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Research Article

Indoor Gardening with Automatic Irrigation System using Arduino Microcontroller

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ABSTRACT

Gardening is one of the simplest ways to spend time which, oftentimes, provides a means of working out during weekends, exercising creativity, and giving appreciation to the environment for individuals engaged in this activity. Anyone can do gardening as long as the basic needs of the plants are provided like water, soil, air, sunlight and proper nutrients. Provisions of these necessities are possible with the aid of an automatic irrigation system. This system primarily provides a means of monitoring the status of plants that need to be watered once it is needed. This automatic system will also lessen the efforts of manual nursing of the plants.

The researchers implemented a project entitled "Indoor Gardening with Automatic Irrigation System Using Arduino Microcontroller". The focus of this study was to develop an automatic irrigation system for an indoor garden that uses a moisture sensor to detect the soil humidity and an Arduino microcontroller to regulate the flow of water that irrigates the garden. Specifically, the study achieved to identify the system requirement necessary to develop the proposed project and build the proposed project with suitable features. The study also aimed to determine the major issues and challenges related to system implementation, perform tests and evaluate the accuracy of the proposed project. Researchers made use of a system methodology called Systems Development Life Cycle (SDLC), which was used as a guide in developing the project. This methodology involved four phases: planning, analysis, design, and implementation.

Testing was conducted to test the different ranges of moisture content of the soil variable and evaluate the accuracy of the system in delivering water to the subject which is the plant. Results were satisfying in terms of the overall process of the system

KEYWORDS

Irrigation, Arduino Microcontroller, Systems Life Development Life Cycle, gardening, Indoor Gardening

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INTRODUCTION

Gardening is a leisurely activity where plants are grown and cared for to yield food or create landscapes with skillfully-arranged flowers, shrubs, vines and trees. For some, it is a form of exercise, a way to save money on food, and a full-time profession. Unlike farming, where huge quantities of crops are produced using intricate and automatic equipment and enormous manpower, gardening usually depends on manual and simpler tools such as spades, rakes, trowel and hoes, and small power tools like mowers and tillers. The basic and vital tasks like irrigation and fertilization are also made simple in gardening compared to farming.

The plant requires a significant number of unique requirements in order to grow. These basic needs include water, soil, air, sunlight and proper nutrients. Providing these needs is commonly done manually where effort and time are frequently sacrificed. In this study, an indoor garden was built with an automatic irrigation system using an Arduino microcontroller. This study focused on making an automatic system for gardening to lessen the efforts of growing plants. A system was designed for the evolution of automation in the gardening process. To achieve this constructive engineering design, mathematical calculations and programming techniques were developed and employed. Several adjustments were executed during the construction of the project. The stability of the project in terms of its physical and internal aspects including programs improved every after the adaptation of new techniques and adjustments. These modifications were implemented to adapt the whole system to the changing variables that could only be encountered during the actuation of the project.

Increased productivity and lesser maintenance have been two of the biggest reasons in the use of automation. The system was designed for the development of automation in gardening process specifically in the irrigation section. The accuracy of the codes embedded in the system yields greater control and consistency of the product. Sensors were also used to perceive, measure and record the physical property of the subject or its environment. In addition to this, the increase in the control process makes the use of materials more efficient resulting in less scrap. The automation of the distribution of water for the plants was monitored and controlled to optimize the use of water and maintain the nourishment of the plant.

Balaga, Cube, and Duran (2015) stated that the most prevalent way that gardeners use to water their plants in the garden is through manual process. With the increasing problems of the demands of water supply, gardeners should be responsible in water conservation to save resources and workforce. The main purpose of their design project is the provision of technological upgrades at community extension services for consumers. The design of the project is only restricted to the use soil moisture sensor (in four sets), relay switch and solenoidal valve; (each set is correlated to a specific plant). The program reads the sensor value one after the other starting from the first plant up to the last plant. The process continues until the power supply is discontinued. The whole program runs in a continuous loop. After a series of tests, results gathered from the soil are either wet or dry. It was concluded that the device is fully functional and could be adapted at various settings in a botanical garden.

