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On

"AN APPROACH TOWARDS DEVELOPMENT AND ANALYSIS OF A SMART AEROPONIC SYSTEM"

Submitted in partial fulfilment for the award of degree of

BACHELOR OF ENGINEERING

In

ELECTRONICS & COMMUNICATION ENGINEERING

Submitted By

Chethan S [1JB19EC022]
Indupriya B [1JB19EC029]
Kruthi N [1JB19EC041]
Manjukishore P [1JB19EC050]

Under the Guidance of

Dr. Chandrappa D N
Professor and Head
Dept. Of ECE, SJBIT

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

SJB INSTITUTE OF TECHNOLOGY

B G S HEALTH AND EDUCATION CITY
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BGS Health & Education City, Kengeri, Bangalore-560060.

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CERTIFICATE

Certified that the Project Phase- II report entitled **"AN APPROACH TOWARDS DEVELOPMENT AND ANALYSIS OF A SMART AEROPONIC SYSTEM"** carried out by **CHETHAN S [1JB19EC022], INDUPRIYA B [1JB19EC029], KRUTHI N [1JB19EC041], MANJUKISHORE P [1JB19EC050]** are bonafide student of **SJB Institute of Technology** in partial fulfilment for the award of **"BACHELOR OF ENGINEERING"** in **2022-2023** as prescribed by **VISVESVARAYA TECHNOLOGICAL UNIVERSITY, BELAGAVI** during the academic year **2022-23**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. This report has been approved as it satisfies the academic requirements in respect of Project Phase-2 prescribed for the said degree.

Dr. Chandrappa D N	**Dr. Chandrappa D N**	**Dr. K V Mahendra Prashanth**
Professor & Head	**Professor & Head**	**Principal**
Dept. of ECE	**Dept. of ECE**	**SJBIT, Bangalore**

EXTERNAL VIVA- VOCE

Name of the Examiners	**Signature with Date**
1. ______________________	______________________
2. ______________________	______________________

  

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Regards,

Chethan S **[1JB19EC022]**
Indupriya B **[1JB19EC029]**
Kruthi N **[1JB19EC041]**
Manjukishore P **[1JB19EC050]**

Declaration

We, the undersigned, solemnly declare that the Project Phase - II report entitled An Approach towards Development and Analysis of a Smart Aeroponic System is based on our own work carried out during the course of our study under the supervision of Dr. Chandrappa D N, Professor and Head, Dept. of ECE.

We assert the statements made and conclusions drawn are an outcome of our Project Phase - II work. I further certify that,

1. The work contained in the report is original and has been done by us under the general supervision of our supervisor.
2. The work has not been submitted to any other institution for any other degree/diploma/certificate in this university or any other university of India or abroad.
3. We have followed the guidelines provided by the university in writing the report.
4. Whenever we have used materials (data, theoretical analysis, and text) from other sources, we have given due credit to them in the text of the report and given their details in the references.

Chethan S [1JB19EC022]
Indupriya B [1JB19EC029]
Kruthi N [1JB19EC041]
Manjukishore P[1JB19EC050]

ABSTRACT

. Currently, IoT technologies are being applied in many fields and is changing lives in many areas such as smart homes, smart cities, smart grids, autonomous cars, and the industrial internet. Howbeit, traditional agriculture is still waiting for many changes to occur in networking technology, especially in IoT. Many researchers and engineers are working towards applying IoT technology to traditional agricultural methods. Aeroponics farming is an efficient and effective process for growing plants without using soil. Our Project report discusses the development of a smart aeroponic system that utilizes technologies such as Internet of Things (IoT) and automation. The system is designed to monitor and control various parameters such as nutrient levels, temperature, humidity, light intensity, and CO2 levels to provide optimal conditions for plant growth. The sensors collect data and the IoT platform analyzes it to provide insights into the state of the system, allowing the farmer to make informed decisions and take corrective action when necessary. Automation can be integrated for automatic adjustments. The benefits of a smart aeroponic system include increased yield, reduced water and nutrient usage, and improved plant growth rates.

