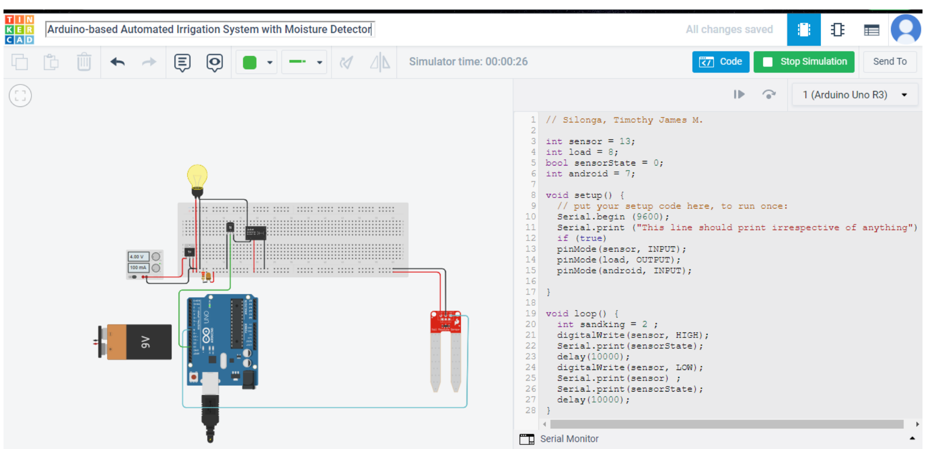


Figure 5.3. Online Simulation of the Model without Smartphone Application



Note: The LED bulb serves as the alternative replacement for the Solenoid Valve

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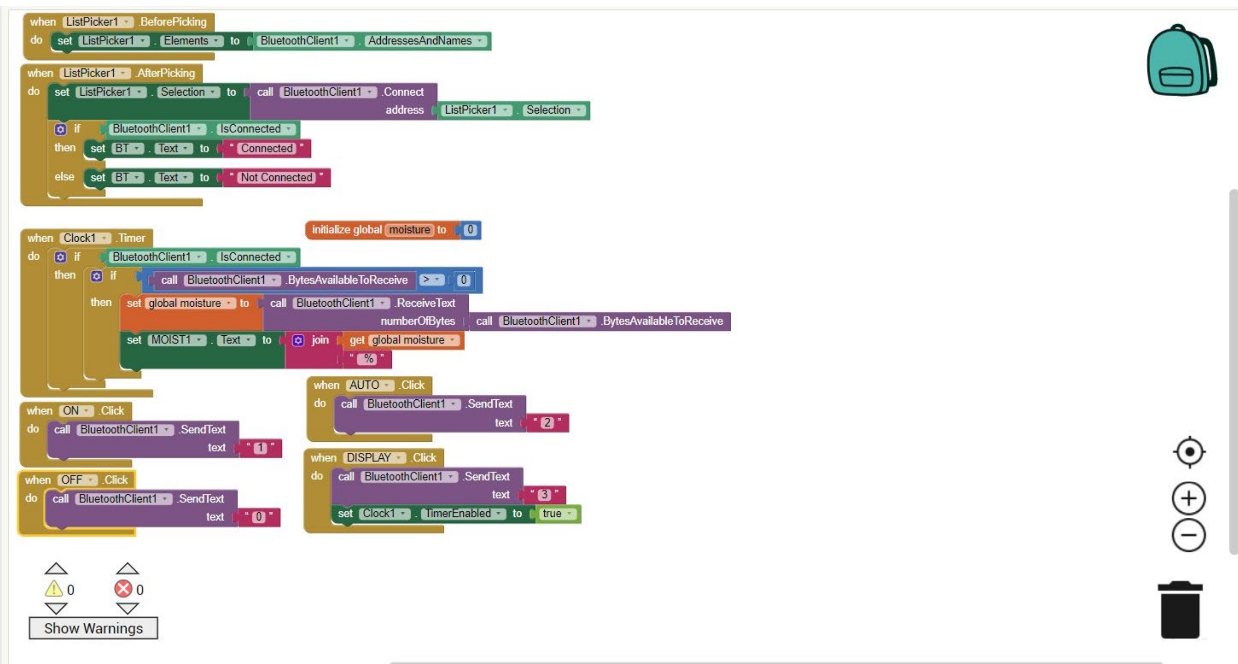
Development of Android Application as Platform

a.) Selection of Development Environment

In this study, the smartphone application was developed through MIT App Inventor, a block-type programming environment that builds fully functional apps in various Operating Systems (Android, iOS) and devices. These block-based tools accelerate the creation of complex and high-impact apps since it requires only the fundamentals of programming logic.

Figure 6.1. Block Window of the Smartphone Application in MIT App Inventor



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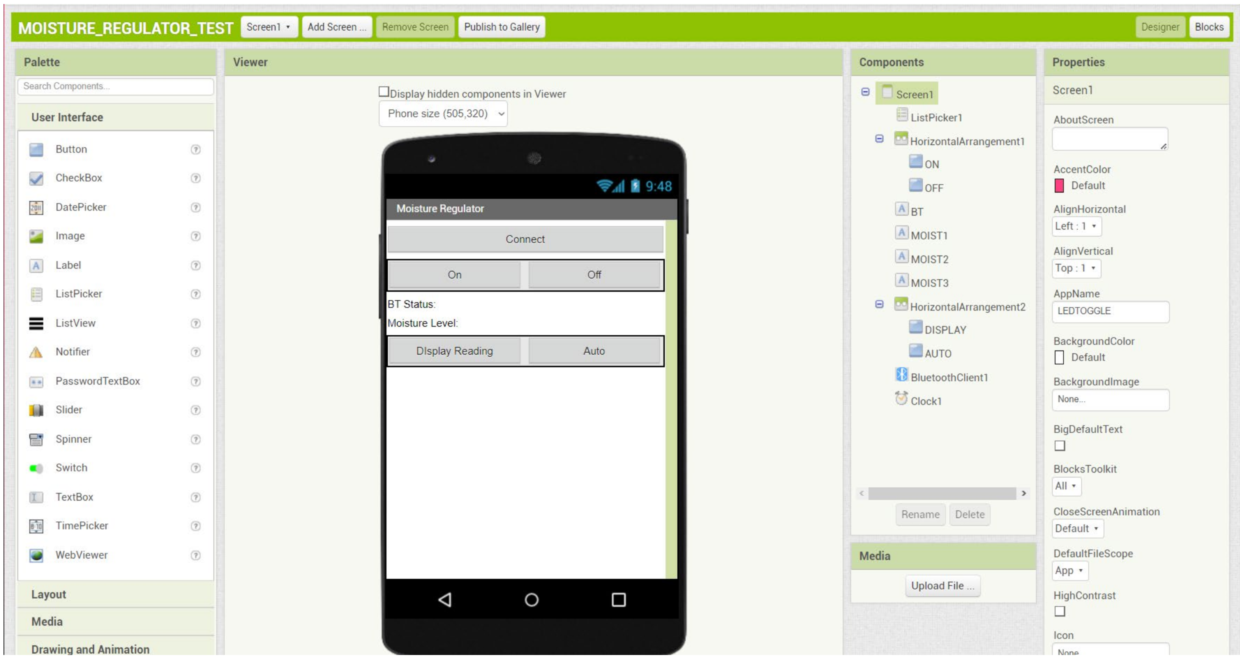
b.) Features and User Interface of the Application

Figure 6. 2. Illustration of the Android Smartphone Application UI Design



The application contains five (5) toggles: Connect, On, Off, Display Readings, and Auto. And three (3) features: Bluetooth Connection, Automatic, and Moisture Content Reading. First, the Bluetooth Connection Feature allowed the user to wirelessly connect to the smartphone and interact with the Arduino-based model through Universal Asynchronous Receiver-Transmitter (UART). Second, using a simple button, the Automatic Feature enabled the user to automate the model's water release when there is low-moisture content in the soil. Third, the Moisture Content Reading allowed the user to track the Moisture Content of the soil in real-time.

In addition, the app's User Interface (UI) contained a Bluetooth Status and Moisture Content display for the user to see the data the app was receiving.

