Automated Hydroponic System

DETAILED PROJECT REPORT

HYDROPONIC CULTIVATION

Submitted on : 25-02-2025

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Course Name : Human Computer Interaction

Course Code : CSC 317 1.5

Introduction

Hydroponics is an innovative method of growing plants without soil, using nutrient-rich water solutions instead. This technique has gained significant attention in recent years due to its ability to conserve water, reduce land usage, and produce higher yields compared to traditional farming methods. However, maintaining optimal conditions for plant growth in hydroponic systems can be challenging, requiring precise control over factors such as pH levels, nutrient concentration (measured in parts per million, or ppm), water temperature, air humidity, and lighting schedules.

To address these challenges, we developed the **Automated Hydroponic System Tower** to grow plants indoor with using low space, a smart and scalable solution that integrates advanced sensors, actuators, and software to monitor and regulate the environmental parameters essential for plant growth. The system not only automates critical processes but also provides real-time monitoring and remote-control capabilities through a webbased interface. This project aims to demonstrate how modern technology can enhance the efficiency, sustainability, and accessibility of hydroponic farming.

The Automated Hydroponic System Tower is designed to cater to both hobbyists and commercial growers, offering a user-friendly platform for managing hydroponic systems. By leveraging Internet of Things (IoT) technologies, this system ensures that plants always receive the ideal growing conditions, thereby maximizing yield and minimizing resource consumption.

Objectives

The primary objectives of this project are:

1. **Automation of Hydroponic Processes:**
    a. Automate the regulation of key parameters such as pH, TDS (Total Dissolved Solids), water level, temperature, humidity, and lighting.
    b. Minimize manual intervention by enabling the system to self-adjust based on sensor data.
2. **Optimization of Plant Growth Conditions:**
    a. Maintain optimal pH levels (typically between 5.5 and 6.5 for most hydroponic crops).
    b. Ensure consistent nutrient delivery by monitoring and adjusting TDS levels.
    c. Regulate water temperature and air humidity to create an ideal microclimate for plant growth.

3. **Remote Monitoring and Control:**
    a. Develop a web application that allows users to monitor sensor data and control system components remotely.
    b. Enable real-time alerts for critical events, such as low water levels or abnormal pH values.
4. **Resource Efficiency and Sustainability:**
    a. Conserve water and nutrients by implementing precise control mechanisms.
    b. Reduce energy consumption by optimizing the operation of pumps, lights, and other components.
5. **Scalability and Modularity:**
    a. Design the system to be modular, allowing users to expand it by adding more towers or sensors.
    b. Ensure compatibility with a wide range of plants and growing environments.

Design and Implementation

Hardware Design

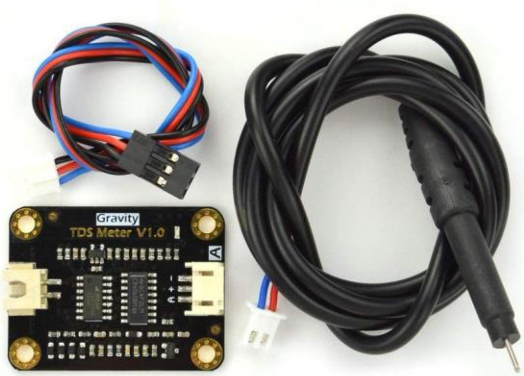
The hardware design of the Automated Hydroponic System Tower is composed of several interconnected components, each serving a specific function in the overall system. Below is a detailed breakdown of the hardware architecture:

1. **Sensors:**
    a. **pH Sensor:** Measures the acidity or alkalinity of the nutrient solution. The sensor outputs analog signals that are converted into digital values by the

microcontroller. A pH range of 5.5–6.5 is typically maintained for hydroponic crops.

b. **Ultrasonic Sensor:** Monitors the water level in the reservoir. It uses sound waves to measure the distance between the sensor and the water surface, providing real-time feedback on water availability.

c. **TDS Sensor:** Measures the concentration of dissolved solids in the nutrient solution, expressed in parts per million (ppm). This helps ensure that plants receive adequate nutrients.



d. **DS18B20 Temperature Probe:** Provides accurate readings of the nutrient solution's temperature. Maintaining the correct temperature is crucial for nutrient uptake and root health.
e. **DHT11 Humidity/Temperature Sensor:** Monitors ambient air temperature and humidity. These parameters influence transpiration rates and overall plant health.

