<u>IoT-Based EC Monitoring & Controlling System For Hydroponics</u>

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IoT Project 2024

THAPAR INSTITUTE

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CERTIFICATE

This is to certify that the Project titled "**IoT-Based EC Monitoring & Controlling System For Hydroponics**" has been successfully designed and implemented as a part of the course "**IoT-based Systems"** at Thapar Institute of Engineering and Technology, Patiala, Punjab under the valuable guidance of **Dr. Amit Munjal**. The project demonstrates proficiency in IoT technology and showcases innovative solutions for water Hydroponics.

ACKNOWLEDGEMENT

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ABSTRACT

Hydroponics offers a controlled environment for plant growth, but manually monitoring and adjusting factors like nutrient levels (Electrical Conductivity or EC) can be labor-intensive. This report explores how the Internet of Things (IoT) can revolutionize hydroponics by enabling real-time monitoring and automated control. By leveraging IoT technology, the system facilitates seamless communication between sensors, microcontrollers, and user interfaces. Water level sensors are strategically placed within tanks or reservoirs to continuously measure water levels.

We propose an integrated IoT framework that utilizes pH sensors, EC sensors, and TDS sensors to continuously monitor crucial plant growth parameters. The data collected by these sensors is transmitted wirelessly to the Arduino controller board, which serves as the central processing unit. Through the Console Output, users can visualize water level analytics, receive alerts, and remotely control the system to maintain desired water levels. This abstract encapsulates the essence of the project, highlighting its innovative approach to water management.

INTRODUCTION

Tending crops and vegetables, especially in hydroponic systems, presents unique challenges. The success or failure of yields depends on various factors and external conditions. Traditionally, yield quality assessment relied on manual observations and measurements, which proved ineffective and insufficient. In today's information-rich era, accurate data collection and presentation are crucial for maintaining the integrity of farming systems.

Smart farming, driven by technological advancements and globalization, integrates data and information technologies into machinery, equipment, and sensors for horticultural stock systems. Hydroponics, often considered the future of agriculture, allows for creative cultivation methods. Automated hydroponic farms, equipped with sensors and actuators, produce higher-quality crops by precisely monitoring and controlling parameters such as water level, pH, electrical conductivity, water temperature, and relative humidity.

In this Report, we propose an automated system for hydroponic farming. Our objective is to streamline crop monitoring throughout the growth process using a network of sensors and actuators. By implementing decision-making algorithms and messaging systems, we manage real-world issues efficiently. Test results demonstrate minimal variations in sensor states, enabling effective automated control. Our work leverages data from legacy sensors, transferring it to a centralized database via remote protocols. The system provides timely feedback to farmers regarding nutrient values and other critical factors, ultimately leading to informed decisions.

What Is Hydroponics?

Hydroponics is an advanced horticultural method where plants are cultivated in a soilless environment. This agronomic innovation leverages aqueous solutions enriched with essential mineral nutrients, facilitating plant growth through direct nutrient absorption by the roots. The term hydroponics originates from the Greek words 'hydro' (water) and 'ponos' (labor), reflecting the technique's reliance on water as the primary medium for plant sustenance.

In hydroponic systems, plants are supported by inert substrates such as perlite, rockwool, or clay pellets, which provide physical stability while allowing the roots to access the nutrient solution. This method circumvents the need for soil, which traditionally acts as a reservoir for water and nutrients. Instead, hydroponics delivers these vital elements directly to the plant roots in a controlled manner, optimizing growth conditions and resource utilization.

The nutrient solution, a meticulously balanced mix of water and fertilizers, contains the necessary macro and micronutrients in precise proportions. These include nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements essential for plant development. The solution's composition is tailored to the specific requirements of the plants being cultivated, ensuring optimal growth rates and yields.

Hydroponics offers several advantages over conventional soil-based agriculture. It allows for higher density planting and increased productivity per unit area, as the reduced root system size enables closer spacing of plants. Moreover, it facilitates faster plant growth and can yield crops multiple times greater than traditional methods. The controlled environment also minimizes the occurrence of soil-borne diseases and pests, reducing the need for pesticides.