When rainfall is not sufficient, the plants need additional water. Archana and Priya (2016) implemented sensors which detect the humidity in the soil (agricultural field) and supplies it with water. The project is a microcontroller-based design which controls the water supply and the field to be irrigated. Ecija, et al. (2015) in the study Automatic Soil Moisture Sensing Water Irrigation System with Water Level Indicator discussed that soil moisture is an important parameter in the monitoring of plant growth. The study developed a device that regulates the moisture level of the soil. It triggers the water irrigation system to release and give adequate water for the plants. This is based on the knowledge that the soil moisture determines the amount of liquid or water content of a soil where an automatic irrigation system is provided. It uses a sensor that determines the soil moisture (through soil moisture sensor), and a pumping system which aims to deliver the required amount of water. It also includes the design of a microcontroller that detects the condition of the soil. The system uses a microcontroller called Arduino. Various sensors are connected in its ports. The sensor determines the change and gives a signal to the microcontroller that would trigger the relay driver. It makes the pump activated whenever differences in the moisture content of the soil occur. The system also includes an indicator for the water level at the water tank. The system designed by Ecija et al. (2015) was also implemented by Patidar and Belsare (2015) wherein the automatic irrigation system is designed to optimize the water use for agricultural crop. The system has integrated the wireless sensor network of soil moisture, temperature and humidity sensors into the root zone of the plant. The system aims to find the conditions of the field and provide automatic irrigation. It also aims to automate the environment around the variable by building the necessary components. The Zigbee and GSM (Global System for Mobile Communications) is used to monitor the system.

The optimal management of the greenhouse environment is the primary issue of greenhouse-based-horticulture. External conditions like pests and diseases, and extremes of heat and humidity, have to be controlled to provide adequate water. The solution of this problem is by provision of an automatic controlled system. Bin Jafry (2007) improved a system by converting the work from manual to automatic for an easier remote monitoring of the greenhouse condition. A framework is proposed by Hassan, Noor, and Abdullah (2015) that could collect identified data from a greenhouse environment. It could yield status and automatically manipulate the system. By the observation of the recurring conditions, it was measured by the security of the connection between the sensor flags and base information. Different parameters have been taken into consideration such as light, temperature, humidity, soil moisture, etc. to monitor the environment inside the greenhouse. It was interfaced with the microcontroller. A closed loop system is used to detect any unwanted errors in the adjustment of temperature, humidity, light intensity and soil moisture.

According to Saho (2016), the implementation of an automated irrigation system aims to improve the use of water for the agricultural crops. It provides a network of wireless soil and moisture sensors placed in an agricultural land as the setting. In addition to this, the program handles the sensor data. It extracts the required data from the string which prompts the relay circuit to regulate the pump. The Web Socket nodes send data to a control station and display the received information through desktop via MoteView (a MoteWorks software from Crossbow). The data received is diverted to the microcontroller and the data in de-mand from the entire string is extracted. Through programing, the gathered temperature and humidity values are correlated with the threshold value. Through the process, irrigation is established. The management of an effective water distribution is an issue in numerous trimming frameworks in the semiarid and parched zones. Sensor-based irrigation framework offers a solution in the management problem. It allows researchers to expand the profitability while saving the consumption of water.

Technological developments have made sensors available for the efficient and automatic operation of irrigation system (Muñoz-Carpena & Dukes, 2005). The automatic irrigation based on sensors aims to maintain a range of water supply in the root zone of the plants. The ideal range of soil water is usually set with the consideration of soil tension or metric potential (expressed in kPa or cbar), or through volumetric moisture. Furthermore, another benefit of the automatic irrigation is the convenience.

In a study conducted by Agbituyi and Oroywode (2016), the facilitation of the automated supply of sufficient water to a field of crops at all seasons has been the aim of the provision of an automatic irrigation control system. It aims to observe the effect of the elimination of human involvement in irrigation and enhance the use of water supply. The method involves the monitoring of the moisture content of the soil and providing its needed water level by a pumping mechanism. The process is categorized into four subsystems namely; power supply, sensing unit, control unit and pumping subsystems. They make up the automatic irrigation control system. The following components are used in the system: moisture sensor (to determine the electrical resistance of the soil); a regulated 12 volts power supply (provides power to the system); the control circuit with operational amplifier and timer, and the pumping subsystem (submersible low-noise micro water pump using a small dc-operated motor). Several tests for the system response were provided to determine the time rate of irrigation. Sandy soil requires less water compared to loamy soils. The clay soils need the most water among the soil types. A properly configured soil moisture sensor could be used to optimize the usage of water by up to 62% in comparison to manual irrigation. The watering of plants (when in need) could increase the health of landscape, promote the deeper growth roots, and enables the plant to be resistant in diseases (Baseline Irrigation Solutions, 2011).

