CAPSTONE PROJECT

REPORT

On

DESIGN OF AN IOT-BASED SEMI-AUTOMATED HYDROPONIC FARMING SYSTEM

Project Team Members: EIC, 7th SEMESTER

Abhishek Joshi (102105032)

Priyansh Kanwar (102105015)

Nishant Gaur (102105018)

Chaya Shri Medisetti (102105053)

Trishika Singh (102155011)

Akshobya Jandial (102105010)

Under the guidance of

Dr. Yanamula Venkata Karteek

(Associate Professor)

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

2024

Thapar Institute of Engineering and Technology

Electronics & Instrumentation Engineering Department

(Declared as Deemed-to-be-University u/s 3 of the UGC Act., 1956)

Post Bag No. 32, Patiala – 147004 Punjab (India)

DECLARATION

We hereby declare that project entitled ‘Design of an IoT-Based Semi-Automated Hydroponics Farming’ is an authentic record of our work carried out in the Electronics & Instrumentation Engineering Department, Thapar Institute of Engineering and Technology, Patiala, under the guidance of Dr. Yanamula Venkata Karteek (Associate Professor) during Jan-December 2024.

Date: 17/09/24

S. No.	Name of the Student	Roll No.	Signature
1	Abhishek Joshi	102105032	
2	Priyansh Kanwar	102105015	
3	Nishant Gaur	102105018	
4	Chaya Shri Medisetti	102105053	
5	Trishika Singh	102155011	
6	Akshobhya Jandial	102105010	

Faculty Supervisor: **Signature**

Dr. Yanamula Venkata Karteek

(Associate Professor)

ACKNOWLEDGEMENT

We want to extend our heartfelt gratitude to all those who have contributed towards the successful completion of the project and converge thanks to our supervisors, Dr. Yanamula Venkata Karteek, and all the faculty & staff members of the Electronics and Instrumentation Engineering Department, Thapar Institute of Engineering & Technology for generously extending their support and for sparing their valuable time to guide us towards the completion of this project work. They constantly wanted the best for us, and we appreciate their assurance. In conclusion, we also want to thank everyone who has contributed legitimately or by implication towards this venture.

S. No.	Name of the Student	Roll No
1	Abhishek Joshi	102105032
2	Priyansh Kanwar	102105015
3	Nishant Gaur	102105018
4	Chaya Shri Medisetti	102105053
5	Trishika Singh	102155011
6	Akshobhya Jandial	102105010

ABSTRACT

This report examines the potential of hydroponic farming, a modern method of growing plants without soil by using nutrient-rich water solutions. Hydroponics offers farmers better control over growing conditions, enhancing efficiency, reducing environmental harm, and addressing issues common in traditional farming. The system is designed to manage nutrients to optimize plant growth. It also emphasizes the environmental benefits, including water conservation, reduced land use, and the ability to cultivate crops year-round.

The project also integrates advanced technology, such as automated sensors and data systems, to monitor crucial factors like nutrient concentration, pH balance, and humidity. This real-time monitoring ensures optimal conditions for plant growth, resulting in better nutrient uptake, healthier crops, and more efficient use of resources. In depth analysis is conducted to evaluate the system's effectiveness, demonstrating how the combination of hydroponics and modern automation can contribute to the future of sustainable agriculture.

TABLE OF CONTENTS

LISTS OF FIGURES

LISTS OF TABLES

CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

As the global population continues to rise, reaching an estimated 9.7 billion by 2050, the agricultural sector faces increasing pressure to produce more food while confronting significant environmental challenges. Traditional farming methods are proving inadequate due to limitations in land availability, water scarcity, and the impacts of climate change. In this scenario, hydroponic farming has emerged as a transformative solution, offering a sustainable approach to meet the growing food demands. [1]

Hydroponics, a method of growing plants without soil using nutrient-rich water solutions, represents a significant advancement in agricultural technology. This method addresses key challenges associated with conventional farming by optimizing water use and enabling cultivation in environments with limited arable land. The advantages of hydroponics include enhanced control over nutrient delivery, reduced water consumption, and the ability to grow crops in urban settings, thus mitigating issues related to land scarcity and soil degradation. Recent studies highlight the effectiveness of hydroponic systems in various applications. For instance, Taguchi method demonstrates how vertical farming techniques, including hydroponics, can optimize growth conditions for crops like lettuce and basil. Their research, illustrates significant improvements in yield and resource efficiency. Economic analysis shows that hydroponic lettuce production can be more cost-effective compared to traditional soil-based methods, despite the higher initial setup costs [2-6].

The integration of smart technologies further enhances the potential of hydroponic systems. IoT-based frameworks for real-time monitoring and data analysis play a crucial role in optimizing hydroponic farming operations. By leveraging sensors and automated systems, farmers can closely monitor plant health, nutrient levels, and environmental conditions, leading to better management and reduced resource wastage. However, there are challenges to overcome, including the high costs associated with hydroponic systems and the need for advanced automation and control technologies. Despite these obstacles, ongoing research and technological advancements continue to improve the feasibility and efficiency of hydroponic farming, making it a viable solution for future food production [7-10].

This report explores the current state of hydroponic farming, focusing on its benefits, challenges, and the role of smart technologies in enhancing its effectiveness. By examining recent research and case studies, this report aims to provide a comprehensive overview of how hydroponic farming can contribute to sustainable agriculture and address the pressing issues of global food security.

1.2 LITERATURE REVIEW

Hydroponic farming represents a significant shift in agricultural practices, offering solutions to many of the limitations inherent in traditional soil-based farming. Research comparing hydroponic and soil-based systems underscores the advantages of hydroponics in terms of growth efficiency and yield. Studies reveal that hydroponic systems often enable faster plant growth and higher productivity by utilizing nutrient solutions more effectively and reducing the potential for soil-borne diseases. This research highlights how hydroponics enhances food production through intensified agricultural practices. By optimizing nutrient delivery and environmental control, hydroponics mitigates some of the constraints associated with soil-based farming, such as nutrient deficiencies and contamination. [2-3]

Recent advancements in hydroponic technology further illustrate its potential benefits. For instance, "SMART GROW," a low-cost automated hydroponic system designed specifically for urban farming, incorporates automation to manage nutrient delivery and environmental conditions, making hydroponic farming more accessible and efficient in urban settings. This system builds upon existing methods by applying the Taguchi method to vertical farming, with a focus on optimizing growth conditions for crops like lettuce and basil. The study demonstrates that refined environmental controls can lead to substantial improvements in crop yields, reinforcing the effectiveness of hydroponic systems in maximizing productivity [4-5].

Technological innovations are pivotal in the advancement of hydroponic systems. Research explores various automation and control systems used in hydroponic greenhouses, detailing how these technologies improve nutrient delivery and environmental regulation. This technological progress is complemented by an IoT-based framework for real-time monitoring and analysis of agricultural data. The framework enhances the precision and efficiency of hydroponic farming by integrating real-time data collection and analysis into the management of nutrient and environmental conditions [7-9].

Other research echoes this by reviewing the application of smart sensors and data analytics in precision agriculture, highlighting their role in optimizing agricultural practices. Similarly, the benefits of IoT in smart agriculture are emphasized, noting that these technologies provide valuable insights and control mechanisms for improving farming practices [11-15].

Economic aspects are crucial in assessing the feasibility of hydroponic farming. An economic analysis of hydroponic lettuce production found that despite the higher initial costs associated with hydroponic systems, they can become economically advantageous over time. This is due to increased yields and more efficient resource use, which can offset the initial investment. The studies emphasize the economic and environmental benefits of hydroponics, noting its lower environmental footprint compared to traditional agriculture. Their assessments highlight reduced land use, lower pesticide requirements, and overall sustainability, contributing to the growing interest in hydroponic systems as a viable alternative to soil-based farming [16-20].

Overall, the integration of advanced technologies and optimized growth conditions in hydroponic systems underscores their potential to transform agricultural practices. The research indicates that while hydroponic systems involve higher initial costs, their long-term benefits including improved yields, reduced environmental impact, and enhanced efficiency make them a promising solution for modern agriculture. By leveraging technological advancements and focusing on economic viability, hydroponics represents a forward-looking approach to addressing the challenges of food production in an increasingly urbanized world.

1.3 NEED ANALYSIS

Earlier models of IoT based Hydroponic Farming System had some problems and limitations, including:

- Quality and Consistency
- Crop Variety needed
- Data-Driven Decision Making
- Precise Nutrient Delivery
- Controlled Environment

1.4 AIM

To develop an IoT-based Semi-Automated Hydroponic Farming System.

1.5 OBJECTIVES

- To automate the manual process of nutrient doping by controlling four peristaltic pumps to dispense specific volumes of solutions: acid, base, nutrient A, and nutrient B.
- To measure and control pH, EC, temperature and humidity for crop health by controlling relays to modulate lights, air exhaust fan, and humidifier.
- Configure dashboards with gauges, graphs, camera feed, and other widgets to view all relevant data on a single page using Blynk cloud.

1.6 PROBLEM STATEMENT

The problem at hand revolves around measurement and control of various parameters like pH, EC, temperature, humidity and nutrient doping which are important for the plant health and also to increase the quality and consistency of the yield. Another problem also evolves where different kinds of crop varieties are needed such as exotic varieties all year round. An automated model is needed to measure and control all the above-mentioned parameters. In response to the above issues, we propose an innovative approach which is an IoT based Hydroponic System. This approach involves the development of a highly specialized convolutional neural model, meticulously fine-tuned for optimal performance in this context.

1.7 CONCLUSION

Several research papers were referred to, and various limitations were drawn for the earlier existing model of hydroponic farming system before deciding the need analysis. In this chapter, Overview, Literature Review, Need Analysis, Aim, Objectives, and Problem Statement were discussed.