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CHAPTER 1

INTRODUCTION

By the year 2050, the population of Earth is expected to rise by 3 billion people. Approximately 109 hectares of additional traditional farmland will be needed to feed them. It is estimated that 80% of the arable land on Earth suitable for farming is presently in use. Roughly 15% of this land has been rendered unusable for farming due to poor management and climate change has claimed even more. More locally, the produce industry of the US is inefficient and insufficient. Populations in the northeast buy produce for at least 6 months out of the year from farms over 3,000 miles away, according to multiple produce vendors in the area. This product has been engineered to survive the long trip and extend shelf life in local stores. Better quality and tasting locally grown produce are only available for a few months out of the year, and in a relatively limited quantity. Jobs associated with farming are often seasonal, low paying, and with no benefits. Even in the East, these jobs are often occupied by migrant workers. Another issue is that crop yields are highly dependent on weather. A single poor growing season can cause thousands to starve in many areas of the world. In the US, this at minimum causes a significant rise in imported produce resulting in higher prices and dollars leaving the local economy.

The proposed solution is an integration of currently available technologies in a Controlled Environment High-Rise Farm (CEHRF). The system is based on an aeroponic growing system, chosen for its 90% reduction in water use, 60% reduction in nutrient use, stimulated crop growth, and higher density capabilities as compared to traditional farming. Aeroponic literally means “growing in air.” An aeroponic system is medium-less in that the roots of the plant are free hanging inside an open root-zone atmosphere. The vegetation zone is separated by the supports used to hold the plants in the top of the unit. Nutrients are mixed in with water in a reservoir basin; this is then filtered and pumped into a pressurized holding tank that is intermittently misted onto the root system. The water droplet size must be big enough to carry the nutrients to the roots in sufficient quantity, but small enough to not immediately precipitate out of the root mass. Unused solution drips down into the base of the unit and is strained, filtered, and pumped back into the reservoir.

1.1. AEROPONICS

Aeroponics or air culture uses the application of nutrient dissolved mist over exposed plant roots which enable growth without soil. Aeroponics is usually regarded as a type of hydroponics since water is used as a nutrient dissolution medium. The suspended plant roots are enclosed in a sealed chamber and the plant canopy is exposed to the outside. For small plants the sheath of cell foam is compressed and wrapped around the bottom stem and inserted in to the aeroponic setup. For large fruit bearing plants trellising is used. Trellising is fixation of wooden or metallic supporting frames with the plant body. The plant grows vigorously in an aeroponic system due to the sterile environment and abundant oxygen present in the chamber. The droplet size of a nutrient mist is a crucial element in aeroponics.

An oversized droplet may reduce the oxygen supply. An undersized droplet may stimulate root hair growth which prevents lateral root growth which influences the efficiency of an aeroponic system. Aeroponic systems are more water resource efficient than hydroponic systems. Another remarkable advantage of aeroponics is the minimal contact between the support structure and plant, due to which unconstrained growth of the plant is possible. The aeroponics system are widely used for NASA space research programs.

The hydro-atomized mist also significantly contributes to the effective oxygenation of the roots. For example, NFT has a nutrient throughput of 1 liter/min compared to aeroponics throughput of 1.5ml/min. The reduced volume of nutrient throughput results in reduced amounts of nutrient required for plant development. Another benefit of the reduced throughput, of major significance for space-based use, is the reduction in water volume used. This reduction in water volume throughput corresponds with a reduced buffer volume. Both of which significantly lighten the weight needed to maintain plant growth. In addition, the volume of effluent from the plants is also reduced with aeroponics, reducing the amount of water that needs to be treated before reuse. The relatively low solution volumes used in aeroponics, coupled with the minimal amount of time that the roots are exposed to the hydro-atomized mist, minimizes root-to-root contact and spread of pathogens between plants.

