Smart Garden System: Enhancing Plant Care Through IoT and Sensor Technology

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Abstract: The Smart Garden System utilizes the Internet of Things (IoT) and sensor technology to automate plant care. With the integration of soil moisture, temperature, humidity, Light Dependent Resistor, and Passive Infrared Ray sensors, these systems can monitor the environment in real time. Gardening processes that require the most manual power, such as watering and harvesting, will now be done through the use of actuators, such as Direct Current motors, Light Emitting Diode, and servo motors. These systems were designed on Tinkercad and programmed with C++ for better real world performance. The study assesses the efficiency of the developed system in terms of water and energy consumption, as well as its impact on agriculture. Data security, protection against unauthorized access, and reliability of the system were other aspects considered in this study. This project works toward achieving specific Sustainable Development Goals by facilitating resource saving, gardening in cities, and better agricultural methods. Enhancements in the future involve logging data in the cloud, mobile application, and machine learning based development of plant care methods. The findings show great promise in the use of Internet of Things powered smart gardening tools to automate as well as optimize plant cultivation towards environmentally sustainable and beneficial agricultural practices.

Keywords: *Smart Garden System, Internet of Things, Sensor Technology, Soil Moisture, Temperature, Humidity, Light Dependent Resistor, Passive Infrared Ray Sensors, Actuators, Direct Current Motors, Light Emitting Diodes, Tinkercad, C++ Programming, Water Consumption, Agricultural Impact, Data Security, System Reliability, Sustainable Development Goals, Urban Gardening, Cloud Data, Mobile Application.*

1. INTRODUCTION

A garden is a planned outdoor area used for the purpose of growing, showcasing, and enjoying plants and the natural world. A subset of these are home gardens, which are often tiny spaces intended for family usage that surround residential neighborhoods. Occasionally, domestic animals may also be present. Such gardens are often planted with a combination of annuals and perennials, and, in addition to the ponds, greenhouses, and green roofs, these gardens often have goats, sheep or cows (Santos et al., 2022). Amidst the benefits linked to gardening, the practice is increasing in popularity. Although it has always existed in conjunction with human dwelling, its function has changed through time. In particular, in modern societies, especially in the cities that are isolated from nature, gardening has become a typical hobby. Urban areas have many advantages for nature, such as parks, and are important for people's mental and physical well being as well. Gardening results in greater life satisfaction and physical health outcomes, while reducing stress, anxiety, and depression. Today, gardening is often recognized as a complementary approach to health care and even as a form of treatment for individuals with mental illnesses (Soga *et al.*, 2017).

The Internet of Things (IoT) is a dynamic worldwide network architecture that facilitates internet-based communication between systems, sensors, and objects. It incorporates Machine-to-Machine (M2M) communication, in which intelligent interfaces allow virtual and physical devices to interact with one another in a seamless manner. Through the incorporation of technology within our daily lives IoT aids in achieving bisecting ranges of efficiency by automating decision making processes (Song, 2020). The automatic collection and processing of data allows for decision making to happen in real time. With the integration of IoT, various sectors like medicine, appliances, transport, and even security have experienced advancements. Among such industries great impact is seen in gardening industry as well (Biswajit Mallick, 2024).

Nowadays, because gardening needs constant observation and monitoring throughout the life of plants, many people shun gardening because it is a laborious chore. Because of this, it is quite difficult for them to garden in addition to their regular tasks. The majority of individuals are also not very knowledgeable about proper plant cultivation. The type of plant to be grown, soil characteristics like moisture, and ambient temperature are all necessary for irrigating plants (Cheema et al., 2019). The Internet of Things made it possible for people to communicate with actual items and this is the exact solution of gardening being a laborious chore (Singh et al., 2020). Smart garden systems include utilization of sensors such as soil moisture sensor, photoresistor, temperature sensor, humidity sensor and PIR (Passive Infrared) sensor to make the monitoring of the garden more easier without having the need of any physical interference of human beings. Similarly, the concept of connection of actuators such as artificial growth light, servo motor, buzzer, LEDs (Light Emitting Diode) and cooling fans can save a lot of time in everyday life, making smart garden systems a gift of advancement in technologies (Amudha *et al.*, 2025).

Objective: The goal of this article is to analyze the design and features of a specific smart garden system created in Tinkercad. It includes a variety of sensors such as temperature, humidity, light, and pest sensors to help with plant care and growth automation. The goal is to analyze the functions of each component, including the Arduino board, and the means of data collection, processing, and system control. This paper attempts to show how effective monitoring and management of environmental factors can be utilized to further automate agriculture.

2. LITERATURE REVIEW

2.1 Current Computing Trends

According to the paper(Mihailović *et al.*, 2023), the connection of people, devices, and networks has drastically changed modern agriculture, including the development of smart garden systems. With the help of AI(Artificial Intelligence) and ML(Machine Learning), indoor farming is more precise and efficient than ever. Crops are now grown and harvested with the aid of LED lighting, which is low energy and improves the yield. This has made the smart garden systems more efficient and sustainable. In addition, enhanced automation and IoT enable real-time monitoring and control of smart gardening systems helping in further maximization of productivity and sustainability.

2.2 Future Computing Trends

The evolution and expansion of the Internet of Things IoT are driving the growth of autonomous and strategic Systems in various industries, including agriculture. Later improvements in the software architectures, in addition to improvements in communication networks, will improve the processing, contextualization, and sharing of information, resulting in the development of sophisticated IoT-based applications. In addition, the incorporation of relatively novel autonomous technologies such as robots and drones are bound to transform smart farming along with smart gardening as they automate monitoring, irrigation, and pest control. All these improvements will be consequential towards the future of smart gardening systems as they will become more efficient, autonomous, and intelligent (Olawepo et al., 2020).

2.3 IoT as Enabler of Digitisation

The paper(Kumar. P et al., 2021) suggests, IoT is revolutionizing gardening and plant cultivation with the help of real time automation and data processing. The system presented here digitizes the physical world through the automation to monitor temperature, humidity, and soil moisture in the garden. The data is acquired by sensors through wireless communication and then sent to the central system for processing. The analysis triggers automation of actuators: fans and lights, and water pumps are turned on or off depending on how much energy is needed to create optimal conditions for the plants. Instead of concentrating on accomplishing the task of growing plants, in these modern systems the farmers focus on planning and regulation. The IoT takes care of everything else. As a result, the integrative development of manipulation and farming gives new height and enables modernization of agriculture to bear IoT's positive draws.

2.4 Modern Networking

With modern networking, IoT smart gardening systems can be efficiently accessed remotely and in real-time. One novel aspect of the proposed system's smart garden feature is the integration of smartphones, which enables mobile device access and management of the system. Through wireless technologies, sensor data is relayed. Temperature, humidity, as well as soil moisture will be continuously tracked in real-time. For effective data storage and transfer, Firebase is utilized. Firebase serves as a bridge between the IoT devices and user interface while ensuring reliable data transfer. Also, the Kodular app development platform enables responsive mobile applications. This allows users to receive alerts, view sensor data, and review system status in an easily digestible user interface. All of these technologies combined improve automation and remote accessibility to the system which makes the garden smarter(Annapoorna et al., 2024).

2.5 System Security Approaches

As detailed in the paper(Chakraborty *et al.*, 2022), to ensure that the system operates effectively, the smart gardening system has to be secure to protect sensitive data. There's a Z-Wave Protocol that securely transmits sensor data to the microcontroller. The controlled wireless connection prevents unauthorized access to the system. The communication between the IoT devices and the database of the cloud, through MQTT(Message Queuing Telemetry Transport) ensures the encryption of the connection. Cloud messaging services enable authorized users to view and control the actual condition of the garden, which eliminates the chance of unauthorized users accessing the systems. Hardware and software error handling increases the system's sophistication to cyber attacks and failures and maintaining privacy and security for remote gardening systems.

3. METHODOLOGY

Fig-1: Research methodology of development of smart garden system

3.1 Computational Setup for Simulation

While constant research, deep involvement and consistency are essential for creating effective digital prototypes, choosing the right device or platform plays a critical role in ensuring compatibility, performance optimization, user experience enhancement, and cost-effectiveness throughout the process of building the prototype (, 2023). Considering the critical role of computing devices in digital prototyping, the Smart Garden System was prototyped on a high-performance device to ensure efficient simulation, analysis, and development.The hardware specifications of the laptop used for system design, simulation, and testing are as follows:

- **Device:** Acer Predator Helios Neo 16
- **Processor:** Intel® Core™ i9-14900HX @ 2.20 GHz
- **Installed RAM:** 16.0 GB
- **Graphics Processing Unit (GPU):** 8GB Dedicated GPU
- **System Type:** 64-bit operating system, x64-based processor

Tinkercad was employed as a core simulation environment, to design and simulate the smart garden system. Based on the paper(Juanda and Khairullah, 2021), tinkercad's users do not need any physical components because this simulation platform created by Autodesk allows designing of electronic circuits in the cloud. Simulation and modeling circuits at a cost-effective price is simple with the user-friendly interface, easy design alterations, 3D modeling, circuit simulation, and even Arduino programming. These features make Tinkercad an ideal choice for educational and research-focused institutions. It has also been proven that Tinkercad improves learning outcomes by actively engaging and motivating students and teaching electronics and microcontroller programming to them. Beginner friendly simulation based method without the actual need of building an actual hardware is the main reason in it's utilization in prototyping of smart garden system.

3.2 Hardware Components and Circuit Design

While building the smart garden system on Tinkercad, various electrical components were integrated in order to simulate the environment and carry out different functions. The system was designed to be able to monitor light intensity, temperature, humidity, soil moisture, intruders and control devices such as grow lights, alert buzzers and so on. The microcontroller acted as the master unit that received signals from various sensors and processed them in order to implement control logic for automating the system's actions.