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c.) Debugging the Application

After creating the User Interface and the backend logic of the application in the MIT Programming Environment, the user tested the app's responsiveness and functionality using MIT AI2 Companion. This smartphone application connects the MIT App Inventor's Programming Environment and the user's smartphone. Through AI2 Companion, the user was able to access the smartphone app while editing it in real time on the MIT App Inventor. The user also accessed the smartphone app through the built-in emulator, USB connection, and build function, which compressed the project into an APK File. In addition, the user was able to access and download the application by scanning QR Codes in the AI2 Companion, generated by the MIT App Inventor.

d.) Connection of Arduino-based Model to the Android Application

The Arduino-Based model utilized HC-05 Bluetooth Module (Serial Port Protocol Module) to communicate between the system and the Android Application, which allowed them to exchange information wirelessly. In addition, necessary codes in setting up the Bluetooth connection between the model and the Application were also added to the backend of the Android Application. In this setup, the user connected the app and the model through Bluetooth. The user then controlled the model through the Application and exchanged information from Arduino UNO R3.

The Arduino board and the smartphone app were able to communicate through the HC05 using a Serial Protocol called Universal Asynchronous Receiver – Transmitter (UART). In UART, data is transmitted asynchronously and identified through special bits called Start and Stop bits (Anusha, 2018). In this study, UART was the key component that the researchers used to exchange information between the smartphone app and the Arduino model. The transmission of data was done asynchronously, using two (2) lines – Tx (Transmit) and Rx (Receive). In order for the UART communication to work, both devices must have the same baud rate. According to Campbell, 2021), the Baud rate measures the speed of data transfer, expressed in bits per second (bps). The researchers utilized the 9600 baud rate for communicating with the Arduino-based model.

Calibration of Moisture Sensor

The researchers calibrated the Capacitive Soil Moisture Sensor to the desired amount of water in the soil. According to Laurenzi (2018), the general reference for soil moisture are: Fine (Clay) soil requires 60% to 80%, Medium (Loamy) soil requires 70% to 88%, and Coarse (Sandy) soil requires 80% to 90% water content. Specifically, this study utilized Medium (Loamy) soil due to its wide availability in the region (Corsiga et al., 2018). In the next section, the calibration of Moisture Sensors will be introduced.

In determining the threshold value using Arduino IDE, a set of codes were applied to set up the accurate standard inputs. The researchers first connected the Moisture Sensor's circuit board to the Arduino UNO-R3. Then, the Arduino Uno-R3 was connected to a laptop for calibration. According to SME Dehradun (2022), the following steps are the proper ways to program the Moisture Sensor: First, dry air the capacitive soil moisture sensor by leaving it on a surface and wait until the data will become stable on the Serial Monitor before the researcher will input the data as dry value. Second, pour 100mL into a cup of water and dip the capacitive moisture sensor. Likewise, once the data has become stable, input the data as wet value. Afterward, invert the values between 0 and 100. Lastly, upload the updated program to the Arduino UNO R3. Repeat the process to calibrate the three (3) Capacitive Soil Moisture Sensors.

Figure 7. Code for Moisture Sensor Calibration

Arduino Uno

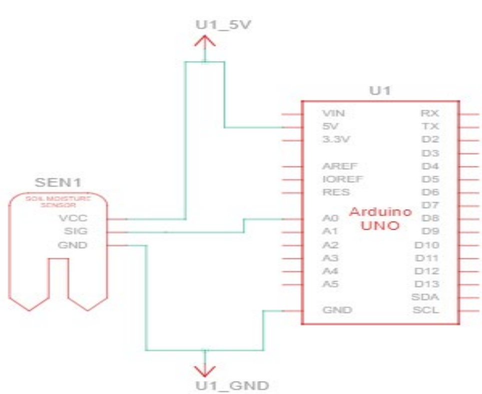
SirGeorgeCode.ino

```
  pinMode(soilMoisture, INPUT);
  Serial.begin(9600);

}

void loop() {
  moistureValue = analogRead(soilMoisture);
  moisturePercent = map(moistureValue, dryValue, wetValue, 0, 100);

  Serial.print("Moisture is: ");
  Serial.print(moistureValue);
  delay (1000);

  /*
    Adjust the lines of code below to reflect how your program will
    receive/send the moisture values
  */
  if (moisturePercent >= 100) {
    moisturePercent = 100;
    Serial.println("   100%");
  }
  else if (moisturePercent <= 0) {
    moisturePercent = 0;
    Serial.println("   0%");
  }
  else {
    Serial.print("   ");
    Serial.print(moisturePercent);
    Serial.println("%");
  }

}
```

Connection of Capacitive Soil Moisture Sensor to the Arduino UNO R3

The following pins were connected using male jumper wires:

Figure 8. Soil Probe to Arduino Board Circuitry



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Moisture Sensor		Arduino UNO R3
SIG	→	A0
VCC	→	5V
GND	→	GND

Functionality Test

(a) Smartphone App

After testing the app's effectiveness and responsiveness using MIT AI2 Companion, the researchers then tested the features and toggles of the app using a simple Bluetooth LED Toggle. To ensure that the app is fully-functioning, Bluetooth connection and all five (5) buttons were tested separately with the use of Arduino Bluetooth LED Toggle codes. Toggle buttons (On and Off) were tested by toggling them to control the power of the LED. The Display Reading function was tested by creating a code in Arduino that printed "OK" and then sent it to the smartphone app. The auto button, when clicked, allowed the LED to blink.

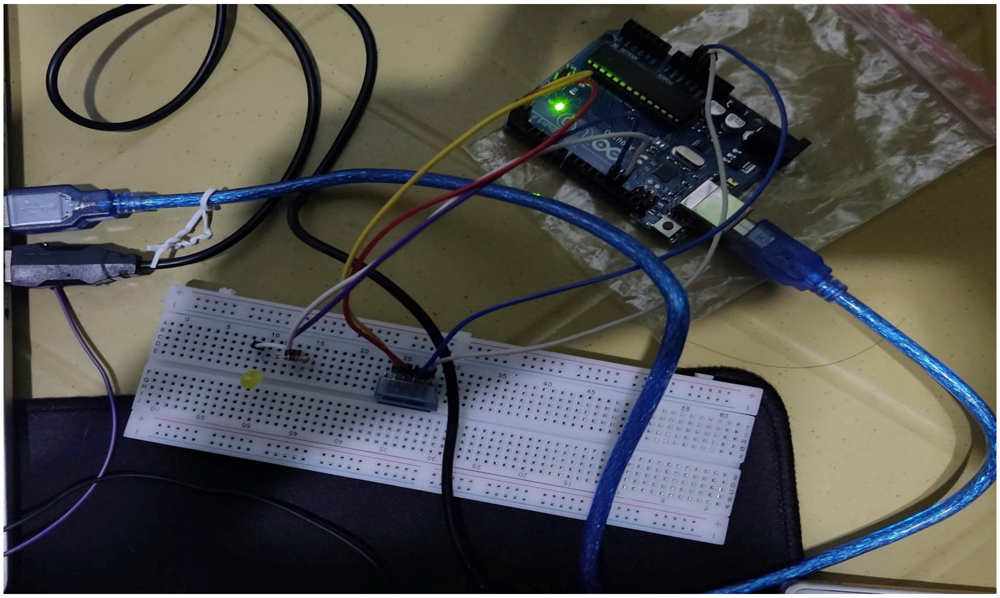
Figure 9.1. Code for the Simple Bluetooth LED toggle

```
#define LED 13
char data = 0;

void setup(){
Serial.begin(9600);
pinMode(LED, OUTPUT);
}

void loop(){
  if (Serial.available()) {
    data = Serial.read();
    Serial.print(data);
    Serial.print("\n");
  }
    if (data == '0'){
      digitalWrite(LED, LOW);
    }else if (data == '1'){
      digitalWrite(LED, HIGH);
    }else if (data == '2'){
      digitalWrite(LED, HIGH);
      delay (500);
      digitalWrite(LED, LOW);
      delay (500);
    } else if (data == '3'){
      Serial.print("OK \n");
      delay (100);
      Serial.print("OK \n");
      delay (100);
      Serial.print("OK \n");
      delay (100);
    }
    }
```

Figure 9.2 Setup for the Bluetooth LED Toggle



(b) Moisture Regulator

After connecting the Arduino-based model and the android application, the researchers compared the Arduino model to the traditional method of measuring the soil moisture content. As Kirkham (2014) claimed, a soil reader is a device consisting of a cylindrical pipe, a porous ceramic cup attached to one end, and a vacuum gauge on the other. It is used to measure soil moisture tension and provide readings for a long period.

Materials Cost

The total cost of materials for the development of the Arduino-based irrigation system is Php 3,203. Specific details on the costs of materials may be found in Appendix C (Table C.1.).