CHAPTER 2

THEORY STANDARDS AND CONSTRAINTS

2.1 OVERVIEW

An IoT based Hydroponic Farming System uses data acquired from various sensors such as pH sensor, TDS sensor, LDR sensor, Humidity sensor and Soil moisture sensor. This model also comprises of actuators such as Grow light, peristaltic pumps, Water Pump, Exhaust fan and Humidifier. The data collected from the sensors is then sent to the Blynk cloud where the data is displayed and output is controlled. Raspberry Pi 3 is used as a microcontroller. Detailed analysis of each component will be discussed in this chapter.

Humidity sensor:

Humidity sensor measures moisture in the air. It is used to maintain comfortable and healthy environments, especially in weather stations, HVAC systems, and industrial settings. [7]

The specifications are:

- Model: DHT11
- Humidity Range: 20% to 90% Relative Humidity (RH)
- Operating Voltage: 3V - 5.5V
- Output Type: Digital signal on a single pin (1-wire protocol)
- Response Time: 5-10 seconds

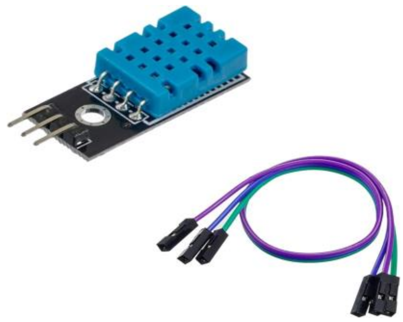


Fig 2.1: Humidity sensor (DHT11)

Soil moisture sensor:

A soil moisture sensor measures the water content in soil by passing an electric current through two probes to detect resistance. It outputs analog signals, compatible with microcontrollers like Arduino or Raspberry Pi. The sensor consists of probes and a control board, providing real-time data on soil moisture levels, commonly used in agriculture and irrigation systems. [8]

The specifications are:

- Model: SMR110
- Operating Voltage: 3.3V - 5V
- Output Type: Analog (voltage) or Digital (depending on the version)
- Output Range: 0-3V

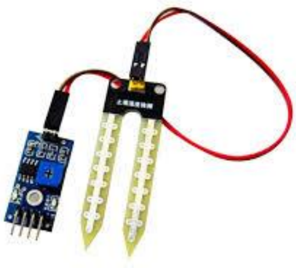


Fig 2.2: Soil moisture sensor (SMR110)

pH sensor:

pH sensor is a rugged, reliable water pH measuring device. It has an operating range between 0-14. It has an accuracy of <= (0.01 pH). Response time is less than or equal to 1 minute. It has a mV reading of up to 1250mV to 1250mV. It may consume more than 5mA during start-up or less than 2 seconds. Ph probe is connected to the Ph sensor through a BNC connector. It has an mV Reading of 1mV. [11]

The specifications are:

- Model: SUP-PH5011
- Type: Analog pH Sensor/Probe
- Measuring Range: 0 - 14 pH
- Operating Voltage: 5V
- Output: Analog voltage (0-3V)

Fig 2.3: pH sensor (SUP-PH5011)

TDS sensor:

A TDS (Total Dissolved Solids) sensor is a device used to measure the concentration of dissolved solids in a liquid. It works by measuring the electrical conductivity of the liquid, which is directly related to the concentration of dissolved solids. TDS sensors are commonly used in water quality monitoring applications to ensure the water is suitable for various purposes such as drinking, agriculture, and industrial use. [11]

The specifications are:

- Model: XH2.54
- Type: Analog TDS Sensor
- Output Voltage: 0 - 2.3V
- Operating Voltage: 3.3V - 5V
- Connection: 2.54mm XH2.54 3-pin connector

Fig 2.4: TDS sensor (XH2.54)

LDR sensor:

LDR (Light Dependent Resistor) is a resistor whose resistance varies inversely with the amount of light falling on it. It is also known as a photoresistor, photocell, photoconductive cell, etc. LDR are available in 5mm, 8mm, 12mm and 25mm dimensions. LDR is made of high-resistance semiconductor material. The semiconductor material used for the photoresistors is cadmium sulphide, CdS. When it’s dark, LDR has high resistance, known as dark resistance. Usually, dark resistance will be in the range of mega ohms. When light falls on LDR, resistance reduces to the kilo-ohms range. [11]

The specifications are:

- Model: NSL-19M51
- Maximum Voltage: 150V DC
- Operating Temperature: -30°C to +70°C
- Spectral Response: 400 nm to 700 nm

Fig 2.5: LDR sensor (NSL-19M51)

Raspberry Pi 3:

The Raspberry Pi 3 is a versatile single-board computer with a 64-bit quad-core ARM Cortex-A53 processor running at 1.2 GHz. Unlike microcontrollers, it supports a full operating system, commonly Raspbian. It features 40 GPIO pins for sensor connections, 4 USB ports, HDMI output, and offers both wired Ethernet and Wi-Fi connectivity, making it ideal for various computing and IoT applications. [11]

The specifications are:

- CPU: Quad-core 1.2 GHz ARM Cortex-A53
- RAM: 1GB LPDDR2
- Ports: 4x USB 2.0, HDMI, 3.5mm audio jack, Ethernet
- Wireless: 802.11n Wi-Fi, Bluetooth 4.1

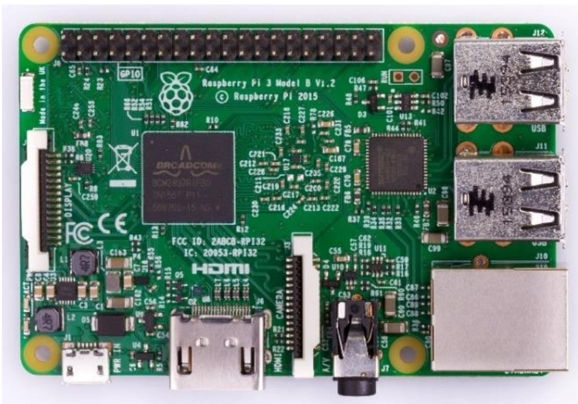


Fig 2.6: Raspberry Pi 3

Peristaltic Pump:

Peristaltic pumps are also known as hose pumps, tube pumps or roller pumps. They provide a reliable and simple solution for moving almost any fluid in a wide variety of markets and applications. At the core of the pump is an elastomeric hose. This tube fully contains the fluid, virtually eliminating the possibility of product contamination. [12]

The specifications are:

- Model: DC-506D
- Type: 12V DC
- Flow rate: 1-3 litres per minute
- Tubing size: Inner Diameter (ID) 3-5 mm, Outer Diameter (OD) 6-8 mm

Fig 2.7: Peristaltic pump (DC-506D)

Water pump:

Because of their limited power, submersible pumps are only suitable for hydroponic systems with a total GPH (Gallons Per Hour) requirement of 1200 or less. - This should be more than adequate for most home growers. Inline pumps are so powerful that they are not measured in GPH but rather in HP (horsepower). [12]

The specifications are:

- Type: Submersible 12V DC
- Flow rate: 1-5 litres per minute (depending on the model)
- Max lift: 1-3 meters

Fig 2.8: Water pump

Exhaust fan:

An exhaust fan removes stale air, fumes, or moisture from an area by using a motor to spin blades and push air outside. It is powered electrically and can be integrated with smart systems via microcontrollers like Arduino or Raspberry Pi. [12]

The specifications are:

- Type: 12V DC, 120mm fan
- Power: 2.5-4W
- Airflow: 40-70 cubic feet per minute (CFM)
- Purpose: Removing excess heat and ensuring proper air circulation

Fig 2.9: Exhaust fan

Grow light:

Grow light is an artificial light source designed to stimulate plant growth by emitting electromagnetic radiation suitable for photosynthesis. Grow lights are used in situations where natural light is insufficient or unavailable, such as in indoor gardening or commercial greenhouses. [20]

The specifications are:

- Type: LED Grow Light
- Spectrum: Full-spectrum (3000K-6000K)
- Features: Designed for plant growth, low heat output, energy-efficient

Fig 2.10: Grow light

2.2 TECHNICAL STANDARDS USED

This section briefly discusses the standards used in the project.

- **IEEE 802.15.1:** This standard specifies the Wireless Medium Access Control (MAC) and Physical Layer (PHY) protocols for Bluetooth Wireless Personal Area Networks (WPANs. It defines the specifications for Bluetooth technology, focusing on Wireless Personal Area Networks (WPANs) [23]
- **IEEE 802.11:** This standard specifies the Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) protocols for local and metropolitan area networks. It provides requirements and specifications for wireless LAN communication, enhancing wireless network performance and interoperability. This standard has been used as wireless LAN standard for sending data to cloud and Wi Fi connectivity. [24]
- **IEEE Std 802.3 series:** This standard for Gigabit Ethernet, details the specifications and advancements that enable high-speed Ethernet communication at 1 Gbps. It provides requirements for the technical aspects and implications of implementing Gigabit Ethernet in network environments. This standard has been used for connecting Ethernet. [25]

CHAPTER 3
DESIGN METHODOLOGY

3.1 OVERVIEW

The semi-automated hydroponics farming system relies on a Raspberry Pi 3 and a range of sensors to monitor and manage the growing environment. The system's operation involves several key steps, as outlined in Fig-3.1:

- **Data Collection:**

  Assume we are developing an automated system for maintaining pH and TDS levels in a solution. The system collects data from various sensors for monitoring and controlling these parameters.

  - pH and TDS sensors collect data at 1 sample per 5 seconds.

  - Data is collected periodically at 1 sample per 2 min to ensure real-time control.

- **Data Pre-Processing:**

  The raw data collected will be processed to remove noise, normalize, and format it. pH sensor values are adjusted using a calibration factor, offset, and slope to obtain accurate pH readings.

  Normalized pH = (7 - (Raw pH Value - Offset) / Slope) * Calibration Factor

  TDS sensor values are converted to a voltage and then adjusted using a calibration factor and offset.

  TDS Voltage = Raw TDS Value * (Reference Voltage / Max ADC Value)

  Normalized TDS = (((Voltage / 2.3) * 1000) + Offset) * Calibration Factor

  Filtering: If the standard deviation of a series of sensor values is unusually high (indicating noise), we apply a smoothing filter, such as a moving average:

  Smoothed Value = (raw value[i-1] + raw value[i] + raw value[i+1]) / 3

- **Input to the Software Feature Extraction:**

  Feature Extraction: From the pre-processed data, extract features like mean and variance for pH and TDS levels.