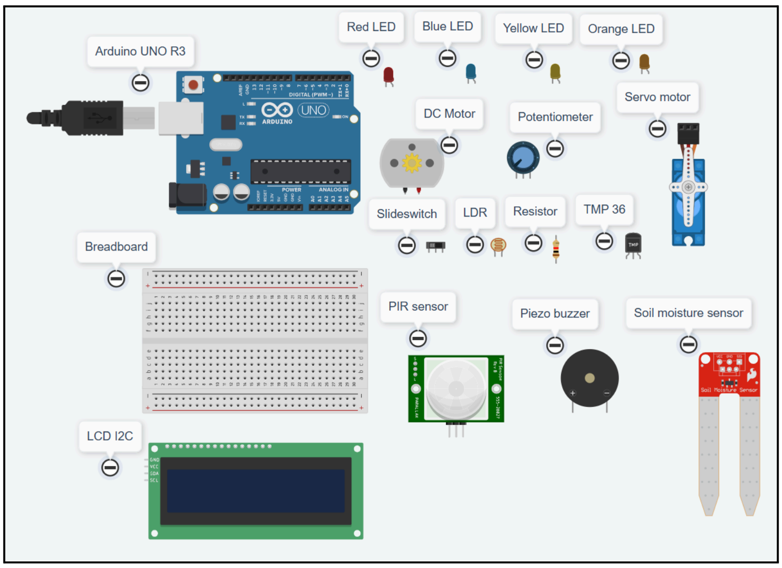

Fig-2: All the hardware components used in the smart garden system.

Below is a selection of the most important hardware elements that were incorporated in the system and which are critical for fulfilling its functional and automated gardening tasks.

a) Arduino Uno R3

Arduino UNO has six analog inputs and 14 digital I/O pins, out of which 6 are PWM. The C++ and C programming languages can be used for device control. The Arduino UNO, equipped with ATMEGA-328 chip runs on 5V and can be supplied with 7V to 12V DC. The ATMEGA-328 microcontroller processes both digital and analog inputs to allow control and automation with great accuracy. It is also quite evident that ATMEGA328 is quite widespread in the different industries including the gardening industry (Sudhan et al., 2015). Because the Arduino UNO is mostly used by beginners, it was implemented as the main controller in the smart garden system.

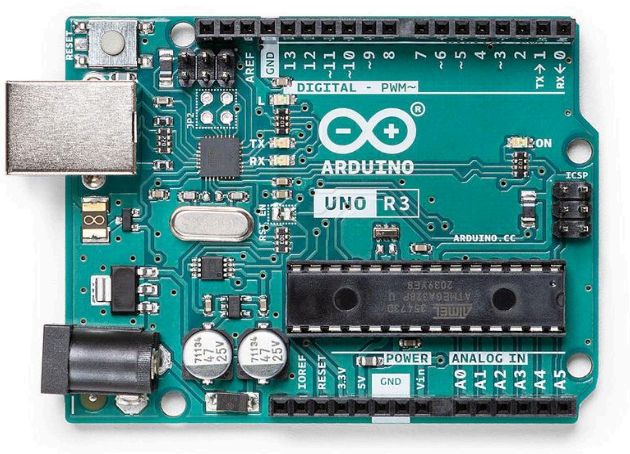

Fig-3: (Arduino Uno Rev3, 2025) Arduino UNO diagram (Accessed: 14 February, 2025)

b) Temperature Sensor (TMP 36)

Temperature Sensor (TMP36) is utilized in the system to measure the temperature so that effective measures can be taken to optimize plant growth. Based on(*Temperature Sensor - TMP36*, 2025), with an accuracy of ±1°C at +25°C, the TMP36 temperature sensor has a precision rating that is typical as compared to other sensors. The TMP36 boasts a voltage output that is linearly proportional to the temperature. The TMP36 operates at a scale factor of ±10 mV/°C, or between 2.7V and 5.5V. In addition to a scale factor, the TMP36 also boasts an extremely low quiescent current lower than 50 µA. These factors make the TMP36 ideal for the monitoring of environmental conditions.

Fig-4: (Temperature Sensor - TMP36, 2025) TMP 36 diagram
Available at: https://www.sparkfun.com/temperature-sensor-tmp36.html
(Accessed: 14 February, 2025)

c) Soil Moisture Sensor

A soil moisture sensor is the instrument that gauges moisture level in the soil, which depends on the soil properties and some salts. It plays an important role in scheduling irrigation by determining the quantity of water required by the crops. This sensor is very important within resource conservation and precision farming because accurate readings allow for evading overwatering and crop wilting(Khanna *et al.*,). Soil moisture sensor was embedded in the smart garden project to observe soil conditions so that automatic irrigation can be activated. This ensures that plants receive a sufficient amount of water and grow properly.

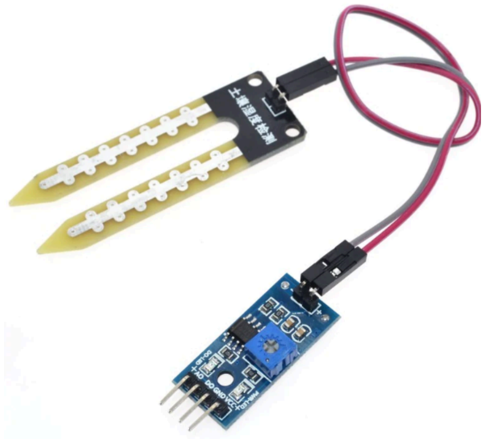

Fig-5: (E, 2020) Soil moisture sensor diagram
Available at: https://arduinodiy.wordpress.com/2020/08/24/soil-moisture-sensors/
(Accessed: 14 February, 2025)

d) Light Dependent Resistor(LDR)

Measurement of the light levels in the surrounding environment for the smart garden system is conducted using a light-dependent resistor (LDR). Every time there is light present, the LDR decreases its level of resistance(Setya et al., 2019). This enables the smart garden to keep track of the light levels to make sure that adequate light is provided for adequate plant growth. The LDR is a big contributor in the efficiency automation features of the system since it is able to turn on or off the grow lights as well as schedule a plethora of other activities in the smart garden at different light levels during the day and the night while considering the needs of the plant.

Fig-6: (techZeero, 2018) LDR diagram
Available at: https://techzeero.com/sensors-modules/ldr-sensor/
(Accessed: 14 February, 2025)

e) Passive Infrared Sensor(PIR)

The PIR sensor detects human activities as a motion detector. It's primary application is to detect presence of humans or animals by infra-red radiation within its range and to detect proximity of a person. The sensor works by detecting motion and changes in infrared levels, enabling it to trigger an action that is appropriate(Aishwarya *et al.*, 2024). For the smart garden system, the PIR sensor works to monitor any movements around the garden area for pest and intrusion security. The system is also used to provide alert signals, or even activate protection controls remotely after the unwanted movements are detected and monitored.

Fig-7 (Passive Infrared Sensor, 2022) PIR sensor diagram
Available at: https://www.sciencedirect.com/topics/computer-science/passive-infrared-sensor
(Accessed: 14 February, 2025)

f) Humidity Sensor

The percentage of water vapor in the air is measured by a humidity sensor which is helpful for environmental and climate monitoring(Lee and Lee, 2005). This sensor is used in the smart garden system to control irrigation for proper moisture levels in the air and soil. Proper hydration is provided to the plants without the risk of over watering. Since there wasn't any model of humidity sensor present in tinkercad, a potentiometer was used instead of the humidity sensor for the smart garden system.

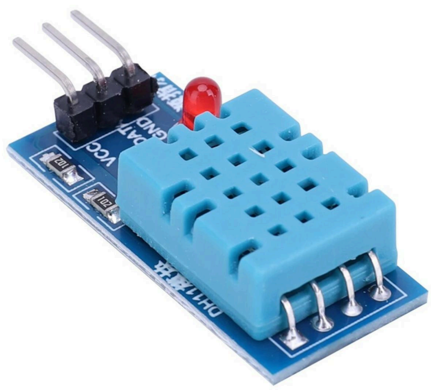

Fig-8: (, 2025) Humidity sensor(DHT 11) diagram
Available at: https://probots.co.in/dht11-humidity-and-temperature-sensor-module-for-arduino.html
(Accessed: 14 February, 2025)

g) Breadboard

A non-solderable breadboard also known as protoboard, is a term used to label a base of construction for semi-permanent prototypes of electronic circuits(Breadboard, 2025). The smart garden system utilized the breadboard to test components such as microcontroller, LDR, humidity sensor, soil moisture sensor, PIR sensor, temperature sensor, Light Emitting Diode(LED), buzzer, servo motor, Direct Current(DC) motor, Liquid Crystal Display Inter-Integrated Circuit(LCD I2C) and other electrical components such as resistors, jumper wires it made modifying and troubleshooting the components before finalizing the design flexible.

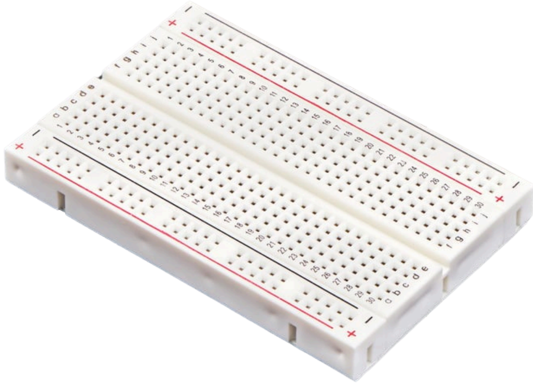

Fig-9: (Ada, 2025) Breadboard diagram
Available at: https://www.adafruit.com/product/64
(Accessed: 14 February, 2025)

h) LCD I2C

The I2C protocol (Inter-Integrated Circuit) utilizes two data contacts for many devices in order to reduce I/O pins on a microcontroller. It's often employed for peripheral connections of LCDs (16x2, 20x4 displays) to a microcontroller. An I2C Address can be set and communications can happen by using an I2C scanner (Oo and Tt, 2018). In the smart garden project, this bus is used to display information from temperature, PIR, humidity, and soil sensors in an LCD interface to the system, complementing the limited I/O while communicating critical system data.