Data Gathering

Data were gathered by testing the functional efficiency of the Arduino-based irrigation system design. Three (3) Capacitive Soil Moisture Sensors were plugged un the surface of the soil that are five (5) inches apart.

To read the moisture value of the soil, the researchers calibrated each capacitive soil moisture sensor to determine their threshold values. The values obtained in the experiment will then be converted into moisture percentage using the "Moisture Percentage Formula" (Figure 11). When the device was programmed automatically, it determined the response time of the solenoid valve in producing water satisfying the moisture content of the soil needs.

In line with the model's response time, a set of parameters were considered to determine if there was a significant relationship between the distance and the time when the system reacts. The researchers observed the system's function at the following parameters: 1 meter, 5 meters, 15 meters, and 20 meters. Data were based on the average response time of the system according to its function.

Theoretically, when programmed automatically, the solenoid valve is turned on when the moisture sensor detects the soil's moisture content is higher than the threshold value. Then, it turned off once it exerted the desired amount of water. Meanwhile, the solenoid valve did not function when the moisture sensor detected the soil's moisture content was below the threshold value. Data were based on the system's function with respect to the detected value from the moisture sensor.

Proper Waste Disposal

After the experimentation, the model was deconstructed. The materials used were cleaned up, and all the unnecessary garbage was distributed according to their classification. Furthermore, the equipment, including the Arduino UNO R3, Moisture Sensor, reusable wires, resistors, and moisture probes, were placed in the researcher's hardware storage for future use. Lastly, the researchers kept all the hazardous materials in safe storage that were out of reach of children.

Data Analysis

Data were analyzed and described after observing and experimenting with the developed Arduino-based irrigation system based on its performance. The calibrated threshold value of the Moisture Sensor were used to measure the moisture percentage of the soil using the following equation:

Calculate the moisture percentage using the map function of the Arduino IDE:

Figure 10. Moisture Percentage Formula

$$\frac{(x - in\_min)(out\_max - out\_min}{(in\_max - in\_min)} + out\_min$$

x	- Moisture Value
in_min	- Calibrated Dry Value of the Moisture Sensor
in_max	- Calibrate Wet Value of the Moisture Sensor
out_max	- Highest Range of the Percentage
out_min	- Lowest Range of the Percentage

Each gathered data in the experiment were recorded in order for the researchers to analyze and interpret the information thoroughly. Data from the project's model design were then compared to test if there was significant evidence to reject/ accept the null hypotheses.

Statistical Treatment

The gathered data were handed to the researcher's statistician to provide accurate results, further using a respective statistical tool that was interpreted in the study. These types of statistical treatment were used in the study by combining descriptive statistics and inferential-parametric tests due to the considerable amount of data and underlying trends. The mean was utilized to measure the average time taken by the system to function after receiving input from the user. In addition, Pearson Product Moment Correlation was used in the study to interpret if there was a significant relationship between the response time of the Arduino-based Irrigation System and the given set of distances that potentially affected the system's functionality. Lastly, one- way Analysis of Variance (ANOVA) at 5% or 0.05 level of significance was used in the study to test if there was a significant difference among the readings of three (3) capacitive soil moisture sensors based on their moisture percentage values.

Ethical Considerations

The researchers' mission as a university and a learning center is to advance our field by churning out work that meets or exceeds the highest quality standards. The researchers treated everyone who participated in the study process with the utmost respect and emphasized research ethics. Firmly upholding the principles of integrity, honesty, openness, and involvement. Citing sources was also one factor that the researchers prioritized to fully utilize being attributive and appreciative. The study followed the third principle as each researcher recognized and adhered to the high scientific standards that come with being a competent researcher. Lastly, this study also complied with the standards of Principle 6 by acknowledging and meeting the needs of the community, engineers, and/or industry that the final project may contribute.

Chapter 3

RESULTS, DISCUSSION, AND IMPLICATIONS

This section presents and discusses the data obtained during and after the experimentation, The researchers was able to acquire and interpret the data by utilizing statistical treatments, specifically, Mean, One-way ANOVA, and Pearson Product Moment Correlation. In addition, a thorough discussion of the important differences and relationships between the substrates is provided, along with tables, line graph, and implications to elaborate on the findings in relation to the study's main goal.

Results and Discussion

Table 1. Calibrated Threshold Values of three (3) Calibrated Soil Moisture Sensors

Capacitive Soil Moisture Sensor	Dry Value	Wet Value
S1	473	190
S2	479	203
S3	465	195
Moisture Percent	0%	100%

Table 1 shows the Calibrated Threshold Values of three (3) Capacitive Soil Moisture Sensors based on the set of codes prepared by the researchers. The dry values (0%) of Sensors 1, 2, and 3 are 473, 479, and 467 respectively. On the other hand, the wet values (100%) of Sensors 1, 2, and 3 are 190, 203, and 195 respectively.

Table 2. Difference in the moisture percentage value of the three (3) Capacitive Soil Moisture Sensors based on their respective threshold values.

Treatment	M	F	df	p
Soil Moisture Sensor 1	0.51	0.004	2	0.996
	(0.40)		12	
Soil Moisture Sensor 2	0.50			
	(0.41)			
Soil Moisture Sensor 3	0.49			
	(0.42)			

Note: the difference in the means is significant when $p \leq 0.05$, means that shares a letter was not significantly different

One-way Analysis of variance was used to determine the significant difference in the reading of moisture percentage value of capacitive soil moisture sensors based on a given time interval during water distribution. Table 2 indicates that there was no significant difference in the reading of moisture percentage values among capacitive soil moisture sensors [$F(2,12) = 0.004$, $p=0.996$]. According to the data, at the first minute of the water distribution, S1 was the only sensor that was able to receive data since S1 was the nearest sensor from the water supply, solenoid valve. Moreover, the average moisture percentage of the three (3) sensors shows that it took 5 minutes to reach 50% to reach the threshold value of wet soil. After five (5) more minutes, the irrigation was fully moisturized as the moisture percentage reached its maximum wet value. Due to this, the null hypothesis was accepted since the data showed no significant difference in the readings of moisture percentage values. Despite the deviation of threshold values from the moisture sensors, the data showed that this factor did not affect the overall readings of the system.

Figure 11. Line Graph of the three (3) moisture sensors according to time and moisture percentage

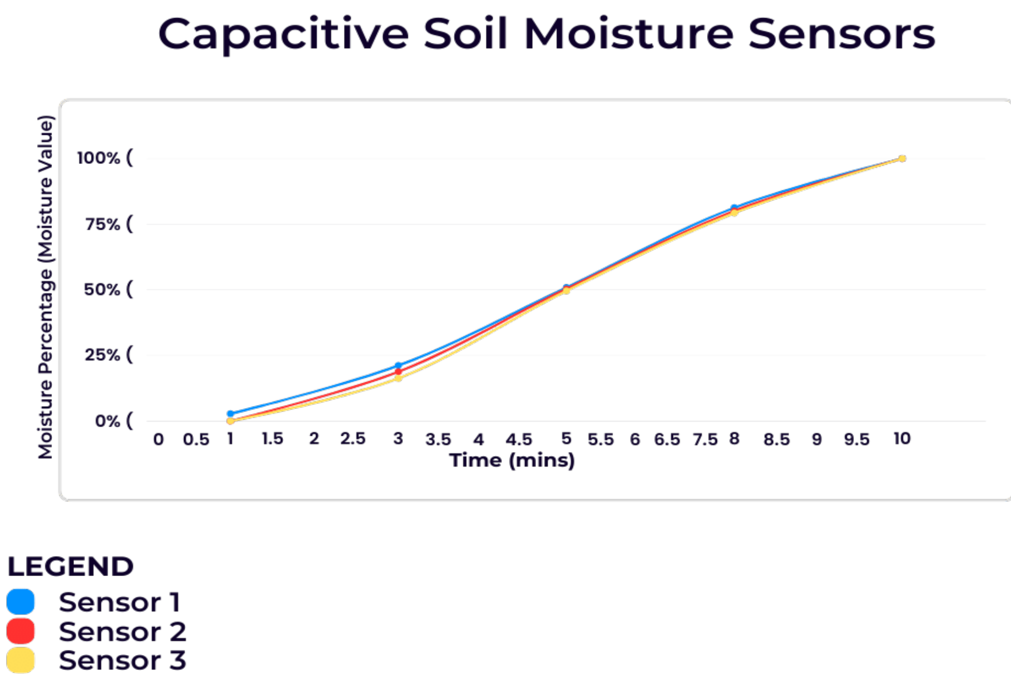


Table 3. Relationship between the response time of the model and the distance of the user from the HC-05 Bluetooth SPP (Serial Port Protocol) module

Variable			**r**	**df**	**p**
Distance	x	Response Time (sec)	0.982	2	0.018*

Pearson Product Moment Correlation was used to determine the significant relationship between the model's response time and the user's distance from the HC-05 Bluetooth SPP (Serial Port Protocol) module. Table 3 indicated that the relationship was significant [r (2) = 0.982, p = 0.018]. There was a strong positive correlation between the model's response time and the user's distance from the HC-05 Bluetooth SPP (Serial Port Protocol) module. Table 3 indicates that as the user increases its distance from the HC-05 Bluetooth module, the system's response time also increases. The project indicated a quick response (1 sec) at the least distance given parameter (1m). On the other hand, the system functioned at the greatest given parameter (20 m) at 4 seconds delay. Overall, the rapid performance of the project throughout the experiment was excellent. With this, the given data from Table 3 showed sufficient evidence to reject the null hypothesis since there was a significant relationship between the user's distance from the HC-05 Bluetooth Module and the system's response time.

