Design of Smart Garden Watering and Lighting Using Arduino

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2023 16th International Conference on Developments in eSystems Engineering (DeSE) | 979-8-3503-8134-4/23/$31.00 ©2023 IEEE | DOI: 10.1109/DeSE60595.2023.10469214

***Abstract*— A developing technology called a "smart garden" employs analytics, sensors, and automation to make gardening simpler and more productive. Plant cultivation is a laborious process, so to produce crops healthily, farmers must routinely visit the farming area to assess the many environmental parameters, including humidity, temperature, soil moisture, and light intensity. Through the interlinking of these microclimatic factors, all parameters can be monitored automatically without human assistance using automatic garden monitoring and control. In this study, we employ an Arduino microcontroller to activate a light and a motor for pumping water, respectively, and monitor and control humidity, soil moisture, and temperature using sensors. With the use of the Android app, information will be supplied to the monitoring screen in the event of any abnormal circumstances, and the appropriate solution will be offered. The control and monitoring system for smart gardens is moving toward an intelligent, remotely accessible, real-time, and fully automatic system. A simple way to provide the perfect humidity, temperature, and moisture conditions for plant growth has evolved. As a result, this research tried to understand the idea, trends, and perception of smart gardens, a relatively new idea.**

Keywords— *Arduino, Smart Garden, temperature, humidity, Soil moisture*

I. INTRODUCTION

The idea of smart gardening has been around for a while, yet it hasn't been made a reality until now without technological advancements. Smart gardens are a fairly new type of garden technology that could aid in automating gardening as well as maximizing plant growth while also giving users more information regarding their gardens [1]. There is now a Smart Garden system that makes it simple to provide the best humidity, temperature, moisture, and sunlight conditions for plant growth. Therefore, the Internet of Things (IoT) will be concerned with supplying information that may be utilized in the future, and this kit is utilized to track the daily growth of plants with the use of various wireless communication technologies [2][3]. Controllers and sensors are the most popular types of technology utilized in smart gardens. These Sensors could monitor, manage, and measure the moisture and temperature in the soil, and controllers could change the environment to meet the needs of particular garden plants [4]. A smart garden may help in making the most of the garden while saving energy, time, and money. The popular microcontroller Arduino UNO is utilized for sensor-based measurements like DTH 22 sensors of temperature, moisture, and humidity in nurseries, gardens, and greenhouses based on the application case, activate a water pump and/or lights, a fully automated garden system is implemented [5][6]. The Smart for gardening monitoring and control system is created in this research and managed by an Arduino UNO microcontroller. This device offers certain capabilities for monitoring soil temperature and humidity in addition to air temperature and humidity. Also, using data collected from the system, gardeners could operate the irrigation system, which includes the water pump. Additionally, gardeners will be aware of the quantity and timing of their needs. As well as this technology gives gardeners the ability to control the light by using LEDs. Outdoor and indoor gardening both use this technology.

Outline: The remainder of the paper is structured as follows. Section II gives some related work and gives details about the smart garden. Section III the principal electronic components of the system. Section IV (Methodology) deals with the system description of automated gardening control and the flow diagram of the method employed. Section V give the Hardware of Plants Monitoring System. Section VI presents realistic verification results for the efficiency of the system. Section VII concludes. Section VIII Limitation and Future Work.

• The contributions: In the presented work, we created a resilient, affordable smart garden to shorten the experiential learning curve for those who enjoy technology, yet are not knowledgeable about gardening. Data visualization was utilized for controlling water consumption using an Arduino board, a pump, and sensors. This app was put into place for facilitating the actions of gardeners and enhance app compatibility. The robust smart garden system has the following effects:

- Bridges technology gaps for gardeners with limited prior technological experience and decreases cognitive efforts;
- Lessens the experiential learning curve for those who have a preference for technology but little prior gardening experience.
- Serves as a link between the fields of biology, computer engineering, environmental studies, and computer science.
- Modern agriculture, outdoor and indoor gardening both use this approach.