This soilless cultivation method is particularly advantageous in environments where arable land is scarce or soil quality is poor. Hydroponics is also a cornerstone for sustainable urban agriculture, enabling food production in metropolitan areas with limited space. Additionally, it holds promise for extraterrestrial agriculture, as demonstrated by research conducted by space agencies like NASA, where hydroponics could support human colonization efforts by enabling food production in space.

In summary, hydroponics represents a sophisticated and ecologically sound approach to modern agriculture, harnessing the principles of plant physiology and nutrient dynamics to create highly efficient, soil-free farming systems.

LITERATURE REVIEW

The principal limitation of hydroponic systems is the financial outlay, which surpasses that of traditional soil-based agriculture due to the requisite infrastructure for soilless cultivation, inclusive of monitoring and control apparatus, as well as the technical acumen necessary for effective operation. Moreover, these systems necessitate vigilant oversight; for instance, aqua-cultured pathogens can proliferate swiftly, and manual intervention is imperative during electrical failures. Nonetheless, these concerns are relatively minor when juxtaposed with large-scale agricultural production.

Recent advancements in agricultural technology have been significant, with hydroponic farming emerging as a notable method for crop cultivation in a soil-free environment, utilizing nutrient-fortified aqueous solutions. Despite its myriad advantages, hydroponic agriculture entails more intricate processes compared to traditional farming, with an elevated risk of system failure due to the interplay of multiple growth factors.

Empirical evidence indicates that sensor calibration and definition adhere to established standards. The deployment of straightforward mechanisms facilitates regulated irrigation and nutrient solution delivery. Data acquisition from sensors, coupled with cloud-based computational technology, underpins this methodology.

Hydroponics, the practice of cultivating plants sans soil, ensures the provision of essential nutrients directly from an aqueous solution. Various hydroponic modalities exist:

Aeroponic Systems: These require minimal nutrients and air exposure. Plants are positioned on a tray above a nutrient solution, with roots suspended in the air and periodically misted with nutrient-laden water, controlled by a timer-regulated pump. This approach is viable primarily for substantial economic ventures due to its complex installation and maintenance requirements.

Drip Systems: Nutrient-rich water is conveyed through diminutive conduits, dripping onto the plant crowns, with a timer governing the submersible pump.

Ebb and Flow Systems: Plant support trays are transiently flooded with a nutrient solution, which subsequently recedes into a reservoir. A timer-activated submersible pump orchestrates this inundation and drainage cycle multiple times daily, utilizing perlite or gravel for plant stability. This system is amenable to domestic applications.

Nutrient Film Technique (NFT) Systems: In NFT systems, plants reside in small molded baskets within a tray, their roots extending into a nutrient solution. The design ensures a continuous flow of nutrient solution over the tray, directly above the plant roots. Subsequently, the solution drains back into a reservoir. This method is particularly suitable for crops such as tomatoes and cucumbers.

Water Culture Systems: In water culture systems, a Styrofoam platform supports plants, immersing their roots in nutrient-rich water. An air pump supplies oxygen to a bubbling rock, facilitating nutrient solution release and root oxygenation. This approach is best suited for specific plant varieties, such as leaf lettuce.

Wick Systems: The wick system operates without moving parts. Growing mediums like perlite or rock wool are placed in the tray. A nutrient solution is gradually released into the tray through wicks. The primary advantage of this method lies in its simplicity—it requires no timers or pumps.

METHODOLOGY

Hardware Setup:

- **Arduino Uno Controller Board:** This microcontroller board is chosen for its compatibility with IoT applications and its ability to connect to Wi-Fi networks, enabling seamless data transmission.
- **pH Sensors:** A pH sensor is a scientific instrument that measures the hydrogen-ion activity in water-based solutions, indicating its acidity or alkalinity expressed as pH. The sensor uses a glass electrode to measure the concentration of hydrogen ions in the solution. A reference electrode is also used in conjunction with the glass electrode to provide a stable baseline or reference for the measurement.

- **TDS Module:** A Total Dissolved Solids (TDS) module measures the total ions present in a solution, commonly water. It is an indicator of water quality. The TDS module typically includes a sensor that measures the conductivity of the water, which can be converted into TDS values, indicating the concentration of dissolved solids in parts per million (ppm).