Implications

Based on the study's findings, it shows that integrating the integration of the Arduino-based irrigation system with a moisture detector using an invented android application of the project holds great potential for addressing the issue of water scarcity in the irrigation field. The system, which was developed and tested by the researchers, proved to be effective in providing an automated and reliable irrigation solution that can improve crop yields and conserve water resources. In addition, the Arduino-based irrigation system can serve as a blueprint for constructing related systems in places facing similar challenges, which can be refined to a more efficient and creative approach.

According to the research results, the study has great capabilities to advance several industries, especially the agricultural sector, in terms of irrigation systems. The utilization of subsurface drip irrigation of water distribution mechanism, buried pipes under the soil, is highly efficient since the water is delivered directly to plant roots. This particular type of method reduces water loss due to evaporation or surface runoff. In addition, it gives the plant roots a constant and controlled water supply, which encourages healthy growth and increases production. The study's data indicates that the subsurface drip irrigation system is a clever sort of water distribution system to boost agricultural effectiveness and sustainability. The system has many benefits over conventional irrigation techniques, including a decrease in water waste, a reduction in soil erosion, and a promotion of plant health. Farmers can ensure a sustainable future for agriculture and assist in reducing the effects of climate change by putting these cutting-edge strategies into practice.

The data obtained from the study is highly beneficial to farmers living in rural areas where wi-fi and internet signals are weak. The usage of Bluetooth connection via the HC-05 Bluetooth module ensures that data communication is relayed quickly without the existence of internet connection. As a result, the capabilities of the system can offer a significant degree of convenience to address the cliche problem of the farmers in the irrigation areas.

By utilizing the most recent innovations, the researchers were able to integrate technical breakthrough invention of smartphone application, as fully as possible. Overall, the system can assist in finding solutions to issues facing modern society and can benefit the agricultural industry.

Chapter 4

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study aims to construct a model of an automated irrigation system controlled by an interactive smartphone application with the help of Arduino programming to manipulate the water flow, rate, and timing of water application to align with soil absorption and water holding capabilities. The innovation of advanced technology in this study resulted in much better solutions to the problem of poor soil quality that affects the production and quality of crop yields due to a lack of monitoring. In line with this, the researchers constructed an Arduino-based irrigation system, specifically utilizing sub-surface drip irrigation implemented on a plant box set-up.

After conducting the experiment and interpreting the data gathered, the researchers found the capacitive soil moisture sensors accurate enough to determine the moisture content in the soil. Using Pearson Product Moment Correlation, the results yielded [$r(2) = 0.982$, $p = 0.018$]. Table 3 indicated strong evidence to reject the null hypothesis since the results showed that there was a significant relationship between the distance of the user from the HC-05 Bluetooth module. The findings of the study showed that the integrated Arduino-based irrigation system of this study is highly efficient and very responsive. The use of technological advancements that enhanced the capabilities of the researchers in inventing a smartphone application served as a major contribution to creating quality performance and approach to address the problem. In a realistic scenario, regardless of the distance of the smartphone application user from the HC-05 Bluetooth module, the system can still operate efficiently when the user interacts by sending commands. Furthermore, the distance of the user of the smartphone application from the HC-05 Bluetooth module has a directly proportional relationship, wherein as the distance increases, the response time also increases.

The use of codes and algorithms in the Arduino IDE greatly contributed to determining the threshold values of each capacitive soil moisture sensor. Using ANOVA at 5% or 0.05 level of significance that yielded [$F(2,12) = 0.004$, $p=0.996$], showed that there was no significant difference among the readings of three (3) capacitive soil moisture sensors based on their moisture percentage values. Thus, the first null hypothesis is accepted. Despite the deviation of threshold values, it did not cause major problems as with the system readings regarding Table 2, which indicated no significant difference between the readings of three (3) capacitive soil moisture sensors. Therefore, the varying values recorded do not affect the overall outcome of the efficiency of the researchers' Arduino-based irrigation system.

Therefore, with these significant findings, the researchers conclude that the integrated Arduino-based automated irrigation system with moisture detectors: interactive smartphone application of this study is capable of addressing the lack of monitoring of the farmers with water irrigation systems in their fields through on-time water application to align with soil absorption and water holding capabilities.

Recommendations

The researchers recommend various innovations for the integrated system. For the programming language, there are a lot of other programming languages other than C++, such as Java, Python, HTML, and many more. Alternatively, the researchers recommend exploring other languages to be utilized in this project.

The UNO-R3 Arduino may also be programmed using an Android 4.0 or later device incorporated with a USB OTG cable for the mobile application to run on the Android OS.

For the app inventor, a more up-to-date mobile application maker is recommended by the researchers that could cater to phones that are version Android 11 or better for compatibility. Specifically, the researchers suggest using beginner-friendly apps like Kodular.

As an alternative to the generic type of diode called IN4007, future studies may also implement the use of the IN5819 diode since it has a specific function for the system as it offers a very low forward voltage drop, high current density, and fast reverse transit times compared with similarly sized p–n junction diodes. This makes the IN5819 diode a good protector against fast transient signals and spikes.

Furthermore, the use of a capacitive soil moisture sensor is an ideal option for the system to receive more reliable data from the probe to the Arduino UNO R3. However, to maximize the capabilities of future projects, the researchers recommend trying other soil sensors such as Temperature, Humidity, Soil pH meter, and Soil NPK sensor. It is also recommendable to use different types of sensors simultaneously to obtain wider results.

For the recording and storing of data, the researchers recommend implementing a database or server to be able to store and monitor data by a given time interval. In addition, interpreting the data through a linear regression as a way to introduce the average soil moisture will be more.

For the fabrication of the plant boxes, the researchers recommend increasing the dimension, allowing more moisture spaces for the sensors to be plugged. The researchers also recommend deploying plants in the garden; measure the plant growth (by height) as the dependent variable to test if the system is efficient to an actual irrigation system.

For the data gathering, the researchers recommend using a tensiometer or a soil reader to compare the performance and data of their system rather than the traditional one. Using a tensiometer or soil reader, can identify soil moisture content.

Lastly, the researchers suggest a more potent and reliable DC power source for the consolidated systems power supply to enhance the design and support the prototype's continuous monitoring.

REFERENCES

Agarwal, T. (2020, December 2). Types of Arduino Boards: Working and Their Comparison. ElProCus - Electronic Projects for Engineering Students. Retrieved October 8, 2022, from https://www.elprocus.com/different-types-of-arduino-boards/

Allen, S. (2022). The Art and Science of Agriculture. *National Geographic.* Retrieved from https://education.nationalgeographic.org/resource/agriculture

Amiri, Z., Gheysari M., Mosaddehgi R., Amiri S., Sadat M., & Tabatabaei M. (2022). *An attempt to find a suitable place for soil moisture sensor in a drip irrigation system. Information Processing in Agriculture, 9*(2), 254-265. Retrieved from https://doi.org /10.1016/j.inpa.2021.04.010.