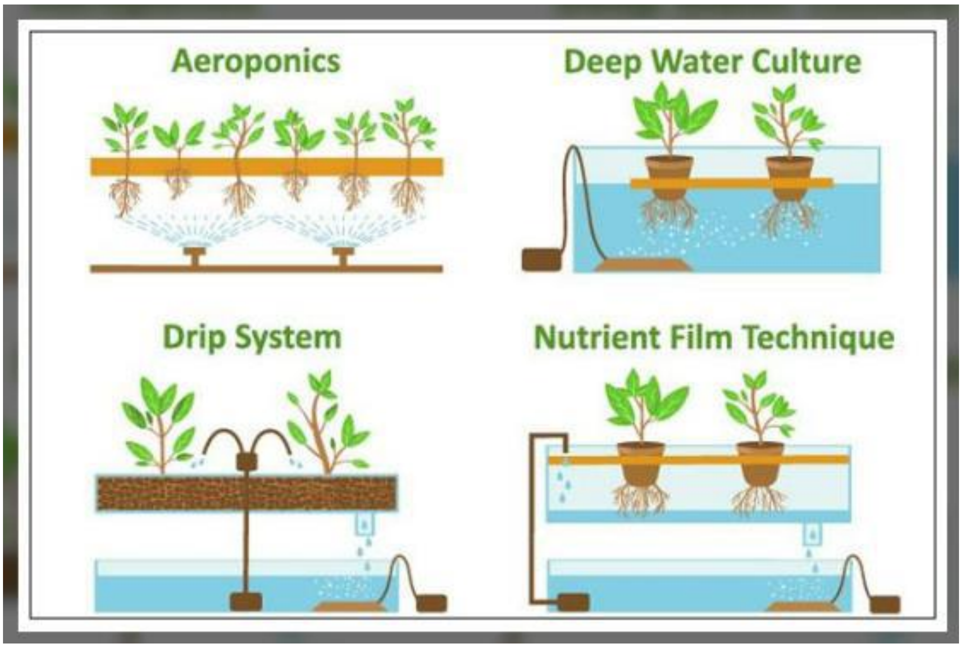

Figure 1.1.1: Different types of farming techniques

1.2 THE AEROPONICS GROWING SYSTEM

The principles of aeroponics are based on the possibility of cultivating vegetables whose roots are not inserted in a substratum (the case with hydroponics) or soil, but in a container filled with flowing plant nutrition. In these containers root can be found in the best condition regarding the best oxygenation and moisture. These conditions allow for better plant nutrition assimilation in a more balanced way, with consequential faster development of the cultivated plant.

Plant containers can be mounted on top of one another and because they are light and handy, they can be easily moved according to agricultural needs. Numerous plants are mounted in vertical columns within a greenhouse or shade house space. Nutrients are allowed to trickle down through the growth columns. Most agricultural plants need direct exposure to the sun during the first vegetative development. Afterwards this direct exposure is no longer relevant. Based on this observation, plant containers are periodically displaced. Young plants are placed at the highest level of the growth column. Afterwards they are progressively lowered utilizing a rotational mechanical system. With the rotation periodically repeated, this permits constant production without any interruption. The Aeroponic system is agriculture with a non-stop production cycle. Plant nutrition is supplied into a closed circuit. Consumption is consequently limited to only the quantities absorbed by the plants, allowing for substantial water savings. For example: to produce a kilogram of tomatoes using traditional land cultivation requires 200 to 400 liters of water, hydroponics requires about 70 liters, aeroponics utilizes only about 20 liters. Because the aeroponic system is a continuous cycle in an enclosed space it reduces agricultural labor into a series of mechanical routine operational tasks which are carried out daily and throughout the year. This enables workers to acquire considerable skill within a short period of time, a few months. In traditional agriculture commercial production is obtained only with skilled workers qualified by many years of experience. The aeroponic equipment is sheltered within greenhouses or anti hail-storm coverings according to the latitude. Climate controls within the greenhouse ensure optimal growing conditions, assuring high yields.

1.3 NUTRIENTS USED IN AEROPONICS SYSTEM

An indoor aeroponics system uses less water and nutrients because the plant roots are sprayed in intervals using a precise drop size that can be utilized most efficiently by osmosis to nourish the plant. Little excess nutrient solution is lost to evaporation or runoff. Plant disease is minimized because the roots are left open to air, avoiding soaking is a stagnant moist medium. Carbon, oxygen and hydrogen are present in air and water. Water may contain a variety of elements according to your local treatment plant additions and should be factored into your final factor, or primary nutrients are nitrogen, phosphorus, potassium and are used by plants in different amounts according to the growth stage. Secondary nutrients are calcium, magnesium, and sulfur, micro-nutrients are iron, zinc molybdenum, manganese, boron, copper, cobalt and chlorine. Complicating the formula more, roots use nutrients as ions in water positively charged cations, or negatively charged anions. An example of a cation is ammonium, NH_4^+, and anion nitrate, NO_3^-, both important nitrogen sources for plants. As plants use the ions, the pH of the solution can change, meaning it can lean too far positive or too far negative. The optimal pH for plant growth is between5.8 and 6.3. In aeroponic system where water and nutrients are recycled.it is important to measure the acid/base or pH measurement to allow plants to absorb nutrients. Aeroponic spray to nourish roots use much less liquid resulting in easier management of nutrient concentration with greater pH stability.