II. Related Work

Dr. R. M. S. et al. (2019) [7][8] suggested a system for maintaining the plants' nature through continuously monitoring the parameters, resulting in the increased life of plants Utilizing sensors to assess soil moisture as well as temperature and automatically manage water flow to the garden. The sensors were utilized by the researchers to collect parameter values, process those results utilizing a microcontroller, and manage the life of plants in the garden. The amount of water a plant needs is determined by the kind of soil and the plant. Periodically, the user also provided updates on the state of plants. S. Arunachalam (2020) [9] proposes a smart garden system with the use of Arduino to eliminate the difficulties of manual watering, lower the upkeep needed for the garden system, along with automating such watering process. A dual-axis solar tracker system powers Arduino, sensors, relays, pumps, and valves utilized in the standalone garden system. The suggested system's key benefits include simplicity of installation, low maintenance requirements, need-based watering of the garden, and water conservation. B. I. Maria et al (2020)][10], suggested and designed an automatic plant watering system for use in small gardens inside homes to assist individuals in taking care of plants. The researchers proposed a wireless network and sensor-based IoT solution for small indoor gardening. Information on the soil's moisture content is necessary for plants to be watered automatically. By monitoring the plant watering system, they employed an Arduino Uno for controlling all system functions. T. Roderick and A. Meljohn (2020) concentrated on creating an online garden monitoring application that employs a humidity and temperature (DHT) sensor and an AC light dimmer to regulate light levels inside the garden. Additionally, the project utilized a Wi-Fi module for sending and receiving data over the Internet. For storing and filtering data from the DHT sensor, the digital garden system incorporates a web-based monitoring application built with HTML, PHP, and SQL. According to the results of numerous testing, the digital garden system has effectively created a stable environment [11]. M. Wantanee, and et al.(2022) [12] suggested a system to raise the humidity inside the southern Thai mango canopies. The automated smart system enhanced humidity inside the mangosteen canopy and automatically supplied water to boost yields and profit. According to S. B. Aldi (2022), with the use of a solar cell made of semiconductors that works for directly converting sunlight into electric power, an autonomous garden watering device was created. A timer, rain sensor, relay, and inverter are utilized. The goal of the design and development of the tool is to evaluate the effectiveness of the automatic garden watering system by using solar cells as a voltage source and to learn how the control system functions by including rain sensors during optimal plant watering [13]. A system was created by U. Z. Rokon (2022) for smart irrigation and is built on a solenoid valve, drip irrigation system, and digital timer that can be programmed. The technology, a programmed digital timer, sends a signal to the electric pump and solenoid valve which opens or closes the entire irrigation system, watering the crop at the chosen interval and frequency [14]. Y. Anshori, and et al. (2022), suggested a prototype for an IoT-based Smart Garden system that uses fuzzy logic controllers for monitoring humidity and temperature using sensors and processing data by a microcontroller. A spray pump is utilized to reduce the temperature that is sent to the server viewable on a smartphone, actuator status, and sensor data are both available [15]. S. Ratnawati, et al. (2022), used statistical analysis of inference carried out on the data from the measurement of temperature and humidity in the smart indoor garden system. From the results of the analysis of the air temperature data, they were found that there was no difference in the average air temperature measured using a digital thermometer and a DHT22 sensor, with a p-value of 0.174. Meanwhile, from the results of the data analysis of humidity, the authors found that there was a difference in the average humidity of the air measured using a digital thermometer and a DHT22 sensor, with a p-value of 0.001[16]. Lamsen et al. (2022), implemented an Indoor Gardening with Automatic Irrigation System using an Arduino Microcontroller. This technique primarily offers a way to keep tabs on the health of plants that require watering as necessary. They worked to create an autonomous watering system for an indoor garden that makes use of an Arduino microcontroller to manage the water flow and a moisture sensor to measure soil humidity. Results were pleasing in terms of the system's overall operation [17]. In this project, a smart garden was constructed to create an automatic watering system for an indoor garden that employs an Arduino microcontroller to manage the water flow and sensors to measure the temperature and humidity of both air and soil. This work concentrated on developing an automated gardening system to reduce the labor-intensive process of growing plants. The system was created to test the system both inside and outside and to track the development of automated irrigation in gardening.