The usage of Thermo-Electric Generator (TEG) as a soil moisture detector could be implemented in an automated irrigation system. The difference between the temperature of the air and the soil (which correlates the soil's moisture condition) is being determined through the TEG inserted in two heat exchangers. A microcontroller is used to gather the moisture level of the soil from the TEG output and automate the irrigation system. The irrigation system irrigates the soil based on the soil condition detected by the TEG. It also controls the water distribution to the soil therefore promoting water conservation (Bathan, Belen, Lao, Tiu, &Manzano, 2013). The design of the system by Balaga et al. (2015) was based on previously discussed studies with the consideration of being cost-effective, easy to develop and efficient. A microcomputer-based soil moisture analyzer was incorporated in watering system of a botanical garden to automate the process.

In the system developed by Allousy (2012), the quantity of the water output (H2O) is dependent on the setting or area where the system is set up. Indoor gardening requires lesser water consumption compared to an outdoor setting. Allousy (2012) cited Mose Wrighton who stated that the soil outside gardens could easily adjust itself compared to the soil in an inside garden setup. The regulation of water is one of the major challenges in setting an au-tomatic irrigation system. Manual provision of water is done in an indoor setup while out-door plants could receive periodic rainfalls. The excessive supply of water for indoor garden could cause rot and fungal inspection.

Brouwer (1986) stated that the type of the crop plays a role in the daily consumption of that particular plant. A fully developed maize crop and crop of onion need different amount of water a day. Crops need the highest amount of water when they are fully grown. References are made to determine the effect of the daily consumption of water to the crops.

In the development of an automatic irrigation system by Ecija et. al (2015), the system that uses moisture sensor and a water-pumping system was established. Three soil conditions were identified and modified into the system. This includes the wet, soggy, and dry conditions. In Hassan (2015), the quantity of moisture could be modified according to the plant used. The modification would require the researchers to adjust values encoded in the program. The process makes the current study and its coding scheme a versatile tool for watering a large variety of plants.

According to Chandran and Mohana (2014), the advantages of automating the system implies higher productivity rate, efficient use of the materials, better quality of the output and shorter work days. The biggest reasons in justifying the use of automation are the higher output and increased productivity. The manufacturing process is usually performed by the automated systems resulting in greater control and consistency of the quality of the output (Asia Pacific MetalWorking Equipment News, 2018). In addition, the increase in the control process makes use of materials that are more efficient and results in less waste. In this study, automation of the distribution of water for the nourishment of plants was monitored and controlled to optimize the use of water.

The focus of this study was to develop an automatic irrigation system for an indoor garden that uses a moisture sensor to detect the soil humidity and an Arduino microcontroller to regulate the flow of water that irrigates the garden. Specifically, the study achieved to identify the system requirement necessary to develop the proposed project and build the proposed project with suitable features. The study also aimed to determine the major issues and challenges related to system implementation, perform tests and evaluate the accuracy of the proposed project.

METHODOLOGY

The development of the proposed project was realized through a series of procedures guided by the Systems Development Life Cycle (SDLC). SDLC is a representation of procedures in the development and configuration of the system through its overall system duration. It is a systematic approach which categorizes the overall work into various phases. ("Systems Analysis and Design," 2015). This study also incorporates a combination of qualitative and quantitative approaches in data analyses and data gathering.

Building a system using SDLC follows a similar set of four fundamental phases: planning, analysis, design, and implementation, as shown in Figure 2 below. Each phase is itself composed of a series of steps, which rely on techniques that produce deliverables (Dennis, Wixom, and Roth, 2012).

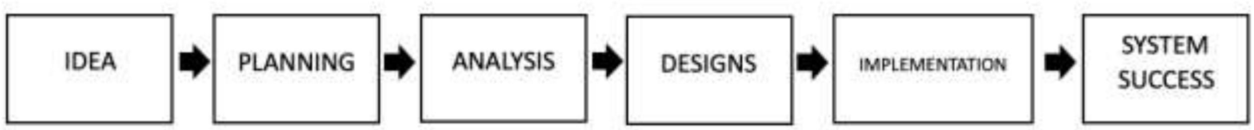

Figure 1. The Systems Development Life Cycle

Planning. This is a basic process where the reflection of the objective of the project and the determination of the building process that it will undergo is undertaken. (Dennis, Wixom, and Roth, 2012). In this phase, the researchers sought the approval of the proposed project and started identifying the needed requirements for the project. The project leader disseminated the work for each team member to keep track of the progress of the proposed project.

Analysis. This phase contains the usage of the system. This phase evaluates the current system and determines the improvements that it could undertake. (Dennis, Wixon and Roth, 2012). In this phase, several meetings were held in order to collate ideas and provide an initial design of the project. The researchers gathered information on existing systems which was used as the basis of conceptualizing the design of the proposed project. The current systems were also evaluated for improvement and be employed as the basis for the new system. During this phase, the general objective of the project was also conceptualized. This phase was mainly discussed in the literature review of this project.