Android Studio. (2018, October). Tech Target: Mobile Computing. Retrieved from https://www.techtarget.com/searchmobilecomputing/definition/Android-Studio

Anusha (2017, June 17). Basics of UART Communication. Electronics Hub. Retrieved March 24, 2023, from https://www.electronicshub.org/basics-uart-communication/#How_ UART_ Works

Arduino (2022, October 10). *Arduino Integrated Development Environment (IDE) v1.* Arduino Documentation. https://docs.arduino.cc/software/ide-v1/tutorials/arduino-ide-v1-basics

Babbie, E. (2022). Quantitative methods main objective. *USCS Libraries.* Retrieved October 10, 2022, from https://libguides.usc.edu/writingguide/quantitative

Balboa, M. (2021). Arduino UNO R3. Pololu Robotics and Electronics. Retrieved December 19, 2022, from https://www.pololu.com/product/2191

Banzi M. & Shiloh, M. (2022). *Getting Started with Arduino: The Open Source Electronics Prototyping Platform.* (4th ed.). Make Community, LCC.

Bisen, N. (2018). Watering System Using Arduino Uno. *Project Hub*. Retrieved from https://create.arduino.cc/projecthub/neetithakur/automatic-plant- watering-system-using-arduino-uno-8764ba

Brigth, L. (2022). *Can I program the Arduino board in C?* Arduino. Retrieved from https://suppo -rt.arduino.cc/hc/en-us/articles/360018448219-Can-I-program-the- Arduino-board-in-C-

Campbell, S. (2021, November 14). *Basics of UART Communication. Circuit Basics.* https://www.circuitbasics.com/basics-uart-communication/

Corsiga, C. A., Badayos, R., Sanchez, P., Paterno, E., & Sta. Cruz, P. (2018). Soil classification, suitability assessment, and constraints analyses of major soil series grown to sugarcane in Negros Occidental, Philippines. *Annals of Tropical Research*, *40* (1), 53–70. https://doi.org/10.32945/atr4015.2018

Crowell, G. (2019, February 2014). *What is Breadboard?* Circuit Bread. Retrieved from https://www.circuitbread.com/ee-faq/what-is-a-breadboard

Functions of Water in Plants. (n.d.). Retrieved October 9, 2022, from http://www.personal.psu.edu/faculty/a/s/asm4/turfgrass/education/turgeon/lessons/lesson05/corefiles/links/effects moist/1.html

Girma, M., & Jemal, A. (2015). Irrigation system in Israel: A review. International Journal of water resources and environmental engineering, 7(3), 29-37.

James, L. (2020, February 26). *Basic Knowledge Diode: What is a diode and what is it used for?* Power & Beyond. Retrieved from https://www.power-and-beyond.com/what-is-a-diode-and-what-is-it-used-for-a-908189/

Jocoson, M. (2023). A Guide to Universal PCB: One sided- Printed Circuit Boards. Retrieved March 24, 2023, from https://hillmancurtis.com/universal-pcb/

Kirkham, M.B. (2014). *Principles of Soil and Plant Water Relations.* (2nd ed.). Science Direct.

Laurenzi, T. (2018, September 3). *What's the Ideal Moisture Level for Soil to Grow Crops?* Delmhorst Intrument Co. Retrieved December 12, 2022, from https://www.delmhorst.com/blog/whats-the-ideal-moisture-level-for-soil-to-grow-crops

Li, X. (2015, May 1). Importance of soil-water relations in assessing the endpoint of bioremediated soils. SpringerLink. Retrieved October 9, 2022, from https://link.springer.com/article/10.1023/A:1004280626976?error=cookies_not_supported&code=cbc1f3b9-e443-48ff-b67e-a4b8b6cd099e

Lorvanleuang, S & Zhao, Y. (2018). Automatic Irrigation System Using Android. *Scientific Research, Open Access Library Journal, 5*(4), 1-7. doi: 10.4236/oalib.1104503.

Marcelo, L., Fernandez, J., Santos, E., Estrella, J., Hernando, C. & Bobis, D. (2020). *Automated Plant Irrigation with Message Alert*. *Innovatus, 3*(1). Retrieved from http://ejournals.ph/form/cite.php?id=15398

Mishra, D., Khan, A., Tiwari, R., & Upadhay, S. (2018, February). Automated irrigation system-IoT-based approach. In 2018 3rd International conference on internet of things: Smart Innovation and Usages (IoT-SIU) (pp. 1-4). IEEE.

Mittelbach. H., Lehner I., & Seneviratne I. (2012, April 2). *Comparison of four soil moisture sensor types under field conditions in Switzerland. Journal of Hydrology, 430*(4). Retrieved from https://doi.org/10.1016/j.jhydrol.2012.01.041.

Morallo, N. (2017). *Designing of Lighting Automation System Based on ArduinoBluetooth Interface using Android Smartphone as Platform*. Retrieved from https://ejournals.ph/article.php?id=12301

Oliver, R., Kranz, M. & Mayer, K. (2015). A Reactive Soil Moisture Sensor Network: Design and Field Evaluation. *International Journal of Distributed Sensor Networks. 2005, 1*(2):149-162. doi:10.1080/15501320590966422

Onsite Installer. (2017, December 8). *The ABCs of Soil Perc Testing Success.* Retrieved October 9, 2022, from https://www.onsiteinstaller.com/online_exclusives/2014/11/the_abcs_of_soil_perc_testing_success

Paunlagui, A. (2020). Women in agriculture, environment and rural production. *Bureau of Communication Services.* Retrieved October 10, 2022, from https://www.fao.org/3/ae946e/ae946e03.htm

Petruzzello, M. (2016). Why Do Plants Wilt? Retrieved October 10, 2022, from https://www.britannica.com/story/why-do-plants-wilt

Peña, Eric & Legazpi, Mary Grace. (2017). UART: *A Hardware Communication Protocol Understanding Universal Asynchronous Receiver/Transmitter. Analog Dialogue.* https://www.analog.com/en/analog-dialogue/articles/uart-a-hardware-communication-protocol.html.

Riordan, M. (2022, December 10). *Transistor | Definition & Uses*. Encyclopedia Britannica. Retrieved December 9, 2022, from https://www.britannica.com/technology/transistor

Shukla, M. K., Lal, R., & Ebinger, M. (2016, May 17). Determining soil quality indicators by factor analysis. ScienceDirect. Retrieved October 9, 2022, from https://www.sciencedirect.com/science/article/pii/S0167198705001200#:~:text=Soil%20properties%20were%20grouped%20into,(Factor%205)%20moisture%20status.

SME Dehradun. (2022, December 5). *Calibration of Soil Moisture Sensor for Plant Monitoring and Other Agriculture use* [Video]. YouTube. https://www.youtube.com/watch?v=uJAh_YCYLgc

"Soil Quality." (n.d.). Retrieved October 8, 2022, from https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/co/home/?cid=nrcs144p2_063020

Thakare, S. & Bhagat, P. (2018). *Arduino-Based Smart Irrigation Using Sensors and ESP8266 WiFi Module. Second International Conference on Intelligent Computing and Control Systems (ICICCS), 8*(3), 1-5. doi: 10.1109/ICCONS.2018.8663041.

The Role of Agriculture: Rebooting the Philippine Economy. (2022, March 23). *PearlPay*. Retrieved October 10, 2022, from https://pearlpay.com/the-role-of-agriculture-rebooting -the-philippine-economy/

Types of Agricultural Water Use. (n.d.). Retrieved October 9, 2022, from https://www.cdc.gov/healthywater/other/agricultural/types.html

United States Department of Agriculture. (2020, August 19). Soil Health Principles and Practices. Farmers.gov. Retrieved October 8, 2022, from https://www.farmers.gov/conservation/soil-health

Vedantu. (2022, April 27). Water Absorption in Soil. VEDANTU. Retrieved October 9, 2022, from https://www.vedantu.com/biology/water-absorption-in-soil

Vetter, S, & Sullivan, F. (2021, October 1). True Experimental Design - Types & How to Conduct. *Voxco*. Retrieved from https://www.voxco.com/blog/true-experimental-design/#:~:text=True%20experimental%20design%20is%20a,support%20the%20existence%20of%20relationships.

What is Agriculture? Ask a Farmer. (2021). *Real Farm Lives.* Retrieved from https://realfarmlives.ca/what-is-agriculture/

What is Soil?. (n.d.). Retrieved October 8, 2022, from https://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=nrcs142p2_054280

Yasin, H., Zeebaree, S., & Zebari, I. (2019). *Arduino Based Automatic Irrigation*

System: Monitoring and SMS Controlling. *Scientific International Conference Najaf (SICN)*, *7*(1), 109-114. doi: 10.1109/SICN47020.2019.9019370.

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APPENDICES

Appendix A: Raw Data

Table A.1. Readings of three (3) Capacitive Soil Moisture Sensors based on their respective threshold values and moisture percentage.