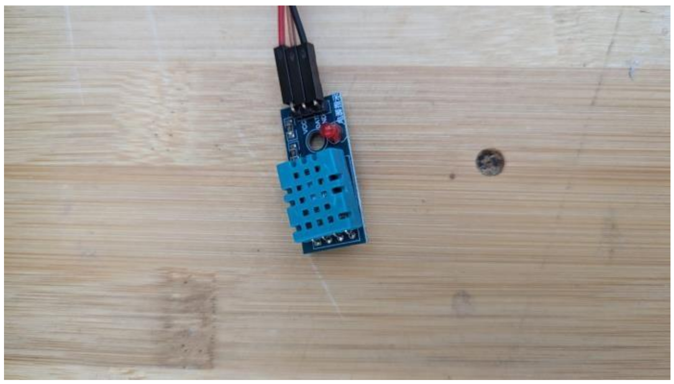


Figure – Humidity Sensor

Figure – Temperature Sensor

2. **Actuators:**
   a. **Relay Module:** Controls six key components:
      i. **Water Pump:** Circulates nutrient solution throughout the system.

      ii. **pH-Up Motor:** Adds alkaline compounds to increase pH when necessary.
      iii. **pH-Down Motor:** Adds acidic compounds to decrease pH when necessary.

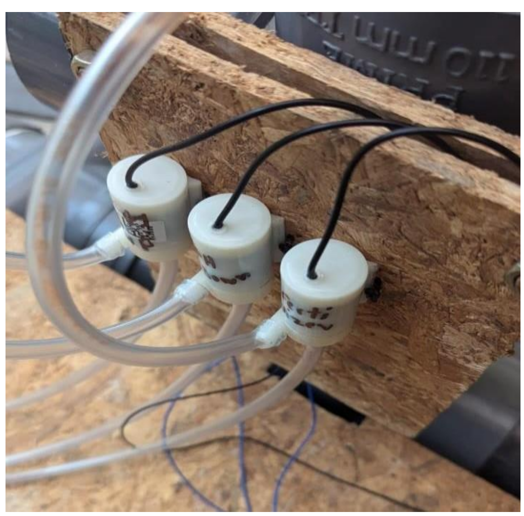
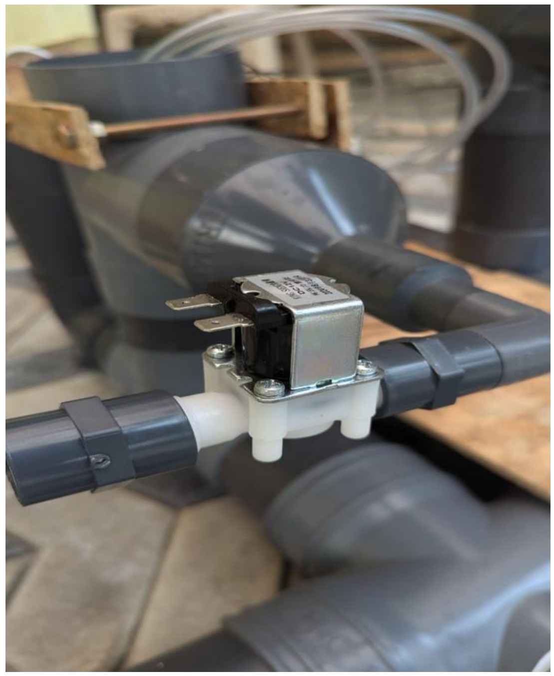


Figure – DC Motors

b. **Solenoid Valve:** Regulates water inflow from an external source.