Design. The design phase determines the operation of the hardware, software and network infrastructure of the system. (Dennis, Wixom, and Roth, 2012). In this phase, the researchers started the initial structure of the project with the construction of the plant box for the garden. Components and other equipment were purchased to start the design of the prototype of the irrigation system. The irrigation system includes the pipes and the water source for the plants. The soil and the plant arrangement were set after the construction of the plant box. The quantity of the soil and the arrangement of the plants were configured based on the design of the plant box. After the actual construction of the prototype, the microcontroller was programmed to achieve the necessary results. Minor components such as the lightning system were configured on the plant box during this phase.

This study focused on the design and development of an indoor garden with an automatic irrigation system using Arduino microcontroller. Preliminary data about system requirements were gathered to establish an initial design analysis. Results were acquired upon system implementation. Data are presented, analyzed and interpreted in the following section.

Data Presentation, Analysis and Interpretation

(1) System Requirements

One of the objectives of this study is to identify the system requirements of the proposed project. The study focused on identifying the appropriate components for the irrigation system which is the essential part of this project. These requirements were based on the objective of the project. Table 1 and 2 show the minimum hardware and software requirements for the proposed project.

Software	Specifications
Programming Language	C/ C++
Controller Support	ATmega 328
Installation Media	Arduino Software (IDE) – 1.0.6.1

Table 1. Software Requirements

Arduino UNO is a microcontroller supported by an 8-bit ATMega328p. Along with the controller support, other components such as the crystal oscillator, serial communication and voltage regulators are used to support the microcontroller. UNO has fourteen (14) digital input/output pins in which six (6) pins could be used as PWM outputs, six (6) as analog pins, a USB connector, a power barrel jack, an ICSP header and a reset button.

Hardware Components	Specifications	Quantity
Microcontroller	✓ Brand Name: Arduino UNO ✓ Operating Voltage: 5V ✓ Input Voltage (recommended): 7-12 V ✓ Input Voltage (limits): 6-20 V ✓ Digital I/O Pins: 14 (of which 6 provide PWM output) ✓ Analog Input Pins: 6 ✓ DC current per I/O Pin: 40 mA ✓ DC current for 3.3 V Pin: 50 mA ✓ Flash Memory: 32 KB of which 0.5 KB used by bootloader ✓ SRAM: 2KB (ATmega 328) ✓ EEPROM: 1 KB (ATmega 328) ✓ Clock Speed: 16 MHz	1
LCD	✓ Brand Name: Unbranded ✓ Model:1602 16x2 Character LCD Module Display HD44780 with I2C ✓ Text Color: White ✓ Back Light: Blue LED backlight ✓ Dimension: 80 mm x 36 mm x 18 mm ✓ Display Size: 2.5	1
Water Pump	✓ Brand Name: HX-2000 ✓ Power:10W ✓ Voltage: 110/220 V -240 V ✓ Frequency: 50/60 Hz ✓ Flow: 650 L/H ✓ Max Jet: 1. 0 M ✓ Calibre: ⌀ 15. 5 mm ✓ Weight: 0.50 kg ✓ Size: 90 x 73 x 110 mm	2
PVC (Polyvinyl Chloride) Pipes	✓ Size: ½ inches ✓ Color: Blue	2
Moisture Sensor	✓ Brand Name:FC-28 soil moisture sensor ✓ Input Voltage: 3.3-5V ✓ Output Voltage:0-4.2 V ✓ Input Current:35 mA ✓ Output Signal: both analog and digital Pin-Out ✓ VCC:Power ✓ A0:Analog Ouptut ✓ DO:Digital Output ✓ GND:Ground ✓ Contains a potentiometer ✓ Attached with LM33 comparator	1
LED	✓ Color: Blue and Red	2

[1] Table 2. Hardware Requirements

The fourteen (14) digital input/output pins could be used as input pins by using pinMode(), digitalRead(), and digitalWrite functions in arduino programming. Each pin operates at 5V and can provide or receive a maximum of 40mA current, and has an internal pull-up resistor of 20-50 kilo ohms which are disconnected by default. Some pins have specific functions listed below:

- **Serial Pins 0 (Rx) and 1 (Tx):** Rx and Tx pins are used to receive and transmit TTL serial data. They are connected with the corresponding ATMega328p USB to TTL serial chip.
- **External Interrupt Pins 2 and 3**: These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value.
- **PWM Pins 3, 5, 6 9, and 11**: These pins provide an 8-bit PWM output by using analogWrite() function.
- **SPI Pins 10 (SS), 11 (MOSI), 12 (MISO) and 13 (SCK):** These pins are used for SPI communication.
- **In-built LED Pin 13:** This pin is connected with an built-in LED.