THE MAIN NUTRIENTS USED IN AEROPONICS ARE

- Phosphorus
- Potassium
- Calcium
- Magnesium
- Iron
- Manganese
- Boron

- Copper
- Zinc
- Molybdenum

These are the main nutrients used in aeroponic cultivation. The concentration of the above-mentioned nutrients is different for different crops.

1.4 INTERNET OF THINGS(IOT)

As technology develops, it will bring great advantages to human beings in all areas of life. Especially, the development of network technology is changing many areas of our lives such as smart homes, smart cities, smart grids, autonomous cars, and the industrial internet. Smart agriculture systems are an area that would benefit from this technology. By adapting the recent innovations in technology for farming it would add many benefits for farmers and reduce our carbon footprint. The Internet of Things (IoT) is an emerging technology that provides internet connectivity and powerful data analytic capabilities to create a system in which objects in the physical world could be connected to the internet by sensors. However, smart farming is still in its infancy about using IoT devices for agriculture. Aeroponics farming is an efficient and effective process for growing plants without using soil as a medium as well as with little water. We propose a new automated aeroponics system using IoT devices that will help the farmer by increasing productivity in farming. To the best of our knowledge, this is the first work to design and implement automated aeroponics systems using IoT devices.

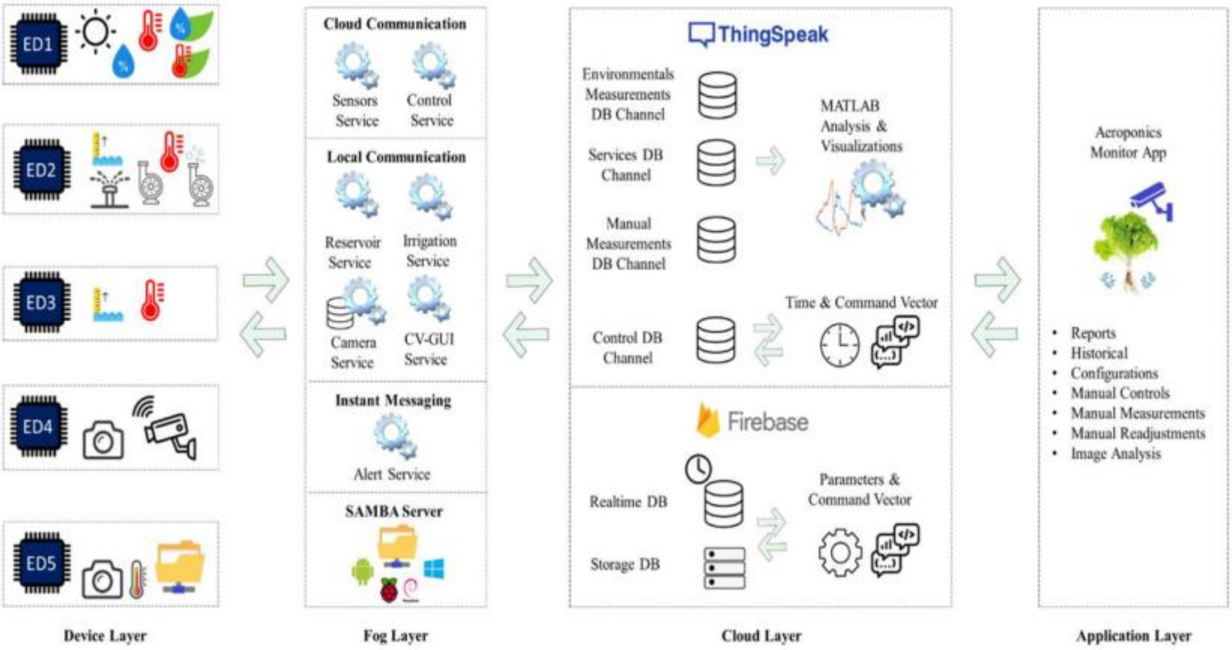

Figure 1.4: Architecture of 4-layer application layer

CHAPTER 2

LITERATURE REVIEW, CHALLENGES, MOTIVATION AND OBJECTIVES

2.1 LITERATURE REVIEW

Several projects were implemented based on hydroponics system, which is the motivating idea behind the aeroponics system. The first person is W. Carter in 1942, who had done research on air culture growing and proposed a method of growing plants in water vapor to facilitate the examination of roots. L.J. Klotz in 1944, discovered vapor misted citrus plants in a facilitated environment for his research about the diseases of citrus and avocado roots.