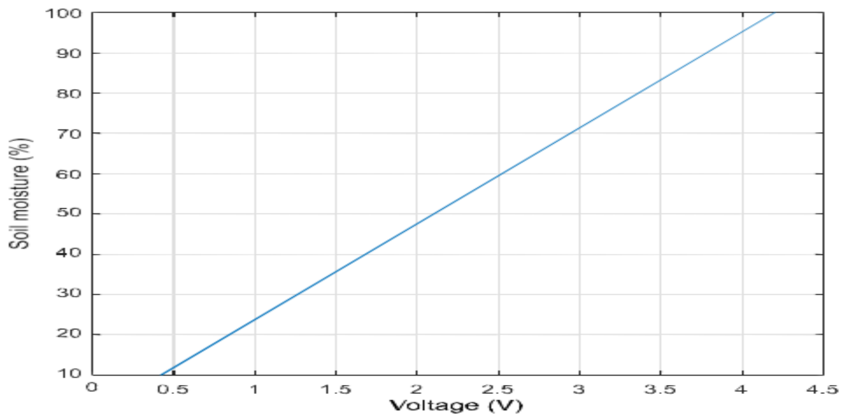
	Moisture Percentage (Moisture Value)		
Time (minutes)	S1	S2	S3
1	2.83% (473)	0% (479)	0% (465)
3	21.20% (413)	18.84% (427)	16.30 % (421)
5	50.89% (329)	50. 36% (340)	49.63 %(331)
8	81. 27 %(243)	80.07 (265)	79. 26 (251)
10	100% (190)	100% (203)	100% (195)

Table A.2. The Response Time of the Arduino- based Irrigation System based on given parameters.

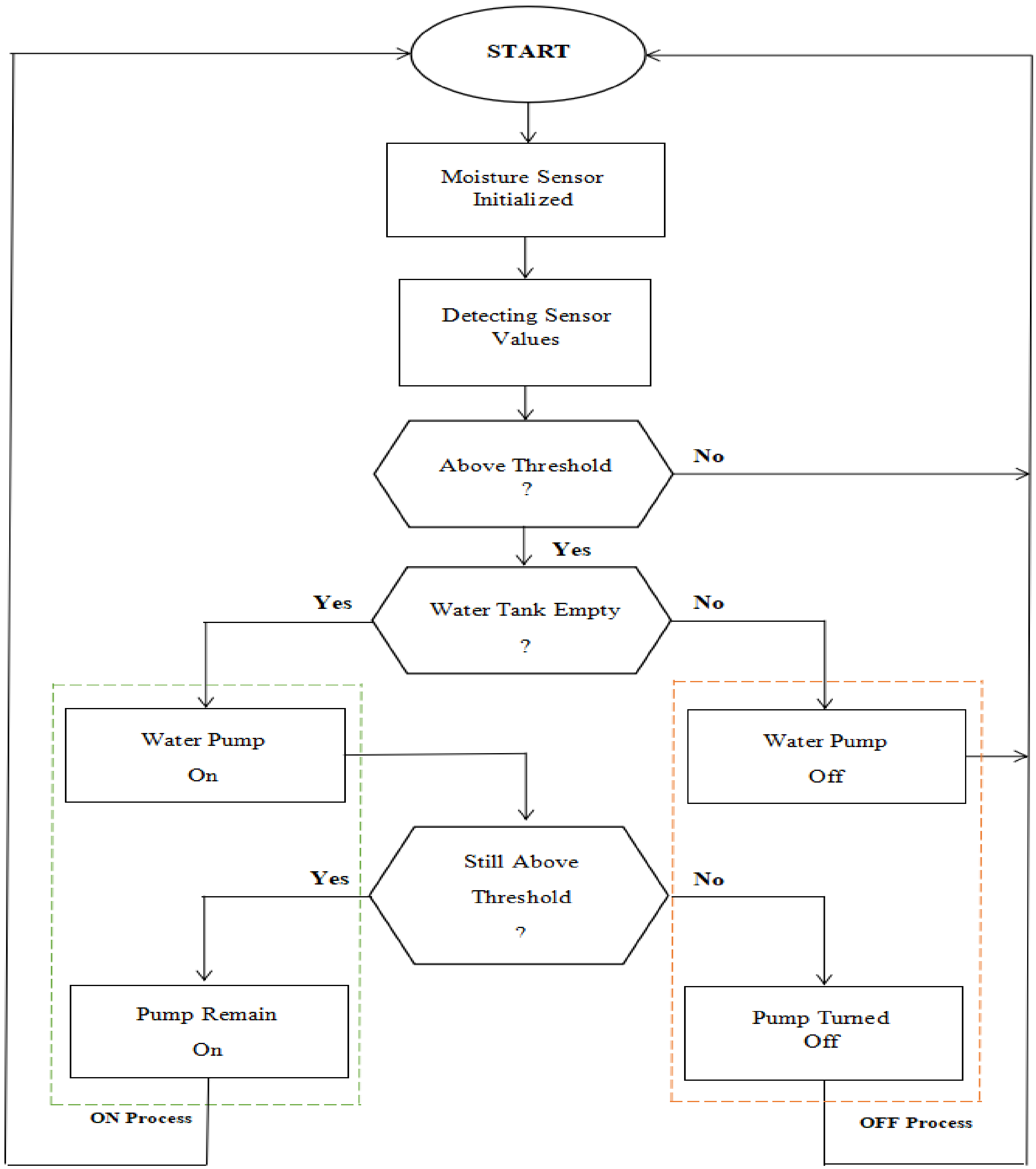
Trial	Distance(m)	Response Time (sec)
1	1	1
2	5	1
3	15	3
4	20	4

Figure A.1. Relationship of Sensor Voltage and Soil Moisture Percentage

Sensor voltage (V)	0.42	0.84	1.26	1.68	2.10	2.52	2.94	3.36	3.78	4.20
Soil moisture (%)	10	20	30	40	50	60	70	80	90	100



Appendix B: Flowchart of the Entire Prototype



Appendix C: Materials Cost

Table C.1.

Components	Cost	Quantity	Total
Arduino Uno R3 Kit • Jumper Wires • USB Cable • Resistor 1k,	410.00	1	410.00
Soil Moisture Sensors	59.00	3	177.00
HC-05 Bluetooth Module	124.00	1	124.00
Solid State Relay 3-32VDC	504.00	1	504.00
Solenoid Valve	149.00	1	149.00
Capacitive Soil Moisture Sensor	89.00	3	267.00
IN5819 diode	2.00	1	25.00
1K Ohm Resistor	52.00	1	52.00
Universal PCB	150.00	1	150.00
Loam Soil	100.00	½ Sack	100.00
Copper Wires	17.50	2 Meters	35.00
Soldering Lead	25.00	3 Meters	75.00
Tape Measure	49.00	1	49.00
Multi-purpose Plastic Container	245.00	1	245.00
Plywood	700.00	1	700.00
Iron Nails	75.00/kilo	1	75.00
Hammer	89.00	1	89.00
		TOTAL	3226.00

Table C.1 presents all the materials used in designing and fabricating the consolidated system. The columns, in order, show the materials for the system, their individual costs, the quantities used in the study, and the subtotal costs for each material.

Appendix D: Codes and Algorithms

(a) Arduino

Figures D.1.