Fig-10: (, 2025) LCD I2C diagram
Available at: https://shorturl.at/bFeQy
(Accessed: 14 February, 2025)

i) Servo Motor

Servomotor is a type of motor combined with a position detection element such as an encoder, thus allowing for precise control of position and speed. In contrast to common motors, servo motors have high precision and high speed control. The most popular ones are brushless, featuring a rotor with a permanent magnet and a stator with conductor coils. The rotor rotates when the stator coils are switched on in a particular order(Servomotors, 2025). In the smart garden system, servo motors modulate the angle of the sensor to control the amount of water given based on different moisture levels.

Fig-11: (, 2025) Servo Motor diagram
Available at: https://www.electronicwings.com/arm7/servo-motor-interfacing-with-lpc2148
(Accessed: 14 February, 2025)

j) DC Motor

Electric energy is transformed to mechanical energy in the form of rotation with the help of a dc motor. They have very good speed characteristics, high starting torque, and overload capacity. For these reasons, they are preferred in most of the systems that require accurate control (Zhou, 2016). In the smart garden system, a DC motor works as an actuator of the fan that regulates temperature and humidity, thus, enabling the fan to function in accordance to the readings taken by the system. This allows the optimal values of temperature and humidity to be maintained for healthy plant growth.

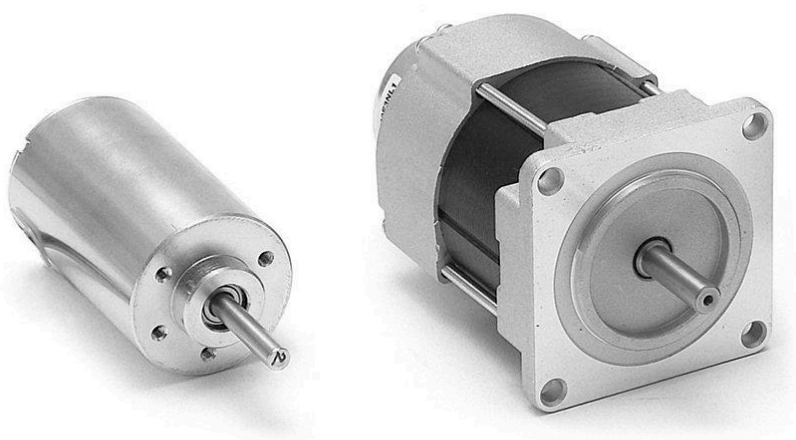

Fig-12: (, 2025) DC Motor diagram
Available at: https://us.aspina-group.com/en/learning-zone/columns/what-is/001/
(Accessed: 14 February, 2025)

k) LED

LEDs or light emitting diodes are devices made of semiconductors that emit light when an electric current passes through them due to the combination of electrons and holes in a PN junction. It is used in many industries because of its energy efficiency, long life span, and toughness(Rakib Sakhawat Hossen, 2015). In the smart garden system, LEDs serve as additional growth lights to adequately support the photosynthesis of the plants with regard to the day-light period of the plants. Additionally, they also act as alarm lights for the sensors that monitor temperature, humidity, and the moisture content in the soil.

Fig-13: (LEDs Group, 2025) LED diagram
Available at: https://www.arborsci.com/products/leds
(Accessed: 14 February, 2025

l) Piezo Buzzer

Piezoelectric materials are utilized for a variety of devices such as doorbell buzzers, barbecues, igniters, and scanning probe microscopes. These materials invent electrical potentials while undergoing mechanical stress, and during the process of inverse piezoelectric effect, they expand or contract when voltage is applied. The Soberton Inc. PT-2404 5.5- KHz Buzzer is an example of a piezo buzzer which utilizes this effect to create noise(Lloyd and Paetkau, 2010). In the smart garden system, a piezo buzzer serves as an actuator for the PIR sensor, It gives audible warning when the motion is detected, indicating intrusion in the garden's environment.

Fig-14: (, 2019) Piezo buzzer diagram
Available at: https://www.solarbotics.com/product/17855
(Accessed: 14 February, 2025

3.3 Circuit Design

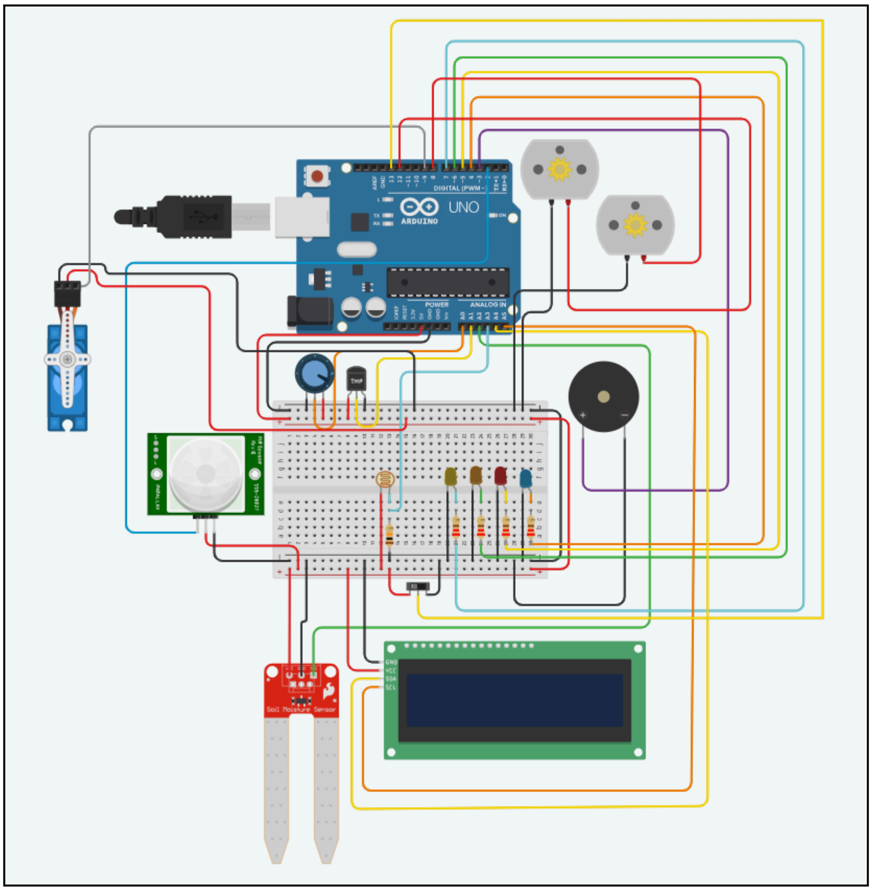

Fig-15: Circuit design of smart garden system

3.4 Block Diagram

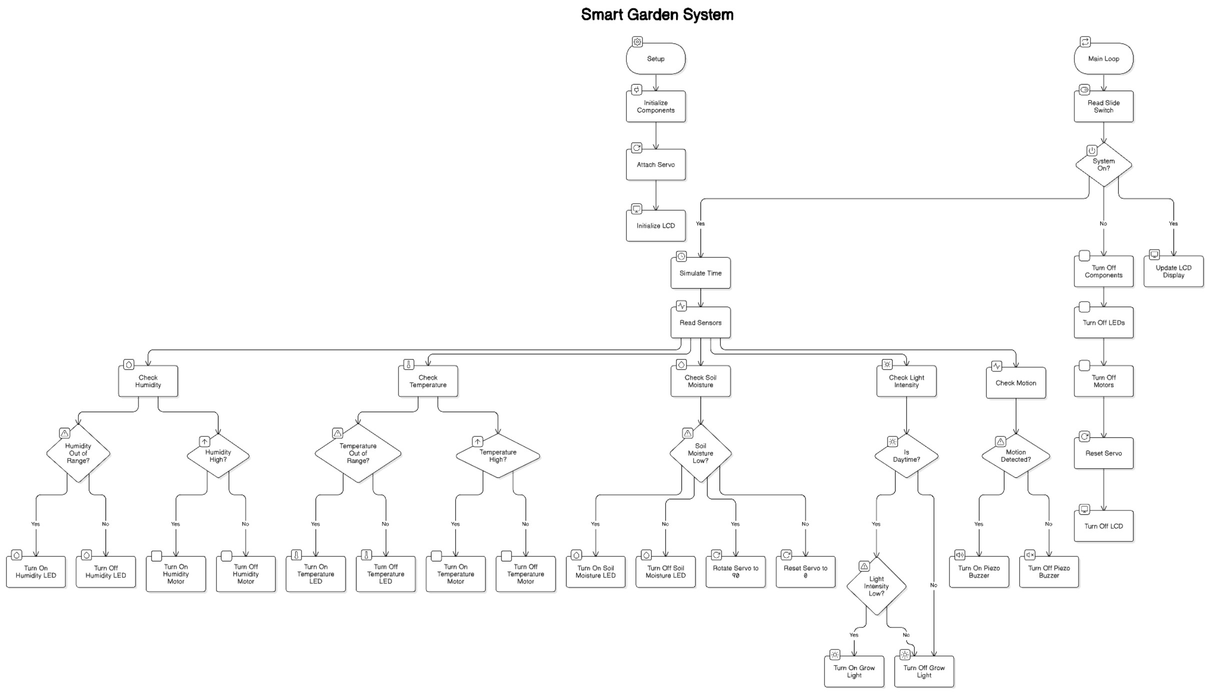

Fig-16: Block diagram of Smart Garden System

3.5 Software Development

The smart garden system's prototype was built using Tinkercad and implemented in C++. The decision to use C++ stems from its effectiveness, hardware-level control, and popularity in platforms such as Arduino(Barney, 2025). The code developed on Tinkercad enabled reception of multiple sensor inputs that include temperature, humidity, light, motion via infrared rays, and soil moisture along with the ability to respond to such inputs. These responses include adjusting the fan speed, servo motor position, LED lights, piezo buzzers, and triggering alarms. In addition, real time information was able to be displayed using the I2C LCD with the help of C++. The system behavior was diagnosed, the prototype was optimized and tested on Tinkercad. Steps were taken to ensure the smooth operation of the system.

