School of Engineering and Technology

Main Campus, Off Hennur-Bagalur Main Road, Chagalahatti, Bengaluru-562149

***CAPSTONE PROJECT WORK* - 4CAPS4010**

REPORT

on

"AUTOMATED HYDROPONICS SYSTEM"

Submitted to

School of Engineering and Technology, CMR University

In partial fulfillment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

In

COMPUTER SCIENCE AND ENGINEERING
&
COMPUTER AND COMMUNICATION ENGINEERING

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DEPARTMENT OF *COMPUTER SCIENCE AND ENGINEERING*
CMR UNIVERSITY
2024 – 2025

School of Engineering and Technology

Main Campus, Off Hennur-Bagalur Main Road, Chagalahatti, Bengaluru-562149

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

CERTIFICATE

*This is to Certified that the Capstone Project Work entitled **"AUTOMATED HYDROPONICS SYSTEM"** has been successfully carried out by **Deepika H : 21BBTCS071, Jagdesh Kumar S : 21BBTCC007, Sadashiv B : 21BBTCC018** in partial fulfillment for the award of the **BACHELOR OF TECHNOLOGY** in **COMPUTER SCIENCE AND ENGINEERING & COMPUTER AND COMMUNICATION ENGINEERING** by **SCHOOL OF ENGINEERING AND TECHNOLOGY,*** **CMR UNIVERSITY**, during the year 2024-25. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the report. The capstone project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

Signature of the Guide	*Signature of the HOD*	*Signature of the DEAN*
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Examiners

Name of the examiner	Signature of the examiner
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DECLARATION

We, ***Deepika H 21BBTCS071, Jagdesh Kumar S 21BBTCC007, Sadashiv B 21BBTCC018,*** *students of School of Engineering and Technology, CMR university, hereby declare that the report titled* ***" AUTOMATED HYDROPONICS SYSTEM"*** *embodies the report of our Capstone Project Work – 4CAPS4010 carried out independently by us during the final year of* ***Bachelor of Technology in Computer Science and Engineering & Computer and Communication engineering,*** *under the Guidance/ supervision of* **Dr. S Elango,** Professor of *Department of Computer Science and Engineering - AIML and this work has been submitted in partial fulfilment for the award of the* ***Bachelor of Technology*** *degree.*

We have not submitted the project for the award of any other degree of any other University or institution.

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ACKNOWLEDGEMENT

*We express our foremost gratitude to **Dr. Kannan N,** Dean, SOET, CMR University, Lakeside Campus, Bagalur for his constant support and guidance.*

*We would like to express our thanks to **Dr. S Elango**, Professor of Dept. of CSE-AIML, SOET, CMR University, Lakeside Campus, Bagalur for their encouragement that motivated us for the successful completion of project work.*

*We also would like to express our gratitude to our project coordinators to **Dr. Manjunath C R,** Professor and Head, Dept. of CSE (AI & ML), and **Dr. S Elango**, Associate Professor Dept. of CSE-AIML, and SOET, CMR University for the successful completion of project work.*

*We consider ourselves privileged to express gratitude and respect to our Project Guide **Dr. Rubini P**, Professor and Head, Department of Computer Science and Engineering SOET, CMR University, Lakeside Campus, Bagalur for his /her inspiration, adroit guidance, constant supervision, direction and discussions in successful completion of this project work.*

Our sincere thanks to all teaching and non-Teaching Staff of Computer Science & Engineering for all the facilities provided, without which, we could not have progressed with my work. Thanks to our parents who have been a great source of strength in the completion of this project work.

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ABSTRACT

The Automated Hydroponics System presented in this project is an advanced Internet of Things (IoT)-enabled agricultural solution designed to enhance plant growth through precise control of environmental parameters. Hydroponics, being a soil-less farming technique, requires accurate management of water quality, nutrient levels, temperature, and humidity. This system addresses these needs by employing an ESP8266 microcontroller, which provides Wi-Fi connectivity for real-time data communication and remote system management. A network of sensors, including pH, Total Dissolved Solids (TDS) conductivity, temperature, humidity, and float sensors, is integrated to monitor vital conditions continuously. These sensors collect and transmit data to a cloud-connected system, which processes the information to control various components, such as nutrient and pH dosing mechanisms and water pumps. The 12V water pump, in particular, is governed by both automated logic and a manual toggle switch accessible through a user-friendly web dashboard hosted over a local IP address.

The data collected from the sensors is simultaneously logged to Google Sheets using Google Apps Script, creating a historical record of environmental variables. This enables growers to analyze trends and make data-driven decisions to improve crop yield and system efficiency. The dashboard, designed with HTML and CSS, offers clear visualization of real-time data, ensuring easy monitoring and control even for non-technical users. This automation significantly reduces manual labor, minimizes water and nutrient waste, and ensures optimal plant growth conditions with minimal supervision. The modular design allows scalability from small-scale home gardens to larger commercial hydroponic farms, making it adaptable for various applications. Additionally, the system supports urban agriculture by enabling controlled indoor farming with year-round productivity.

By integrating sensor technology, cloud-based logging, and a dynamic control interface, the proposed system represents a modern approach to sustainable agriculture. It offers a practical and affordable solution to traditional farming challenges, supporting food security and promoting eco-friendly practices in both rural and urban settings.

Keywords: Automated Hydroponics, IoT Agriculture, ESP8266, Real-Time Monitoring, pH Sensor, TDS Sensor, Web Dashboard, Data Logging, Google Apps Script, Urban Farming, Smart Farming, Precision Agriculture, Sustainability.

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CHAPTER – 1

INTRODUCTION

The automated hydroponics system proposed in this project integrates advanced IoT capabilities, comprehensive sensor monitoring, and a user-friendly web-based dashboard to create a smart and scalable agricultural solution. By leveraging real-time tracking of critical environmental parameters such as pH, TDS conductivity, temperature, humidity, and water levels, the system ensures optimal growing conditions for hydroponic cultivation. An ESP8266 microcontroller forms the core of the system, interfacing with various sensors and providing seamless connectivity to a web dashboard, developed using HTML and CSS for enhanced user experience and accessibility.

Agriculture remains the cornerstone of human civilization, yet traditional farming methods face challenges such as resource inefficiency and environmental degradation. Hydroponics, a soil-free cultivation method using nutrient-rich water, offers a promising alternative, particularly in urban areas with limited arable land. By directly supplying essential nutrients like nitrogen, phosphorus, and potassium through controlled water solutions, hydroponic farming enables faster plant growth, higher yields, and up to 90% less water usage compared to conventional methods. The system also promotes pesticide-free, healthier crop production by eliminating soil-borne contaminants.
While the technology's initial setup cost, involving pumps, sensors, controllers, and lighting systems, can be higher than traditional farming, the long-term benefits, including water conservation, reduced land dependency, and year-round production, outweigh the investment. In this project, automation extends to the operation of a 12V water pump, toggled automatically or manually through the web dashboard, offering precise water and nutrient management. Data from all sensors is logged automatically to Google Sheets using Google Apps Script, enabling historical tracking and analysis of crop conditions.

The system's web dashboard, enriched with custom CSS styling and responsive HTML design, provides real-time data visualization, intuitive control buttons, and actionable alerts, making it easier for growers to make informed decisions. Whether for a small personal setup or a larger commercial hydroponic farm, the modular and scalable nature of the system ensures adaptability and future upgrades. By combining IoT, automation, and smart user interfaces, this project sets a foundation for efficient, sustainable, and technologically advanced farming practices, bridging the gap between traditional agriculture and modern smart farming innovations.

1.1 Background

Hydroponics is an advanced, soil-free agriculture method that allows plants to grow in a water-based, nutrient-rich solution rather than traditional soil. This approach to plant cultivation has gained popularity as an efficient and sustainable alternative to conventional farming, especially in urban and resource-limited areas. Hydroponics offers a viable solution to various agricultural challenges, including the scarcity of arable land, limited water resources, and the need for higher productivity in confined spaces. Unlike traditional farming, where nutrient availability and soil conditions can vary greatly, hydroponics provides plants with an ideal, controlled environment, leading to faster growth and higher yields. This study delves into the evolution, principles, and advantages of hydroponic vertical farming, shedding light on its potential to revolutionize the future of agriculture.

However, it was in the 20th century that hydroponics gained scientific recognition. The concept involves cultivating plants in nutrient-rich water solutions, providing essential minerals directly to the roots. Over time, hydroponics evolved into various systems, including the vertical farming approach. Historically, agriculture has relied heavily on soil, climate, and natural conditions, which can be unpredictable and increasingly impacted by environmental issues like climate change. Hydroponics bypasses many of these challenges by allowing plants to grow in fully controlled indoor or greenhouse environments, insulated from weather and climate fluctuations. This technology is particularly relevant in urban areas, where space is limited, and the demand for locally grown, fresh produce is high. Hydroponics offers several advantages over conventional farming, including faster plant growth, reduced water usage, minimal space requirements, and the ability to cultivate crops indoors or in urban environments. Despite these benefits, traditional hydroponic systems still rely heavily on manual labor for monitoring and controlling vital parameters such as pH, temperature, humidity, and nutrient levels.

This can lead to inconsistencies in crop health and quality, especially when parameters are not maintained within optimal ranges. To address these limitations, the integration of Internet of Things (IoT) technologies into hydroponic systems has emerged as a promising solution. IoT enables real-time data collection, remote monitoring, and automation of key processes, improving the efficiency and reliability of hydroponic farming. By leveraging Wi-Fi-enabled microcontrollers like the ESP8266, along with a variety of environmental sensors, it becomes possible to create a self-regulating system that adjusts conditions automatically or allows users to make remote decisions based on live data.

This project focuses on developing a prototype for an automated hydroponics system using IoT principles. The system incorporates sensors to monitor essential parameters such as temperature, humidity, light intensity, pH level, Total Dissolved Solids (TDS), and water level. The data is transmitted to Google Sheets via Google Apps Script, where it is visualized through a dashboard that also includes manual pump control. This approach aims to reduce human intervention, increase consistency in plant growth, and make hydroponics more accessible, efficient, and scalable especially for urban and farmers.

1.2Problem Statement

Hydroponics is an advanced, soil-free agriculture method that allows plants to grow in a water-based, nutrient-rich solution rather than traditional soil. This approach to plant cultivation has gained popularity as an efficient and sustainable alternative to conventional farming, especially in urban and resource-limited areas. Hydroponics offers a viable solution to various agricultural challenges, including the scarcity of arable land, limited water resources, and the need for higher productivity in confined spaces. Unlike traditional farming, where nutrient availability and soil conditions can vary greatly, hydroponics provides plants with an ideal, controlled environment, leading to faster growth and higher yields. This background study delves into the evolution, principles, and advantages of hydroponic vertical farming, shedding light on its potential to revolutionize the future of agriculture.

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As urbanization continues to rise and arable land decreases, there is an urgent need for solutions that can maximize food production with minimal resource input. Automated systems that can monitor and adjust environmental conditions autonomously would not only alleviate the labour burden on farmers but also ensure a more consistent and reliable growing environment.