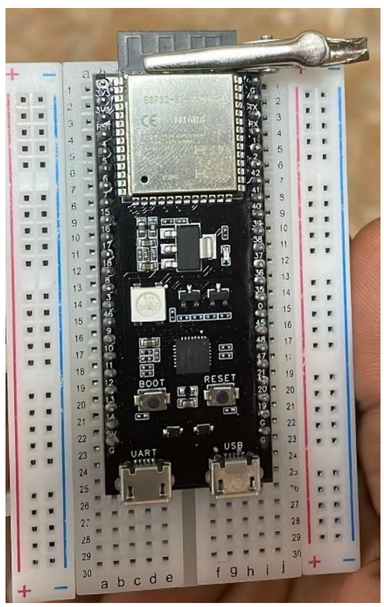
c. **Grow Lights:** Provides artificial lighting for photosynthesis, especially in indoor or low-light environments.

i. **Fertilizer Pump:** Injects liquid fertilizer into the nutrient solution.

3. **Real-Time Clock (RTC) Module:**
   a. Ensures accurate timekeeping for scheduling tasks such as turning grow lights on/off and triggering periodic sensor readings.

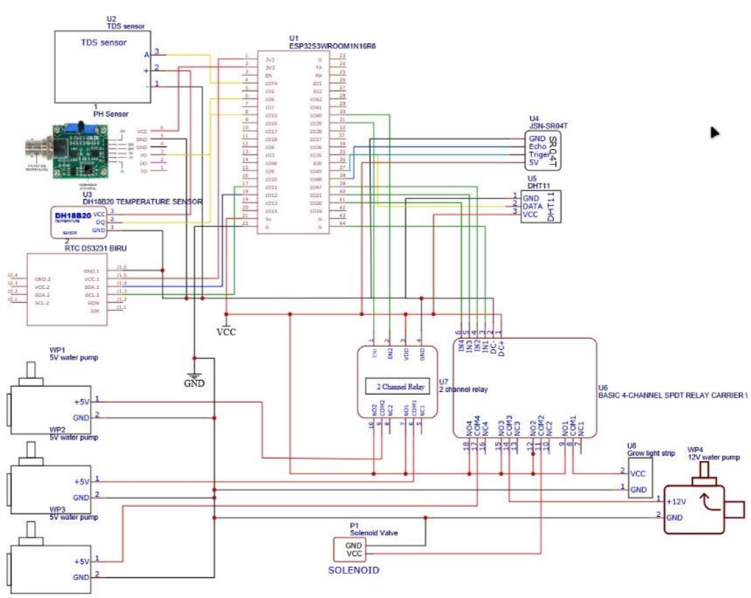
4. **Display Module:**
   a. An LCD or OLED display shows real-time sensor data, system status, and any alerts or notifications.

5. **Microcontroller:**
   a. The system is powered by an Arduino Mega or ESP32 microcontroller, which serves as the central processing unit. It reads sensor data, processes it, and sends commands to the actuators.



6. **Tower Structure:**
   a. The physical structure of the tower is constructed using PVC pipes, with holes drilled at regular intervals to accommodate net pots for plants. The base houses the reservoir, plumbing connections, and electronic components.

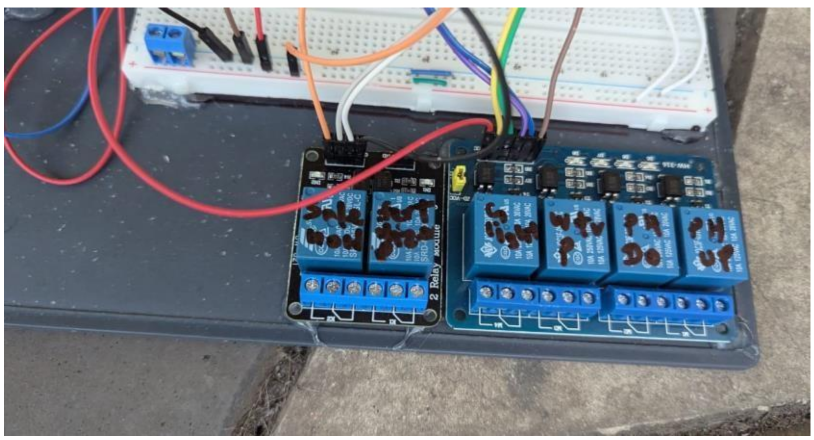
7. Circuit Diagram:



Software Design

The software component of the system is divided into two main parts: **microcontroller programming** and **web application development.**

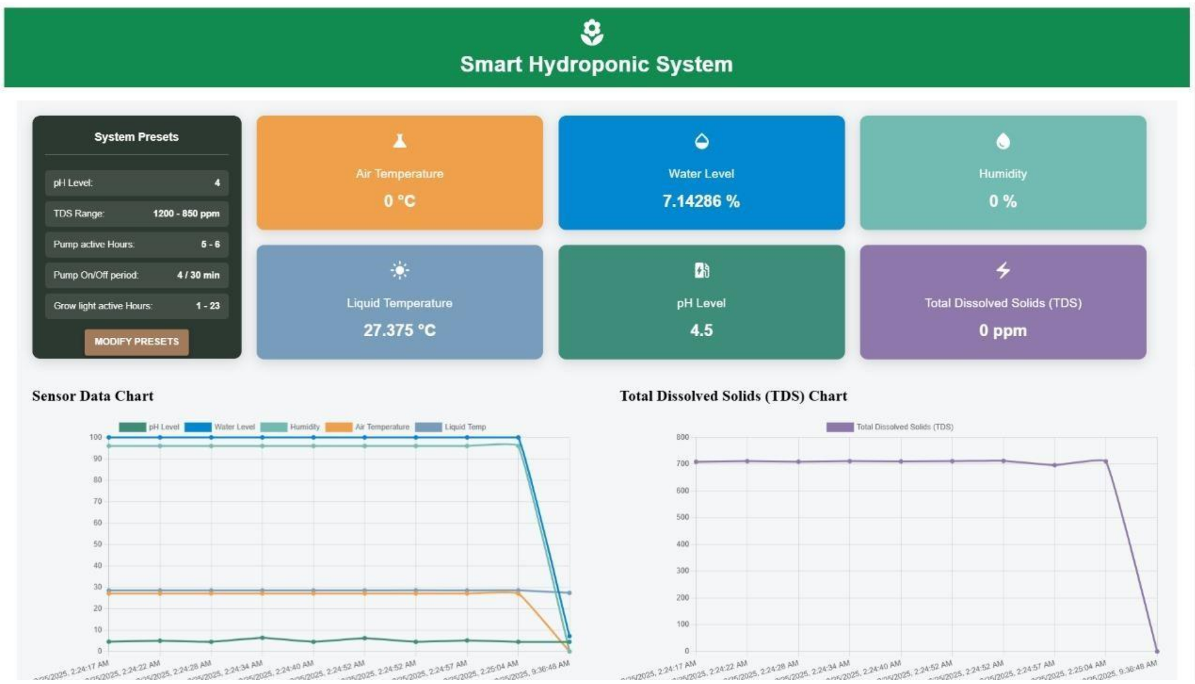
1. **Microcontroller Programming:**
    a. The microcontroller is programmed using the Arduino IDE or Platform IO. The code includes:
        i. **Sensor Data Acquisition:** Reading values from pH, TDS, ultrasonic, DS18B20, and DHT11 sensors. ii. **Control Logic:** Implementing algorithms to adjust pH, TDS, and other parameters based on predefined thresholds.
        iii. **Relay Control:** Activating or deactivating relays to control pumps, motors, valves, and lights.