- **Relay Module:** The relay module acts as a switch to control the water pump based on the water level readings. It is triggered by the ESP8266 board.
- **Water Pumps:** Water pumps are devices that move water from one location to another. They are used in various settings, including residential, commercial, and industrial. Pumps can be submersible, centrifugal, or diaphragm types and are selected based on the application needs. They are essential for ensuring the supply of water for various uses.

- **Power Supply:** A stable power supply is essential to ensure the continuous operation of the system components.

Software Implementation:

- **Arduino IDE:** The Arduino Integrated Development Environment (IDE) is utilized for programming the Arduino Uno controller board. It provides a user-friendly platform for writing and uploading code.

- **Relay Module:** A relay module is an electronic device that functions as a switch. It uses a low-power control signal to activate a circuit that can handle much higher power.

- **TDS Module:** A TDS (Total Dissolved Solids) meter is an instrument used to measure the total amount of dissolved solids (including both organic and inorganic substances) in a liquid.

System Operation:

❖ **Data Acquisition:** The data acquisition process involves collecting real-time data from the physical environment. In your hydroponic system:

→The **pH sensor** measures the acidity or alkalinity of the nutrient solution.

→The **TDS module** assesses the total dissolved solids in the water, which indicates the concentration of nutrients.

→ Both sensors send their readings to the Arduino Uno, which acts as the central processing unit.

❖ **Data Processing:** Once the data is acquired, the Arduino Uno processes it:

→ The microcontroller reads the analog signals from the pH sensor and TDS module, which are then converted into digital values using the onboard Analog-to-Digital Converter (ADC).

→ The Arduino runs a program (sketch) that interprets these values to determine if the nutrient solution's pH and TDS levels are within the desired range for optimal plant growth.

- **User Interaction:** User interaction with the hydroponic system can take various forms:

  → **Monitoring**: The user can monitor the current pH and TDS readings through a connected display or by sending the data to a computer or smartphone.

  → **Adjustments**: If the readings are outside the desired range, the user can manually adjust the nutrient solution by adding more water or nutrients.

  → **Automation**: The system can be programmed to automatically adjust the levels by controlling the relay module, which in turn can switch the water pumps on or off to add water or nutrients.

WORKING

1. **Power On** :The system is powered on. The power supply provides the necessary electrical energy to the Arduino Uno, sensors, relay module, and water pumps.

2. **Initialization**: The Arduino Uno initializes the connected sensors (pH sensor and TDS module) and the relay module during its setup routine.

3. **Data Acquisition**:

- The pH sensor measures the pH level of the nutrient solution and sends an analog signal representing this value to the Arduino.

- The TDS module measures the electrical conductivity of the nutrient solution, which correlates to the total dissolved solids and sends this data to the Arduino.

4. **Data Conversion**: The Arduino Uno converts the analog signals from the sensors into digital values using its onboard Analog-to-Digital Converter (ADC).

5. **Data Processing**:

- The Arduino Uno processes the digital data to determine the current state of the nutrient solution.

- It compares the pH and TDS readings against the predefined optimal ranges for the plants being grown.

6.**Decision Making**:

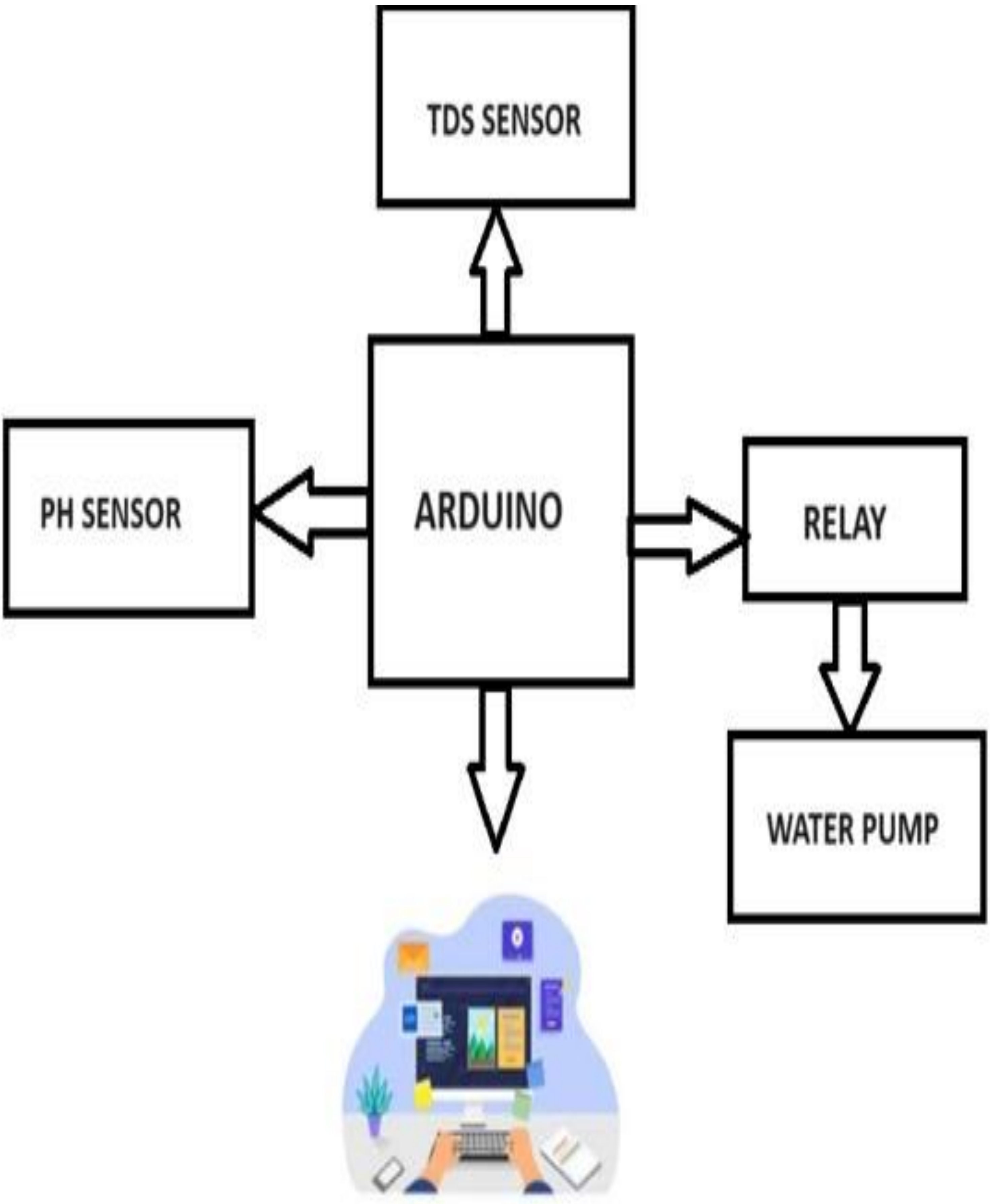
- If the readings are within the optimal range, the system continues to monitor without any changes.

- If adjustments are needed, the Arduino determines the appropriate action, such as adding more water to dilute the solution or adding nutrients to increase the TDS.

7.**Actuation**: change in the nutrient solution is required.

- The relay module, acting as an electrically operated switch, powers the water pumps on or off based on the signal from the Arduino.

BLOCK DIAGRAM:


TDS SENSOR
PH SENSOR
ARDUINO
RELAY
WATER PUMP

8.**Nutrient Adjustment**:

- The water pumps add fresh water or nutrient solution to the hydroponic system to adjust the pH and TDS levels.

- The system may also include peristaltic pumps for dosing specific nutrients if required.

9.**Feedback Loop**:

- After the adjustments, the sensors take new readings of the nutrient solution.

- These readings are sent back to the Arduino, creating a feedback loop that ensures the nutrient solution remains within the optimal range.

10.**User Interaction**:

- The system can provide real-time data to the user via a connected display or through a web interface.

- The user can interact with the system by setting thresholds, viewing logs, or manually overriding automated functions.

11.**Continuous Monitoring**:

- The Arduino continuously monitors the sensor readings and maintains the nutrient solution within the desired parameters.

- This process repeats, ensuring that the plants receive the optimal conditions for growth throughout their lifecycle.