  For pH and TDS readings:

  Calculate the mean and variance of the readings over a specific period to monitor stability and accuracy.

  Mean Value = Σ (Value) / No of Samples

  Variance = Σ (Value - Mean Value) ^ 2 / No of Samples

- **Control System Logic:**

  Based on the processed sensor data, the control system operates pumps to maintain the desired pH and TDS levels.

  - For pH: Operate pH up/down pumps to keep pH within the range of 6.5 to 7.5.
  - For TDS: Operate pumps to add solution A/B if TDS drops below 800.

- **Implementation:**

  The system uses a set of relay pins to control the pumps and sensors. Data is acquired and processed using an ADC (ADS1115), and real-time data is sent to a monitoring platform.

  - Relay pins are set up to control the operation of the pumps.
  - Sensor values are continuously read and processed to maintain the desired conditions.

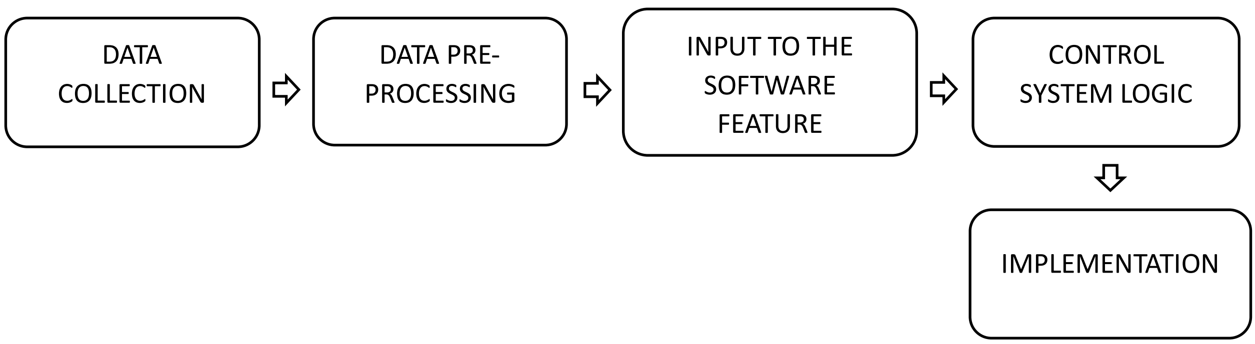


Fig 3.1: The working process of designing of Hydroponic System

3.2 PROPOSED HARDWARE

To create an IoT based Hydroponic Farming System, we would require:

A. **Humidity sensor:** It collects humidity data that is measures the moisture from the surroundings. Refer Fig 2.1. [7]
B. **Soil moisture sensor:** It collects the water content present in the soil by passing an electric current through two probes to detect resistance. Refer Fig 2.2. [8]
C. **pH sensor:** It collects the pH value that is the amount of alkalinity and acidity in water. Refer Fig 2.3. [11]
D. **Total Dissolved Solids (TDS) sensor:** It measures the concentration of dissolved solids in a liquid. Refer Fig 2.4. [11]

E. **Light Dependent Resistor (LDR) sensor:** Its resistance varies inversely with the amount of light falling on it. Refer Fig 2.5. [11]

F. **Raspberry Pi-3:** It is a single-board computer with a 64-bit quad-core ARM Cortex-A53 processor. It supports a full operating system. Refer Fig 2.6. [11]

G. **Peristaltic Pump:** It is a type of displacement pump used for pumping pH and nutrient solutions to the plants. Refer Fig 2.7. [12]

H. **Water pump:** It is used to pump the water to the plants. Refer Fig 2.8. [12]

I. **Exhaust fan:** It removes stale air, fumes, or moisture from an area by using a motor to spin blades and push air outside. Refer Fig 2.9. [12]

J. **Grow light:** It is used to stimulate plant growth by emitting electromagnetic radiation suitable for photosynthesis. Refer Fig 2.10. [20].

3.3 ENGINEERING DESIGN SPECIFICATIONS

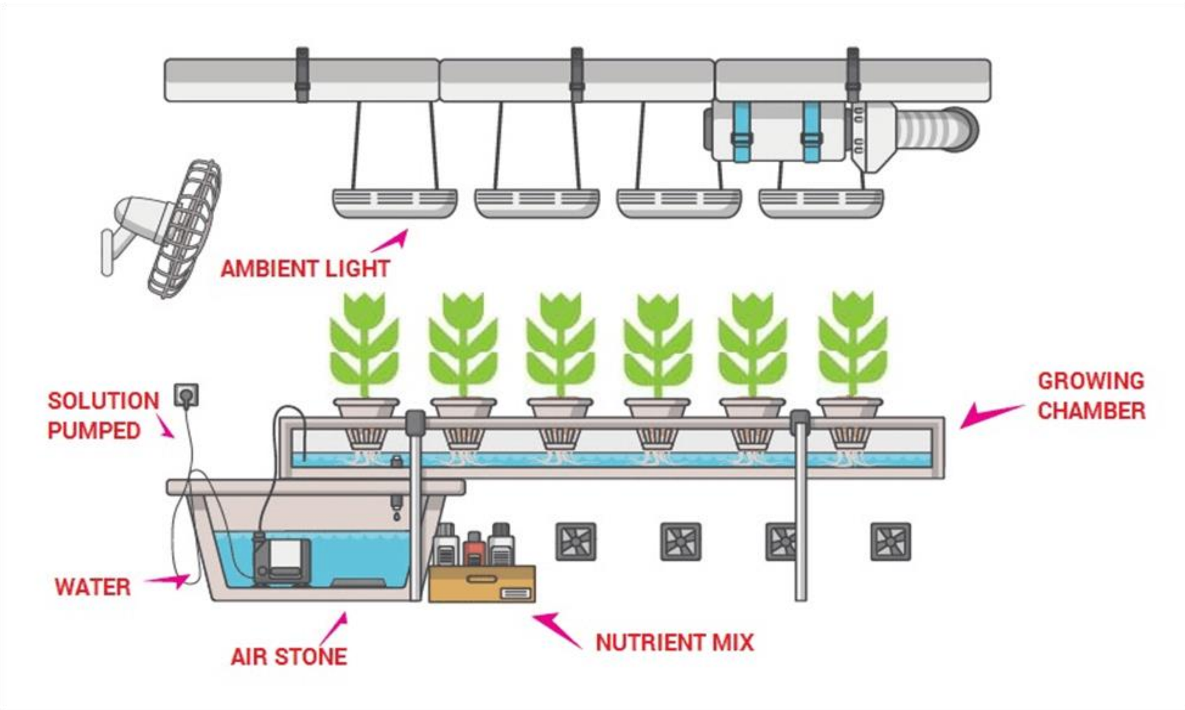
To interface the sensors with the Raspberry Pi-3 microcontroller and actuate them, the following hardware components are required:

Table 3.1: Design Specifications

S. No	Name of Equipment	Specifications	Purpose
1.	Raspberry Pi-3	Raspberry Pi-3 Model B Quad core 1.2GHz	Collects and transmits data in real-time.
2.	Humidity Sensor	DHT11 5V/6mA	Measures moisture level of air
3.	Soil moisture sensor	SMR110 5V/15mA	Measures moisture level
4.	pH sensor	SUP-PH5011 5V/6mA	pH measuring sensor
5.	Total Dissolvable Solids (TDS) sensor	XH2.54 5V/6mA	Concentration of dissolved solids

6.	Light Dependent Resistor (LDR) sensor	NSL-19M51 5V/20mA	Monitors light intensity
7.	Peristaltic Pump	DC-506D 12V DC 1-3 litres/min flow rate	Pumping pH and nutrient solutions
8.	Water Pump	12V DC, 5-10W	Pumping water
9.	Exhaust Fan	230V	Regulates air flow and temperature
10.	Grow Light	LED Grow Light 24W	Artificial light source

The Fig-3.3 illustrates a hydroponic farming system design where water and nutrient solutions are pumped into a growing chamber that holds the plants. The air stone aerates the water, and nutrients are mixed for plant growth. Ambient light, provided by grow lights, ensures plants receive the required light spectrum for photosynthesis. The system is designed for efficient delivery of water, air, and nutrients to the plants without the need for soil.



Fig–3.3: Hydroponic System Design

The Nutrient Film Technique (NFT) represents a hydroponic cultivation method that enables efficient plant growth within a controlled environment. This technique optimizes nutrient and water usage, facilitating rapid development of plants. The essential steps and considerations necessary for the successful implementation of an NFT hydroponics system, focusing on operational efficiency and plant health. [4]

To begin with, selecting an appropriate location with reliable access to water and electricity is essential for the successful setup of the system. In this project, NFT channels were constructed using circular PVC pipes, each measuring 16 inches in diameter and 4 feet in length. These pipes are arranged in three layers and supported by a steel rod frame measuring 3.5 feet in width. This setup ensures both stability and optimal space utilization.

The system incorporates a reservoir designed to hold the nutrient solution. To deliver nutrients effectively, four peristaltic pumps were installed, providing a steady and controlled flow of the solution to the NFT channels. A 50W submersible pump was also used to circulate the nutrient solution from the reservoir to the channels, capable of lifting the solution up to 5 feet through a hose pipe into the perforated PVC pipes.

In preparing the nutrient solution, it was mixed with water according to the instructions and its pH adjusted to meet the specific needs of the plants. This careful preparation ensures that the plants receive the necessary nutrients and maintain optimal growth conditions. For planting, some seedlings were chosen and placed in the NFT channels. The seedlings were positioned to ensure their roots made consistent contact with the nutrient solution, thereby facilitating efficient nutrient uptake and supporting healthy growth.