File Edit Sketch Tools Help

Arduino Uno

Moisture-Regulator.ino

```
#define soilMoisture1 A0
#define soilMoisture2 A1
#define soilMoisture3 A2
#define solenoid 13
char data = 0; // Data receive from bluetooth

// max values from the calibration of three sensors
const int dryValue[3] = {473, 479, 465};
const int wetValue[3] = {190, 203, 195};

int moistureValue[3] = {0, 0, 0};
int moisturePercent[3] = {0, 0, 0};


void setup() {
  Serial.begin(9600);
  delay(100);
  pinMode(soilMoisture1, INPUT);
  pinMode(soilMoisture2, INPUT);
  pinMode(soilMoisture3, INPUT);
  pinMode(solenoid, OUTPUT);

}

void loop() {
  //read data from sensor, then convert to percentage
  moistureValue[0] = analogRead(soilMoisture1);
  moistureValue[1] = analogRead(soilMoisture2);
```

Arduino Uno

Moisture-Regulator.ino

```
void loop() {
  //read data from sensor, then convert to percentage
  moistureValue[0] = analogRead(soilMoisture1);
  moistureValue[1] = analogRead(soilMoisture2);
  moistureValue[2] = analogRead(soilMoisture3);
  moisturePercent[0] = map(moistureValue[0], dryValue[0], wetValue[0], 0, 100);
  moisturePercent[1] = map(moistureValue[1], dryValue[1], wetValue[1], 0, 100);
  moisturePercent[2] = map(moistureValue[2], dryValue[2], wetValue[2], 0, 100);

  if (Serial.available()){
    data = Serial.read();
    Serial.print(data);
    Serial.print("\n");
  }

  if (data == '0') {
    digitalWrite (solenoid, LOW);
  }
  else if (data == '1') {
    digitalWrite (solenoid, HIGH);
  }
  else if (data == '2') {
    // You can transfer the entire if-else condition statement into a function of type void
    automatic();
  }
  else if (data == '3') {
   Serial.println(moistureValue[0] + "%\n");
   Serial.println(moistureValue[1] + "%\n");
```


Moisture-Regulator | Arduino IDE 2.0.3
File Edit Sketch Tools Help
Arduino Uno
Moisture-Regulator.ino
automatic();
}
else if (data == '3') {
Serial.println(moistureValue[0] + "%\n");
Serial.println(moistureValue[1] + "%\n");
Serial.println(moistureValue[2] + "%\n");
}
}
void automatic() {
if ((moisturePercent[0] < 3) || (moisturePercent[1] < 3) || (moisturePercent[2] < 3)) { // 3 = dry :: 98 = wet max values (in percent)
while (true) {
// Adjusted the code so that your analogRead is being used properly
// It needs to throw its value to a variable
moistureValue[0] = analogRead(soilMoisture1);
moistureValue[1] = analogRead(soilMoisture2);
moistureValue[2] = analogRead(soilMoisture3);
// If any percentages are less than 98, keep the valve open
if ((moisturePercent[0] < 98) || (moisturePercent[1] < 98) || (moisturePercent[2] < 98)) {
digitalWrite(solenoid, HIGH);
delay(5000);
}
else {
digitalWrite(solenoid, LOW);
// Once valve is closed, this will break it out of the loop
break;
}


Moisture-Regulator | Arduino IDE 2.0.3
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Arduino Uno
Moisture-Regulator.ino
}
}
void automatic() {
if ((moisturePercent[0] < 3) || (moisturePercent[1] < 3) || (moisturePercent[2] < 3)) { // 3 = dry :: 98 = wet max values (in percent)
while (true) {
// Adjusted the code so that your analogRead is being used properly
// It needs to throw its value to a variable
moistureValue[0] = analogRead(soilMoisture1);
moistureValue[1] = analogRead(soilMoisture2);
moistureValue[2] = analogRead(soilMoisture3);
// If any percentages are less than 98, keep the valve open
if ((moisturePercent[0] < 98) || (moisturePercent[1] < 98) || (moisturePercent[2] < 98)) {
digitalWrite(solenoid, HIGH);
delay(5000);
}
else {
digitalWrite(solenoid, LOW);
// Once valve is closed, this will break it out of the loop
break;
}
}
}
else {
digitalWrite(solenoid, LOW);
}
}

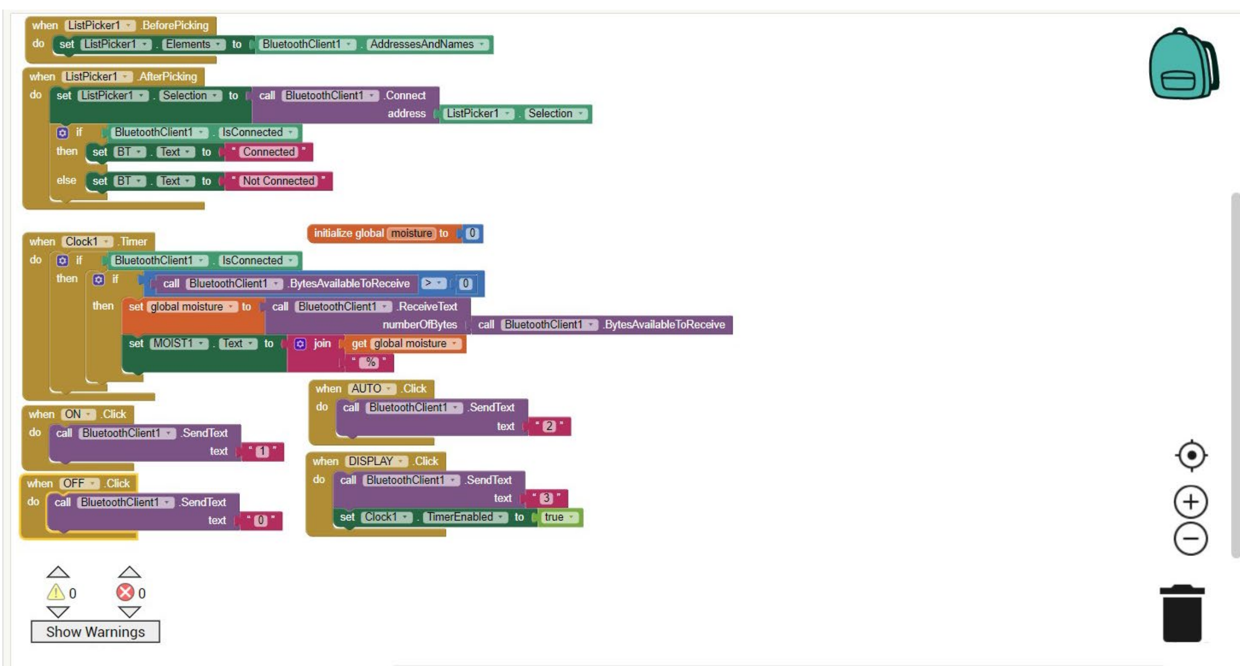
.

(b) Calibration

Figures D.2.

(c) MIT App Inventor

Figure D.3.



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Appendix E: Documentation

Figure E.1. Connection and Integration of whole circuitry

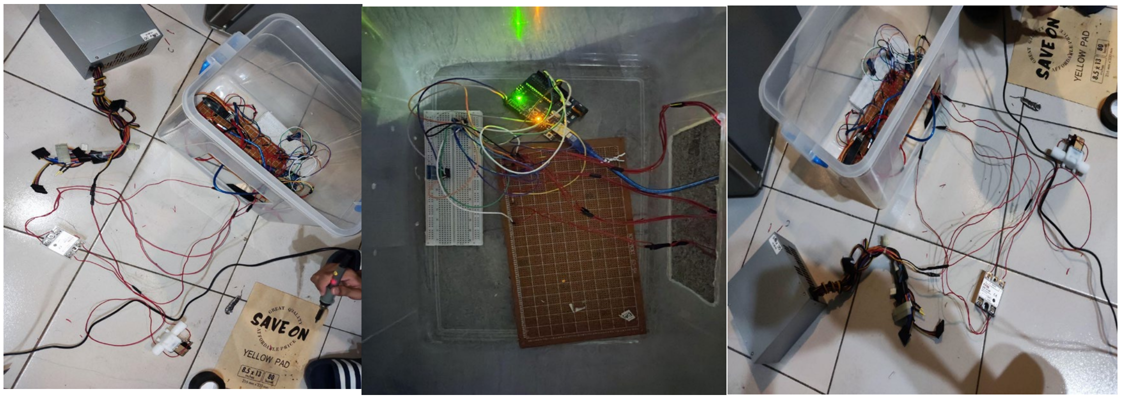

Figure E.2. Construction of Garden-like Design (plant box)

Figure E.3. Creation of Reservoir

Figure E.4. Functionality Test

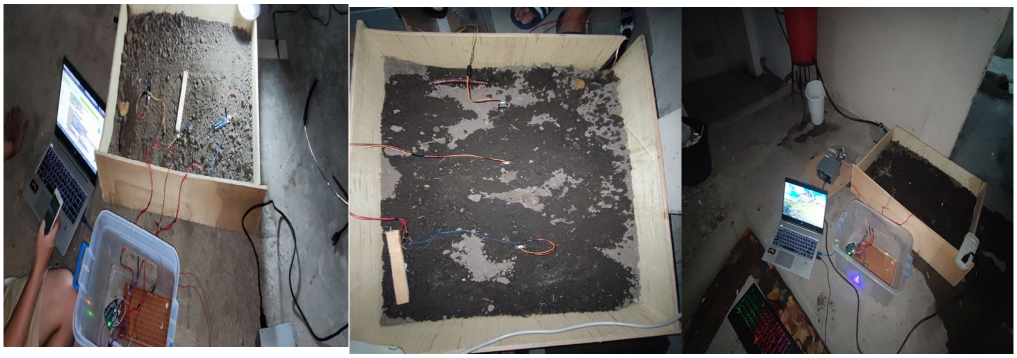

Figure E.5. Preparation of set-up (actual testing)