Another significant challenge is the integration of technology into hydroponic systems. While various sensors and controllers are available to monitor environmental conditions, many existing systems lack user-friendly interfaces that allow growers to easily interact with the technology. This gap often results in underutilization of available tools and technologies that could enhance productivity.

In summary, the core problems facing hydroponics today include:

i. **Labor Intensity:** Continuous manual monitoring and adjustments are required.
ii. Human Error: Manual interventions can lead to mistakes that adversely affect plant health.
iii. **Scalability Issues:** Traditional systems struggle to scale effectively in response to growing food demands.
iv. **Technological Integration:** Existing automated solutions often lack intuitive interfaces for user interaction.
v. **High Initial Setup Costs:** This high initial cost can be a barrier for many potential growers, particularly small-scale farmers or startups looking to enter the market.
vi. **Dependence on Continuous Power Supply**: Hydroponic systems rely heavily on electricity to power pumps, sensors, and climate control systems. Any interruption in power supply can lead to system failures, jeopardizing plant health and potentially resulting in crop loss.

Efficiency Gains Comparison

Metric	Automated Hydroponics	Traditional Farming
Water Usage	Uses 90% less water (10-25% of soil farming)	High water usage (depends on irrigation)
Crop Yields	Higher yields per sq ft (up to 7-14 times more)	Lower yields per sq ft
Labor Requirements	Reduced labor needs (due to automation)	Labor-intensive
Carbon Footprint	Lower emissions (due to reduced transport)	Higher emissions (fertilizers & fuel)
Year-Round Production	Possible (indoor setups)	Seasonal limitations

Figure 1.1 Gain comparison of Plants

1.3 Objectives

The development of an automated hydroponics system aims to address several key objectives that enhance the efficiency, sustainability, and productivity of modern agriculture.

i. Integrate DHT11, LDR, and soil moisture sensors into the hydroponic system for real time monitoring of temperature, humidity, light intensity, and water content.

ii. Implement the ESP8266 Node MCU microcontroller as the central control unit, enabl1ng seamless communication with integrated sensors and efficient data processing.

iii. Develop an automated irrigation system using a l2V DC water pump controlled by the ESP8266, ensuring precise delivery of water and nutrients at optimal intervals.

iv. Incorporate IoT technologies for remote monitoring and control.

v. Conduct iterative testing to optimize sensor accuracy, data processing speed, and overall system reliability.

These objectives are crucial for meeting the growing global food demands while minimizing resource usage and environmental impact.

i. Real-Time Monitoring and Control: create a system that continuously monitors critical environmental parameters such as pH levels, electrical conductivity (EC), temperature, humidity, and nutrient concentrations. By utilizing advanced sensors, the system can provide real-time data to ensure optimal growing conditions for various plant species. This capability allows for immediate adjustments to be made automatically, reducing the need for manual intervention.

ii. Automation of Nutrient Delivery: automate the nutrient delivery process based on real time sensor feedback. The system will adjust the nutrient solution's composition, ensuring that plants receive the appropriate nutrients at different growth stages. This automation not only enhances plant health and growth rates but also minimizes waste by optimizing nutrient usage.

iii. Water Conservation: implement efficient water management practices that recycle and reuse water within the system, thereby conserving this precious resource. By maintaining optimal water levels and minimizing evaporation losses, the system contributes to sustainable agricultural practices.

iv. User-Friendly Interface: To encourage widespread adoption among growers of all skill levels, the system aims to provide a user-friendly interface that allows users to easily monitor and control their hydroponic setup. This interface mobile application that provides access to real-time data, alerts, and system status updates. Simplifying user interaction is essential for making hydroponics accessible to novice growers.

v. Data Logging and Analysis: The system will incorporate data logging capabilities to track environmental conditions over time. This objective enables growers to analyze trends in plant growth and environmental factors, facilitating informed decision-making regarding crop management practices. By leveraging historical data, users can optimize their growing strategies for improved yields.

vi. Remote Monitoring and Control: Integrating Internet of Things (IoT) technology into the automated hydroponics system enables remote monitoring and control capabilities. This feature enhances flexibility and responsiveness in managing crops.

vii. Integration of Machine Learning: Incorporate machine learning algorithms that can predict plant needs based on historical data and current environmental conditions. By analyzing patterns in sensor data, the system can optimize nutrient delivery schedules and environmental controls, leading to enhanced growth rates and resource efficiency.

viii. Scalability: Easily expanded or adapted for different types of crops or growing environments. This flexibility is essential for meeting diverse agricultural needs, from small home gardens to larger commercial operations.

ix. Intelligence in the field of hydroponics make the system work automatically. This increases the productivity in agriculture with minimum water resources and available cultivable land. Automation is done through IoT which is Machine-to-Machine interaction. Recurrent Neural Network (RNN) -Long Short-Term Memory (LSTM) prediction algorithm would increase the accuracy in automation

x. Sustainability and Reduced Environmental Impact: To promote sustainable agricultural practices that reduce reliance on chemical fertilizers and pesticides while maximizing crop yield per unit area. By creating a controlled environment that minimizes disease pressure and resource waste, supports environmentally friendly farming practices.

xi. Educational Tool: system aims to serve as an educational tool for aspiring farmers and students interested in agriculture technology. By providing insights into plant biology, nutrient management, and automated systems operation, it fosters a deeper understanding of modern agricultural practices.

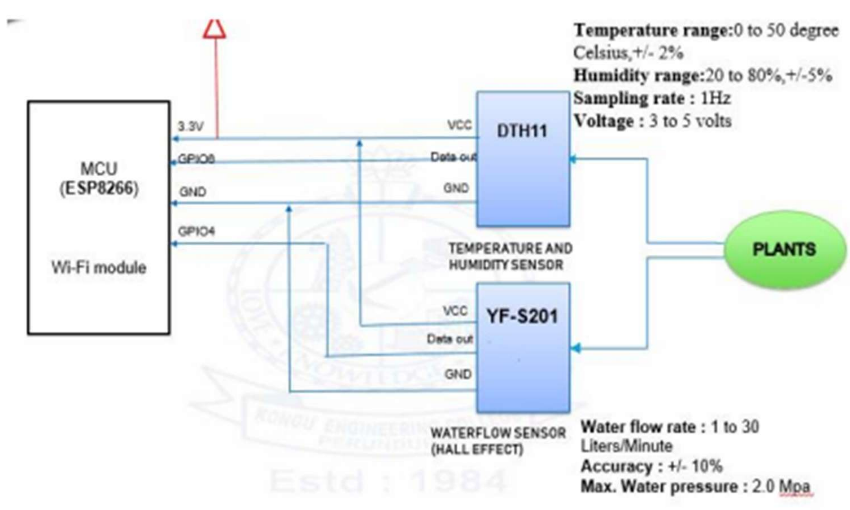


Figure 1.2 Circuit Diagram for collecting information

1.4 Challenges

While developing an automated hydroponics system using IoT and Wi-Fi connectivity offers numerous advantages, it also presents several technical and practical challenges that must be addressed to ensure reliable performance, accuracy, and scalability. This section outlines the key challenges encountered during the design and implementation of the prototype.

i. Sensor Calibration and Accuracy The reliability of the system depends heavily on the accuracy of sensor data. Sensors like pH and TDS often require precise calibration and may drift over time, leading to incorrect readings. Environmental factors such as temperature and electrical noise can also affect sensor accuracy, especially in a moist hydroponic environment.

ii. Power Management Managing power for multiple components, including a 12V pump, a 5V pump, sensors, and the ESP8266 microcontroller, is a critical challenge. Ensuring the stability of voltage levels and avoiding power surges requires proper voltage regulation and circuit design, particularly when both AC and DC components are involved.

iii. Reliable Wi-Fi Connectivity Since the system depends on real-time data transmission to Google Sheets and dashboard access, it requires a stable and continuous Wi-Fi connection. In areas with weak or unstable connectivity, data loss or delayed updates can hinder system performance and user control.

iv. Google Script Limitations Although Google Apps Script is effective for logging data into Google Sheets, it has execution time and quota limits, especially when dealing with frequent or high-volume data submissions. Managing these constraints while maintaining real-time functionality is a significant challenge.

v. Dashboard Integration and Responsiveness Creating an intuitive, responsive, and reliable dashboard that displays real-time data and allows for remote pump control is essential. Compatibility across devices (PC, mobile, tablet) and real- time syncing between cloud logs and dashboard display require careful planning and implementation.

vi. Environmental Variability External environmental changes such as heat, humidity, or water splash can affect sensor performance and hardware reliability. Enclosures and protective design are necessary to safeguard components in real- world applications.

Addressing these challenges is crucial to building a robust and scalable hydroponics automation system that can be deployed reliably in both experimental and real farming environments. Overcoming these obstacles will ensure that the system can provide consistent performance, improve efficiency in agricultural practices, and contribute to the future of sustainable farming on a larger scale.

CHAPTER 2

LITERATURE SURVEY

2.1Survey

The integration of automation and Internet of Things (IoT) technologies into agriculture has revolutionized the way farming systems are managed, particularly in the field of hydroponics. Over the past decade, hydroponic farming has emerged as a highly efficient, water-saving, and space-optimized method of growing crops. However, traditional hydroponic systems require constant human monitoring and intervention, limiting scalability and efficiency. Several studies and projects have focused on automating these systems to improve efficiency and reduce manual labor. This survey reviews the existing literature on automated hydroponic systems and their integration with IoT technologies.

Hydroponic Automation
Systems In a study by A. G. M. Y. O. Mahdavi et al. (2019), an automated hydroponic system was proposed using Arduino-based controllers along with a set of sensors for monitoring essential parameters like pH, temperature, and nutrient concentration. The study demonstrated how automation could reduce human intervention while maintaining optimal growth conditions for plants. However, it also highlighted challenges related to system scalability, sensor calibration, and real-time monitoring.

A significant development in this field was presented by H. J. Kim et al. (2020), who explored the use of wireless sensor networks (WSNs) for real-time monitoring and control of hydroponic systems. The study integrated temperature, humidity, pH, and water level sensors, all connected wirelessly to a central control unit. The system allowed users to monitor parameters through a mobile application, making it more convenient for users. This IoT-based design offered substantial improvements in remote access and automated control, though challenges in network reliability and sensor accuracy remained key concerns.

Integration with Cloud Computing
Recent advances in cloud computing and data analytics have also enhanced the capabilities of automated hydroponic systems. In 2021, D. P. Sharma et al. presented an advanced cloud-based hydroponic monitoring system that employed Raspberry Pi for system control and Google Firebase for cloud data logging. The system collected data from various sensors, stored it on the cloud, and provided real-time analysis through a web dashboard. This allowed users to monitor and manage the system from anywhere in the world. The study concluded that cloud-based systems offer greater scalability and more sophisticated data analysis capabilities compared to traditional methods. However, ensuring reliable internet connectivity and managing data security remained major challenges.

Another significant project by Z. Li et al. (2022) focused on IoT integration in precision agriculture, specifically in hydroponics. Their system utilized ESP8266 microcontrollers connected to various sensors to monitor parameters such as light intensity, temperature, humidity, and nutrient concentration. Data was processed locally and transmitted to a cloud platform for storage and analysis. The study noted that such a system could significantly reduce resource consumption and enhance yield predictions, though issues of device calibration and long-term maintenance of the system were raised.