MODELLING AND CODE ANALYSIS

CODE:

```
#define PH_SENSOR_PIN A0    // Analog pin connected to the pH sensor

#define TDS_SENSOR_PIN A1   // Analog pin connected to the TDS sensor

#define RELAY1_PIN 2        // Digital pin connected to relay 1

#define RELAY2_PIN 3        // Digital pin connected to relay 2

#define PH_THRESHOLD 7.0    // pH threshold value

void setup() {

  Serial.begin(9600);     // Initialize serial communication

  pinMode(RELAY1_PIN, OUTPUT); // Set relay 1 pin as output

  pinMode(RELAY2_PIN, OUTPUT); // Set relay 2 pin as output

}

void loop() {

  float pHValue = getPH(); // Read pH value

  float tdsValue = getTDS(); // Read TDS value

  Serial.print("pH Value: ");

  Serial.println(pHValue);

  Serial.print("TDS Value: ");
```

```
  Serial.println(tdsValue);

  if (pHValue < PH_THRESHOLD) {

    digitalWrite(RELAY1_PIN, HIGH); // Turn on relay 1

    digitalWrite(RELAY2_PIN, LOW);  // Turn off relay 2

  } else {

    digitalWrite(RELAY1_PIN, LOW);  // Turn off relay 1

    digitalWrite(RELAY2_PIN, HIGH); // Turn on relay 2

  }

  delay(1000); // Delay before next reading

}

float getPH() {

  int sensorValue = analogRead(PH_SENSOR_PIN); // Read the analog value from
pH sensor

  float voltage = sensorValue * (5.0 / 1024.0); // Convert to voltage (0-5V)

  float pHValue = 10 - voltage; // Convert voltage to pH value

  return pHValue;

}

float getTDS() {
```

int sensorValue = analogRead(TDS_SENSOR_PIN); // Read the analog value from TDS sensor

// Convert analog value to TDS value

float tdsValue = sensorValue * 500.0 / 1024.0; // Assuming TDS sensor provides linear output

return tdsValue;