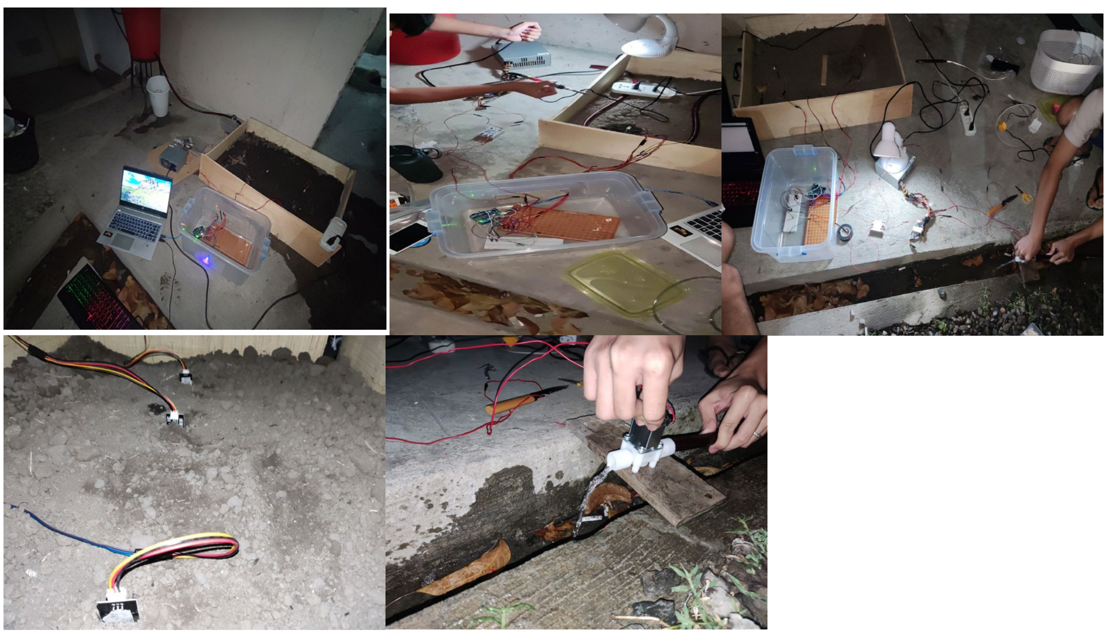

Figure E.6. Smartphone Application testing

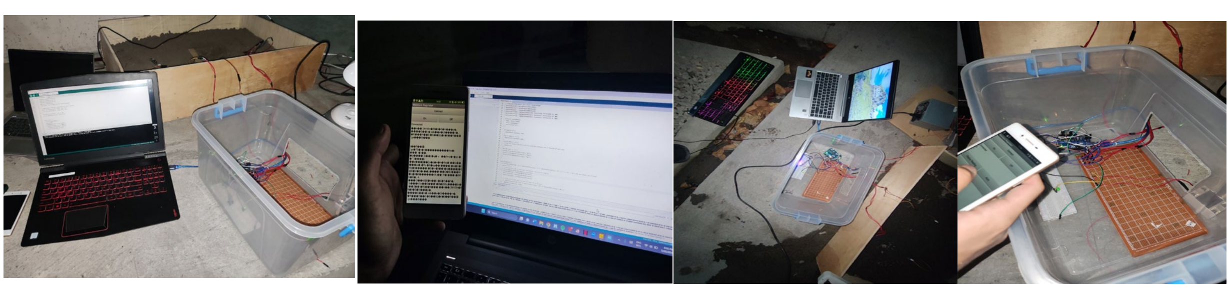

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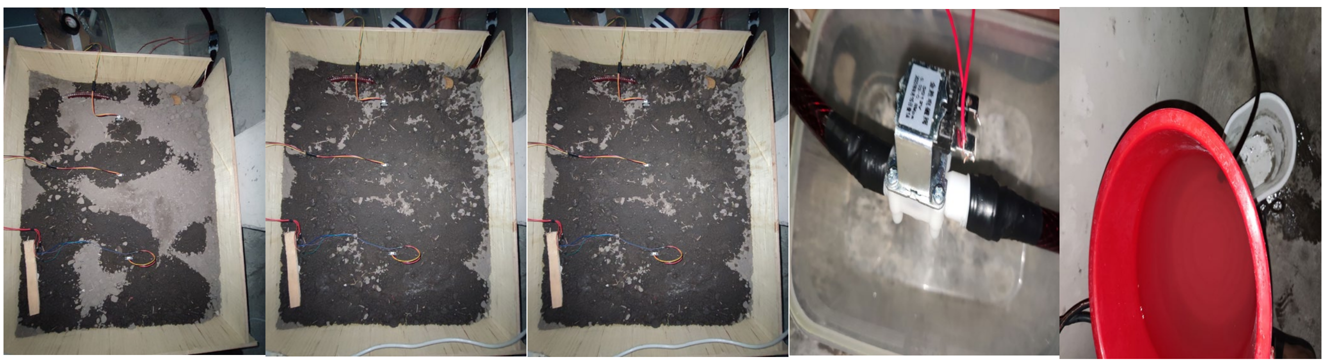
Figure E.7. Soldering of copper wires and jumper wires to the Universal PCB

Figure E.8. Water application through solenoid valve



Appendix F: Curriculum Vitae

Curriculum Vitae

Name: Timothy James M. Silonga

Address: Villa Caridad Subdivision, La Carlota City, Negros, Occidental

Email: silonga.tj@gmail.com

Date of birth: October 21, 2004

Place of birth: Riverside Hospital

Age: 17

Sex: Male

Height: 165 centimeters

Weight: 49 kilograms

Civil Status: Single

Religion: Baptist

Nationality: Filipino

Secondary education: University of Negros Occidental-Recoletos

Primary education: La Carlota South Elementary School

Curriculum Vitae

Name: Franznell Jonn T. Bedaure

Address: Brgy, Palaka, Valladolid, Negros, Occidental

Email: franzbedaure101@gmail.com

Date of birth: April 10, 2004

Place of birth: Riverside Hospital

Age: 18

Sex: Male

Height: 175 centimeters

Weight: 80 kilograms

Civil Status: Single

Religion: Baptist

Nationality: Filipino

Secondary education: University of Negros Occidental-Recoletos

Primary education: Valladolid Elementary School

Curriculum Vitae

Name: Andrei Benedict L. Eusebio

Address: Lot 20 Blk 3 Cesar Avenue, Villa Celia Subs.,

Brgy Taculing, Bacolod City

Email: andreibenedicteusebio@gmail.com

Date of birth: November 10,2004

Place of birth: Riverside Medical Center, Bacolod City

Age: 18

Sex: Male

Height: 167cm

Weight: 55kg

Civil Status: Single

Religion: Roman Catholic

Nationality: Filipino

Secondary education: University of Negros Occidental Recoletos

Primary education: University of Negros Occidental Recoletos

.

Curriculum Vitae

Name: Archie Dane Arielle M. Gemarino

Address: Lot 11, 2nd Street, FJE Village,

Brgy. Batuan, La Carlota City

Email: adagemarino@gmail.com

Date of birth: March 30, 2005

Place of birth: Doctors Hospital, Bacolod City

Age: 17

Sex: Male

Height: 177 cm

Weight: 69 kg

Civil Status: Single

Religion: Roman Catholic

Nationality: Filipino

Secondary education: Doña Hortencia Salas Benedicto National High School

Primary education: La Carlota South Elementary School II

Curriculum Vitae

Name: John Roland L. Octavio

Address: Block 9 Lot 22, DC3, Regent Pearl Homes Subdivision, Alijis, Bacolod City, Negros Occidental, 6100

Email: johnrlnd1704@gmail.com

Date of birth: June 17, 2004

Place of birth: Bacolod City

Age: 17 years old

Sex: Male

Height:174 cm

Weight: 79.9 kg

Civil Status: Single

Religion: Baptist

Nationality: Filipino

Secondary education: University of Negros Occidental - Recoletos

Primary education: Evangelical Christian Montessori School