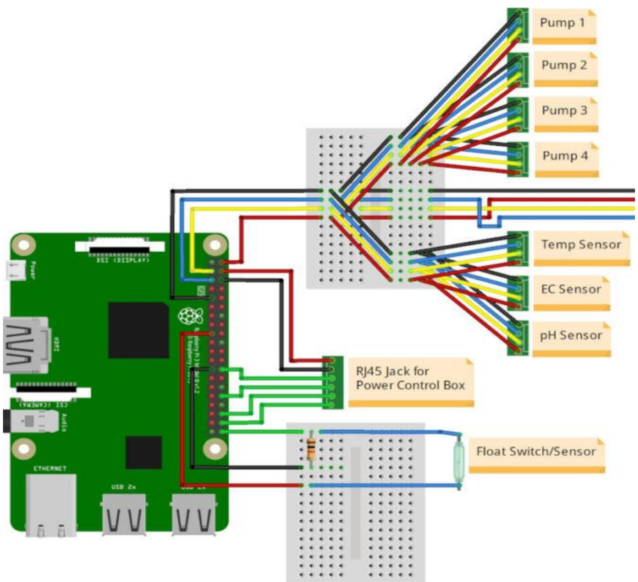


Fig-3.4: Circuit Diagram

The Fig-3.4 showcases the hardware configuration involving a Raspberry Pi connected to various sensors (temperature, electrical conductivity (EC), pH, and a float switch/sensor) as well as multiple pumps. The Raspberry Pi serves as the central controller, gathering data from the sensors and controlling the water and nutrient pumps. IEEE 802.15.1 standard defines the specifications for Bluetooth technology, focusing on Wireless Personal Area Networks (WPANs) [23]. IEEE Std 802.3 series is used for connecting Ethernet. [25]

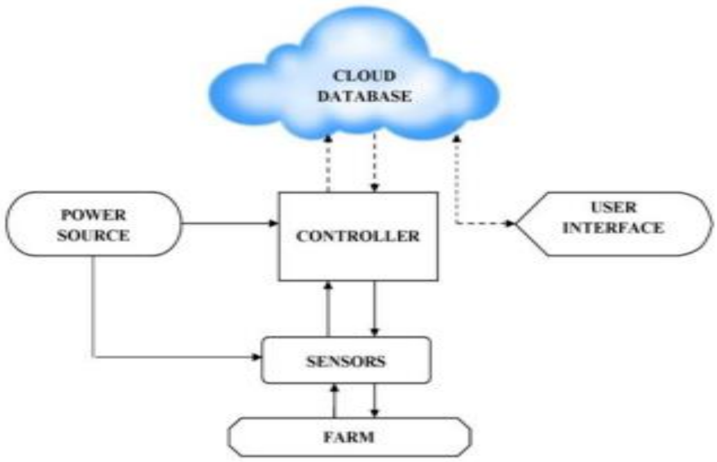


Fig-3.5: Flow Chart of System Architecture and Cloud Integration

The Fig-3.5 emphasizes the integration of sensors, controllers, and cloud infrastructure. The Raspberry Pi serves as the central controller, interfacing with the farm's sensors to monitor environmental parameters such as temperature, pH, and moisture levels.

Data collected by the sensors is uploaded to a cloud database, where it can be accessed and analysed remotely. Additionally, the use of Blynk IoT allows for real-time monitoring and control of the system via a mobile or web-based interface, providing users with the ability to manage the farm's operation from anywhere, making it a robust IoT-based solution for efficient farm management. IEEE 802.11 is used as Wireless LAN standard for sending data to cloud and Wi-Fi connectivity. [24]

3.4 COMPARATIVE ANALYSIS

Comparative analysis for the hardware components for different specifications is shown below in TABLE 3.2.

TABLE 3.2: Comparative Analysis

Component Name	**Type A**	**Type B**	**Type C**	**Remark**
Raspberry Pi	Raspberry Pi 3 Model B	Raspberry Pi 4 Model B	Raspberry Pi Zero W	Used Raspberry Pi 3 Model B due to its affordability, processing power and GPIO pins.
Peristaltic Pump	DC-506D Peristaltic Pump	KKmoon 80 GPH Peristaltic Pump	Vevor Peristaltic Pump	Used DC-506D as it offers precise nutrient delivery, with appropriate power.
Water Pump	12V DC, 5-10W Submersible Water Pump	80 GPH Submersible Pump	396 Submersible Water Pump	Chosen 12V DC, 5-10W Pump for its low power consumption and ability to pump water to a height of 5 feet.
Exhaust Fan	230V Exhaust Fan	4-Inch 195 CFM Inline Duct Fan	AC Infinity CLOUDLINE T6	Used 230V Exhaust Fan due to the easy availability and sufficient airflow for maintaining a controlled environment.
Grow Light	24W LED Grow Light	P1500 LED Grow Light	Phlizon 600W LED Plant Grow Light	Chosen 24W LED Grow Light because it provides just the right intensity for plant growth without consuming too much energy

TDS Sensor	XH2.54 TDS Sensor	Grove TDS Sensor	DFRobot Gravity TDS Sensor	Used XH2.54 TDS Sensor as it is cost-effective and provides accurate measurements needed for maintaining nutrient levels.
pH Sensor	SUP-PH5011	Atlas Scientific EZO-pH Sensor	Gravity Analog pH Sensor	Chosen SUP-PH5011 for its accuracy and lower cost.
Soil Moisture Sensor	SMR110	Capacitive Soil Moisture Sensor	SEN0193 Gravity Analog Capacitive Soil Moisture Sensor	Used SMR110 because it provides reliable and stable readings in a hydroponic environment.
Humidity Sensor	DHT11 Humidity and Temperature Sensor	DHT22 Humidity and Temperature Sensor	AM2302 Humidity and Temperature Sensor	Used DHT11 because it offers sufficient accuracy for temperature and humidity monitoring at a lower cost.
LDR Sensor	NSL 19M51	GL5539 Light Dependent Resistor (LDR)	BH1750 Light Sensor	Used NSL 19M51 for its high sensitivity to light changes, ideal for monitoring light levels in the hydroponic system.

3.5 HARWARE DESIGN

The design of hydroponic farming system is made with the help of research paper to ensure efficient and precise plant cultivation by leveraging a combination of advanced components. At the core of the system is the Raspberry Pi 3 Model B, which handles data acquisition from various sensors, processes the information in real-time, and manages the system's components, all while enabling remote monitoring and control through internet connectivity.

Central to the system's functionality are the various sensors integrated into the setup. The humidity sensor tracks the moisture levels in the air, essential for maintaining an optimal growing environment. Soil moisture sensors are used to gauge the water requirements of the plants and ensure adequate hydration. The pH sensor monitors the acidity of the nutrient solution, as pH balance is vital for nutrient absorption. The TDS sensor measures the concentration of dissolved solids in the solution, helping to adjust the nutrient levels as needed. An LDR sensor measures light intensity, ensuring that plants receive the appropriate amount of light for photosynthesis.

In preparing the nutrient solution, the following chemicals were used NPK([13-0-45],[0-52-34]), Fe EDTA, $Ca(NO_3)_2$ H2O2, MgSO4.K2SO4, KOH(pH-up), HNO3(pH-down) and Micronutrients pack. They are mixed with water according to the instructions and its pH adjusted to meet the specific needs of the plants. This careful preparation ensures that the plants receive the necessary nutrients and maintain optimal growth conditions.

Fig 3.6: Hardware Design

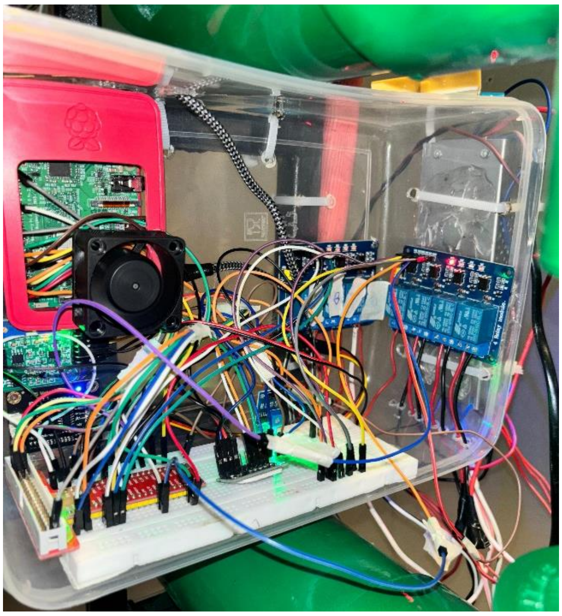


Fig 3.7: Sensor Setup in Hardware design

Central to the system's functionality are the various sensors integrated into the setup. The humidity sensor tracks the moisture levels in the air, essential for maintaining an optimal growing environment. Although soil moisture sensors are more typical in traditional farming, they are included here to gauge the water requirements of the plants and ensure adequate hydration. The pH sensor monitors the acidity of the nutrient solution, as pH balance is vital for nutrient absorption. The TDS sensor measures the concentration of dissolved solids in the solution, helping to adjust the nutrient levels as needed. An LDR measures light intensity, ensuring that plants receive the appropriate amount of light for photosynthesis.

To manage the delivery of nutrients and water, the system employs a Peristaltic Pump DC-506D and a 12V DC water pump. The peristaltic pump allows for precise and contamination-free dispensing of the nutrient solution, while the water pump circulates the solution to ensure even distribution and prevention. An exhaust fan is also incorporated to regulate airflow and temperature within the growing area, preventing overheating and promoting healthy plant growth. Complementing these components is a Grow light, which provides the necessary light spectrum to support vigorous plant development.

A breadboard facilitates the connection and configuration of the various electronic components, while cables and wires ensure reliable electrical connections between the Raspberry Pi, sensors, and actuators. For enhanced functionality, the Blynk IoT platform is utilized, enabling users to remotely monitor and control the system via a mobile app. This integration allows for real-time data access, notifications, and adjustments, making the system both convenient and effective.

Overall, the hardware design of this hydroponic farming system exemplifies a sophisticated approach to plant cultivation. By integrating these components, the system ensures optimal conditions for plant growth, ultimately leading to healthier plants and improved yields.