Advancements in Automation
The implementation of machine learning (ML) and artificial intelligence (AI) in automated hydroponics systems has also been a subject of recent interest. A project by S. A. M. Ali and M. A. S. K. Omer (2023)

investigated the use of AI algorithms for predictive analysis and automation in hydroponics. The system used real-time data from IoT sensors to adjust nutrient levels, temperature, and lighting based on predicted plant growth patterns. This AI-driven automation improves the system's adaptability to changing environmental conditions, leading to higher efficiency and lower operational costs.

2.2 Existing work

Automated hydroponics systems are revolutionizing the way we approach agriculture, especially in urban environments where space and resources are limited. These systems integrate advanced technologies such as sensors, robotics, artificial intelligence (AI), and cloud computing to manage the various aspects of plant growth, including nutrient delivery, water levels, temperature, and light. Below is a brief overview of some key existing systems that demonstrate the capabilities and innovation in automated hydroponic farming. Several existing systems and research initiatives have explored automated platforms to assist farmers with decision-making and improve agricultural productivity:

1. **Automatic robotic system design and development for vertical hydroponic farming using IoT and big data analysis**

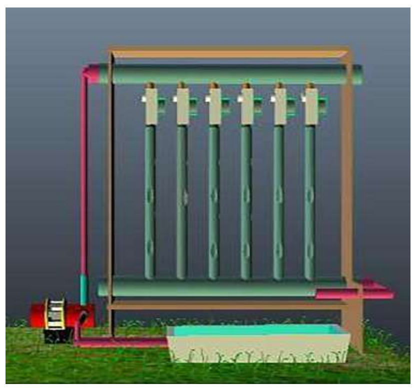


Figure 2.1 Vertical farming using IoT

It also monitors the plant nutrition and PH whether it is correct or not. It determines the air circulation and lighting then controlled with the temperature.
Limitations:

i. This system is only used for small scale farmers.
ii. Implemented only in smaller lands.

2. **State of the Art of Urban Smart Vertical Farming Automation System: Advanced Topologies, Issues and Recommendations**

Figure 2.2 Smart Vertical Farming

SF collects data from various sensors such as moisture sensors, humidity sensor, temperature sensors, gas sensors, and pH sensors utilizing IoT devices.

Limitations:

i. Reduces human intervention to a minimum which causes unemployment
ii. High starting cost.

2.3 Survey Summary

The integration of automation and Internet of Things (IoT) technologies into hydroponic systems has significantly transformed agricultural practices, offering innovative solutions to traditional farming challenges. Based on the reviewed literature and existing systems, it is evident that automation in hydroponics primarily aims to reduce human intervention, improve resource efficiency, and ensure consistent crop yields. Various studies have shown that incorporating controllers like Arduino, Raspberry Pi, and ESP8266, along with sensor networks, enables real-time monitoring and control of crucial parameters such as pH levels, nutrient concentrations, temperature, humidity, and water levels.

Early developments, such as those proposed by Mahdavi et al. (2019), focused on using microcontrollers with basic automation to monitor essential parameters. While effective, these systems faced issues with scalability, real-time responsiveness, and maintenance of sensor accuracy over time. Subsequent research by Kim et al. (2020) introduced wireless sensor networks (WSNs) into hydroponic automation, enhancing remote monitoring capabilities through mobile applications. This advancement marked a major step towards user-friendly and more accessible farming systems but introduced new challenges related to network reliability and power management.

The integration of cloud computing, as demonstrated by Sharma et al. (2021), further pushed the boundaries of what hydroponic automation could achieve. By utilizing platforms like Google Firebase and real-time web dashboards, users were able to access, analyze, and act on data from anywhere, offering unprecedented control and data-driven decision-making. Additionally, Li et al. (2022) emphasized the use of ESP8266 microcontrollers in cloud-integrated hydroponics, showcasing local processing combined with cloud storage for efficient resource management and predictive analytics.

Recent research trends have moved towards incorporating artificial intelligence (AI) and machine learning (ML) into automated hydroponics. Ali and Omer (2023) proposed systems capable of predictive analysis, adjusting growing conditions dynamically based on anticipated plant needs. This development not only improves the system's adaptability but also further minimizes resource wastage, operational costs, and human involvement, ultimately enhancing yield and efficiency.

The study of existing systems, such as the "Automatic Robotic System for Vertical Hydroponic Farming Using IoT and Big Data," showcases the application of automation for nutrient monitoring, pH management, air circulation control, and temperature regulation in vertical farming setups. Similarly, "The State of the Art of Urban Smart Vertical Farming Automation System" presents a robust solution by employing a wide range of sensors and IoT devices. While highly efficient, its high initial cost and reduced need for human labor raise economic and social concerns, particularly regarding accessibility and potential unemployment.

In conclusion, the literature and existing systems reveal that while automated hydroponic farming holds great promise for sustainable agriculture, several challenges persist. These include scalability, sensor accuracy over extended periods, network and cloud dependency, cost of implementation, and the technical complexity of integrating advanced AI models. Moving forward, research and development should focus on creating more affordable, scalable, and resilient systems that are easy to maintain and accessible to a broader range of users, from small scale farmers to large commercial operations.

Integrating renewable energy sources, offline operational capabilities, and improved AI models for predictive and adaptive farming can further enhance the future of automated hydroponics.

2.4 Proposed System

The proposed system is an IoT-enabled Automated Hydroponics System that combines environmental sensing, control mechanisms, and a responsive dashboard interface to optimize plant growth in a soil-less environment. It utilizes sensors to monitor vital parameters such as pH level, TDS (Total Dissolved Solids), temperature, humidity, and water level. A 12V water pump is controlled automatically based on float sensor input and system timing, ensuring efficient water circulation.

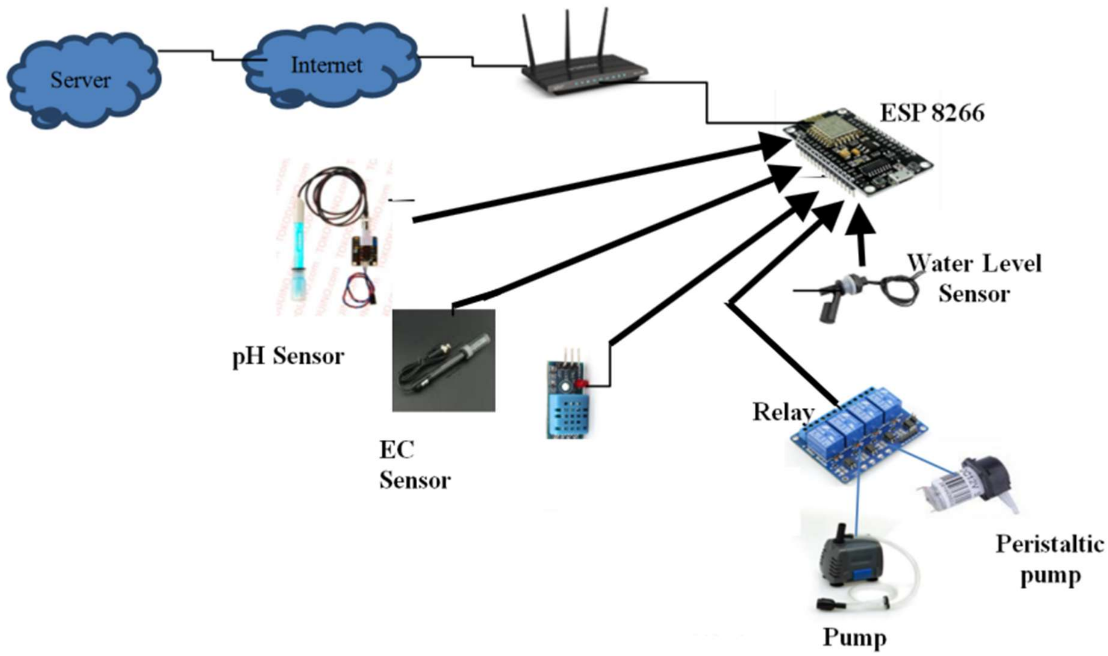


Figure 2.3 IoT enabled hydroponics System

The core of the system is an ESP8266 microcontroller, which processes sensor data and acts based on real-time readings. For example, if the water level drops, the float sensor triggers the pump. The pH and TDS sensors provide data to assess nutrient concentration, helping ensure plants receive optimal nourishment. A major enhancement is the custom-built web dashboard, styled with HTML and CSS, hosted on the ESP8266's local IP. This interface offers real-time visualization of sensor readings and allows users to monitor the system from any device on the network. Additionally, the system logs data to Google Sheets using Google Apps Script, providing long-term monitoring and historical analysis without additional storage modules. The automation eliminates the need for constant manual supervision. The system can be scaled from small home-based hydroponics setups to larger, semi-commercial installations. It is energy-efficient, cost-effective in the long term, and significantly reduces water usage compared to traditional soil farming. In summary, this hydroponics solution delivers an intelligent, adaptable, and easy-to-use approach to modern farming, integrating IoT, automation, and web technologies for sustainable plant cultivation.

CHAPTER 3

METHODOLOGY

3.1 Method

The development of the Automated Hydroponics System followed a structured approach beginning with the identification of key environmental parameters necessary for plant growth, such as temperature, humidity, pH level, light intensity, nutrient concentration (TDS), and water availability.

The hardware setup was designed around the ESP8266 (NodeMCU) microcontroller for its built-in Wi-Fi capability and ease of sensor integration. Various sensors were used: a DHT11 sensor measured air temperature and humidity, a pH sensor monitored the acidity of the nutrient solution, an LDR measured ambient light levels, a TDS sensor approximated nutrient concentration, and a float switch detected water levels. Relays controlled dosing pumps and the water circulation pump, while LEDs provided basic visual feedback.

Software development focused on accurate sensor readings, periodic data sampling, and implementing decision-making logic; for example, when pH readings exceeded predefined thresholds, corresponding pumps were activated to adjust the solution. The ESP8266 established a Wi-Fi connection and communicated sensor data to an online Google Sheet via a Google Apps Script, enabling real-time data logging and analysis. Simultaneously, a simple, responsive web dashboard hosted on the ESP8266 displayed live sensor values and allowed manual control of the pumps.

Automation conditions, such as switching on the pump based on low tank levels or activating LEDs in low light, were implemented based on sensor inputs. After initial coding, all sensors and actuators were carefully tested and calibrated to ensure reliability under real-world hydroponic conditions. Calibration processes included mapping the raw analog values from the pH sensor to an accurate pH scale and adjusting thresholds for light and TDS readings. The final deployment resulted in a fully autonomous system capable of monitoring, adjusting, and reporting the hydroponic environment, thus reducing manual intervention and improving the overall efficiency and health of the plants.