}

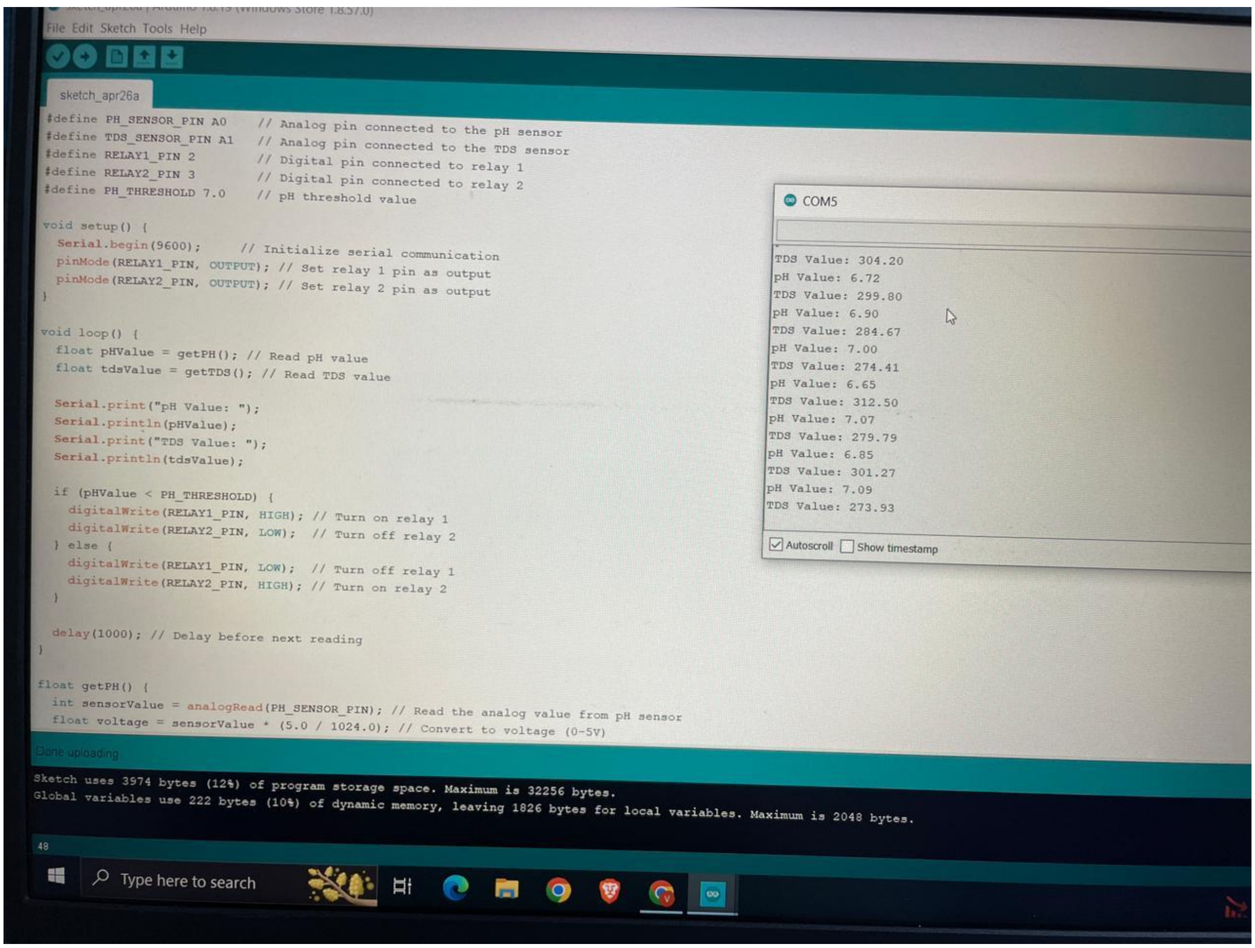


FIGURE 3: CODE SNIPPET

OUTPUT:

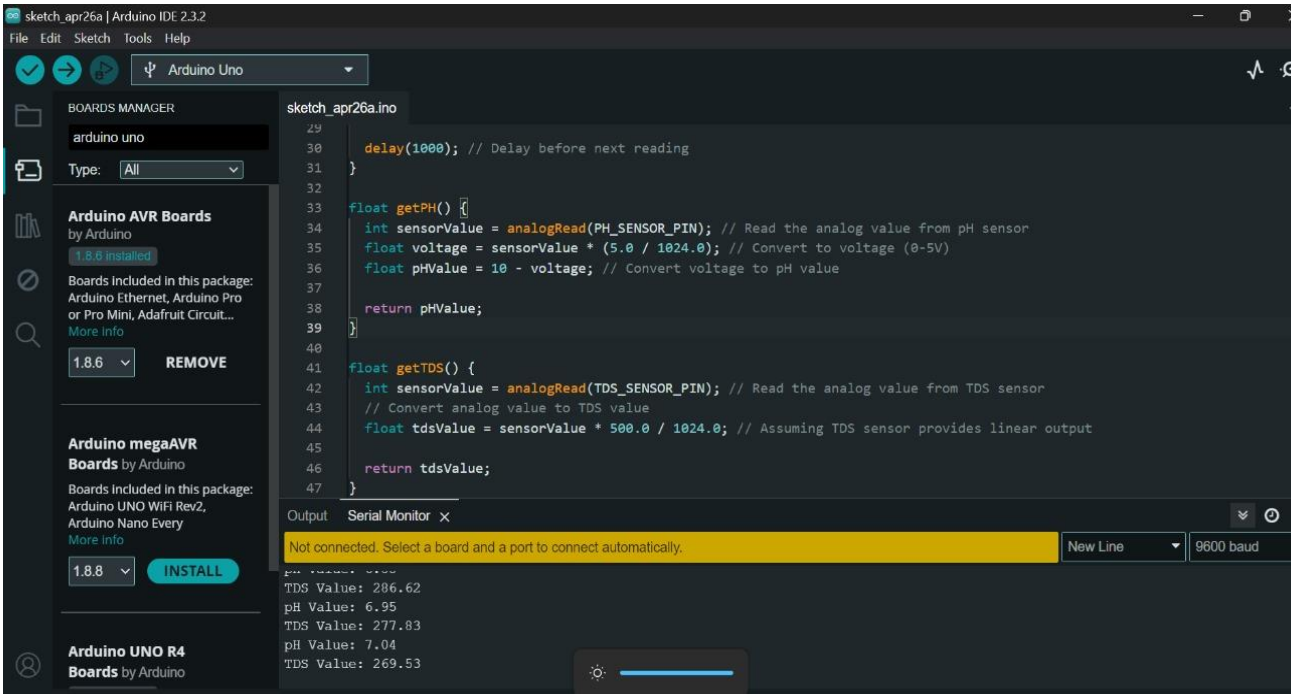


FIGURE 4: CODE SNIPPET

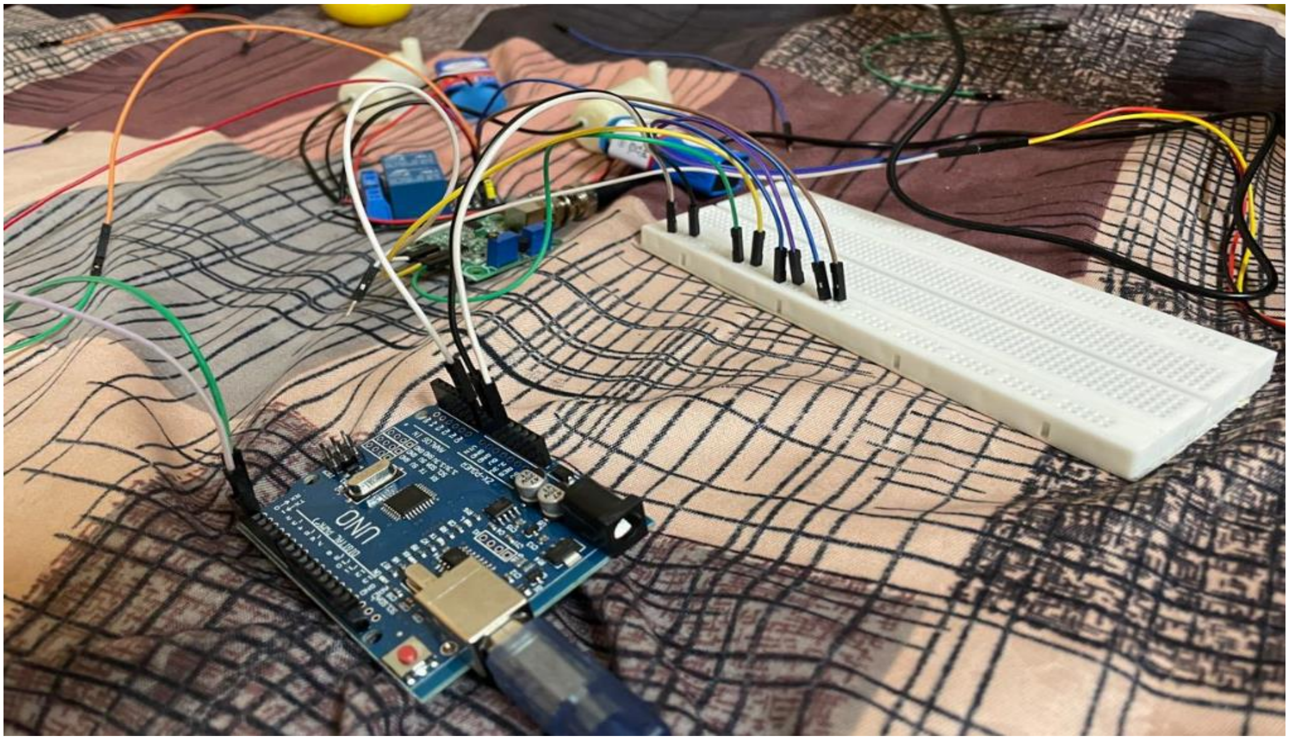


FIGURE 5: SETUP

Conclusion

The integration of an Arduino Uno controller board with pH sensors, TDS modules, relay modules, and water pumps forms the backbone of a sophisticated hydroponic system. This system exemplifies the convergence of technology and agriculture, paving the way for precision farming. Through meticulous data acquisition and processing, the system ensures optimal growth conditions by continuously monitoring and adjusting the nutrient solution's pH and TDS levels. User interaction is streamlined through real-time data feedback, allowing for both monitoring and manual intervention when necessary. The automation of nutrient adjustment via relay-controlled water pumps significantly enhances the efficiency and effectiveness of the hydroponic setup. This project not only demonstrates the potential for increased agricultural productivity but also highlights the importance of sustainable practices in urban farming environments. The successful operation of such a system could lead to advancements in food production, particularly in areas where traditional farming is challenged by environmental constraints. Overall, this hydroponic module stands as a testament to the innovative application of technology in modern agriculture.

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