3.6 COMMUNICATION PROTOCOLS

I2C (Inter-Integrated Circuit) is a communication protocol developed by Philips Semiconductor (now NXP Semiconductors) in the 1980s. It enables communication between multiple devices using just two lines: SDA (Serial Data Line) and SCL (Serial Clock Line). This protocol features a two-wire setup where SDA handles data transfer and SCL provides the clock signal. It supports a master-slave configuration that allows several devices to communicate on the same bus, with a single master coordinating the data. Devices on an I2C bus are assigned distinct addresses, usually 7 bits long but expandable to 10 bits.

The protocol supports various speed modes, including Standard (100 kbit/s), Fast (400 kbit/s), High-speed (3.4 Mbit/s), and Ultra-Fast (5 Mbit/s). Acknowledgment (ACK) is a critical feature that confirms successful data transmission. [2-7]

1-Wire Protocol, created by Dallas Semiconductor, is designed for basic, low-speed communication using a single data line and ground connection. This protocol is characterized by its use of just one wire for data transfer along with a ground. It supports parasitic power, where some devices can function without an external power supply, instead drawing power from the data line. Each device on a 1-Wire network has a unique 64-bit ROM code, and data is transmitted using a bit-banging technique with precise timing patterns. [8-10]

Raspbian is the operating system utilized for Raspberry Pi devices, based on Debian Linux. It is specifically designed to work well with Raspberry Pi hardware and facilitates various applications. IEEE 802.15.1 standard defines specifications for Bluetooth standard for connecting the Raspberry Pi. It outlines the protocols for medium access control (MAC) and physical layer (PHY) to facilitate short-range wireless communication between devices. [23]

In this project, Python 3.9 is used for programming. Python, a widely-adopted and open-source language, is employed to develop neural network algorithms and manage sensor interfaces on both Arduino and Raspberry Pi. Additionally, Python powers a Chatbot service integrated with Firebase, which provides real-time updates on sensor data. [20]

3.7 CONCLUSION

To achieve our objectives, we integrated various sensors with a Raspberry Pi-3, which was connected to the Blynk cloud. This setup enabled real-time data collection from the sensors, allowing for seamless monitoring and control of the Hydroponic farming system.

CHAPTER 4
RESULTS AND DISCUSSION

4.1 OVERVIEW

In developing our hydroponic farming system, we based our design on established research rather than conducting direct surveys. The system, integrates various sensors for monitoring humidity, pH levels, TDS, and light intensity. These sensors are connected to the Raspberry Pi 3 Model B via cables for accurate data collection. Data parameters and system specifications were informed by comprehensive reviews of relevant literature, which guided our implementation to ensure adherence to best practices for effective hydroponic management.[10]

4.2 SIMULATION RESULTS

For our hydroponic farming simulation, we employed the Blynk IoT platform in combination with a Raspberry Pi 3 Model B running Raspbian and Python 3.9 to collect and analyse real-time environmental data. The system was equipped with various sensors for monitoring humidity, pH levels, Total Dissolved Solids (TDS), and light intensity. Additionally, actuators such as a peristaltic pump, a water pump, and an exhaust fan were integrated to manage the growing environment effectively.

Figure 4.1 depicts the monitoring and control of key parameters during the simulation, showing how variables like humidity, pH levels, TDS, and light intensity evolved over time. Main fan, water pump, grow light, humidifier, pH up and down, solutions are the parameters which are controlled using Blynk cloud platform. For example, fluctuations in pH and TDS levels were observed during nutrient delivery phases, prompting automatic adjustments by the system.

The Blynk IoT platform facilitated real-time data visualization and control, allowing users to monitor live data, receive alerts for any deviations, and make adjustments remotely. This integration proved essential for maintaining optimal conditions within the hydroponic system, thereby supporting robust plant growth and maximizing yield.

Fig 4.1: Simulation Results

4.3 HARDWARE RESULTS

The deployment of our hydroponic farming system yielded significant insights into both environmental control and plant growth, focusing on sadabahar flower plant cultivation. By employing sensors to monitor key parameters humidity, pH levels, Total Dissolved Solids (TDS), and light intensity, we were able to collect and analyze data throughout the simulation, as illustrated in Figure 4.1. The system demonstrated its ability to respond effectively to the needs of plants at various growth stages.

Humidity readings showed periodic variations that aligned with the irrigation cycles. Peaks in the data corresponded to watering events, while troughs reflected intervals when the moisture levels decreased, showcasing the system's efficiency in maintaining optimal humidity for lettuce growth. This precise control was crucial for ensuring that the plants received the right amount of moisture throughout their development.

The pH and TDS data revealed the system's dynamic adjustments to the nutrient solution. Figure 4.1 illustrates how the pH was carefully regulated to meet the specific requirements of plant, while it shows TDS fluctuations, indicating the system's ability to maintain appropriate nutrient levels. These adjustments are vital for supporting healthy plant growth and maximizing yield. Light intensity readings, varied to match the plant different growth stages, confirming that the provided lighting conditions were appropriate. Consistent lighting is essential for photosynthesis and overall plant health, making this aspect of the system crucial for successful cultivation.

The integration of the Blynk IoT platform facilitated continuous monitoring and remote management of the system. This setup allowed for real-time adjustments and alerts, ensuring that the environmental conditions were always optimized for plant growth. The data collected not only verified the system's operational effectiveness but also provided a deeper understanding of how each parameter influences plant development. This comprehensive analysis confirms the system's reliability and effectiveness, setting a strong foundation for future advancements in hydroponic farming technology and its applications.

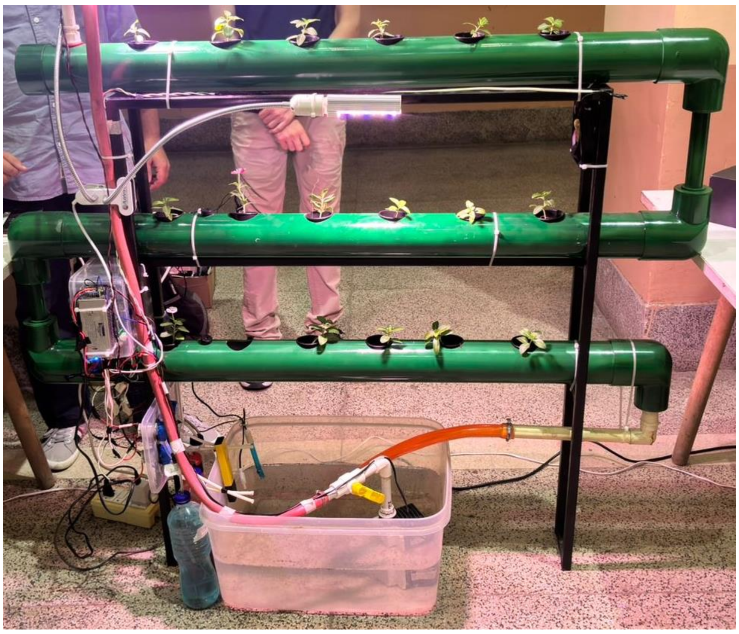


Fig 4.2: Hardware Results of developed Hydroponic System

CHAPTER 5
CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

This project aimed to develop a semi-automated hydroponics farming system utilizing the Raspberry Pi 3 and the Blynk IoT platform for real-time monitoring and automation of critical growing conditions. The key objectives were to design a system capable of collecting environmental data, automating crop care processes, and enabling remote management. Through the integration of various sensors, real-time data on temperature, humidity, pH, and nutrient levels was collected and processed by the Raspberry Pi 3. This data allowed the system to automatically regulate irrigation, nutrient dosing, and lighting to maintain ideal growing conditions for plants. The Blynk IoT platform provided users with an easy-to-use interface for remotely monitoring system performance and making necessary adjustments.

During the evaluation phase, the system performed effectively, automating the adjustment of environmental factors based on real-time data inputs. This not only reduced the need for manual intervention but also ensured the optimal use of resources such as water and nutrients. The system demonstrated that it could reliably maintain a healthy environment for plant growth while allowing for remote oversight and control. Overall, this project presents a practical solution for integrating IoT technology into agriculture, particularly in hydroponics. The semi-automated system has the potential to improve farming efficiency and sustainability. Future improvements could include further automation capabilities, integration with advanced analytics, and scalability to accommodate larger systems.

5.2 FUTURE WORK

Future research for the semi-automated IoT-based hydroponics farming system could focus on enhancing its automation capabilities and optimizing data processing. Integrating advanced machine learning algorithms to analyse sensor data in real-time could lead to predictive adjustments of environmental factors such as temperature, humidity, and nutrient levels, making the system more efficient and reducing the need for manual interventions. Another area of exploration is incorporating additional sensors, such as light intensity or CO_2 sensors, to provide more comprehensive monitoring of the growing conditions. Combining data from multiple sensor types using sensor fusion techniques could improve the accuracy of decision-making and lead to better crop management outcomes.

The system could also benefit from the implementation of real-time alerts and notifications, allowing users to receive automated warnings if the system detects any critical issues, such as drops in nutrient levels or equipment malfunctions. Expanding the system for larger-scale operations is another avenue for research, with attention to optimizing sensor placement and data transmission for commercial hydroponic farms. Moreover, focusing on energy efficiency, such as incorporating renewable energy sources or optimizing battery management for continuous, untethered operation, could make the system more sustainable.

Additionally, integrating cloud-based analytics and artificial intelligence models could provide deeper insights into plant growth trends and resource consumption, helping users fine-tune their growing practices over time. By focusing on these areas, future iterations of the hydroponics system could become even more efficient, scalable, and user-friendly, providing greater value for both small-scale growers and commercial farming operations.

CHAPTER 6

PROJECT METRICS

6.1 CHALLENGES FACED AND TROUBLESHOOTING:

During the development of the IoT-enabled hydroponic farming system, several obstacles emerged, requiring thorough troubleshooting. One of the key challenges was ensuring reliable data collection from various sensors, including pH, TDS, and humidity sensors, which often produced inconsistent or noisy data. To address this, different techniques for data filtering and normalization were tested to improve the accuracy and reliability of the sensor readings.