G.F. Trowel in 1952, grew apple trees in a spray culture medium. In 1957, F. W. Went who first mentioned the air-growing process as “aeroponics” and grew coffee plants and tomatoes with air-suspended roots and applied a nutrient solution to the plants roots. By the early start of 1975, scientists and researchers were involved in developing their first aeroponics system. In 1978 Isaac Nir described an aeroponic system that automated the spraying of mist at the root of the plants and was one of the very firsts of its kind. The apparatus was very simple in comparison to the sophisticated apparatus available in the present market.

The first commercial aeroponic device was introduced by GTi in 1983. It was known by the name Genesis Machine. GTi's device came with an open-loop water driven apparatus, controlled by a microchip, and delivered a high pressure, hydro-atomized nutrient spray inside an aeroponic chamber. The Genesis Machine was simply connected to the water faucet and an electrical outline in 1997, Richard Stoner II founded Agri House, an Agri-biology company, which along with research inputs from NASA produced the Genesis Series Aeroponic System. The system used hydro-atomizing spray jets to deliver mist with a droplet size of less than 50 microns which is just about the ideal size. Digital timers were used to spray mist at regular intervals.

One of the very first aeroponic systems to use ultrasonic foggers was the Aeroponic Growth System invented by Richard W.Zobel and Richard F. Lychalk in 1998 . This system produced fog using ultrasonic foggers and delivered it to the root making it more effective than any of the preceding inventions. Project XGEN by Shyamal Patel and Dr Lance Erickson in 2011 produced a device that was much more sophisticated and modern than the previous apparatuses. This project made extensive use of sensors such as gas sensors, water sensors, and pH sensors to monitor the physical conditions within the system. The idea of transmitting data from an aeroponic system to a computer was first seen in the Aeroponic Growing System which was designed for potato production by Irman Idris and Muhammad Ikshan Sani in 2012.

This system was an upgrade to the project XGEN as it, in addition to the monitoring system, included a regulatory system. An aeroponic system built by J.L.Reyes et al. was very similar to project XGEN in the way that it included a greenhouse system to maintain the atmosphere of the shoot system. However, this project monitored the electrical conductivity of the nutrient solution unlike the case with project XGEN.

An aeroponic system developed by Jing Liu and Yunwei Zhang in 2013 was among the first systems to include a temperature regulator. A P Montoya et al.'s Automatic aeroponic irrigation system was a much-improved version of the previous aeroponic systems. The system included a greenhouse system, pH sensors, EC sensors, temperature and humidity sensors, ultrasonic range finders, and water flow sensors to monitor the system constantly. Moreover, real time data was logged and streamed to a web server making data mining and analysis possible. An aeroponic system that could be used in space was built by V. Arenella et al. in 2016.

There are multiple proposals in the literature referring to IoT architectures used in intelligent agriculture; among the most recent are AREThOU5A, AgriSens, IRRISENS,Agro-IoT, SWAMP and a proposed four-layered architecture by Kour in 2020, each referring to soil agriculture. Kamienski et al. propose SWAMP, a generalized architecture oriented to the intelligent management of irrigation for agricultural systems on the ground incorporating different interconnection strategies between its elements to address the problems of communication in greenhouses on a large-scale using fog nodes in the soil with Lora WAN routers. Its architecture is made up of five layers, which include the sending of information to end users, distribution models for irrigation, use of drones for vision inspection, data analysis models in the cloud fog nodes using as references the relative humidity of the soil, databases, security for data acquisition, sensors, actuators, and weather reports, among others.

A literature survey on the topic of IoT-based aeroponic farming systems reveals that there is a growing interest in the development of these systems. Several research studies have been conducted to explore the potential benefits of IoT-based aeroponic farming systems, including increased crop yield, reduced water and nutrient usage, and improved plant growth.

One study by Koc and Kutlu (2020) investigated the use of IoT-based systems in aeroponic farming to improve crop yield and reduce water usage. The study utilized a wireless sensor network to monitor the growth conditions of plants and automatically adjust the nutrient solution and water delivery. The results showed that the IoT-based system increased crop yield by up to 35% and reduced water usage by up to 50% compared to traditional soil-based agriculture.

Another study by Li et al. (2020) explored the use of machine learning algorithms to optimize the growing conditions in an aeroponic system. The study utilized sensors to collect data on temperature, humidity, and light intensity, and used machine learning algorithms to predict the optimal growing conditions for the plants. The results showed that the machine learning algorithms improved the growth rate of the plants and reduced water usage by up to 30%.