Code Snippet

```cpp
// Humidity check and LED control
if (humidity < humLowThresh || humidity > humHighThresh) {
  digitalWrite(humLed, HIGH);
} else {
  digitalWrite(humLed, LOW);
}

// Humidity motor control
if (humidity > humHighThresh) {
  digitalWrite(humMotorPin, HIGH);
} else {
  digitalWrite(humMotorPin, LOW);
}

// Temperature check and LED control
if (temperature < tempLowThresh || temperature > tempHighThresh) {
  digitalWrite(tempLed, HIGH);
} else {
  digitalWrite(tempLed, LOW);
}

// Temperature motor control
if (temperature > tempHighThresh) {
  digitalWrite(tempMotorPin, HIGH);
} else {
  digitalWrite(tempMotorPin, LOW);
}

// Soil moisture check and servo control
if (soilMoisture < soilMoistThresh) {
  digitalWrite(soilMoistLed, HIGH);
  soilServo.write(90); // Rotate servo to 90 degrees
} else {
  digitalWrite(soilMoistLed, LOW);
  soilServo.write(0);  // Reset servo to 0 degrees
}

// Grow light control
bool isDaytime = currentHour >= dayStartHour && currentHour < dayEndHour;
if (lightValue < lightThresh && isDaytime) {
  digitalWrite(growLightLed, HIGH);
} else {
  digitalWrite(growLightLed, LOW);
}

// PIR sensor control with LED logic
if (motionDetected) {
  digitalWrite(piezoPin, HIGH);
} else {
  digitalWrite(piezoPin, LOW);
}
```

Full code is available at https://gist.github.com/Utu8848/ed1376136c19b641fd2e2223f7285429.

3.6 Truth Table

0 = False
1 = True

Name of sensor & Actuator	Condition	Slideswitch (A)	Sensor (B)	Actuator (Q)
Temperature Sensor & LED, DC Motor	If temperature is between 18 and 30 degree celsius then Sensor = 0	0	0	0
Temperature Sensor & LED, DC Motor	If temperature is not between 18 and 30 degree celsius then Sensor = 1	0	1	0
Temperature Sensor & LED, DC Motor	If temperature is between 18 and 30 degree celsius then Sensor = 0	1	0	0
Temperature Sensor & LED, DC Motor	If temperature is not between 18 and 30 degree celsius then Sensor = 1	1	1	1
Humidity Sensor & LED, DC Motor	If humidity is between 50 and 70 percent then Sensor = 0	0	0	0
Humidity Sensor & LED, DC Motor	If humidity is not between 50 and 70 percent then Sensor = 1	0	1	0

Humidity Sensor & LED, DC Motor	If humidity is between 50 and 70 percent then Sensor = 0	1	0	0
Humidity Sensor & LED, DC Motor	If humidity is not between 50 and 70 percent then Sensor = 1	1	1	1
Soil Moisture Sensor & LED, Servo Motor	If soil moisture is less than 30 percent then Sensor = 1	0	1	0
Soil Moisture Sensor & LED, Servo Motor	If soil moisture is less than 30 percent then Sensor = 1	1	1	1
Soil Moisture Sensor & LED, Servo Motor	If soil moisture is greater than 30 percent then Sensor = 0	0	0	0
Soil Moisture Sensor & LED, Servo Motor	If soil moisture is greater than 30 percent then Sensor = 0	1	0	0

PIR Sensor & Piezo Buzzer	If no motion detected Sensor = 0	0	0	0
PIR Sensor & Piezo Buzzer	If motion detected Sensor = 1	0	1	0
PIR Sensor & Piezo Buzzer	If no motion detected Sensor = 0	1	0	0
PIR Sensor & Piezo Buzzer	If motion detected Sensor = 1	1	1	1
LDR & LED	If daytime and light intensity greater than 300 Sensor = 0	0	0	0
LDR & LED	If night time and light intensity greater than 300 Sensor = 0	0	0	0

LDR & LED	If daytime and light intensity less than 300 Sensor = 1	0	1	0
LDR & LED	If night time and light intensity less than 300 Sensor = 0	0	0	0
LDR & LED	If daytime and light intensity more than 300 Sensor = 0	1	0	0
LDR & LED	If night time and light intensity more than 300 Sensor = 0	1	0	0
LDR & LED	If daytime and light intensity less than 300 Sensor = 1	1	1	1
LDR & LED	If night time and light intensity less than 300 Sensor = 0	1	0	0

Boolean expression: $Q = AB$

3.7 Logic Circuit Diagrams

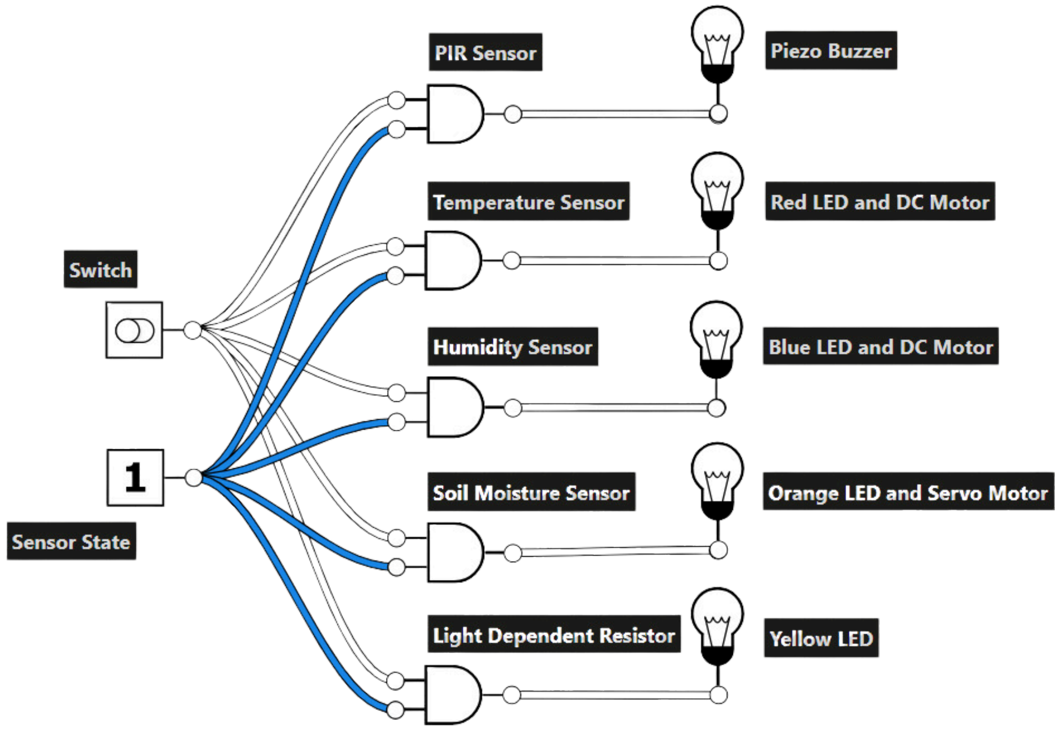

Fig-17: Logic circuit diagram showing output '0' in every actuator when switch is off '0' and sensor is on '1'

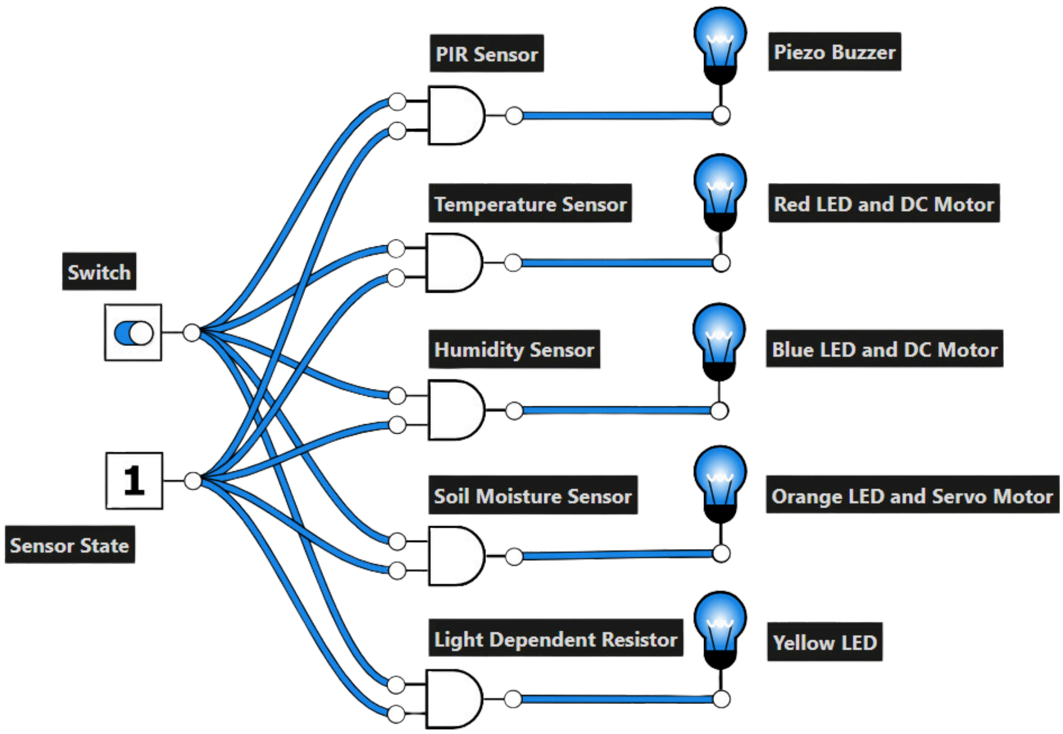

Fig-18: Logic circuit diagram showing output '1' in every actuator when switch is on '1' and sensor is on '1'