III. Principal Electronic Components of the System

The controlling and monitoring sections make up the two parts of the suggested study. With the help of sensors, such as the DHT22 humidity and temperature sensor and the soil moisture sensor, the system is monitored and controlled by the Arduino UNO R3. The motor pump and lights make up the controlling part. An app is utilized to show the sensors' status.

Arduino

Arduino UNO (fig. 1) can be defined as an open-source microcontroller board, allowing users to freely modify the software and hardware, and design, and test electronic components to suit their own needs. An Integrated

Development Environment (IDE) is the program utilized in this case, and it just needs a fundamental understanding of programming[18][19]. In this study, the interface of several sensors is carried out to monitor the environment and soil in real-time for the effective growth of crops as well as saplings.

Fig. 2. Microcontroller: Arduino Uno [20

Fig. 1. Ultrasonic Ranging Module HC - SR04[24].

Sensors

One of the most well-known Arduino boards, the Arduino Uno microcontroller is its central processing unit. It contains a huge number of analog channels and 14 digital input/output pins, which are used to link an analog sensor to it like a temperature and a soil moisture sensor Additionally, the environmental data can be presented.

1. Ultrasonic Ranging Module HC - SR04:

one of the most utilized sensors in a variety of projects is the ultrasonic sensor (fig. 2). HC-SR04 is a user-friendly, low-cost tool that could be utilized for measuring distance and spotting obstacles[21]. In the case when an object is in front of such a sensor, it reflects the ultrasonic that it creates. The sensor's receiver after that picks up such reflected sound. Calculating the sound's velocity and time travelled allows one to determine the distance. Microcontrollers, such as Arduino could be readily interfaced with the HC-SR04 module [22] [23].

2. LM2596

The monolithic IC LM2596 regulator is perfectly suited for the quick and straightforward design of a step-down switching regulator (buck converter). It has good line and load management and can drive a 3.0 A load [25]. The device has a fixed voltage output type, allowing the output voltage to be modified. LM2596 converter (fig. 3) can be defined as a switch-mode power supply. Because LM2596 switches at 150 kHz, fewer filter components are possible than with switching regulators that operate at lower frequencies [26]

Fig. 3. LM2596

Fig. 4. Light Dependent Resistor[29].

3. I2C Serial Interface 20x4 LCD Module

This 20x4 LCD module with an I2C interface serves as a new, high-quality display that could show 4-line 20 characters. The I2C communication interface, adjustment, and backlight are all controlled by the LCD module's onboard contrast. The main board samples the sensors sends the data and displays the measurements on a local LCD module.

4. Light Dependent Resistor

One sensor that could assess light intensity is the light module sensor (LDR). The resistance value for LDR (fig.4) will decrease as light intensity increases. The potentiometer on the sensor could be changed to a setting that will allow it to detect light of the lowest possible intensity, depending on the creator [27] [28].

5. Air sensor

Digital temperature and humidity sensor, model DHT22 generates a digital output by measuring the relative humidity as well as air temperature using a thermistor and a capacitive humidity sensor. It measures temperature with a relative error of 0.5 C and humidity with a relative error of 2% RH the sensor provides a measurement between 0 and 50 degrees Celsius and a humidity range between 20 and 90 % [30][31][32].

6. Temperature sensor NTC 100 K

Thermistors are made of materials that significantly alter in electrical resistance with temperature and are perfect for detecting minor temperature changes. As thermally sensitive resistors, thermometers are capable of having a negative temperature coefficient (NTC) [33][34].

7. Solar heating controller SH-E01

The solar heating controller type SH-E01 regulates the flow of heat energy from a solar collector to a hot water storage tank using the difference in temperature between two temperature sensors. Those temperature sensors are semiconductor resistors with thermal sensitivity that exhibit a reduction in resistance with rising temperature. Sensor units are made up of a 100 K NTC (negative temperature coefficient) resistance element that is after that enclosed in a copper tube with a tight seal.