[1]Arduino could be used to communicate with a computer, another Arduino board or other microcontrollers. The ATMega328p microcontroller provides UART TTL (5V) serial communication which could be done using digital pin 0 (Rx) and digital pin 1 (Tx). An ATMega16U2 on the board channels appears as a virtual com port to software on the computer. The ATMega16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. There are two RX and TX LEDs on the Arduino board which will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (not for serial communications on pins 0 and 1). A SoftwareSerial library allows for serial communications on any of the UNO's digital pins. The ATMega328p also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify the use of the I2C bus.

(2) System Design

This hardware and software design concentrated on the requirements needed to evaluate the moisture content of the soil and provision of water (H2O) to the subject (plants).

An initial prototype was made to initially calibrate the software. It serves as a tool for calibrations and adjustments on the hardware and software of the project. The first prototype was made up of a cardboard box covered in a protective layer to avoid deterioration from external conditions. The components were set in a tentative position inside a box. The final prototype was set after the final calibration of the program. The final calibration was decided after the accomplishment of data collection.

The moisture represents the resistivity of the soil. The resistivity serves as the data needed to be analyzed and evaluated in the microcontroller. The microcontroller was embedded with a program to classify the soil if it falls in the wet or dry category. The category was set with different ranges. The data will then be categorized and triggers an output based on the range it falls. The output will turn on/off the water pump and the water will or will not be released to the subjects (plants). An indicator (a red Light-Emitting Diode (LED) for a dry soil and green LED for a soil with sufficient moisture) was also configured on the system to determine the condition of the soil. The length of the time in which the water pumps the water depends on the current condition of the soil. Figure 3 below shows the conceptual framework of the proposed project.

Figure 2. Conceptual Framework

<u>Construction of the Plant Box</u>. One of the needed constructions for the proposed project is the plant box. This will serve as the container for the garden. Below is the given measurement and specifications of the plant box.

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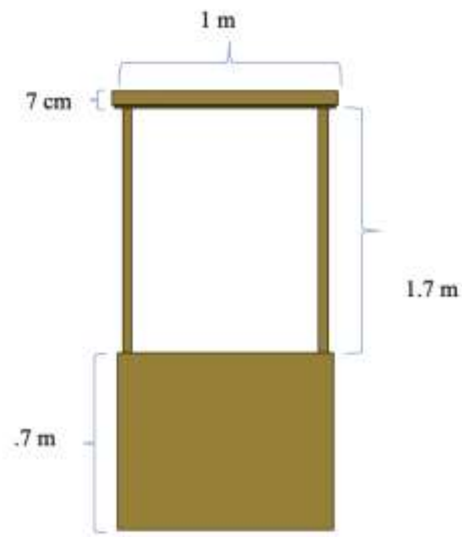


Figure 3. Drawn Model of the Plant Box

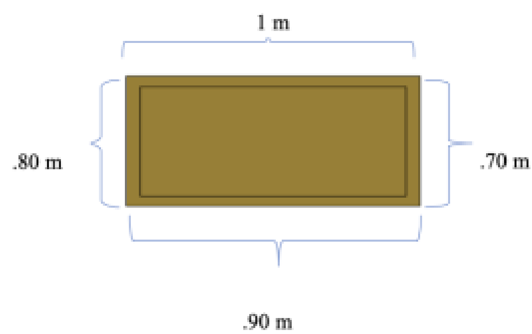


Figure 4. Upper View of the Plant Box

The base of the plant box was designed to allow water in the soil to drain freely so that an adequate air could supply the roots. The interior of the plant box was covered inside with polyethylene to prevent the water from decaying the plant box. The base was provided with a space below in order for water to drip. The pillars of the plant box were built to provide coverings and support for the lightings for the plant. Furthermore, the length of the pillar was set to an unusual height to prevent the plants from burning out due to heat induction of the light source.

Preparation of the Garden. A combination of rice husks, sand and loam was used as the ground for the plants in this study. “The members of the Aloe genus require sandy or gravelly soil and drainage to reduce the rotting risk of the roots and deficiencies in plant nutrition” (Dorsey & Dorsey, 2020). In this study, the researchers designed the plant box according to the type of soil used in the study.