Additionally, a study by Zhao et al. (2021) explored the integration of blockchain technology into an IoT-based aeroponic farming system. The study utilized sensors and blockchain technology to create a secure and transparent system for tracking the growth and distribution of crops. The results showed that the integration of blockchain technology improved traceability and accountability in the food supply chain.

2.2 MOTIVATION

The motivation for the development of a smart aeroponic system lies in the need for efficient and sustainable agriculture. Aeroponic farming offers several benefits over traditional soil-based agriculture, such as reduced water usage, improved nutrient uptake, and increased yield. However, traditional aeroponic systems require manual monitoring and intervention to maintain optimal growing conditions, making it difficult to scale up.

The integration of IoT, AI, and automation technologies into aeroponic farming offers a solution to this problem by creating a smart aeroponic system that can automatically monitor and adjust the growing conditions. This allows for a more efficient and effective method of plant growth, with higher yields and reduced water and nutrient usage.

Additionally, smart aeroponic systems offer a more sustainable approach to agriculture. They require less water and fertilizer than traditional farming methods, reducing the environmental impact of agriculture. They also allow for the efficient use of space, making it possible to grow crops in urban areas, reducing the need for long-distance transportation of food.

2.3 CHALLENGES

The development of aeroponic systems can be considered as a highly multidisciplinary approach drawing from environmental, mechanical, and civil engineering design concepts and plant-related biology, biochemistry, and biotechnology. Sometimes, specific measurements, schematic view, and control technologies also require abundant knowledge of subjects related to the field of computer science for automatic control systems. This high level of complexity necessarily demands in-depth knowledge and expertise of all involved fields. Furthermore, the electricity connection should be independent of the aeroponic system. Besides, in case of an emergency, additional power sources such as a stand-by generator or battery should always be ready with the system. For those places where power failures are frequent, those areas must need a good generator with an automatic startup system. Considering the initial costs for components and installation, the aeroponic systems with air-assisted and centrifugal atomization nozzle are more expensive than ultrasonic fogger (high-frequency atomization nozzle). In addition, over time, if components are well maintained and used for many years, these higher initial costs can be recovered by reducing the labor costs, minimum inputs of fertilizers and pesticides with significantly higher plant yields.

The development of a smart aeroponic system involves several challenges, such as:

- **Cost:** The cost of developing a smart aeroponic system can be high, especially if advanced technologies such as AI and automation are used. This can make it difficult for small-scale farmers to adopt this technology.
- **Integration:** Integrating different technologies such as IoT, AI, and automation can be challenging, requiring specialized knowledge and expertise.
- **Data management:** The amount of data generated by the sensors can be overwhelming, making it difficult to manage and analyze. Data management systems must be put in place to ensure that the data is properly collected, analyzed, and used.
- **System maintenance:** A smart aeroponic system requires regular maintenance to ensure that it is functioning optimally. This includes checking the sensors, replacing parts when necessary, and updating the software.
- **System reliability:** The reliability of the system is crucial for successful crop growth. Any system failure can lead to crop losses, making it important to have a backup system in place.

- **System optimization:** The optimization of the system requires knowledge of the specific requirements of the plants being grown. A thorough understanding of plant biology and growing conditions is necessary to optimize the system for different types of crops.

2.4 OBJECTIVES

- **To optimize plant growth:** By using sensors, and automation technologies, this system can continuously monitor and adjust these parameters to provide the optimal growing conditions for plants.
- **To increase yield:** This system can increase the yield of crops by providing optimal growing conditions, reducing the risk of disease and pests, and ensuring that plants receive the necessary nutrients and water.
- **To reduce water and nutrient usage**: It can further optimize this by adjusting nutrient delivery and misting frequency based on the data collected by sensors, leading to more efficient use of water and nutrients.
- **To reduce labor costs:** It can reduce labor costs by automating tasks such as nutrient delivery and lighting adjustments.
- **To provide a sustainable and scalable approach to agriculture**: To offer a sustainable and scalable approach to agriculture by reducing water and nutrient usage, optimizing plant growth, and allowing for the efficient use of space.