8. Humidity and Temperature module AM2301 (DHT21)

The interchange of moisture from ventilation, plant transpiration, and soil evaporation influences the amount of water vapor in the garden (or humidity) [35]. The majority of garden systems employ relative humidity to track and manage the microclimate. Moisture content specifically alters the resistance or capacitance values of the sensors according to the type and design of the sensor [36]. The humidity and temperature sensor is AM2301 which is utilized for measuring air temperature and humidity inside the garden. Its measurement range of temperature is -40˜80 C, accuracy is ±0.3 ◦C, and relative humidity measurement range is 0˜100%RH, accuracy is ±3%RH, and sampling period is a minimum of 2 seconds [37]. The component that includes the calibrated digital signal output regarding the humidity and temperature sensor is found in AM2301 capacitive humidity sensing digital humidity and temperature module.

9. Moisture Sensor (SKU: SEN0114)

A moisture sensor works great for checking the water level in the houseplant or an urban garden. This sensor passes current through the soil using the two probes after that detects the resistance to determine the amount of moisture present. In contrast to dry soil, which conducts electricity poorly (with greater resistance), moist soil conducts electricity more readily (with less resistance). It will be beneficial to check the soil moisture in the garden or to set an alarm to remind you to water your indoor plants [38][39].

IV. METHODOLOGY

The entire automatic plant watering system is managed by an Arduino board. The output of the soil moisture sensor and soil temperature sensor circuits are both linked to Arduino's analog pin A3 and digital pin A2, respectively. Pin 7 is connected to the DHT sensor's output to read the air humidity and temperature. The sensor circuit uses an LED, whose OFF state denotes the presence of intense light and ON state, the absence of light. The resistivity of water is used by the moisture sensors to gauge the soil's moisture content. The sensors sense a similar voltage drop caused by a known resistor value after passing a current through one of the nails to determine the resistance between the other two. Using this, we may establish moisture content thresholds by observing that resistance decreases as water content increases. The Arduino can switch the pump on or off automatically thanks to a solid-state relay that connects a miniature fountain pump to the Arduino. Through the library, the Arduino and those communicate with one another. The Arduino determines whether the soil moisture level is low. The hub of the smart garden is an Arduino board to which several sensors, including wetness, temperature, humidity, and ultrasonic sensors, are linked. A water tank is connected to an ultrasonic sensor, which displays the amount of water in the tank. Other sensors that are attached to the appropriate positions give data to Arduino. A diagram for Smart Plant Watering Using Arduino Microcontroller can be seen in Figure 5.

The application design for the proposed smart garden is shown in the following steps:

Step 1: Initialization of Sensors and Arduino Libraries

Assign the required parameters for the temperature, humidity, light, and ultrasonic sensors, and initialize the relevant Arduino libraries for the DHT21 and LCD.

Connect the temperature sensor to pin A2, the humidity sensor to pin A3, the DHT21 to pin 7, the relay to pin 8, and the ultrasonic sensor to echo Pin 6 and trig Pin 5. For the light sensor, use pins 3 and 4.

Step 2: Arduino Setup

Define the ultrasonic sensor's parameters as echo Pin (input) and trig Pin (output).

For the light sensor, define the LED as an output.

Define the relay as an output.

Set the LCD as an output.

Step 3: Loop - Reading and Calculating Data from the Sensor

1. Read the data from the Light Dependent Resistor (LDR) to measure soil moisture.
2. Use the Map filter to convert the raw data to a percentage value (0-100).
3. Calculate the average moisture level using the formula Ava=(M1+M2)/2, where M1 and M2 are two consecutive moisture readings.
4. Read the voltage output (Vo) from the temperature sensor to measure the soil temperature.
5. Calculate the soil temperature using the equation R2 = R1*(1023.0/(float)Vo-1.0), where R1 is the resistance of the sensor at a known temperature, and logR2=log(R2), T= (1.0/(C1+C2logR2+C3(logR2)3) and float TC =T -273.15 are used to convert the resistance value to temperature in Celsius.
6. Read the data from the DHT (Digital Humidity and Temperature) sensor to measure the air temperature and humidity.
7. Calculate the duration and distance of the Ultrasonic pulse using the following equations: duration =pulsing (echo pin, HIGH), and distance = duration* 0.34/2.
8. Use the Map filter to convert the raw Ultrasonic sensor data to a percentage value (0-100) representing the water level in the soil.
9. Display the humidity and temperature readings for both soil and air, as well as the water level.
10. If the average moisture level (Ava) falls below 10, turn on the relay to activate the water pump.
11. If the LDR reading falls below 150, turn on the LED and display the message "Status: Night".
12. End the loop.