Identification of the Plant. Aloe Vera or aloe barbadensis was used in this study. It is a type of succulent with triangular, fleshy leaves with serrated edges It has been known for its health, beauty and medical properties. (Surjushe, Vasani, & Saplee, 2008) This plant requires controlled irrigation that depends on the capacity of the soil to hold moisture. It adapts to dry and high temperatures. (Delatorre-Herrera, Delfino, Salinas, & Silva, 2010)

Wiring the Components. The components were collaborated together and wired according to the efficiency of the whole system. The moisture sensor serves as the channel between the input data and the controller. Each data was evaluated on the microcontroller and produces an output according to the given condition statements encoded. The water pump which serves as the output is directly connected to the microcontroller system.

Program Encoding. The encoded program was based on the system flowchart of the study. Data about the moisture content (soil resistivity) of the soil is taken and analyzed simultaneously in the Arduino software. The data taken from the soil serves as the input. Conditional statements were designed and programmed on the microcontroller to evaluate the input and produce an output afterwards. The opening of the water pump and the delivery of the water to the plants serves as the output of the system.

RESULTS AND DISCUSSIONS

(3) Major Issues and Challenges Related to the System Implementation

Garden enthusiasts and farmers as any other agricultural sector experience manual processing issues and difficulties. Concerns in the current system originate along the areas of system structure, variable availability and data areas. Some of these challenges could be addressed with the implementation of the automatic irrigation system.

System Structure. The collaboration of small powered devices or components to large powered devices like motors is a complicated task. The system structure of this study was designed to conspire the different types of current powered devices to automate an irrigation system. Furthermore, the design of the structure of the system was built according to the environmental conditions and factors that affect the plant. The light was set to a height from the plant that could give enough light and would not burn its parts at the same time. The water pump was also designed to estimate and deliver the desired water the plant needs.

Variable Availabilities. Tomato, the plant which is proposed, initially had a production date during the cool months from October to February. The inflexibility of the plant during the development of the system led to the change of variables.

Data Area. Resistivity of the materials and variables used in the study were taken into consideration. The salinity of a soil represents the quantity of salt present in the soil. The electrical conductivity is related to salinity. The salinity is determined by suspensions to conduct electricity in the middle of two electrodes. The concentration of salt in water determines the conductivity of the soil - the greater the amount of salt concentration, the more current conducted between the two electrodes and vice versa. The conductance is the result of the concentration of salt in the solution. With a given constant voltage, the current is inversely proportional to the resistance of the solution (Corwin & Yemoto, 2017) In this study, the type of water was considered due to its resistive property. The water resistivity has a big factor in the measurement and monitoring of the moisture content of the soil. Tap water was used as a variable in this study. The temperature of the water was limited to 25 degrees Celsius. By the usage of electrical resistance, the standard for observing purity of water is 25 degrees Celsius at a specific resistance. Specific resistance is the resistance of a current between two 1 cm square plates spaced 1 cm apart (measured at 25 degrees Celsius) (Sartorius, 2010).

The study also concentrated on using a uniform kind of garden soil. The kind of soil also has a big effect on the measurement of the moisture content of the ground. The resistivity of the soil varies according to geographical area and the annual period. The electrolytes (moisture, minerals, and dissolved salts) of the soil determine the soil resistivity (Sartorius, 2010).

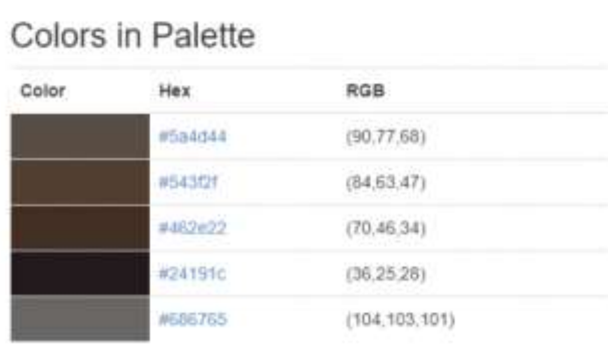
Lastly, the temperature of the environment was also considered. Temperature is a big factor in getting accurate data from the sensor. The probes were designed to have a temperature coefficient. Temperature negatively affects how photovoltaic devices work. (Dupre, et. al., 2015). The sensor used reacts to the change in temperature of its environment. In this study, the plant box was put inside a room with a constant temperature to achieve a constant reading of the data.

These factors were taken into additional considerations by taking adjustments for they add a big effect on the final output.

(4) Evaluation of the Stability of the Project

In the evaluation of the proposed project, several tests were conducted to acquire a positive result.

Classification of a soil whether it falls on the category of wet or dry depends on its water or moisture content. In order for organisms to survive, the amount of moisture needs to be balanced (Agee & Rowland, 2020). According to a study conducted by the Department of Health of Florida, a moist soil will not get any darker when water is added to the sample, and it will not glisten. A sample that is too wet will glisten in the sunlight, or the water puddles on the soil. When texturing, the soil should be easily manipulated by the thumb and forefinger. The figure below shows the color palette of a wet soil.