Another significant hurdle was designing an efficient control system using Raspberry Pi to automate key processes such as water and nutrient pump management, as well as controlling grow lights and exhaust fans. The control logic required continuous optimization to ensure the system operated smoothly. Integrating the hardware components, such as sensors, pumps, and communication modules, into a unified system was complex and demanded careful calibration of the sensors and the use of reliable connections to ensure consistent performance.

Additionally, the integration with Blynk IoT for remote monitoring and control encountered connectivity issues that had to be resolved to maintain real-time data flow and system control. By collaborating with mentor, conducting research, and performing iterative testing, these challenges related to data accuracy, component integration, and system automation were successfully addressed, leading to the creation of a fully functional and reliable hydroponic farming system.

6.2 RELEVANCE SUBJECTS

Table 6.1 – Relevant subjects

SNO	SUBJECT CODE	SUBJECT NAME
1.	UEI514	IOT BASED SYSTEMS
2.	UEI742	SMART SENSOR NETWORKS
3.	UEI501	CONTROL SYSTEMS
4.	UEI733	EMBEDDED SYSTEM DESIGN

6.3 INTERDISCIPLINARY ASPECTS

This hydroponic farming system leverages an interdisciplinary approach combining electrical, computer, mechanical, and environmental engineering to deliver a and efficient farming solution. The core of the project integrates sensor technology and data analytics to monitor and control various environmental factors crucial for plant growth.

Electronics Engineering is applied in designing and integrating sensors (humidity, soil moisture, pH, TDS, LDR) and control systems (peristaltic pump, water pump, exhaust fan, grow light) with the Raspberry Pi 3, enabling precise monitoring and adjustments of the hydroponic environment. Implementing Blynk IoT for remote monitoring and control involves programming and cloud-based technologies to ensure real-time data access and system management.

Mechanical Engineering plays a role in designing and prototyping the physical setup of the hydroponic system, ensuring that the components are effectively integrated and function cohesively within the system. Environmental Engineering is key to understanding and optimizing the conditions necessary for plant health, including nutrient delivery, light exposure, and environmental stability. Together, these interdisciplinary efforts create a streamlined, semi-automated hydroponic farming system that enhances plant growth, system efficiency, and ease of use. The combination of hardware integration, software functionality, and user interaction ensures a well-rounded and effective solution.

6.4 COMPONENT AND COST ANALYSIS

Table 6.2 – Component and Cost Analysis

S.NO	NAME OF EQUIPMENT	SPECIFICATIONS	QUANTITY	ESTIMATED COST (INR)
1.	Raspberry Pi 3	Model 3b	1	Rs.4400.00
2.	pH Sensor	SUP-PH5011	1	Rs.3003.00
3.	Humidity Sensor	DHT11	1	Rs.246.00
4.	TDS Sensor	XH2.54	1	Rs.3200.00
5.	Peristaltic Pump	DC-S06D	4	Rs.2000.00
6.	Grow Light	LED Grow Light	1	Rs.2090.00
7.	Exhaust Fan	4-inch	1	Rs.548.00
8.	Relay Board	4 Ch – 5V	2	Rs.500.00
9.	Nutrient		2	Rs.570.00
10.	pH Base		1	Rs.260.00
11.	Green House Shade		1	Rs.800.00
12.	PVC Pipes & Tools		2	Rs.1100.00
13.	Power Supply	12V 5amp	1	Rs.689.00
14.	RJ45	M F Connector	2	Rs.790.00
15.	Copper Wire	14mm	1	Rs.500.00
16.	Miscellaneous			Rs.3000.00
Total				Rs.23,696.00

6.5 BRIEF ANALYTICAL NOTES

Q: What is the main focus of the project described in this report?

A: The main focus is on developing an automated system for precise pH and TDS control in a hydroponic farming setup using sensor data acquisition and real-time monitoring.

Q: What methods were proposed to collect data for developing the system?

A: The proposed methods include using sensors such as pH, TDS, soil moisture, and LDR to collect real-time data for various parameters, ensuring accurate monitoring and control of the system.

Q: What kind of data pre-processing was suggested before using the data in the control system?

A: The suggested pre-processing includes calibrating the sensor data, filtering to remove noise, normalizing the readings, and converting the data into a format suitable for real-time decision-making in the control system.

Q: What control logic was used in the system to maintain optimal pH and TDS levels?

A: The system uses a control logic that operates pumps for pH adjustment and TDS level maintenance based on calibrated sensor readings. This ensures that the pH is maintained within the range of 6.5 to 7.5, and TDS levels are kept above 800.

Q: How was the system evaluated for performance?

A: The system was evaluated by testing the accuracy and reliability of the sensor data and the effectiveness of the control logic in maintaining the desired pH and TDS levels over time.

Q: What was the intended application area for the developed system?

A: The intended applications include automated hydroponic farming setups where precise control of nutrient levels, pH, and other environmental factors is crucial for optimal plant growth and yield.

Q: What were some of the advantages cited for using an automated control system in hydroponics?

A: Advantages include improved accuracy in maintaining optimal growing conditions, reduced manual intervention, efficient resource utilization, and enhanced crop yield and quality.

Q: What hardware components were decided for building the control system?

A: The components include a microcontroller (such as Arduino or Raspberry Pi), ADS1115 ADC for sensor data acquisition, various sensors (pH, TDS, soil moisture, LDR), and relay-controlled pumps for nutrient and pH adjustment.

Table 6.3 Team Assessment Matrix

Evaluation by	Nishant Gaur	Abhishek Joshi	Priyansh Kanwar	Chaya Shri Medisetti	Trishika Singh	Akshobya Jandial
Nishant Gaur	4.5	4.5	4.5	4.5	4.5	4.5
Abhishek Joshi	4.5	4	4.5	4.5	4.5	4.5
Priyansh Kanwar	4.5	4.5	4.5	4.5	4.5	4.5
Chaya Shri Medisetti	4	4.5	4.5	4.5	4	4
Trishika Singh	4.5	4.5	4	4	4.5	4.5
Akshobya Jandial	4.5	4.5	4.5	4	4	4.5

6.6 WORK SCHEDULE (GANTT CHART)

Table 6.4 Work Distribution Table

SNO	NAME	WORK DISTRIBUTION
1	Nishant Gaur	Literature review, Design Methodology, Hardware, Software Stimulation
2	Abhishek Joshi	Literature review, Design Methodology, Cost Analysis, Hardware, Software Stimulation
3	Priyansh Kanwar	Literature review, Design Methodology, Hardware, Software Stimulation, System Analysis
4	Chaya Shri Medisetti	Literature review, Design Methodology, Hardware, Software Stimulation, System Analysis

5	Trishika Singh	Literature review, Design Methodology, Cost Analysis, Hardware, Software Stimulation
6	Akshobya Jandial	Literature review, Design Methodology, Cost Analysis, Hardware, Software Stimulation

Table 6.5 Gantt chart of the group

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.6 Gantt chart of Nishant Gaur

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.7 Gantt chart of Abhishek Joshi

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.8 Gantt chart of Priyansh Kanwar

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.9 Gantt chart of Chaya Shri Medisetti

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.10 Gantt chart of Trishika Singh

S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

Table 6.11 Gantt chart of Akshobya Jandial

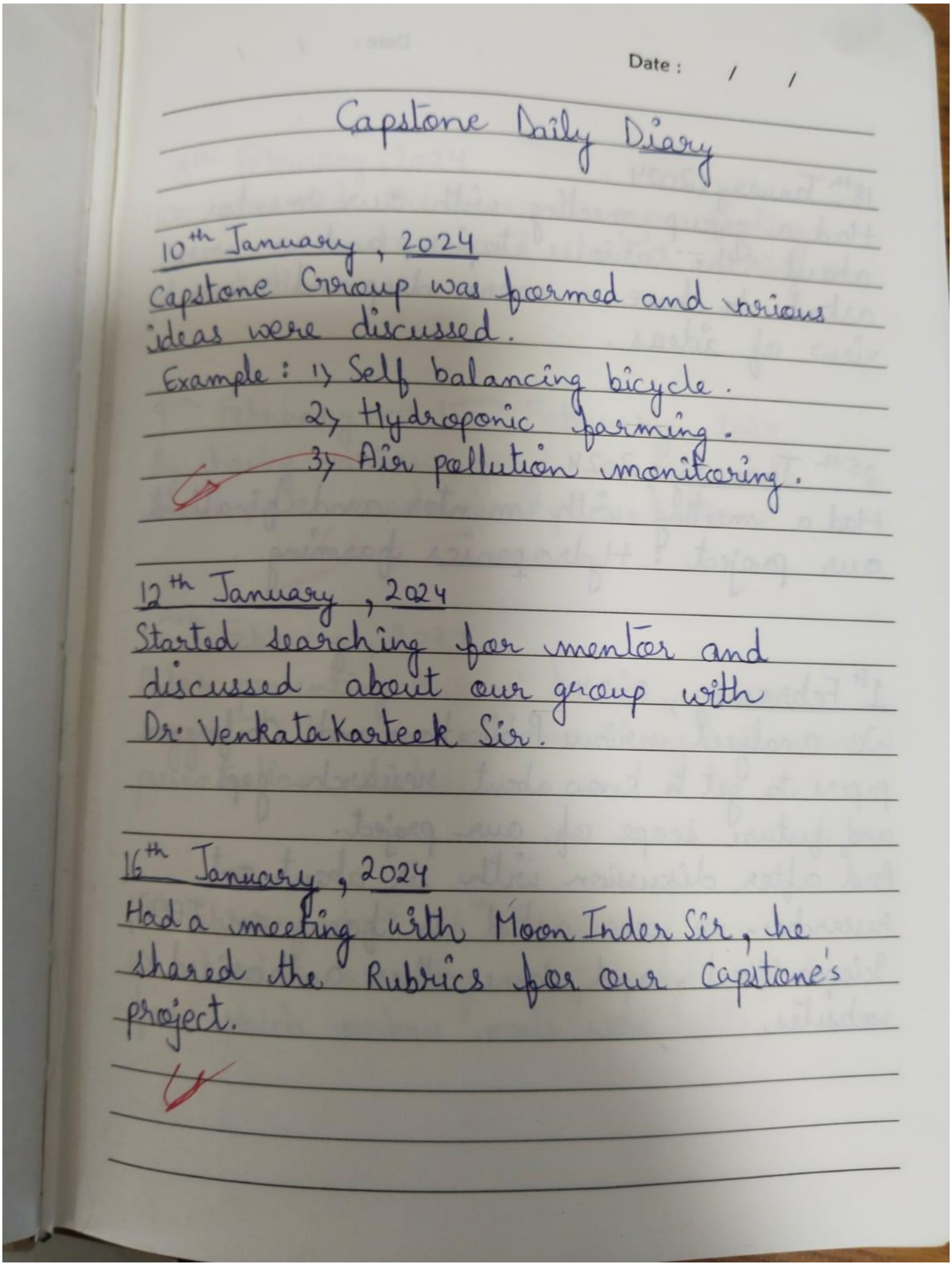
S.NO	Activity	Jan-Feb	Mar-April	May-June	July-Aug	Sept-Oct	Nov-Dec
1	Literature Review						
2	Design Methodology						
3	Hardware Design						
4	Software Stimulation						
5	Results Collection						
6	Testing & Validation						
7	Documentation						
8	Report Writing						
9	Finalize Report						
10	Project Submission						