Figure 3.1 Prototype

3.2 Unique Features

i. Comprehensive Sensor Integration: The system integrates multiple sensors, including pH, TDS, temperature, humidity, LDR, and float sensors, enabling continuous monitoring of critical parameters to maintain optimal water quality, nutrient balance, and climate conditions.

ii. Real-time Remote Monitoring and Control: Using the ESP8266 microcontroller and IoT technology, real-time data is transmitted to a cloud platform, allowing users to remotely monitor system status and control operations through an intuitive web dashboard.

iii. Automation with Adaptive Control: The system features automatic management of water pumps, nutrient dosing, and lighting, dynamically adjusting these elements based on live sensor data to optimize plant growth without manual effort.

iv. Energy-efficient Operation: The setup intelligently activates pumps, dosing systems, and lighting only when needed, significantly reducing power consumption and enhancing the overall energy efficiency of the hydroponic system.

v. Data Logging and Historical Analysis: Sensor data is automatically logged to Google Sheets via Google Apps Script, providing users with access to historical trends and enabling data-driven decision-making for further optimization.

vi. Fail-safe Safety Mechanisms: Float sensors and intelligent system responses protect pumps and plants from dry running or overflow conditions, ensuring system reliability and preventing equipment damage.

vii. Scalable and Modular Design: The modular approach allows easy expansion with additional sensors, actuators, or grow zones, making the system highly adaptable from small DIY setups to larger commercial hydroponic farms.

3.2 Advantages

i. Enhanced Efficiency: The integration of automated controls ensures that every aspect of the hydroponic system, from nutrient levels to water pumping, is optimized for plant growth. This reduces human intervention and minimizes errors in system management, leading to better resource usage and overall efficiency.

ii. Precision in Environmental Control: By utilizing various sensors such as pH, TDS, humidity, and temperature sensors, the system continuously monitors and adjusts critical factors. This ensures that the plants are always in an optimal environment, improving plant health and yields.

iii. Real-Time Remote Monitoring: Leveraging IoT technology, the system allows for real time data transmission to a cloud-based platform.

iv. Scalability for Different Applications: The system is designed to be modular and scalable, which means it can be adapted for various sizes of hydroponic setups-from small home-based gardens to large urban farming operations. This flexibility makes it an attractive solution for diverse agricultural needs.

v. Improved Resource Management: By continuously monitoring environmental parameters and adjusting them as needed, the system optimizes resource usage, such as water, light, and nutrients. This results in a more sustainable approach to farming, especially in water-scarce or resource-limited environments.

vi. Cost-Effective Over Time: Though initial setup costs may be higher, the long-term savings in terms of labor, water, and energy consumption make the system a cost-effective solution. It maximizes the output per unit of input, leading to higher productivity for less resource expenditure.

vii. Data Logging and Analytics: The system logs data over time, providing valuable insights into plant growth patterns, environmental conditions, and system performance. This data can be used for further optimization, troubleshooting, or simply tracking progress to improve farming techniques.

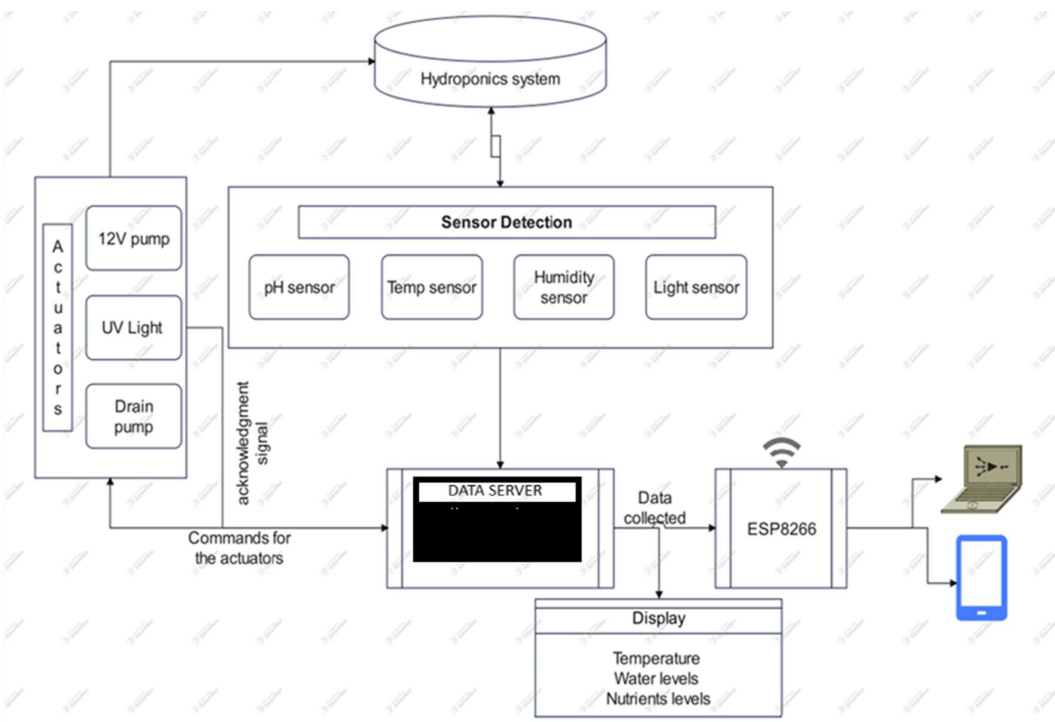


Figure 3.2 Proposed Architecture

CHAPTER 4

SOFTWARE REQUIREMENT SPECIFICATIONS

4.1Requirements

4.1.1 HARDWARE REQUIREMENTS

i. ESP8266 Microcontroller: The ESP8266 serves as the central controller, processing data from the various sensors and transmitting it to a cloud platform. Its Wi-Fi capability allows seamless internet connectivity for remote monitoring.

Figure 4.1 ESP8266 NODE MCU

ii. pH Sensor: Measures the pH level of the nutrient solution in the hydroponic system, ensuring that the water remains within the ideal range for plant growth.

Figure 4.2 PH Sensor

iii. TDS (Total Dissolved Solids) Sensor: Monitors the concentration of dissolved solids in the water, providing insight into nutrient levels. This data is used to adjust the amount of nutrients added to the system.

Figure 4.3 TDS Sensor

iv. Temperature and Humidity Sensor (DHT22): This sensor tracks the environmental conditions (temperature and humidity), crucial for regulating the growth of plants and ensuring the proper climate within the hydroponic system.

Figure 4.4 DHT22 Sensor

v. Float Sensor: Monitors the water level within the system to prevent overflow or dry conditions that could harm the plants.

Figure 4.5 Float Sensor

vi. Water Pump: The pump is controlled by the microcontroller, based on input from the float sensor to maintain the optimal water level in the system.

Figure 4.6 Water Pump

vii. LED Grow Lights: Controlled based on environmental conditions, the lights ensure that plants receive the necessary amount of light for photosynthesis.

Figure 4.7 Grow Lights

4.1.2 SOFTWARE REQUIREMENTS

I. **Google Script for Data Logging**: Google Script is used to log sensor data to a Google Sheets document in real-time. This allows for efficient storage and easy access to historical data for analysis and troubleshooting.

II. **Programming languages:** Python, C++, Java-script, HTML, CSS.

III. **Web Dashboard**: A web-based dashboard is built to allow real-time monitoring and control of the system. The dashboard is accessible through the system's IP address, allowing users to remotely access the data and adjust parameters such as water pump status and light intensity.

IV. **Windows OS**: Operating system software providing the platform for software installation and running various applications required for system configurations and management.

4.2 Brief description about the tools to be used

1. ESP8266 Microcontroller

The ESP8266 is a powerful microcontroller with built-in Wi-Fi and Bluetooth capabilities, making it an ideal choice for IoT projects. In this hydroponics system, the ESP8266 is used to collect data from various sensors (pH, TDS, temperature, humidity, and float sensors) and control actuators like water pumps and LED grow lights. The ESP8266 processes the data and communicates with the cloud (via Wi-Fi) to log data and allow remote control through the web dashboard.

- **Working in this project**: The ESP8266 is programmed to read the sensor data and send it to a cloud platform (Google Sheets via Google Script). It also allows users to control the system remotely by providing an IP address to access the dashboard. The microcontroller controls the water pump based on the readings from the float sensor and adjusts the grow lights based on time or sensor data.

2. pH Sensor

A pH sensor measures the acidity or alkalinity of the nutrient solution in the hydroponic system. It ensures that the water maintains an ideal pH level for optimal plant growth, preventing nutrient deficiencies or toxicities.

- **Working in this project**: The pH sensor continuously monitors the pH level of the water. The data is sent to the ESP8266, and based on the pH reading, adjustments can be made to the nutrient solution if required, ensuring the water is always in the desired pH range.

3. TDS (Total Dissolved Solids) Sensor

The TDS sensor measures the concentration of dissolved solids (nutrients and minerals) in the water. This measurement helps determine the nutrient strength and ensures plants receive the proper amount of nutrients for healthy growth.

- **Working in this project**: The TDS sensor sends data to the ESP8266, which is then logged into the cloud or displayed on the web dashboard. The system adjusts the water flow.

4. DHT22 Temperature and Humidity Sensor

The DHT22 is a digital sensor that measures temperature and humidity levels in the environment. Maintaining the right temperature and humidity is crucial for plant growth and health.

- **Working in this project**: The DHT22 sensor provides real-time environmental data to the ESP8266, which can adjust conditions like grow light intensity or activate fans if necessary. The data can be logged to the cloud for tracking climate conditions over time.

5. Float Sensor

The float sensor is used to monitor the water level in the hydroponic system. It helps prevent the system from overflowing or running dry, ensuring the plants have enough water for growth.

- **Working in this project**: The float sensor detects the water level in the reservoir and sends signals to the ESP8266.

6. Relay Module

The relay module is used to control the actuators, such as water pumps and grow lights. It allows the ESP8266 to switch the electrical devices on and off based on sensor data or user commands.

- **Working in this project**: The ESP8266 sends signals to the relay module to turn the water pump on or off based on float sensor readings, or it adjusts the grow lights depending on environmental conditions or time of day.

7. Google Script (for Data Logging)

Google Script is a cloud-based scripting platform that integrates seamlessly with Google Sheets to log and store sensor data. It allows for real-time logging of the data in an easily accessible format.

- **Working in this project**: Google Script is used to log real-time data from the ESP8266 into a Google Sheets document. The data includes sensor readings for pH, TDS, temperature, humidity, and float levels.

8. Web Dashboard

The web dashboard is a user-friendly interface that allows users to monitor sensor readings, control actuators, and view system status in real-time through the system's IP address.

- **Working in this project**: The web dashboard is built using a cloud platform and is connected to the ESP8266. It displays live data from all sensors and provides controls for the water pump and grow lights. The dashboard updates in real-time and is accessible from any device with an internet connection.

CHAPTER 5

SYSTEM DESIGN

5.1 Overall Architecture

The automated hydroponics system integrates various hardware components, sensors, and software tools to enable real-time monitoring, automation, and remote control. It is designed to provide an efficient and scalable solution for hydroponic farming, ensuring optimal plant growth conditions without requiring constant manual intervention.