Colors in Palette

Color	Hex	RGB
	#5a4d44	(90,77,68)
	#543f2f	(84,63,47)
	#462e22	(70,46,34)
	#24191c	(36,25,28)
	#686765	(104,103,101)

[2] Figure 5. Wet Soil Color Palette

Using these characteristics, the researchers have managed to classify a wet soil from a dry one. The characteristics discussed were also used as the basis for determining the samples as wet or dry.

Table 3 and 4 shows the sensor value read by the sensor for each test. Each test was provided with different soil samples containing different amount of water. The water content for each sample was based on the characteristics of a wet and dry soil described by the study discussed above. Each sample was tested by the use of the designed system. The values were gathered and tabulated.

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Implementation. This is the phase where the actual system or the prototype is built, purchased designed and installed (Dennis, Wixom, and Roth, 2012). In this phase, the researchers integrated individual systems into one whole setup. The researchers also tested the proposed system in this phase.

Testing was conducted several times to ensure the system operates productively. The system was also evaluated by selected end-users to determine the over-all performance of the proposed system. Tests were also conducted after adjustments were implemented on the system for the evaluation of the system. This phase was mainly discussed in the data presentation, analysis and interpretation.

4.1. Testing of the System for the Dry Soil

This test is conducted to examine the values represented by the dry soil in the microcontroller. The researchers conducted thirty (30) trials on thirty (30) different samples of dry soil.

Test Number	Sensor Reading
Test No. 1	764
Test No. 2	881
Test No. 3	756
Test No. 4	981
Test No. 5	1002
Test No. 6	856
Test No. 7	923
Test No. 8	764
Test No. 9	564
Test No. 10	678
Test No. 11	891
Test No. 12	724
Test No. 13	789
Test No. 14	891
Test No. 15	901
Test No. 16	912
Test No. 17	789
Test No. 18	990
Test No. 19	917
Test No. 20	956
Test No. 21	947
Test No. 22	859
Test No. 23	877
Test No. 24	845
Test No. 25	745
Test No. 26	790
Test No. 27	781
Test No. 28	734
Test No. 29	709
Test No. 30	724

Table 3. Data Representation During the Testing the System for Dry Soil

The system was tested in a dry soil. The test was conducted to measure its capability on differentiating the moisture content of a dry to a wet soil. The test was also used to record and analyze the data acquired from the dry soil. The data recorded from each test was seen to have little increments. This means that the data is concentrated to a certain range of value.

4.2. Testing of the System for the Wet Soil

This test is conducted to examine the values represented by the wet soil in the microcontroller. The researchers conducted thirty (30) trials on thirty (30) different samples of wet soil.

Test Number	Sensor Reading
Test No. 1	567
Test No. 2	381
Test No. 3	281
Test No. 4	456
Test No. 5	465
Test No. 6	234
Test No. 7	89
Test No. 8	576
Test No. 9	365
Test No. 10	378
Test No. 11	389
Test No. 12	419
Test No. 13	423
Test No. 14	451
Test No. 15	489
Test No. 16	671
Test No. 17	234
Test No. 18	625
Test No. 19	645
Test No. 20	661
Test No. 21	237
Test No. 22	247
Test No. 23	289
Test No. 24	212
Test No. 25	187
Test No. 26	260
Test No. 27	523
Test No. 28	412
Test No. 29	467
Test No. 30	331

Table 4. Data Representation During the Testing of the System for Wet Soil

The system this time was tested in a wet soil. The test was conducted for the same reason of measuring its capability on differentiating the moisture content of a dry to a wet soil. The test was also used to record and analyze the data acquired from the wet soil. The data acquired concentrates on a certain range of value.

By getting the arithmetic mean, (a value that helps summarize an entire set of numbers) the value which serves as the boundary for the two categories could be determined. The mean is a more precise measure than the median, but can be greatly affected by a few numbers that are very different from the other members of the set. (Shamoeel, 2013) The calculated value for the mean was integrated on the system and used as the standard value for the boundary between the two categories.

$$mean = \frac{sum\ of\ all\ the\ numbers\ in\ the\ set}{total\ numbers\ in\ the\ set} \quad \text{[A.1]}$$

$$mean = \frac{764 + 881 + 756 + 981 + \ldots + 331}{60}$$

$$mean = 615.067$$

The standard deviation for each category was also calculated to present how closely bunched the data gathered around its mean or average value.

$$standard\,deviation = \sqrt{\frac{x_1^2 + x_2^2 + x_3^2 \ldots + x_n^2}{n}} \quad [A.2]$$

$$standard\,deviation\,(wet) = 151.122$$

$$standard\,deviation(dry) = 103.104$$

The standard deviation indicates the degree of variability within a set of numbers. The values were more bunched in the dry category compared to the wet category according to the results.