REFERENCES

1. Zeynab Jouzi, Hossein Azadi, Fatemeh Taheri, Kiumars Zarafshani, Kindeya Gebrehiwot, Steven Van Passel, Philippe Lebailly, Organic Farming and Small-Scale Farmers: Main Opportunities and Challenges, Ecological Economics, Volume 132, 2017, Pages 144-154, ISSN 0921-8009
2. Sikora, J. & Reed, D. (2018). Comparison between growing plants in hydroponic systems and soil-based systems. Journal of Agricultural Science, 11(3), 1–10.
3. Wada, Y. (2019). Hydroponics: An intensified agricultural practice to improve food production. Journal of Plant Nutrition, 42(12), 1476–1490.
4. Kenny Kueh Yung Shin, Tan Ping Ping, Maybelline Goh Boon Ling, Chong Chee Jiun, Noor Alamshah B. Bolhassan, SMART GROW – Low-cost automated hydroponic system for urban farming, HardwareX, Volume 17, 2024
5. Farhangi, H., Mozafari, V., Roosta, H.R. et al. Optimizing growth conditions in vertical farming: enhancing lettuce and basil cultivation through the application of the Taguchi method. Sci Rep 13, 6717 (2023).
6. Garcia, M. & Lee, S. (2017). Economic analysis of hydroponic lettuce production. Journal of Agricultural Resources Economics, 42(2), 234–248.
7. Oguz, F.E., Ekersular, M.N., Sunnetci, K.M. et al. Enabling Smart Agriculture: An IoT-Based Framework for Real-Time Monitoring and Analysis of Agricultural Data. Agric Res (2024).
8. Soheli, Sultana Jahan & Jahan, Nusrat & Hossain, Md & Adhikary, Apurba & Khan, Dr. Md. Ashikur & Wahiduzzaman, M.. (2022). Smart Greenhouse Monitoring System Using Internet of Things and Artificial Intelligence. Wireless Personal Communications. 124. 10.1007/s11277-022-09528-x.
9. Patel, R. & Gupta, S. (2019). Automation and control systems for hydroponic greenhouses. Journal of Agricultural Engineering, 46(3), 123–136.
10. Smith, P. & Johnson, L. (2020). Nutrient management strategies in hydroponic systems. Journal of Soil Science and Plant Nutrition, 20(4), 1067–1080.
11. Srivastava, A., Das, D.K. A Comprehensive Review on the Application of Internet of Thing (IoT) in Smart Agriculture. Wireless Pers Commun 122, 1807–1837 (2022)
12. Vuran, M. C., Salam, A., Wong, R., & Irmak, S. (2018). Internet of underground things in precision agriculture: Architecture and technology aspects. Ad Hoc Networks, 81, 160–173.
13. Soussi, Abdellatif & Zero, Enrico & Sacile, Roberto & Trinchero, Daniele & Fossa, Marco. (2024). Smart Sensors and Smart Data for Precision Agriculture: A Review. Sensors. 24. 2647. 10.3390/s24082647.
14. Bhatt, Harshit & Sharma, Brijbhushan. (2019). IOT: the Current Scenario and Role of Sensors Involved in Smart Agriculture. International Journal of Recent Technology and Engineering. 8. 12011-12023. 10.35940/ijrte.D9285.118419.
15. An IoT Low-Cost Smart Farming for Enhancing Irrigation Efficiency of Smallholders Farmers https://dl.acm.org/doi/10.1007/s11277-022-09915-4
16. Raju, K. Lova & Veeramani, Vijayaraghavan. (2022). A Self-Powered, Real-Time, NRF24L01 IoT-Based Cloud-Enabled Service for Smart Agriculture Decision Making System. Wireless Personal Communications. 124. 10.1007/ s11277-021-09462-4.

17. Pathmudi, Vivek & Khatri, Narendra & Kumar, Sandeep & Abdul-Qawy, Antar & Vyas, Ajay. (2023). A systematic review of IoT technologies and their constituents for smart and sustainable agriculture applications. Scientific African. 19. e01577. 10.1016/j.sciaf. 2023.e01577.
18. Resh, H. M. (1981). Complete guide for growing plants hydroponically. Hort Science, 16(6), 918–922.
19. Panda, A. & Malik, R. (2021). Impact of hydroponics technology. International Journal of Agricultural Biology, 23(4), 1007–1014.
20. Kim, H. & Park, J. (2022). Environmental sustainability assessment of hydroponic farming. Environmental Science and Pollution Research, 29(5), 4567–4580.
21. Brown, R. & White, E. (2016). Hydroponic nutrient solutions: Formulation and optimization. Journal of Plant Nutrition and Soil Science, 179(3), 344–355.
22. Chen, Q. & Wang, L. (2018). Hydroponic tomato production: Challenges and innovations. Journal of Agricultural Science and Technology, 20(6), 1234–1245.
23. IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 15.1a: Wireless Medium Access Control (MAC) and Physical Layer (PHY) specifications for Wireless Personal Area Networks (WPAN)," in IEEE Std 802.15.1-2005 (Revision of IEEE Std 802.15.1-2002) , vol., no., pp.1-700, 14 June 2005, doi: 10.1109/IEEESTD.2005.96290.
24. IEEE Standard for Information Technology--Telecommunications and Information Exchange between Systems - Local and Metropolitan Area Networks--Specific Requirements - Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications - Redline," in IEEE Std 802.11-2020 (Revision of IEEE Std 802.11-2016) - Redline, vol., no., pp.1-7524, 26 Feb. 2021.
25. H. Frazier, "The 802.3z Gigabit Ethernet Standard," in IEEE Network, vol. 12, no. 3, pp. 6-7, May-June 1998, doi: 10.1109/65.690946.

APPENDIX A



Date : / /

Capstone Daily Diary

10th January, 2024
Capstone Group was formed and various ideas were discussed.
Example : 1) Self balancing bicycle.
2) Hydroponic farming.
3) Air pollution monitoring.

12th January, 2024
Started searching for mentor and discussed about our group with Dr. VenkataKarteek Sir.

16th January, 2024
Had a meeting with Moon Inder Sir, he shared the Rubrics for our capstone's project.

Date :   /   /

18th January, 2024
Had a group meeting with our mentor about the various topics, and we were asked to have a more deep and research view of ideas.

25th January, 2024
Had a meeting with mentor and finalized our project : Hydroponics farming.

1st February, 2024
We analysed various Publications and Conference papers to get to know about research gaps and future scope of our project.
And after discussion with sir about out researches, we were asked to focus on IEEE, Science Direct, and some other authorised websites.

Date : / /

8th February, 2024

We presented the research paper findings to our mentor and started working on presentation.

9th February ⟷ 15th February, 2024

By having various google meeting with team, we made our presentation.

15th February, 2024

After presenting our ppt to sir, we were suggested to make some changes in our presentation slides.

16th February ⟷ 26th February, 2024

We started working on proposal report, for which various meets were held.

Date : / /

26th February, 2024
We presented our report and presentation (with some changes) to our mentor.

26th February ⟷ 4th March, 2024
Whole week, we had 3 meetings and did cost analysis, Novelty, objective and made various refinements in the proposal report and ppt.

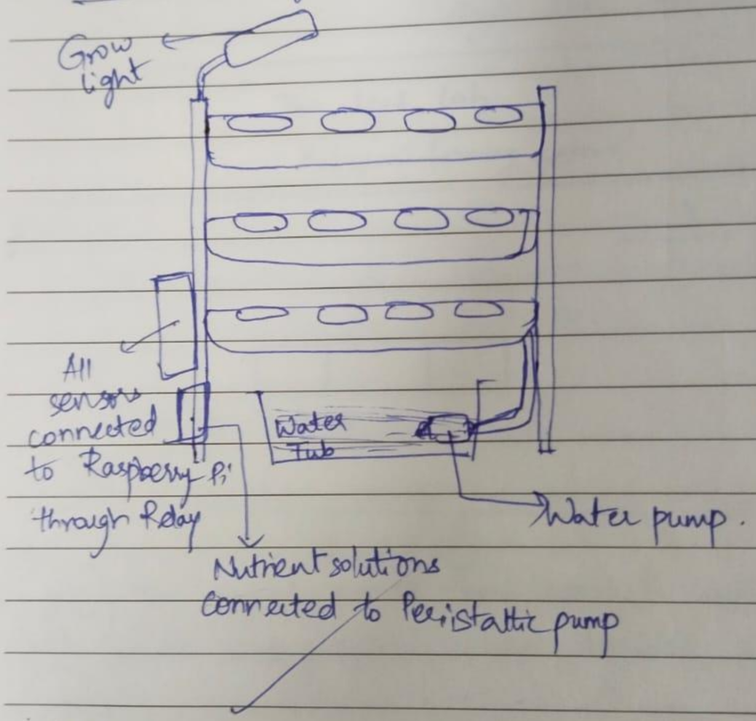
4th March, 2024
We discussed our proposal report and ppt with our mentor and started preparing for Capstone evaluation.