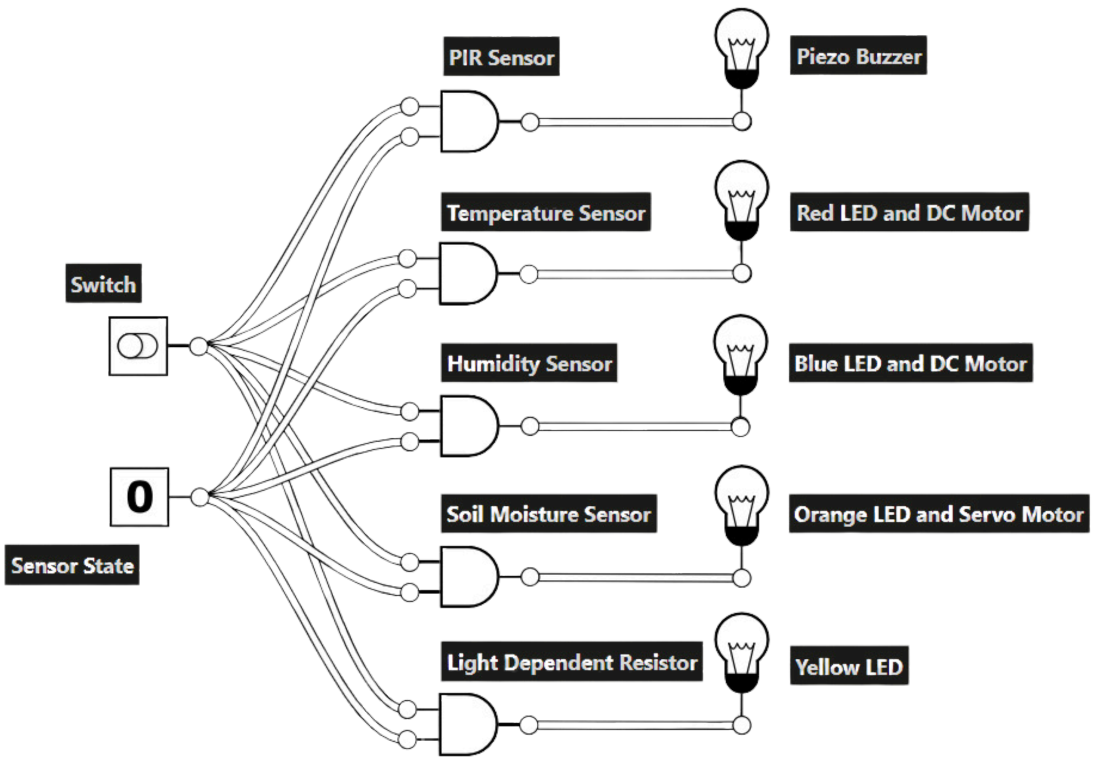

Fig-19: Logic circuit diagram showing output '0' in every actuator when switch is off '0' and sensor is off '0'

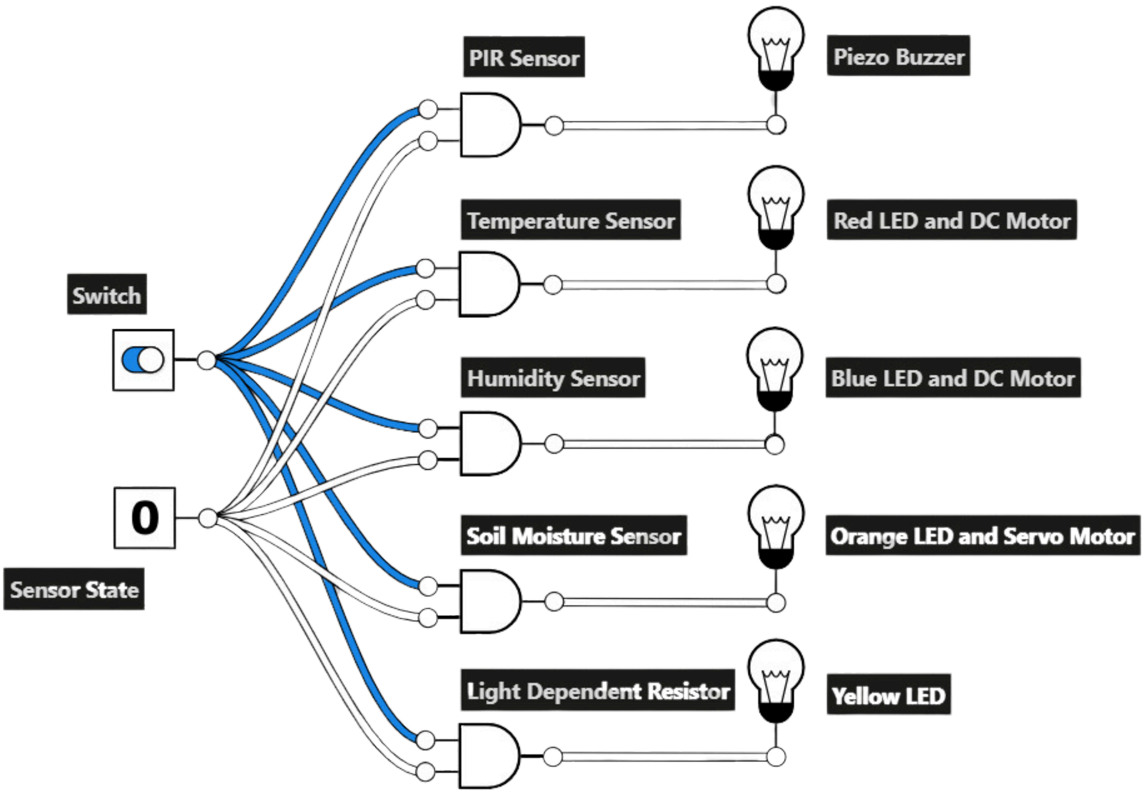

Fig-20: Logic circuit diagram showing output '0' in every actuator when switch is on '1' and sensor is off '0'