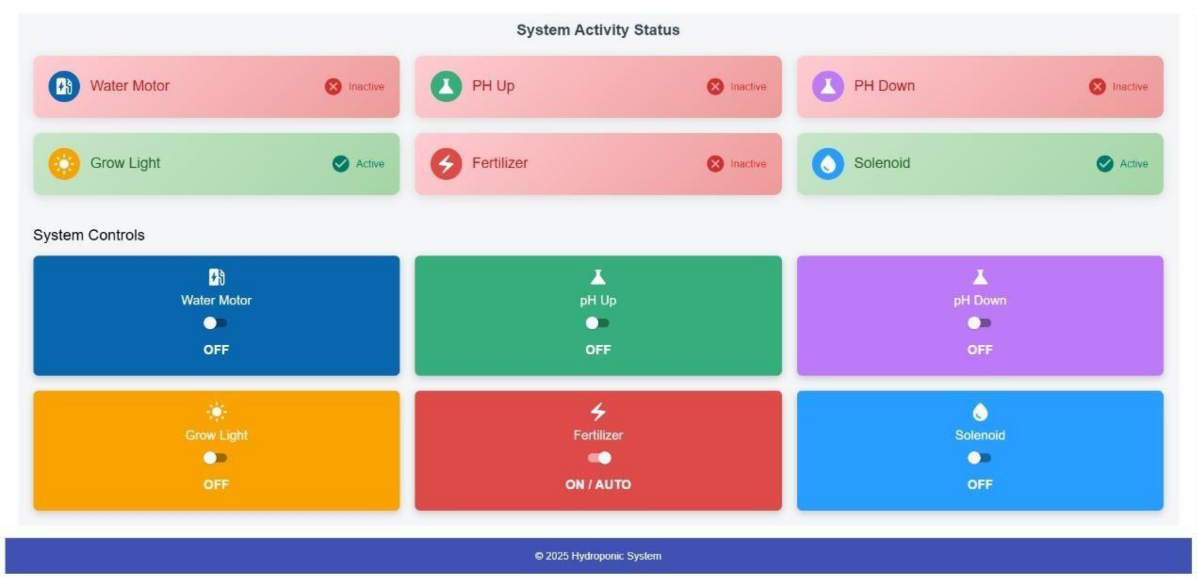
        iv. **Data Logging:** Storing sensor data on firebase or sending it to the web server for further analysis.

2. **Web Application Development:**
    a. The web application is built using HTML, CSS, JavaScript, react and Firebase used as backend with Key features include:
        i. **Dashboard:** Displays real-time sensor data in graphical and tabular formats.
        ii. **Controls:** Allows users to manually override automated functions, such as turning grow lights on/off or adjusting pump schedules.
        iii. **Notifications:** Show alerts on the web app for critical events, such as low water levels or abnormal pH values.
        iv. **Historical Data:** Provides access to logged data for trend analysis and decision-making.

UI Design Figures



UI Figure 1



UI Figure 2

Results

The implementation of the Automated Hydroponic System Tower has yielded several positive outcomes:

1. **Improved Plant Growth:**
   a. Plants grown in the system exhibited faster growth rates and healthier foliage compared to those grown in traditional hydroponic setups. This improvement is attributed to the precise control of environmental parameters.
2. **Resource Conservation:**
   a. Water usage was reduced by approximately 30% due to the system's ability to recycle nutrient solutions and prevent overflows.
   b. Nutrient wastage was minimized by maintaining optimal TDS levels.
3. **User Satisfaction:**
   a. Users found the web application intuitive and easy to navigate. Remote monitoring and control capabilities significantly enhanced convenience and accessibility.
4. **System Reliability:**
   a. The system demonstrated high reliability, with minimal downtime or errors during testing. Sensor accuracy and actuator responsiveness were consistently satisfactory.

Future Improvements

To further enhance the capabilities of the Automated Hydroponic System Tower, the following improvements are proposed:

1. **Advanced Analytics:**
   a. Integrate machine learning algorithms to analyze historical data and predict optimal growing conditions. For example, the system could recommend adjustments to nutrient concentrations based on past performance.
2. **Expandable Architecture:**
   a. Design the system to support multiple towers, enabling large-scale hydroponic operations. This could involve developing a master-slave communication protocol between microcontrollers.
3. **Energy Efficiency:**
   a. Incorporate solar panels or wind turbines to power the system, reducing reliance on grid electricity and enhancing sustainability.
4. **Enhanced User Interface:**
   a. Add mobile app support for iOS and Android devices, providing greater flexibility for users to interact with the system on the go.
5. **Integration with Smart Home Systems:**
   a. Enable compatibility with platforms like Google Home or Amazon Alexa, allowing users to control the system via voice commands.
6. **Feedback Mechanism:**
   a. Implement a feedback loop within the web application to gather user input and continuously improve system performance.