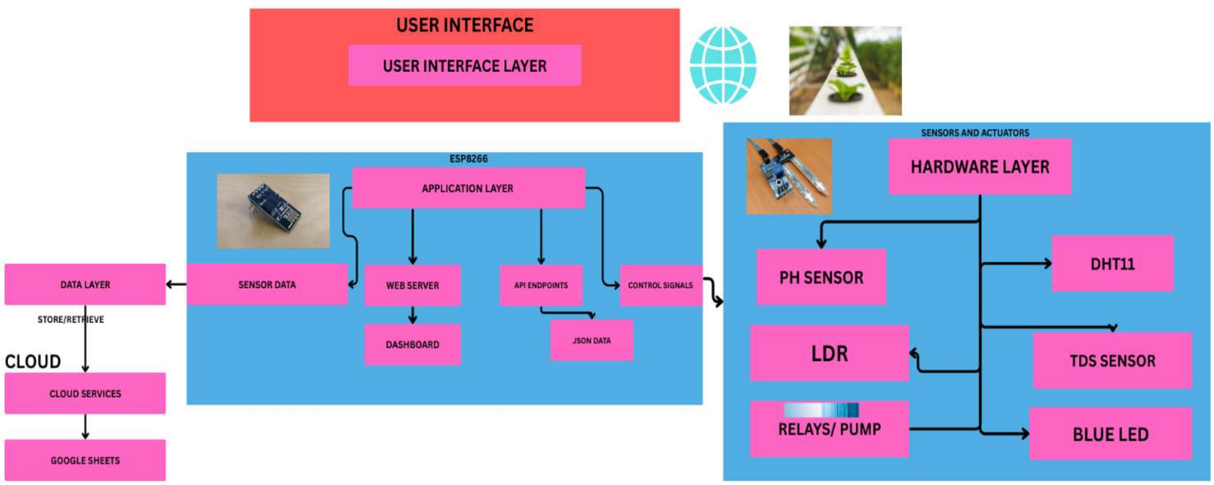


Figure 5.1 Architecture of the Proposed System

1. Sensors Layer

At the base of the system is the **sensors layer**, which consists of multiple sensors that monitor various parameters essential for plant growth in a hydroponic setup:

- **pH Sensor**: Measures the acidity or alkalinity of the nutrient solution, ensuring it remains in the optimal range for plant health.
- **TDS Sensor**: Measures the total dissolved solids (nutrients) in the water to ensure plants receive the required nutrients for growth.
- **DHT22 Temperature and Humidity Sensor**: Monitors the environmental conditions like temperature and humidity, which are crucial for plant development.
- **Float Sensor**: Monitors the water level in the reservoir to prevent overflows or water shortages.

These sensors are connected to the **ESP8266 microcontroller** for data collection and processing.

2. ESP8266 Microcontroller (Central Control Unit)

The ESP8266 microcontroller serves as the central control unit of the system. It is responsible for:

- Reading data from the connected sensors (pH, TDS, temperature, humidity, and float sensors).
- Processing sensor data to evaluate the condition of the hydroponic system.
- Controlling actuators (such as water pumps and grow lights) based on the sensor inputs.
- Sending real-time sensor data to the cloud for logging and monitoring.
- Hosting a web server for the **remote control interface** (web dashboard), where users can view sensor data and control the system remotely.

3. Actuators Layer

This layer includes various **actuators** that carry out the required actions in the system based on sensor data and user commands:

- **Water Pump**: The water pump is controlled based on the water level (via the float sensor) to ensure the reservoir always has enough water for the plants.
- **Grow Lights**: Controlled either based on environmental conditions (temperature and humidity) or on a fixed schedule to simulate the natural light cycle for plants.

The actuators are controlled by the ESP8266 microcontroller through relay modules.

4. Data Logging (Cloud Integration)

- The sensor data is transmitted to **Google Sheets** for data logging via **Google Script**. This allows for continuous storage and easy access to the historical data, which can be used for analysis and optimization of plant growth.
- **Google Script** automatically updates the data in real-time as the ESP8266 sends new readings.

5. User Interface (Web Dashboard)

A web dashboard is developed to provide a user interface (UI) for real-time monitoring and control of the hydroponic system. The dashboard is accessible through a web browser using the IP address of the ESP8266.

- The dashboard displays real-time data from the sensors (e.g., pH, TDS, temperature, humidity, and water level) for monitoring the system's status.
- The dashboard allows users to manually control the system by adjusting the water pump, grow lights, and other settings.
- The interface is designed to be intuitive and responsive, allowing easy interaction from any device connected to the network.

6. Communication and Networking

- The ESP8266 communicates with the cloud (Google Sheets) and web dashboard through its built-in Wi-Fi module. It sends sensor data to the cloud for storage and allows users to access the system remotely via the web dashboard using the system's IP address.
- The system's connectivity allows for real-time control and updates of the hydroponic system from anywhere with internet access.

7. Cloud Services (Google Script Integration)

- **Google Script** is responsible for managing the data logging process. It interacts with **Google Sheets** to store the real-time sensor data that is sent by the ESP8266.
- The **Google Sheets** document serves as the central repository for all data collected from the hydroponic system, including pH, TDS, temperature, humidity, and float sensor data.

This layer enables long-term data storage, monitoring, and troubleshooting based on historical data.

High-Level Architecture Overview

- **Sensors Layer**: Collects real-time environmental data (pH, TDS, temperature, humidity, and water level) and sends it to the ESP8266.
- **ESP8266 Microcontroller**: The central controller that processes data from the sensors, controls actuators, and sends data to the cloud and web interface.
- **Actuators Layer**: Consists of components such as water pumps and grow lights, which are controlled by the ESP8266 based on sensor data.
- **Cloud Integration**: Google Script and Google Sheets store and manage the data, allowing for continuous monitoring and access to historical data.

- **Web Dashboard**: Allows remote monitoring and control via a browser interface, providing real-time updates and system interaction.

Flow of Data and Control

- **Sensor Data Collection**: Sensors continuously monitor the hydroponic system's parameters.
- **Data Processing**: The ESP8266 processes the data and checks if any actions are needed (e.g., adjust water pump, grow lights).
- **Remote Access**: Data is sent to the cloud (Google Sheets) for logging and is displayed on the web dashboard in real-time.
- **Control Actions**: Based on user commands or automated decisions, the ESP8266 controls the actuators (water pump and grow lights).

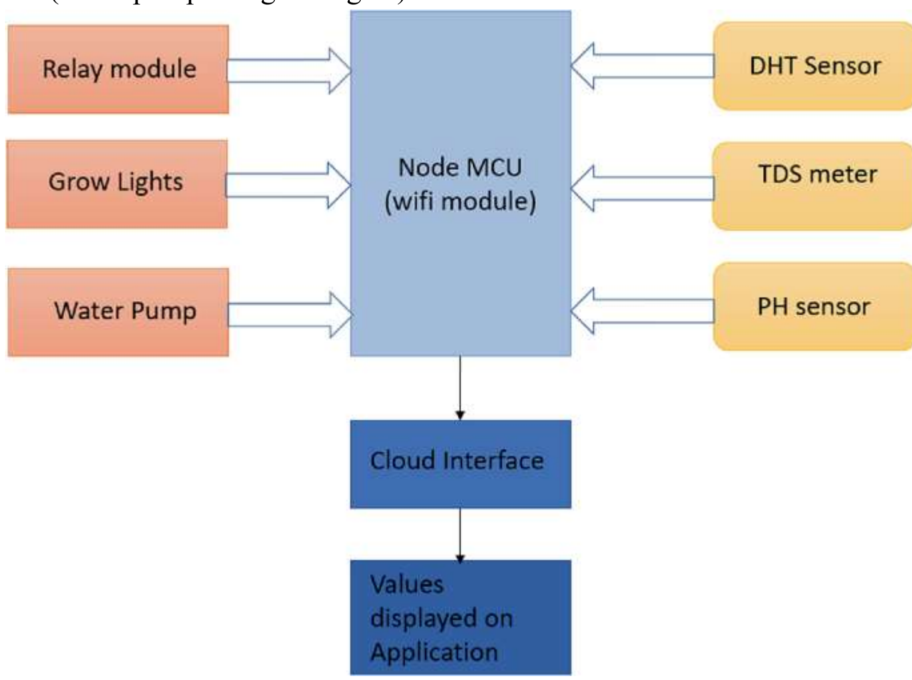


Figure 5.2 Block diagram of NodeMCU connection

5.2 Modules

1. Sensor Module

The sensor module is responsible for monitoring the critical environmental parameters of the hydroponic system to ensure optimal conditions for plant growth. It includes the following sensors:

- **pH Sensor**: Measures the pH level of the nutrient solution, ensuring it is within the optimal range for plant growth. This sensor provides continuous data to the ESP8266 for processing and adjustments.
- **TDS Sensor**: Measures the total dissolved solids (TDS) in the water, providing information on the nutrient concentration in the hydroponic system. This ensures that the plants receive adequate nutrients for healthy growth.
- **DHT22 Temperature and Humidity Sensor**: Monitors the ambient temperature and humidity, which directly affect plant growth and health. This sensor data helps in adjusting the environmental conditions, such as controlling grow lights.
- **Float Sensor**: Tracks the water level in the nutrient reservoir, preventing overflows or insufficient water levels. It provides a signal to the control module when the water level is too high or too low.

2. Control Module (ESP8266 Microcontroller)
The control module, based on the **ESP8266 microcontroller**, is the brain of the system. It processes sensor data, makes decisions on control actions, and interfaces with other modules. Its key functions include:

- **Sensor Data Processing**: Reads data from the connected sensors (pH, TDS, temperature, humidity, and float sensor) and processes it to determine the health of the hydroponic system.
- **Control Logic**: Based on sensor data, it activates actuators such as the water pump and grow lights. For example, if the water level is low, the ESP8266 will trigger the water pump to replenish the reservoir.
- **Data Communication**: Sends real-time sensor data to the cloud (Google Sheets) and web interface for monitoring. It also receives commands from the user interface (web dashboard or mobile app) to control the system.
- **User Interface Hosting**: The ESP8266 hosts a simple web server that allows users to access the system's data, view sensor readings, and control the actuators remotely via a web browser.

3. Actuator Module
The actuator module controls physical components that take action based on sensor data and user commands. It includes:

- **Water Pump**: The water pump is activated by the ESP8266 to maintain the water level in the reservoir based on data from the float sensor. It can be turned on or off to ensure an adequate water supply for the plants.
- **Grow Lights**: Grow lights are controlled to provide the appropriate light cycle for the plants. They can be automated based on environmental conditions (e.g., turning on when the light levels drop) or manually controlled through the user interface.
- **Relay Modules**: The water pump and grow lights are connected to **relay modules** to manage the high-power demands of these components. The relays are controlled by the ESP8266 to switch on/off the actuators.

4. Data Logging and Cloud Integration Module
This module is responsible for storing the real-time data collected from the sensors and making it available for analysis and monitoring. It includes:

- **Google Script Integration**: The ESP8266 sends sensor data to **Google Sheets** via **Google Script** for logging. Google Sheets acts as the central data repository where historical sensor data is stored.
- **Real-Time Data Logging**: The data from the sensors (pH, TDS, temperature, humidity, and float sensor) is automatically updated in the Google Sheet in real-time, providing a log of the system's performance over time.
- **Data Access**: Users can view past data via the Google Sheets document or use it for further analysis to optimize plant growth and system performance.