3.8 System Workflow

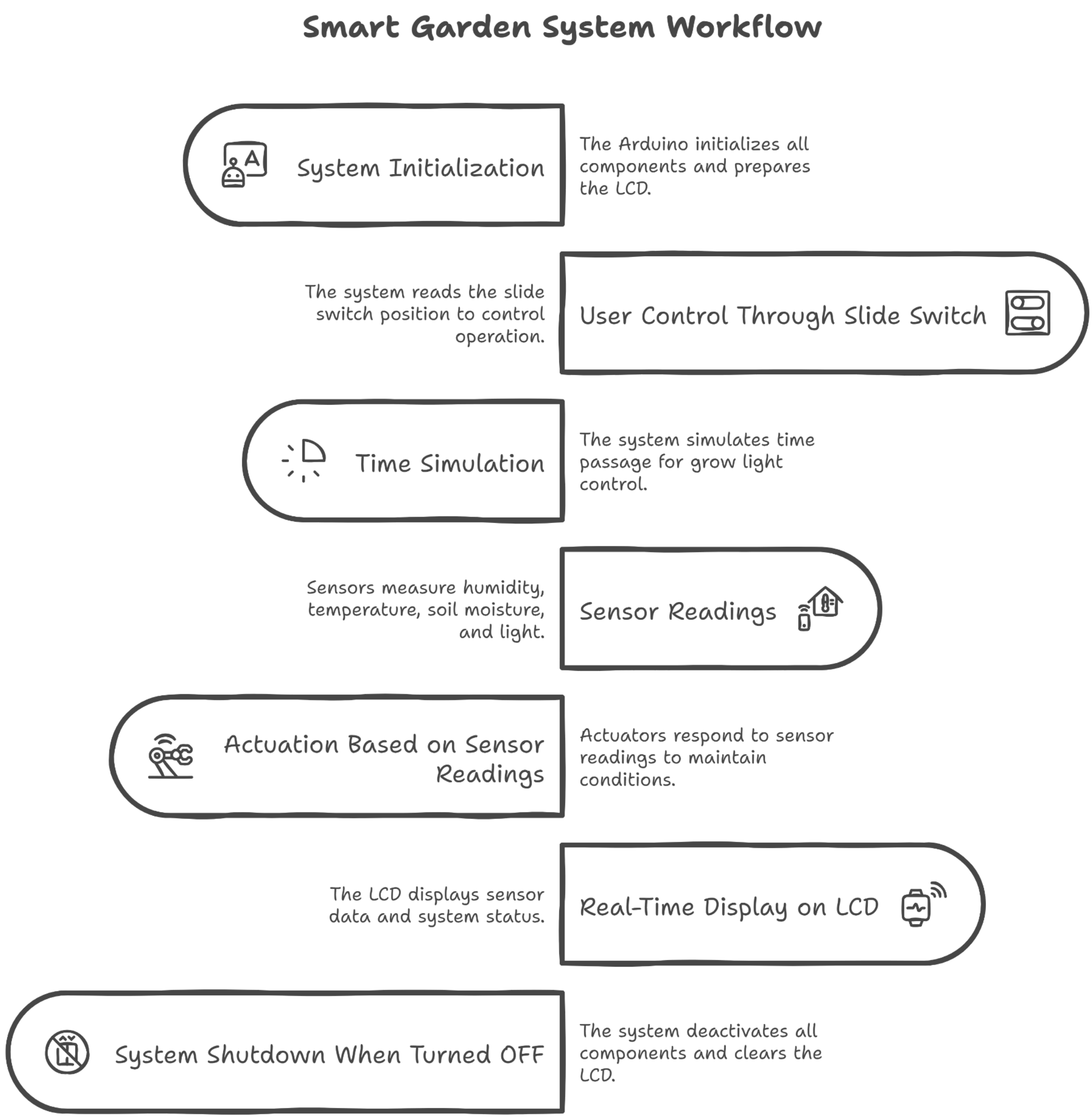

Fig-21: Diagram showing workflow of Smart Garden System

4. RESULTS

4.1 Simulation 1 Automated Soil Moisture Monitoring: Low Moisture Detection and Irrigation Activation

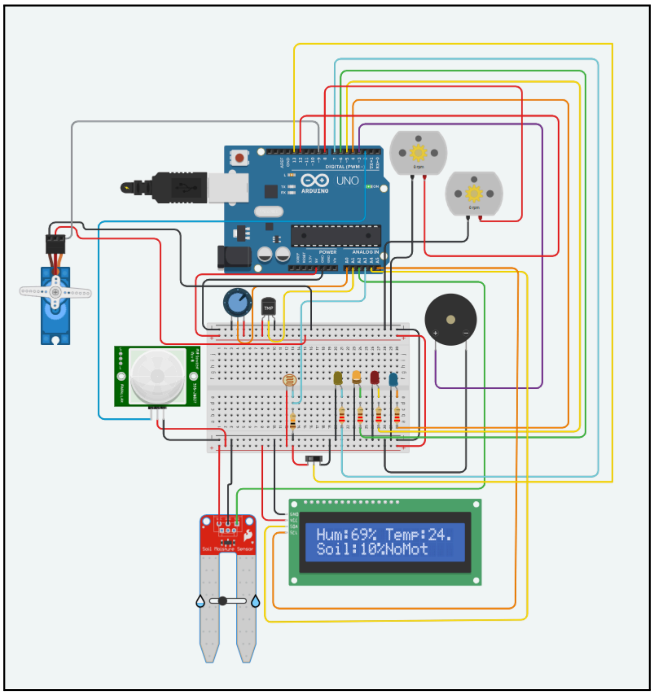

Fig-22: Automated soil moisture monitoring: Low moisture detected (<30%), activating irrigation system and orange LED(alert)

4.2 Simulation 2 Motion Detection Using PIR Sensor with Piezo Buzzer Alert Activation

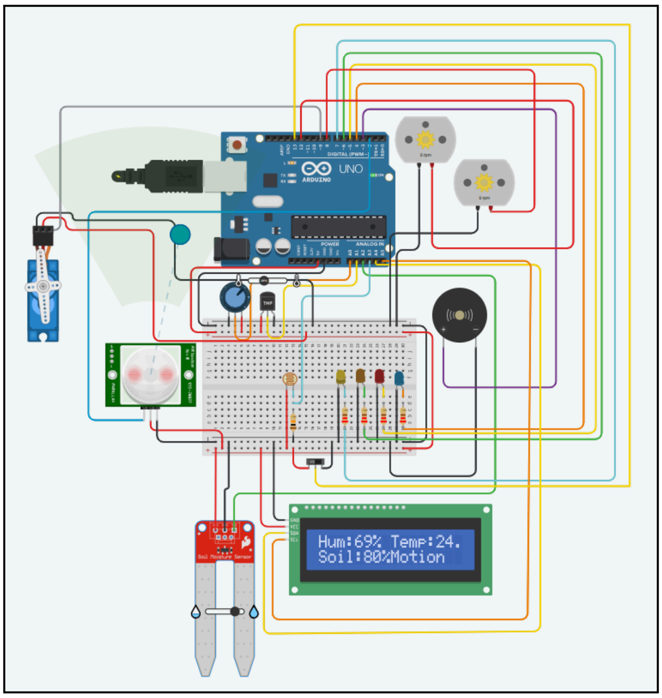

Fig-23: PIR sensor detecting motion: Piezo buzzer activated for alert

4.3 Simulation 3 Photoresistor-Based Low Light Detection: Activation of Artificial Grow Light (Yellow LED) During Daytime

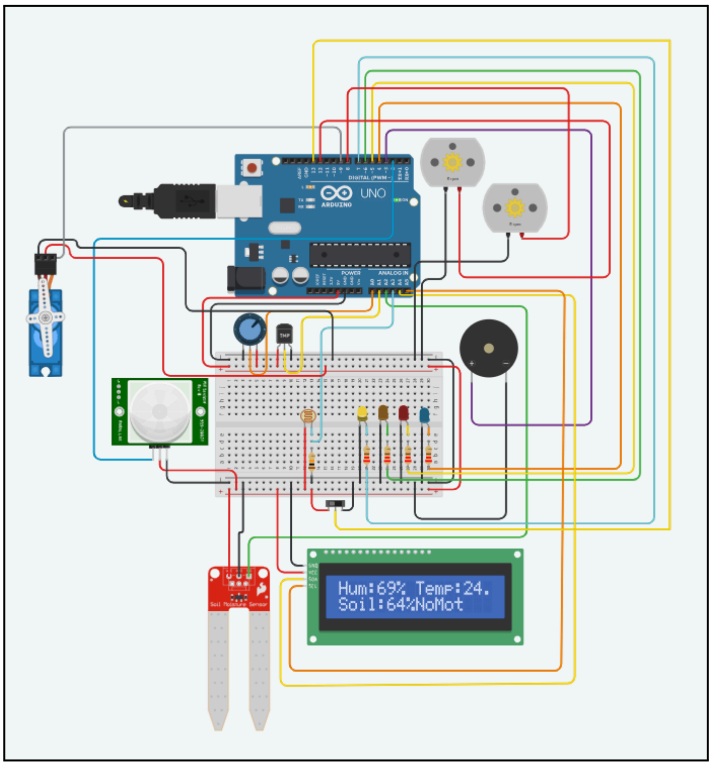

Fig-24: Photoresistor detecting low light intensity(<300): Artificial grow light(yellow LED) activated during daytime

4.4 Simulation 4 Photoresistor-Based Low Light Detection: No Activation of Artificial Grow Light (Yellow LED) During Nighttime

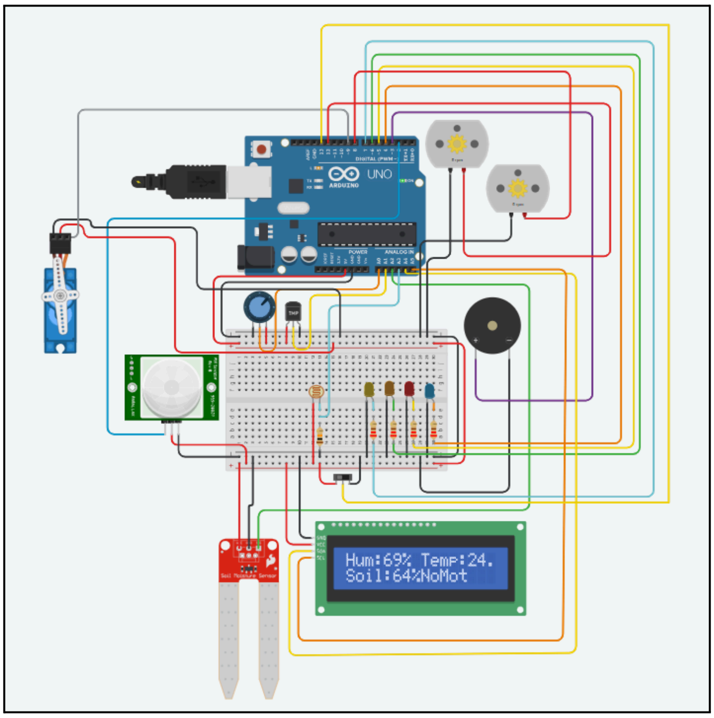

Fig-25: Photoresistor detecting low light intensity(<300): Artificial grow light(yellow LED) didn't activate during night time