TABLE I. THE PARAMETERS OF SYSTEM

parameter	Meaning
V0	Analog Temperature value
R1, R2, T, logR2, C1, C2, C3	Temperatures value
duration	Ultrasonic
Distance	Variable
Idr, moist1, moist2, M1, M2	Soil moisture variable
LED	Light variable

V. HARDWARE OF PLANTS MONITORING SYSTEM

Figure 6 depicts the suggested Plants monitoring system. This system's primary goal is to keep track of a garden's plant metrics. Sensors and Arduino boards are needed as part of the planned plant monitoring systems' requirements. The Arduino microcontroller board is the foundation of the entire system. Data about the environment is gathered via sensors. The associated sensors are used to detect parameters, like air humidity and temperature, soil moisture and temperature, Ultrasonic Ranging Module HC-SR04, and light intensity. The I2C 20x4 LCD Module to Display is attached to display the sensor readings and the water level, daylight, and soil conditions at the moment. Information gathered from sensors is transmitted through Arduino. Section III lists the sensors which could be utilized with this system. In this study, the interface of several sensors is completed for monitoring the environment and soil in real-time for plant growth. The method to be used in controlling smart plant watering using the Arduino Uno controller as the main controller, Arduino Uno also plays an important role in controlling the programming flow For programming this system, programming software is needed, namely the Arduino IDE application used for program input to connect to the Arduino microcontroller, besides that, the component used is a 5V Relay which is used for a switch so that the Pump can turn on or off which has been connected to electricity and is also connected to the Arduino microcontroller while the Soil Moisture Sensor module can display if the plant is lacking or excess water Here will explain how the hardware can be connected, the first is the Soil Moisture Sensor will provide soil moisture value input on Arduino Uno then after that it will send output to the 5V Relay so that the device can run, after that, the Pump will flush and distribute water to the plants as ordered.