5. User Interface Module (Web Dashboard)
The user interface module enables users to monitor and control the system remotely. It includes:

- **Web Dashboard**: A web-based interface hosted on the ESP8266 allows users to view real-time data from the sensors, such as pH, TDS, temperature, humidity, and water level. The dashboard also provides control options for adjusting the water pump and grow lights.
- **Control Panel**: The dashboard includes buttons or sliders to manually control the water pump, grow lights, and other parameters. The interface is designed to be intuitive and responsive, ensuring ease of use.
- **Real-Time Monitoring**: Users can view the real-time status of the system, receive alerts for

unusual conditions, and adjust settings for improved plant care.

- **Mobile Access**: Optionally, the system can be accessed through mobile apps (such as Blynk) to provide mobile control and monitoring on-the-go.

6. Communication Module

The communication module is responsible for data transfer between the ESP8266 microcontroller and other components, such as the cloud and user interface. It includes:

- **Wi-Fi Connectivity**: The ESP8266 uses its built-in **Wi-Fi module** to connect to the local network and send data to the cloud (Google Sheets) and web dashboard.
- **Cloud Integration**: Through the Wi-Fi connection, the ESP8266 sends sensor data to Google Sheets and enables remote access via the web dashboard. It also ensures that the system is always connected to the cloud for continuous monitoring.
- **Remote Control**: The system can be controlled remotely via the web interface or mobile app. The communication module ensures that commands sent from the user interface reach the ESP8266 and actuators in real-time.

5.3 Flow Chart

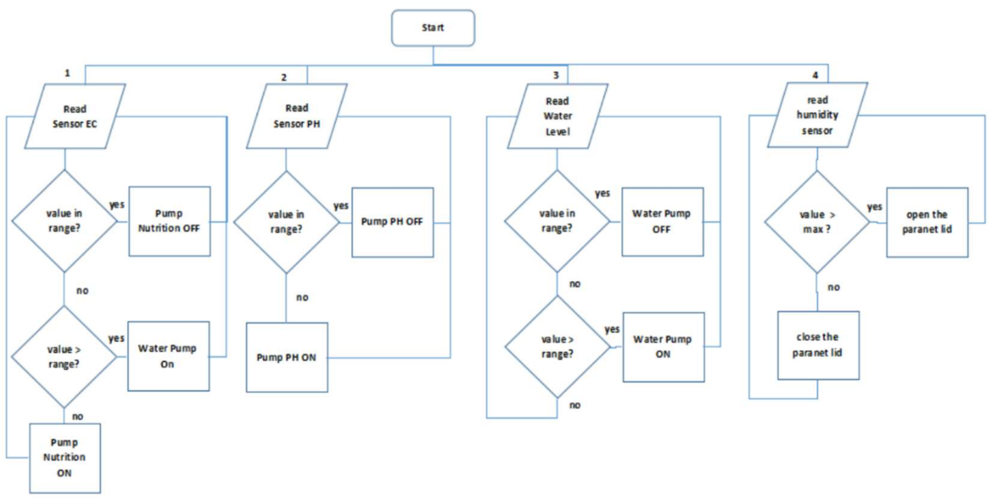


Figure 5.3 Proposed Approach

As illustrated in the above Figure, the flowchart outlines the control logic for an automated hydroponics system based on sensor inputs and automated responses. It begins by reading the EC sensor (Block 1) to assess nutrient levels; if values are within range, the nutrient pump remains off, otherwise, it either activates the water pump to dilute high EC or turns on the nutrient pump for low EC. Block 2 reads the pH sensor and accordingly switches the pH control pump ON or OFF based on the pH value. In Block 3, the system checks the water level using a float sensor—if levels are outside the defined range, the water pump is activated to adjust accordingly. Finally, Block 4 uses a humidity sensor to detect excessive humidity; if the value exceeds the set threshold, the system opens the paranet lid for ventilation, otherwise it remains closed. This automated logic ensures precise environmental control for optimal plant growth in a hydroponic setup.

CHAPTER 6

PLAN OF DEVELOPMENT AND IMPLEMENTATION

6.1 CODE SNIPPETS

1. Sensor Data Reading (pH, TDS, DHT22)

This code demonstrates how to read data from the pH sensor, TDS sensor, and DHT22 temperature and humidity sensor.

```
#include <Wire.h>
#include <DHT.h>
#define DHTPIN 4        // Pin where the DHT22 is connected
#define DHTTYPE DHT22    // Define the sensor type

DHT dht(DHTPIN, DHTTYPE);  // Initialize DHT sensor
int pHSensorPin = 34;      // Pin for pH sensor
int tdsSensorPin = 35;     // Pin for TDS sensor

void setup() {
  Serial.begin(115200);      // Start serial communication
  dht.begin();               // Initialize the DHT sensor
}

void loop() {
  // Read pH, TDS, and DHT22 values
  float pHValue = analogRead(pHSensorPin);  // Read analog value from pH sensor
  float tdsValue = analogRead(tdsSensorPin);  // Read analog value from TDS sensor
  float humidity = dht.readHumidity();       // Read humidity from DHT22
  float temperature = dht.readTemperature(); // Read temperature from DHT22

  // Print sensor values to the serial monitor
  Serial.print("pH: ");
  Serial.println(pHValue);
  Serial.print("TDS: ");
  Serial.println(tdsValue);
  Serial.print("Humidity: ");
  Serial.println(humidity);
  Serial.print("Temperature: ");
  Serial.println(temperature);

  delay(2000);  // Wait for 2 seconds before the next reading
}
```

2. Data Logging to Google Sheets via Google Script

This snippet demonstrates how to send sensor data to a Google Sheets document using **Google Script**

```
#include <WiFi.h>
#include <HTTPClient.h>

// Wi-Fi credentials
const char* ssid = "your_SSID";
const char* password = "your_PASSWORD";

// Google Script Web App URL
const String googleScriptUrl = "https://script.google.com/macros/s/your_script_id/exec";
void setup() {
  Serial.begin(115200);      // Start serial communication
  WiFi.begin(ssid, password);  // Connect to Wi-Fi

  // Wait for the Wi-Fi connection
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }

  Serial.println("Connected to WiFi");
}
void loop() {
  // Read sensor values
  float pHValue = analogRead(34);  // pH sensor pin
  float tdsValue = analogRead(35); // TDS sensor pin
  float temperature = 25.0;  // Example temperature
  float humidity = 60.0;     // Example humidity

  // Create URL to send to Google Script
  String url = googleScriptUrl + "?pH=" + String(pHValue) + "&TDS=" + String(tdsValue) +
               "&Temperature=" + String(temperature) + "&Humidity=" + String(humidity);

  // Send HTTP request to Google Script
  HTTPClient http;
  http.begin(url);   // Initialize HTTP request
```

```
  int httpResponseCode = http.GET();  // Send GET request

  if (httpResponseCode > 0) {
    Serial.println("Data sent successfully");
  } else {
    Serial.println("Error in sending data");
  }

  http.end();  // End HTTP request
  delay(60000);  // Wait for 1 minute before sending the next data
}
```

3. Controlling Actuators (Water Pump and Grow Lights)

This snippet shows how to control a **water pump** and **grow lights** based on sensor inputs or user commands.

```
#define pumpPin 32       // Pin for water pump relay
#define lightPin 33      // Pin for grow light relay

void setup() {
  pinMode(pumpPin, OUTPUT);   // Set pump pin as output
  pinMode(lightPin, OUTPUT);  // Set light pin as output
  Serial.begin(115200);       // Start serial communication
}

void loop() {
  // Example control logic: if pH or TDS goes out of range, turn on the water pump or grow lights

  float pHValue = analogRead(34); // pH sensor reading
  float tdsValue = analogRead(35); // TDS sensor reading

  // If pH goes out of range (example: 6-7), turn on the water pump
  if (pHValue < 6.0 || pHValue > 7.5) {
    digitalWrite(pumpPin, HIGH);  // Turn on pump
Serial.println("pH out of range! Water pump ON");
  } else {
    digitalWrite(pumpPin, LOW);   // Turn off pump
  }

  // If TDS goes below a certain level, turn on the grow light
```

```
  if (tdsValue < 300) {
    digitalWrite(lightPin, HIGH);  // Turn on light
    Serial.println("TDS low! Grow light ON");
  } else {
    digitalWrite(lightPin, LOW);   // Turn off light
  }
  delay(1000);  // Wait for 1 second before checking again
}
```

4. Web Server for Remote Monitoring and Control

This snippet shows how to set up a basic **web server** using the **ESP8266** to monitor sensor data and control actuators through a browser.

```
#include <WiFi.h>
#include <ESP8266WebServer.h>

const char* ssid = "your_SSID";
const char* password = "your_PASSWORD";

ESP8266WebServer server(80);  // Web server runs on port 80

void setup() {
  Serial.begin(115200);  // Start serial communication
  WiFi.begin(ssid, password);  // Connect to Wi-Fi

  // Wait for Wi-Fi connection
  while (WiFi.status() != WL_CONNECTED) {
    delay(1000);
    Serial.println("Connecting to WiFi...");
  }
  Serial.println("Connected to WiFi");

  // Define web pages
  server.on("/", HTTP_GET, []() {
    String html = "<html><body><h1>Hydroponics System</h1>";
    html += "<p>pH: " + String(analogRead(34)) + "</p>";
    html += "<p>TDS: " + String(analogRead(35)) + "</p>";
    html += "<p><a href='/turnon'>Turn ON Water Pump</a></p>";
    html += "<p><a href='/turnoff'>Turn OFF Water Pump</a></p>";
    html += "</body></html>";
```

```
    server.send(200, "text/html", html);
  });

  // Define control actions
  server.on("/turnon", HTTP_GET, []() {
    digitalWrite(32, HIGH);  // Turn on water pump
    server.send(200, "text/html", "<html><body><h1>Water Pump ON</h1></body></html>");
  });
    server.on("/turnoff", HTTP_GET, []() {
    digitalWrite(32, LOW);  // Turn off water pump
    server.send(200, "text/html", "<html><body><h1>Water Pump OFF</h1></body></html>");
  });
server.begin();  // Start the web server
}

void loop() {
  server.handleClient();  // Handle incoming client requests
}
```

5. Connecting to Google Script for Data Logging

Ensure that your **Google Script** is set up to handle data from the ESP8266. Here's an example of the script for Google Sheets:

javascript

```
function doGet(e) {
  var sheet = SpreadsheetApp.getActiveSpreadsheet().getActiveSheet();
  var pH = e.parameter.pH;
  var tds = e.parameter.TDS;
  var temperature = e.parameter.Temperature;
  var humidity = e.parameter.Humidity;

  sheet.appendRow([new Date(), pH, tds, temperature, humidity]);  // Append data to the sheet
  return ContentService.createTextOutput("Success");
```

6.2 System Framework

The system framework of the automated hydroponics system is designed around a modular and scalable Internet of Things (IoT) architecture that ensures precise environmental monitoring and real-time remote control. At its core, the system utilizes the ESP8266 microcontroller, which facilitates data acquisition from various sensors and manages control signals to actuators like pumps and LEDs.