Table 5 shows the testing of accuracy of the system in terms of watering the plant as the output. Time for each test were taken to test the ability of the system to deliver the water for each plant on time. The number of plants watered was also tallied to test the accuracy of the system when it comes to the distribution of the water. This test was conducted to evaluate the accuracy of the delivery of water to the subject.

4.3. Speed Test of the System (During the Watering of the Plants)

This test is conducted to examine the speed of the system on watering the nine (9) plant samples. The researchers provided thirty (30) trials during the experiment.

Test Number	Number of Plants Reached by the Water (9	Time
Test 1	9	7 s
Test 2	9	8.1 s
Test 3	9	11.1 s
Test 4	9	10.7 s
Test 5	9	12.2 s
Test 6	9	13.1 s
Test 7	9	14.1 s
Test 8	9	8.2 s
Test 9	9	9.1 s
Test 10	9	10.4 s
Test 11	9	10.5 s
Test 12	9	9.7 s
Test 13	9	9.7 s
Test 14	9	8.1 s
Test 15	9	8.2 s
Test 16	8	8.5 s
Test 17	7	8.7 s
Test 18	9	9.8 s
Test 19	9	10. 2 s
Test 20	9	10.8 s
Test 21	9	11.7 s
Test 22	9	13.1s
Test 23	9	13.6 s
Test 24	7	7.9 s
Test 25	9	11.7 s
Test 26	9	11.2 s
Test 27	9	11.1 s
Test 28	9	11. 6 s
Test 29	9	11.4 s
Test 30	9	11.7 s

Table 5. Data Representation During the Testing of the Accuracy of the System on Watering the Plants

This test was conducted to measure the length of time for the system to respond to the necessity (water) of the plants. This test also shows the accuracy of the system in terms of how many plants reached by the water. There were nine plants in total. Twenty-seven tests were considered accurate and effective in terms of how many plants were watered during the dry condition.

Accuracy (%) of the system (in terms of plants reached by the water) = (total number of correct test/total number of tests conducted) x 100%
= 27/30 x100%
= 90%

The accuracy of the system was calculated. It was 90% accurate in terms of how many plants were reached by the water based on the thirty tests conducted. The average time to reach the plants was also calculated.

Total Average Time = (total time (30tests)) / total number of tests conducted
= 313.2/30
=10.44 s

According to the tests and calculations, the average time in order for the water to reach the plants is 10.44 seconds. Adjustments were made after the initial implementation of the project. Tests were made during the implementation. Initial data regarding the moisture content of the soil were gathered in this phase. From here, the program was calibrated in accordance with the initial data gathered from the independent variable. Several adjustments and modifications were made to set the program in the right structure. These modifications were also applied to the moisture sensors in order for the microcontroller to get the accurate and precise data from the soil. Furthermore, the adjustments made were made to achieve better and more reliable results.

The result of tests conducted concludes that the whole system achieved its objectives as a reliable water irrigation system based on the acquired and tabulated data.

CONCLUSION

Based on the findings stated, the following conclusions were drawn:

1. The hardware requirements needed to develop the irrigation system are readily available in the market where anyone can buy. Program design however needs to be learned in order for users to code the microcontroller and set control features for the system.

2. In the design of the irrigation system, the soil moisture is the main important element to consider so that the irrigation will function accurately. The Arduino microcontroller is also one of the essential components of this project which controls the overall operation of the irrigation system.

3. In the implementation of the project, several issues and challenges were observed like the system structure, variable availability and data area. The kind of soil and ambient temperature were also considered in the development of the project.

4. Testing was conducted to test the different ranges of moisture content of the soil variable and evaluate the accuracy of the system in delivering water to the subject which is the plant. Results were somehow satisfying in terms of the overall process of the system.

Based from the stated findings and conclusions a temperature sensor that reads the ambient temperature which irrigates the plants automatically may be integrated in the system. A timer on the water source to regulate the water flow to prevent over-watering of the plants, an automatic light regulator that will turn on to supplement the needed light requirement of the plants and the provision of an image processing system to regulate the water level based on the type of plant. The proximity sensor that will monitor the growth of the plant and an automatic fertilizer spray that will provide needed nutrients for the plants is also recommended for future study.

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