Date :

→ 04-04-24

We designed hardware for Hydroponic Farming System. It is shown below:

Hardware Design:



→ 08-04-24

We bought seeds from market and grown it on the organic soil. Here we used some flowers seeds. It requires less time for about 3 months to grow the plants.

Date :

→ 14-04-24 to 18-04-24

We had a meeting to learn about Raspberry Pi coding and simulation of the sensors (pH sensor, Humidity sensor, TDS-Total Dissolvable solids sensor, Soil moisture sensor, LDR- Light Dependent Resistor sensor). Its implementation and use cases in our project.

Understood the python code by online tutorial and made various code and simulated it on Raspberry Pi-3.
Various sensors which are mentioned above are simulated.

Combined various codes and using relay we controlled it automatically.

→ 19-04-24 to 23-04-24

Using Blynk cloud IOT we acquired data from the sensors such as pH, LDR, humidity from the plants.
The user can see the dashboard of the results acquired from the various sensors.

Date :

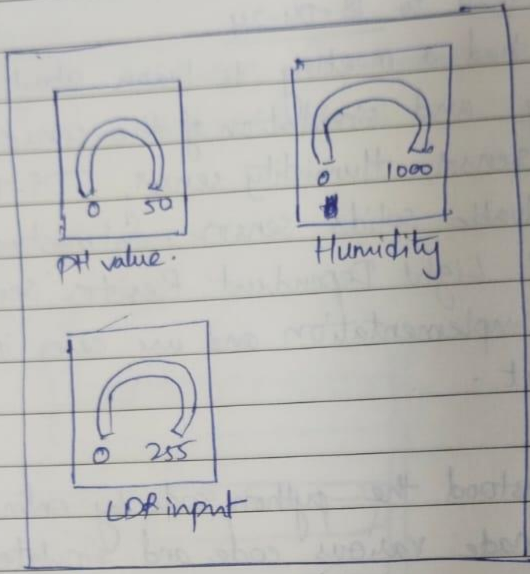


Fig: Blynk Dashboard

The above figure represents Blynk Dashboard results which we obtained from sensors simulation

→ 24-04-24

Nutrient solutions are prepared to provide the soil with proper nutrients, such that the plants do not have deficiency of nutrients.

Acid and Base solutions are also prepared to maintain the pH of the soil.

Date :

→ 28-04-24 to 30-04-24:

We prepared a flowchart of the Design Methodology which is shown below:

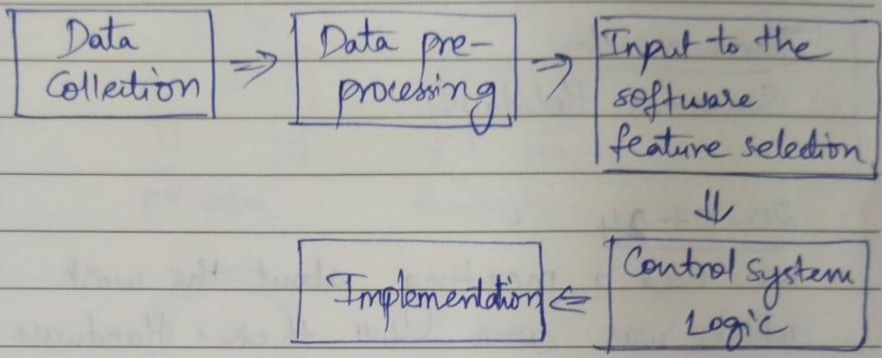


Fig: Design Methodology

We automated the process using sensors, Raspberry Pi-3 till the reading reaches the required level of use. We also observed the results on the Blynk cloud.

Prepsentation and Report for the Evaluation-II has been done according to the requirements and suggestions given from the Evaluation-I.

The report was modified and was checked by our mentor for any corrections to be done further.

Date :

May month.

Sessionals and EST for Semester-6 were taking place.

June month

Semester Holidays.

20-07-24

We had a meeting about the work which was done till then. Hardware of the Hydroponic system was prepared, sensors simulations were done.

We also made a work plan further what to be done.

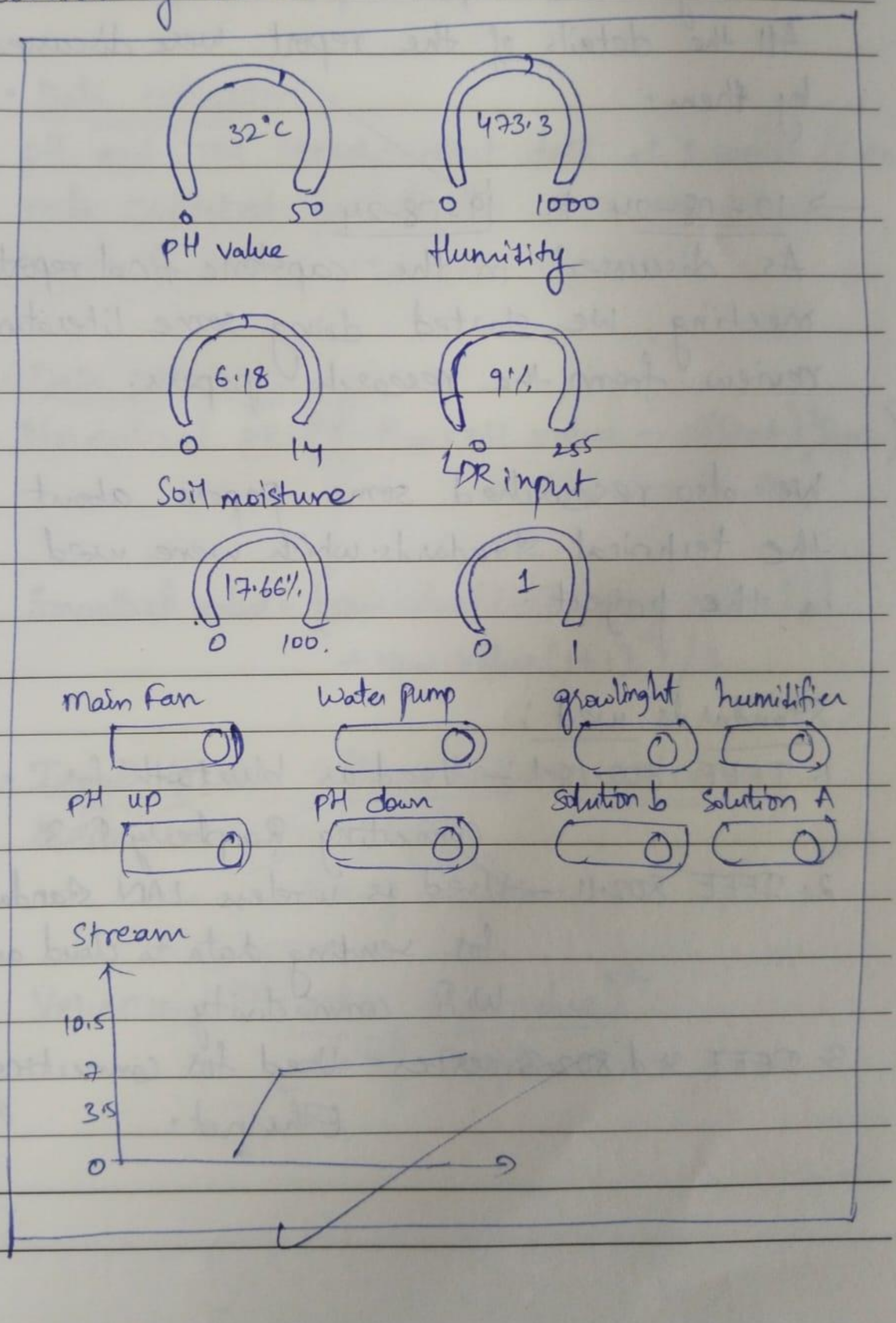
02-08-24 to 08-08-24

We checked upon our hardware setup.

Since we already simulated the sensors, we started controlling the sensors using Blynk-IOT to make our hydroponic system semi-automatic.

Date :

Blynk Dashboard has been shown ~~given~~ below which has sensor simulation results and control of them.



Date : / /

9th August, 2024

We had meeting with our department faculty and all details for final evaluation and final report format was discussed and explained to us.

10th August, 2024 – 19th August, 2024

As discussed in capstone final report meeting, we started doing some literature review from the research papers.
We also researched some papers about technical standards which were used in our project.

Standards we used:

1) IEEE 802.15.1 → Used as bluetooth for connecting Raspberry Pi3

2) IEEE 802.11 → Used as wireless LAN standard for sending data to cloud and WiFi connectivity.

Date : / /

3) IEEE Std 802.3 series → Used for connecting Ethernet.

22nd August, 2024 – 26th August, 2024

Design Methodology was discussed in detail.

→ Data Collection : pH and TDS sensor.
collect data at 1 sample/5 sec.
→ Data collected periadically at 1 sample per 2 min to ensure real-time control.

→ Data Pre-processing : Normalized pH = (7 - (Raw pH value - offset) / Slope) * Caliberation factor.

Smoothed value = (raw value [i-1] + raw value [i] + raw value [i+1]) / 3

Date : / /

→ Input to the Softrare feature Extraction :

Mean Value = Σ (Value) / No of Samples

Variance = Σ (value - mean Value)^2 / No of samples

→ Control System logic :

Based on the processed sensor data, the control system operates pumps to maintain the desired pH and TDS levels

→ for pH :- operate at 6.5 to 7.5

→ for TDS :- operate at A/B below 500.

28th August, 2024

work upon final report and poster was started after this for final evaluation.