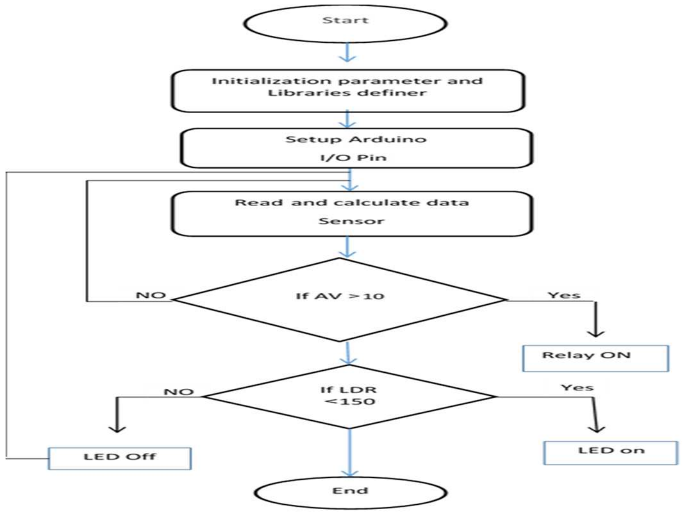

Fig. 5. Flowchart proposes system

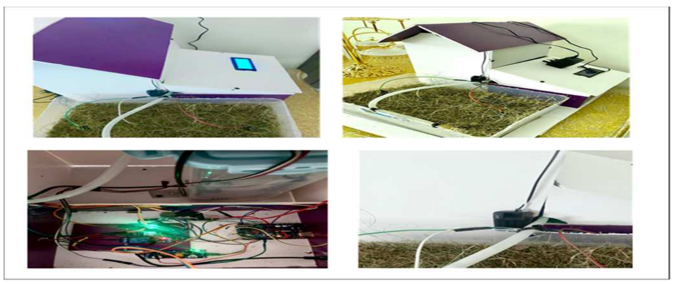

Fig. 6. The proposed Plants monitoring system

VI. Experimental Results and Discussion

TABLE II. Experimental Results of the system

Time and Date	Temp-A	Temp-M	Hum-A	Hum-M	Level of water	Status	led	Spray Pump state
12:11 PM 2/12/2022	20	30	56	52-53	52-57	Day	OFF	OFF
1:29 PM 2/12/2022	21	29-30	54-55	43	57	Day	OFF	OFF
2:24 PM 2/12/2022	21	29	55-56	43	52-57	Day	OFF	OFF
4:35 PM 2/12/2022	21	29	54	42	57	Night	ON	OFF
12:43 AM 3/12/2022	21	29	57	41	57	Night	ON	OFF
1:00 PM 3/12/2022	20	30	56	43	57	Day	OFF	OFF
1:00 PM 4/12/2022	20	30	57	41-26	31	Day	OFF	OFF
1:18 PM 4/12/2022	20	30	57	<10	10	Day	OFF	ON
1:18 PM 4/12/2022	20	30	57	73	10	Day	OFF	OFF
5:45 PM 4/12/2022	25	27	48	12-13	15	Night	ON	OFF
6:37 PM 4/12/2022	25	26-27	50	10-11	15	Night	ON	OFF
7:37 PM 4/12/2022	26	26	49	<10	10-15	Night	ON	ON
7:41 PM 4/12/2022	26	26	47	30	10	Night	ON	OFF
3:41 PM 25/12/2022	17	34	66	0	100	Day	OFF	ON
3:50 PM 25/12/2022	17	34	66	33	21-26	Day	OFF	OFF

Where Temp-A, Hum-A, Temp-M, and Hum-M are the temperature and humidity of air and soil respectively.

From Table 2, At a temperature of air 19-21 and for soil 29-30, and a humidity of air 54-57% and for soil 26- 53 %, the spray pump state turned off and this is by the predetermined fuzzy logic rule base in proposed design steps. This condition is still considered ideal so no spraying is carried out. When the humidity of the soil is less than 10% with different readings in temperature, the spray pump turns on and starts spraying. Likewise, for air 25-26 and soil 26-30, and a humidity of air 48-50 % and soil 10-13 %, the spray pump state was turned off. After spraying, there is a decrease in temperature and an increase in humidity. The light LED is turned on in the status of the night depending on the LDR value base in the proposed design steps.

VII. Conclusion

The design of a smart garden system utilizing Arduino is discussed in this study. The goal of this work was to create an autonomous irrigation system for outdoor and indoor gardens which employs an Arduino microcontroller for controlling the water flow as well as a moisture sensor to measure soil humidity. The research was successful in identifying the system requirements needed for building the suggested project and providing it with the appropriate features. The research also sought to test the suggested project's accuracy, identify the key implementation-related challenges, and assess those findings. Since Arduino makes it possible to observe and interact with external electronic components in real life, it was chosen for this project. In its current prototype form, the resilient smart garden could maintain one plant utilizing two soil moisture sensors, one temperature/humidity sensor, and one temperature sensor.

VIII. Limitation and Future Work

By utilizing sensors, automation, and data analysis, SMART GARDEN systems can increase efficiency, reduce waste, and promote sustainability. While there are still challenges to overcome, such as cost and accessibility, the benefits of SMART GARDEN technology far outweigh the limitations. As we continue to innovate and develop new applications for this technology, we can look forward to a future where gardening is not only easier and more efficient but also more environmentally friendly. So we can choose a design that groups plants that profit from growing together by companion planting. Each Arduino board is used to monitor a single planter box where the plants are located. A web app can offer the front-end user interface along with the embedded component, allowing the gardener to interact with the garden's setup. A companion-gardening design element will make it easier for a novice gardener to arrange the plants. Also, the user can get comments on whether a plant grows well next to another plant in addition to a list of suggested plants that thrive in that particular environment. Users could also change the automatic watering by looking at the graphs of measured data over time. For learning from or inspired by other designs, they could opt-in to make their data public to other gardeners with the use of the same web app and view the history of their garden and compare statistics over time. In this manner, the platform might develop into a teaching aid.

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