4.5 Simulation 5 High Temperature Detection (>30°C): Red LED Alert and Cooling Fan Activation via DC Motor

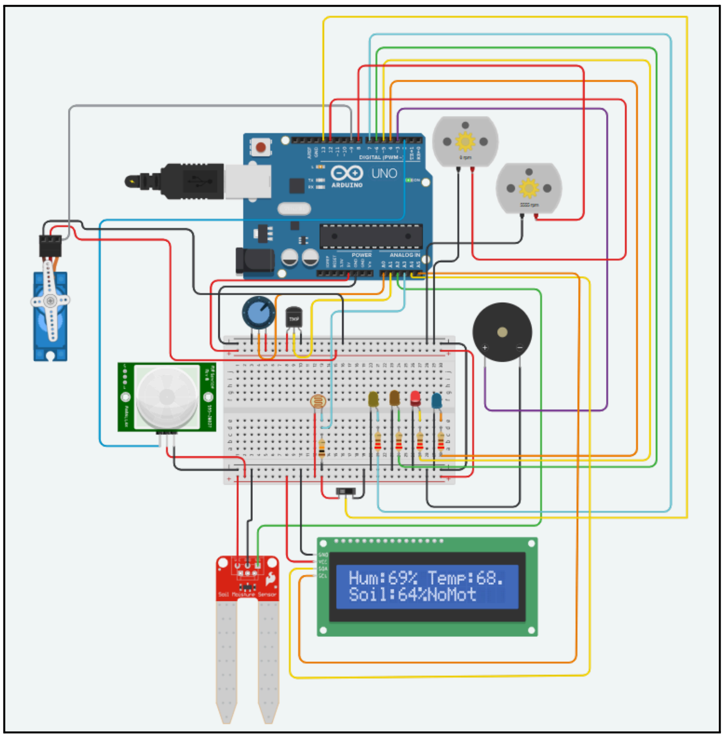

Fig-26: Temperature sensor detecting temperature >30°C: Red LED glowing(alert) and DC motor activated(cooling fan)

4.6 Simulation 6 Low Temperature Detection (<18°C): Red LED Alert Activation

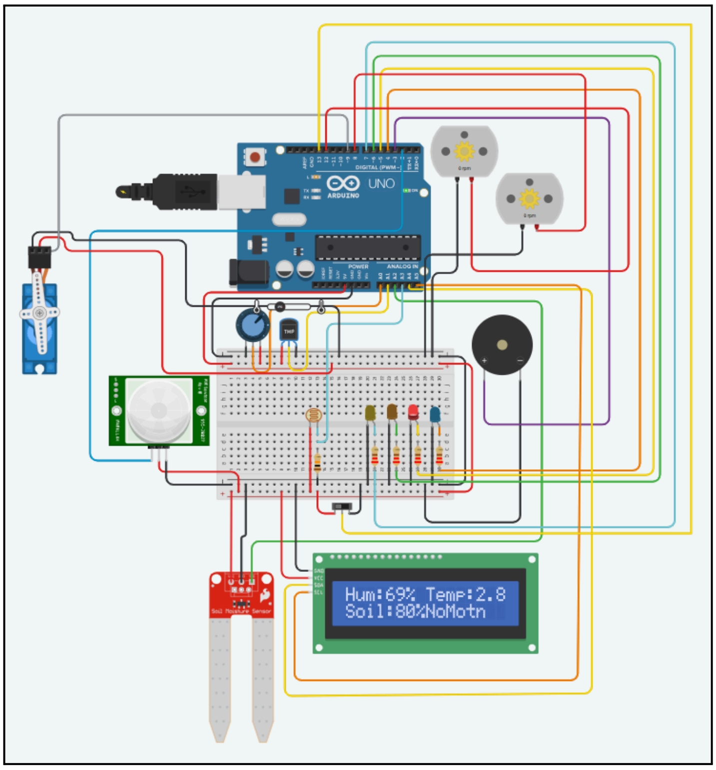

Fig-27: Temperature sensor detecting temperature <18°C: Red LED glowing(alert)

4.7 Simulation 7 Low Humidity Detection (<50%): Blue LED Alert Activation

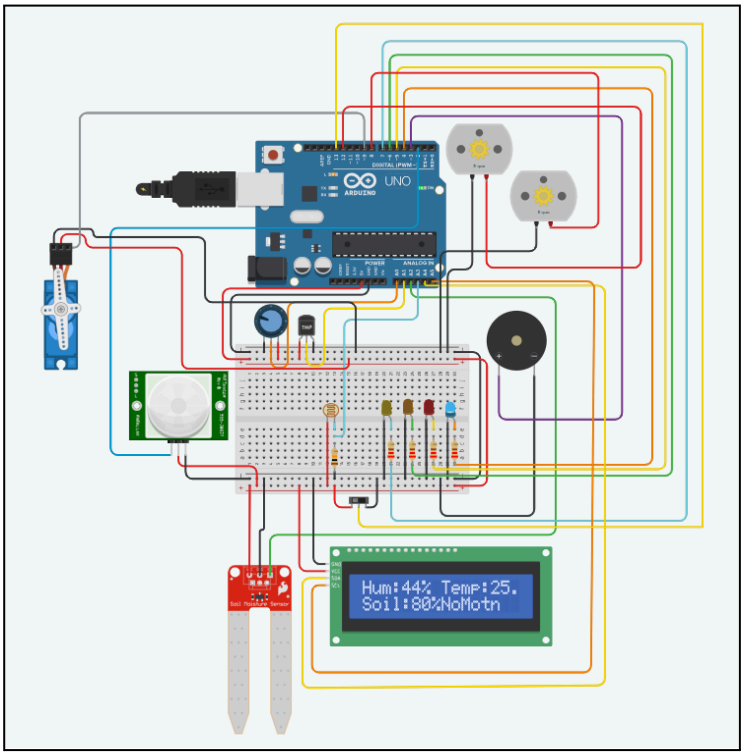

Fig-28: Humidity sensor detecting humidity <50%: Blue LED glowing(alert)

4.8 Simulation 8 High Humidity Detection (>70%): Blue LED Alert and Dehumidifier Fan Activation

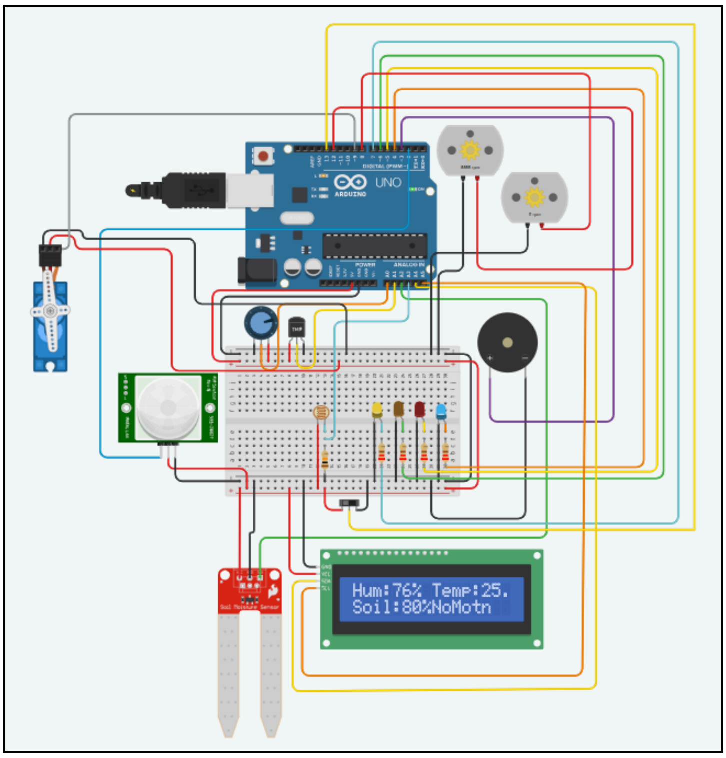

Fig-29: Humidity sensor detecting humidity >70%: Blue LED glowing(alert) and DC motor(dehumidifier fan) activated