The framework begins with a network of integrated sensors including a pH sensor, TDS (Total Dissolved Solids) conductivity sensor, temperature and humidity sensor (DHT11 or DHT22), and a float sensor to monitor water levels. These sensors provide critical real-time information about the hydroponic solution's condition and the surrounding environment. This data is collected by the ESP8266, processed, and then transmitted via Wi-Fi to a custom-built cloud-based dashboard.

The system logs all sensor readings to Google Sheets using Google Apps Script, allowing for easy historical analysis and data backups. Simultaneously, the data is visualized on a responsive web dashboard built with HTML and styled using CSS. The dashboard is hosted on the local IP address of the ESP8266 and provides users with interactive controls and live updates. It allows manual toggling of devices such as the 12V water pump and grow lights, and can display warnings or alerts based on preset thresholds.

The automation logic within the ESP8266 firmware determines whether the pump or lighting should be activated or deactivated based on current sensor readings. For example, if the float sensor detects a low water level, or if the pH value exceeds optimal thresholds, the system can automatically take corrective action.

This framework ensures that the hydroponic environment remains optimized at all times, reducing manual intervention and enabling scalable deployment. It supports remote access and modular enhancements, making it suitable for both small-scale and large-scale hydroponic farming operations.

Algorithm

1. **Start** the system and initialize all hardware components (ESP8266, sensors, relay modules, pumps).
2. **Establish Wi-Fi connection** for cloud logging and web dashboard hosting.
3. **Read sensor values**:
   - Measure water **pH** level using the pH sensor.
   - Measure **TDS** (nutrient concentration) using the TDS sensor.
   - Measure **temperature** and **humidity** using the DHT11 sensor.
   - Check **water level** using the float sensor.
4. **Analyze sensor readings**:
   - If pH is out of the optimal range, log a warning.
   - If TDS is too low or high, note nutrient adjustment needs.
   - If water level is low (float sensor triggered), prepare to refill.
5. **Control Actuators Automatically**:
   - If water level is low, **turn ON** the 12V water pump.
   - If water level reaches the required point, **turn OFF** the pump.
   - Activate or deactivate grow lights based on predefined time cycles (optional).
6. **Log data**:
   - Send all real-time sensor readings to **Google Sheets** via **Google Apps Script** for data logging and history tracking.

7. **Update Web Dashboard**:
   - Host a webpage (using HTML and CSS) showing live sensor readings.
   - Allow manual control for pump and other actuators through web buttons.
8. **Check for Manual Overrides**:
   - If a user manually triggers the pump/light from the web dashboard, execute the command immediately.
9. **Repeat Steps 3–8 continuously** after a small delay (e.g., every 5 seconds).
10. **End** the system only when manually powered off.

Pseudocode

```
Start

Initialize ESP8266, sensors (pH, TDS, DHT11, Float), relay modules, and Wi-Fi connection

While system is ON:
  Read pH sensor value
  Read TDS sensor value
  Read DHT11 sensor values (temperature, humidity)
  Read float sensor status (water level)

  If pH value < minimum threshold OR pH value > maximum threshold:
    Log "pH Level Out of Range" to Google Sheets

  If TDS value < minimum threshold OR TDS value > maximum threshold:
    Log "TDS Level Not Optimal" to Google Sheets

  If float sensor indicates LOW water level:
    Turn ON the 12V water pump
    Log "Pump Activated - Water Refilling" to Google Sheets
If float sensor indicates water level OK:
    Turn OFF the water pump
    Log "Pump Deactivated - Water Full" to Google Sheets

  Upload all sensor values to Google Sheets via Google Apps Script

  Update Web Dashboard:
    Display latest sensor readings
    Check for any manual pump/light control commands from user
```

If manual command received:

Execute pump/light ON/OFF accordingly

Log manual control action to Google Sheets

Wait for a fixed interval (e.g., 5 seconds)

Repeat

End

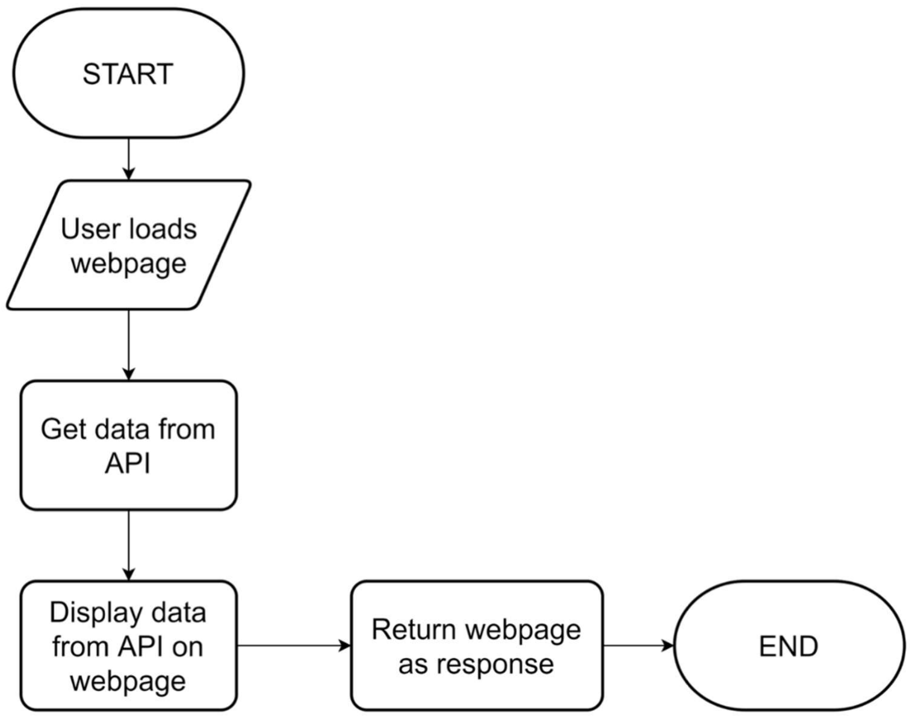


Figure 6.1 Web Dashboard Data Retrieval and Display Flow

CHAPTER 7

RESULTS AND DISCUSSION

7.1 System Inputs

i. **pH Sensor Reading**

Measures the acidity or alkalinity of the nutrient solution.
Input Range: Typically 0 to 14 Ph

ii. **TDS (Total Dissolved Solids) Sensor Reading**

Measures the concentration of nutrients in water.
Input Range: 0 to 1000+ ppm (depending on nutrient mix).

iii. **DHT11 Sensor Readings**

Measures temperature and humidity of the environment.
Input Range:

a. Temperature: 0°C to 50°C
b. Humidity: 20% to 90% RH

iv. **Float Sensor Signal**

Indicates water level in the reservoir (HIGH or LOW).
Input: Digital (ON/OFF)
User Input via Web Dashboard
Manual ON/OFF control for pump or lighting.
Input: HTTP-based command (button press, toggle switch)

v. **Power Supply**

12V DC input to power water pump and sensors
5V regulated for ESP8266 and logic-level devices
Time Interval (Loop Delay)
Controls how frequently the system checks and logs data.
Input: Fixed in code (e.g., every 5–10 seconds).

7.2 System Outputs / Screenshots

i. **Water Pump Control (12V Toggle Pump)**

Activated based on float sensor or nutrient timing logic.
Output: Relay/MOSFET control signal to turn pump ON/OFF.

ii. **Nutrient Dosing Control (Optional)**
Can be used to automatically dose nutrients based on TDS readings.
Output: Signal to dosing pump or solenoid valve (if included).

iii. **Real-Time Dashboard Display**
Outputs live sensor values (pH, TDS, temperature, humidity, water level)
Displayed using HTML/CSS over a local IP-based web interface.

iv. **Data Logging to Google Sheets via Google Apps Script**
Sensor readings pushed at regular intervals.
Output: HTTP GET/POST request sent to Google Apps Script web app.

v. **Grow Light or Fan Control**
Based on temperature or time schedule.
Output: Digital signal to relay/MOSFET switching these components.

vi. **LED Status Indicators**
Indicate system status like "Water Low", "Normal", or "Error".
Output: LED signals controlled via GPIO pins on ESP8266.