4.9 Simulation 9 System Shutdown: Whole System Powered Off by Switch

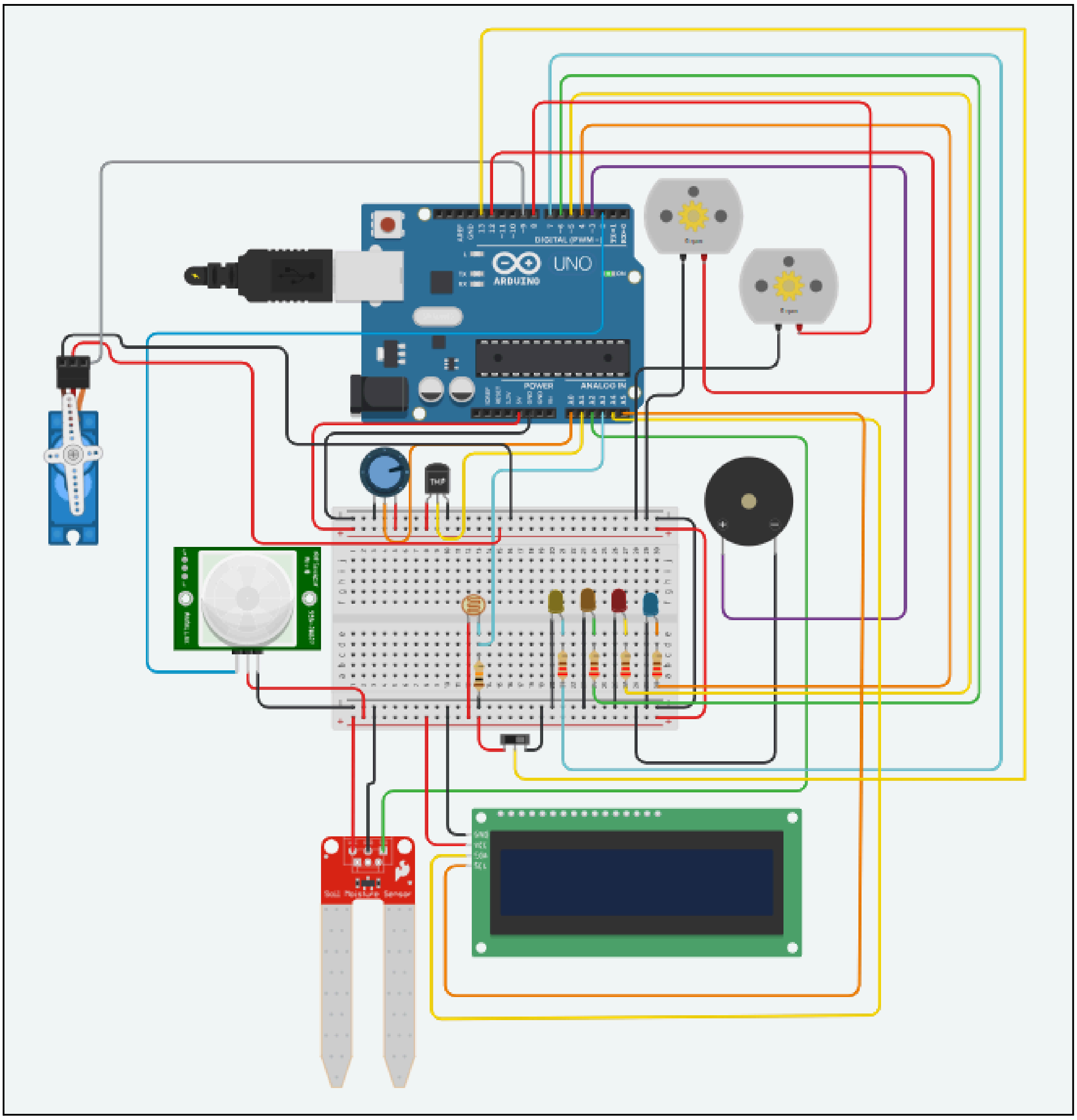

Fig-30: Switch turned off resulting shutdown of whole system

5. DISCUSSION

Building a smart garden system in Tinkercad was a great learning experience for connecting different sensors and actuators towards automating and optimizing plant care. It was intended to automate the monitoring of environmental parameters like temperature, humidity, soil moisture, and light intensity, while also automating irrigation, ventilation, and lights.

4.1 Key Findings

The smart garden system was capable of performing basic maintenance tasks automatically by taking real time readings from the sensors. This was proved in the simulation with the Tinkercad software. An Arduino Uno was used together with an I2C interface LCD to continuously track and show data. Water and ventilation could be controlled through an automated system while monitoring temperature, humidity, LDR, soil moisture, and ventilation to keep the plants inside healthy.

Devices for actuating the cooling and irrigation systems, including the DC motors, were connected to pins 8 and 12. The slide switch on pin 13 was programmed to add other functions as needed. The motors were set to operate within a temperature and humidity range to conserve energy and water.

4.2 Sustainable Development Goals (SDGs)

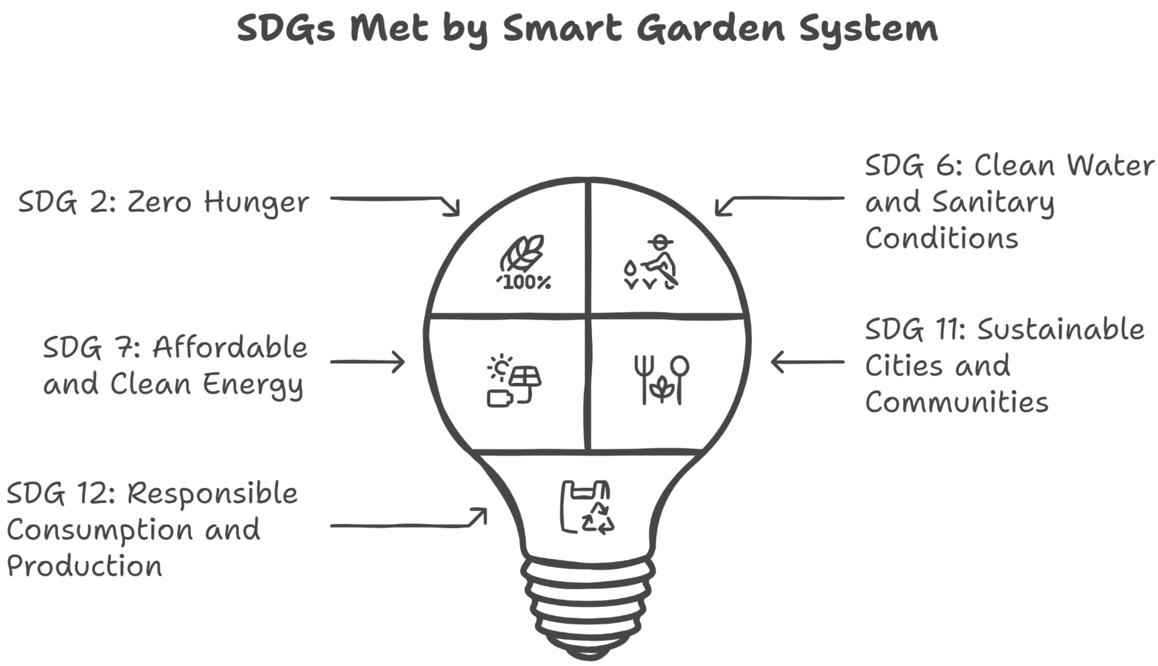

Fig-31: Diagram showing Sustainable Development Goals met by Smart Garden System
(Accessed: 14 February, 2025)

The Smart Garden System helps advance several Sustainable Development Goals set by the UN(United Nations), including:

a) **SDG 2**: Zero Hunger – Throughout the world, the potential for sustainable agriculture increases through food efficiency and optimizing plant growth.

b) **SDG 6**: Clean water and sanitary conditions – The automated irrigation system preserves water by using precise watering according to the soil moisture.

c) **SDG 7**: Affordable and Clean Energy – Uses of renewable sources, for example, solar, can be further expanded.

d) **SDG 11**: Sustainable Cities and Communities – Smart gardening spurs the creation of green belts and urban farming, planting novel ideas in city areas.

e) **SDG 12**: Responsible Consumption and Production – The modern automatic gardener enhances the responsible use of resources through the reduction of water energy waste.

4.3 Challenges Encountered

a) **Precision of the Sensor:** At the course of the simulation, erratic changes in the sensor readings were noted, which resulted in random false triggering of the actuators. This outlines an area of focus with regard to noise filtering and calibration in a real-world scenario.

b) **Weakness in Tinkercad:** Even though Tinkercad provided a good platform for the simulation of the circuit, it did not utilize real-world elements like soil varied textures, external climate conditions, or gradual sensor aging.

c) **Difficulty of Multi Sensor Interfacing:** The complications involving the use of several sensors where the smooth interaction of system elements had to be programmed and tested proved to be a demanding task, one that would require extensive refinement for actual deployment.

4.4 Security Aspects

Considering that sensor data collection and automation is included in the smart garden system, security measures need to be put in place to ensure that the system is reliable and protected against threats:

a) **Risk of Unauthorized Access** – If the system is internet enabled, or uses wireless communication, measures such as authentication and encryption of data should be employed to prevent hacking and unauthorized access.

b) **User Data Protection** – The implementation of remote access and cloud features make user data vulnerable, and therefore appropriate encryption and access control mechanisms are vital to prevent breaches.

c) **Reliability of Sensors and Their Tampering** – There is a possibility of external interference or tampering of the sensors. Employing redundancy checks and calibration mechanisms along with anomaly detection increases data integrity while enhancing system reliability.

d) **Control Security of The Power Supply** – Providing an uninterrupted power supply together with alternative options like battery or solar power can avoid failure of the system due to power outages or attempts of sabotaging the system.

e) **Control Security of The Firmware and Software** – Failure to do regular updates and using poor security policies can make the firmware and software parts of the system vulnerable.

4.5 Efficiency of the Prototype

The obstacles faced were challenging, yet the smart garden prototype was able to showcase the possibility of automated self caring plants. The system was able to react to variations of environmental conditions which proved that IoT based automation could aid in efficient and sustainable gardening. C++ was used in the programming of the Arduino, so the operations of the system could be controlled with the utmost precision. This way, the motors and relay were activated only when absolutely required.

In real world applications, the application of wireless communication, cloud data storage, and machine learning based features could help the system work more efficiently. Further, on testing with real components, the results obtained from the simulation would have to be verified and improved in order to make the system suitable for use.

4.6 Future Considerations

a) **Linking with Mobile or Web Applications** - Allowing users to monitor and control devices remotely in order to improve their experience.
b) **Using Clean Energy** – Using solar energy where possible to increase self sufficiency while decreasing the use of clean electricity.
c) **Expansion of Wireless Communication and IoT** – Incorporation of Wi-Fi or Bluetooth modules to allow real-time data transfer and access from virtually anywhere.
d) **Cloud-based Data Metrology** – Backing up historical data to study planting trends and improve plant care based on previous conditions.
e) **Applying Machine Learning** – Using AI algorithms to more accurately forecast the needs of watering and applying environmental control.
f) **Testing in Real-life Conditions** – Moving from simulation to the actual placement in order to check performance in the real world.
g) **Ability to Expand to Bigger Application Fields** – Adapting the system for use in commercial agriculture and greenhouse automation.

6. CONCLUSION

The intelligent garden system that was created in Tinkercad managed to prove the practicality of unattended automated plant care that incorporated sensors, actuators, and microcontrollers. By observing and reacting to set environmental conditions, the system defined a new way of gardening that is eco-friendly in terms of water and energy consumption. The discussion analyzed major findings, possible errors, security issues, and the need for protection at the system optimization level in the real world.

This project is beneficial in areas relevant to resource efficiency, agriculture, and urban gardening because it supports many Sustainable Development Goals (SDGs). Other possible modifications, such as data clouding, remote interfaces, and machine learning applications, could provide system efficiency and scalability.

This project creates a pathway for more complex projects to be further developed, solving the imbalance of IoT technology and sustainable gardening techniques. Going ahead, it will be important to test the system in real conditions instead of a simulated environment to determine its efficiency, concept, and accuracy.

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