Screenshots

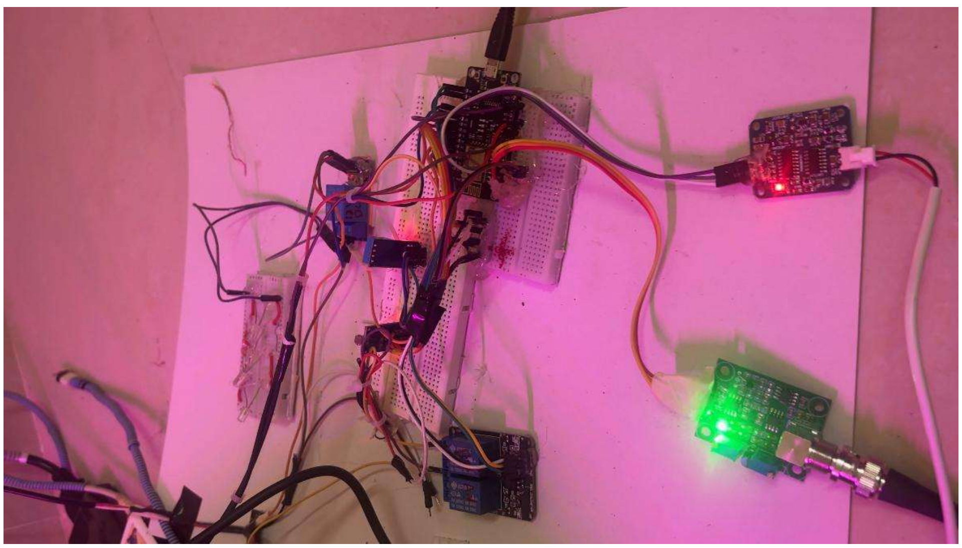


Figure 7.1 Circuit connection in Automated hydroponics System

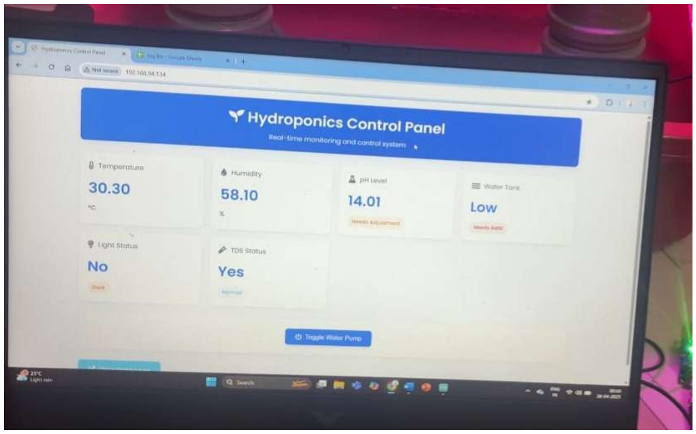


Figure 7.2 Web Dashboard

Figure 7.3 Plant growth stage 1

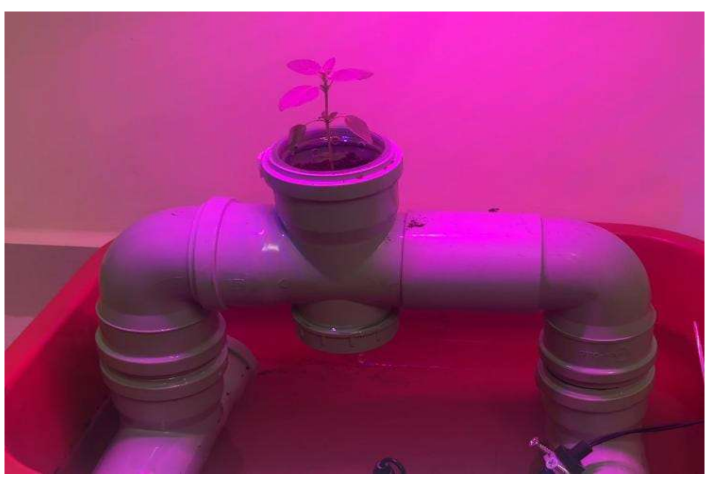
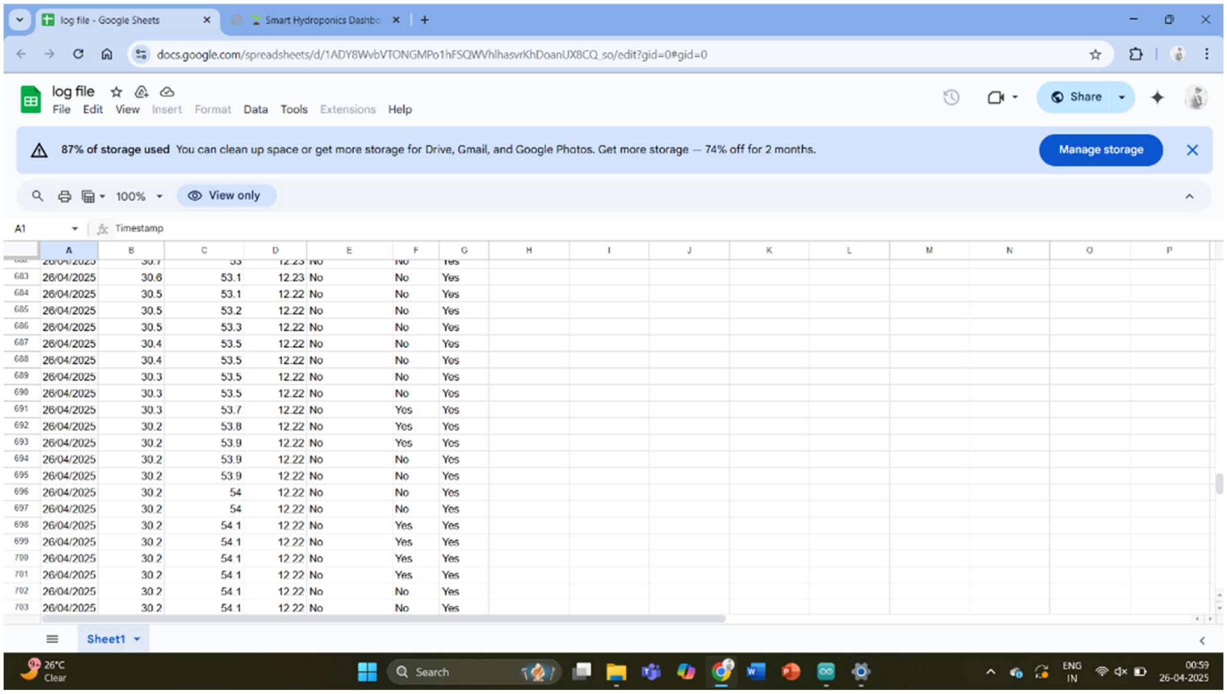


Figure 7.4 Plant growth stage 2



	A	B	C	D	E	F	G
683	26/04/2025	30.6	53.1	12.23	No	No	Yes
684	26/04/2025	30.5	53.1	12.22	No	No	Yes
685	26/04/2025	30.5	53.2	12.22	No	No	Yes
686	26/04/2025	30.5	53.3	12.22	No	No	Yes
687	26/04/2025	30.4	53.5	12.22	No	No	Yes
688	26/04/2025	30.4	53.5	12.22	No	No	Yes
689	26/04/2025	30.3	53.5	12.22	No	No	Yes
690	26/04/2025	30.3	53.5	12.22	No	No	Yes
691	26/04/2025	30.3	53.7	12.22	No	Yes	Yes
692	26/04/2025	30.2	53.8	12.22	No	Yes	Yes
693	26/04/2025	30.2	53.9	12.22	No	Yes	Yes
694	26/04/2025	30.2	53.9	12.22	No	No	Yes
695	26/04/2025	30.2	53.9	12.22	No	No	Yes
696	26/04/2025	30.2	54	12.22	No	No	Yes
697	26/04/2025	30.2	54	12.22	No	No	Yes
698	26/04/2025	30.2	54.1	12.22	No	Yes	Yes
699	26/04/2025	30.2	54.1	12.22	No	Yes	Yes
700	26/04/2025	30.2	54.1	12.22	No	Yes	Yes
701	26/04/2025	30.2	54.1	12.22	No	Yes	Yes
702	26/04/2025	30.2	54.1	12.22	No	No	Yes
703	26/04/2025	30.2	54.1	12.22	No	No	Yes

Figure 7.5 Data logging in google script

FUTURE SCOPE

The future scope of the Automated Hydroponics System is vast, with opportunities to integrate emerging technologies for enhanced efficiency and sustainability. Incorporating artificial intelligence and machine learning can enable predictive analytics for proactive system adjustments, disease prevention, and nutrient optimization. The addition of advanced multi-parameter sensors capable of monitoring dissolved oxygen, CO_2 levels, and nutrient ion concentrations can further refine environmental control and support precision farming. Future developments may also include automated nutrient mixing systems for fully autonomous operation, minimizing manual intervention. One major area of future expansion is the incorporation of artificial intelligence (AI) and machine learning (ML). By analyzing historical sensor data, AI algorithms could predict plant needs more accurately, automate corrective actions, and optimize the system’s performance with minimal human intervention. Predictive analytics could also help anticipate diseases, nutrient deficiencies, or equipment failures before they occur, leading to proactive maintenance and healthier crop yields.

Another exciting possibility is the integration of advanced sensor arrays and multi-parameter probes. Sensors capable of detecting dissolved oxygen, carbon dioxide levels, and nutrient ion concentrations (such as nitrates and phosphates) could provide even more precise control over the growing environment. This would allow for true precision farming tailored to the specific requirements of different plant species at various growth stages.

The system’s scalability makes it suitable for both educational and commercial use, from classroom demonstrations to urban farming enterprises. As connectivity, sensor technology, and data analytics evolve, this hydroponics solution holds significant potential to transform modern agriculture by promoting resource-efficient, smart, and sustainable food production.

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CONCLUSION

The Automated Hydroponics System developed in this project represents a significant step toward modern, sustainable, and efficient agricultural practices. By leveraging microcontrollers like the ESP8266, along with a network of environmental sensors (pH, TDS, temperature, humidity, and float sensors), and integrating IoT technology, we have successfully created a system that can intelligently monitor and control plant growth environments without requiring continuous human intervention. The project achieved its primary goals: real-time data monitoring, adaptive automation of pumps and nutrient dosing, and user access through a cloud-based web dashboard via IP address. This ensures that vital parameters such as nutrient concentration, water level, and environmental conditions are maintained within optimal ranges for plant health. Data logging through Google Script further provides a historical view of system performance, supporting better decision-making and future improvements. By removing manual dependency and introducing smart automation, the system minimizes errors, reduces resource wastage (water, nutrients, and electricity), and maximizes yield efficiency. Its modular and scalable design allows it to cater to various scales, from small home-based hydroponic gardens to large commercial farming setups, showcasing versatility and adaptability. Moreover, the project demonstrates the practical applications of IoT in agriculture, bridging the gap between technology and farming. It emphasizes the importance of sustainable farming techniques, especially in a future where climate change, water scarcity, and the need for urban food production are critical concerns.

The project not only meets current agricultural needs but also opens a pathway for further innovation. With future integration of AI, enhanced sensors, renewable energy, and mobile applications, this Automated Hydroponics System can evolve into an even smarter, more powerful solution that supports sustainable food production globally.

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PHOTOGRAPH (TEAM MEMBERS WITH GUIDE)

Guide : Dr. S Elango (Associate Professor, Dept of CSE-AIML)

Team Members

- Deepika H
- Jagdesh Kumar S
- Sadashiv B

APPENDIX

APPENDIX A: SENSOR DATA DETAILS

The dataset used for monitoring and system control in the automated hydroponics system comprises real-time sensor readings collected from various hardware components integrated into the setup. These readings are logged at regular intervals to a Google Spreadsheet using Google Apps Script for future analysis, visualization, and optimization.

Sensor Types and Measured Parameters:

- **pH Sensor:** Measures the acidity or alkalinity of the nutrient solution.
- **TDS (Total Dissolved Solids) Sensor:** Monitors the concentration of dissolved salts (nutrients) in the water.
- **Temperature Sensor (DS18B20):** Measures the ambient or water temperature.
- **Humidity Sensor (DHT11):** Records air humidity in the grow environment.
- **Float Sensor:** Detects water level in the reservoir (High/Low status).
- **LDR Sensor (optional):** Monitors light intensity for photosynthesis tracking.

Data Logging Features:

- Logged via Google Apps Script to Google Sheets.
- Timestamped entries for each sensor value.
- Used for trend analysis, alerts, and manual override decisions.
- Data exported for visualization in charts or integration with external dashboards.

APPENDIX B: SYSTEM ARCHITECTURE SUMMARY

1. ESP8266 – Central Control Unit

- Acts as the brain of the hydroponic system.
- Connects sensors and actuators.
- Hosts a web dashboard on a local IP for remote monitoring and control.
- Manages automated pump control logic based on sensor inputs.

2. Web Dashboard

- Built using HTML/CSS with JavaScript.
- Displays real-time sensor data.
- Allows manual toggling of water pump.
- Shows system status (Water level, pH, TDS, etc.).

3. Automation Logic

- Based on predefined thresholds:
    - **pH Pump Activation**: If pH is outside the 5.5–6.5 range.
    - **Nutrient Pump Activation**: If TDS levels are below target thresholds.
    - **Water Pump Operation**: Activated periodically or when low water level is detected.
- Uses decision-making flowcharts for each component.
- Fail-safe measures: No pump runs if sensor data is unavailable.

4. Cloud Integration

- Uses Google Apps Script to push data to Google Sheets.
- Enables long-term data storage without local database.
- Supports exporting for further analysis in Excel, Python, or visualization tools.