CHAPTER 3

METHODOLOGY & IMPLEMENTATION

3.1 PREREQUISITES:

HARDWARE &SOFTWARE REQUIREMENTS

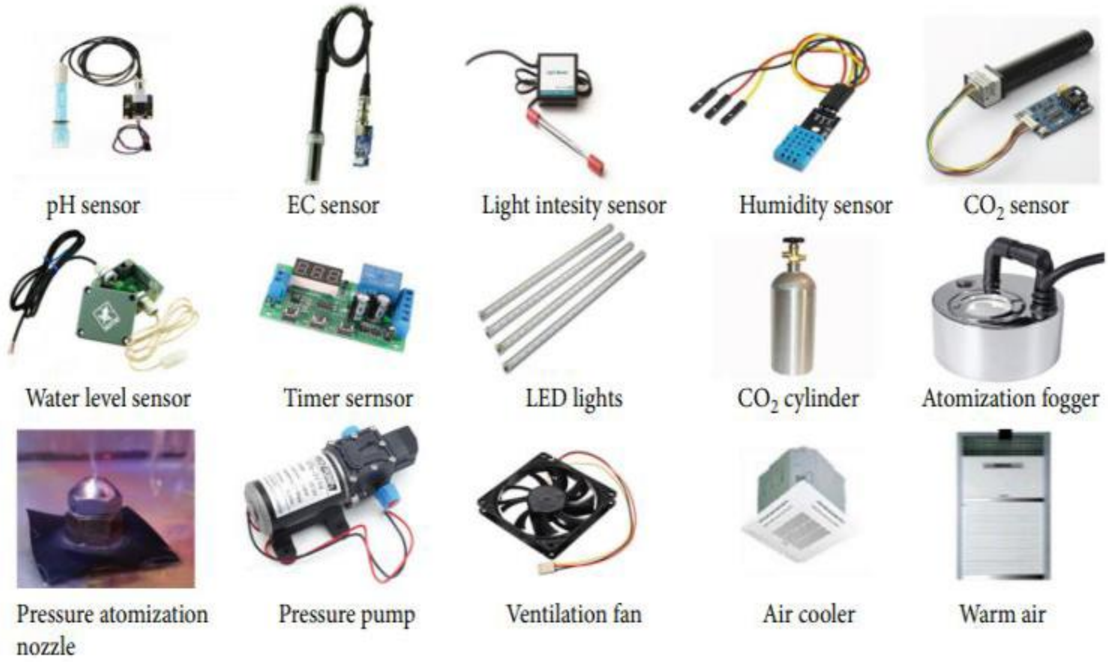

Figure.3.1.0: Sensors and actuators used in aeroponic system.

3.1.1 HARDWARE REQUIREMENTS

- **Arduino Mega 2560:** The Arduino Mega 2560 is a microcontroller board based on the ATmega2560 microcontroller. It is designed for projects that require more I/O pins and more program memory than the Arduino Uno. The board has 54 digital input/output pins, 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

  The Arduino Mega 2560 can be programmed using the Arduino Integrated Development Environment (IDE), which is a free, open-source software application used to write and upload code to Arduino boards. The IDE includes a code editor, a compiler, and a bootloader that allows the code to be uploaded to the microcontroller over a USB connection.

The board is widely used in various applications, including robotics, automation, and data acquisition, due to its large number of I/O pins and its ability to interface with a wide range of sensors, actuators, and other peripherals. The Arduino Mega 2560 is also compatible with a variety of shields, which are plug-in boards that provide additional functionality and expandability to the board.

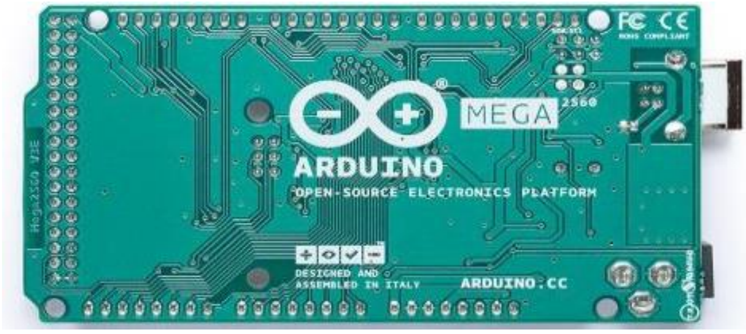

Figure 3.1.1: Arduino Mega 2560

- **Humidity sensor (DHT 11):** The DHT11 is a low-cost temperature and humidity sensor that is used in our project. It consists of a capacitive humidity sensor and a thermistor to measure temperature. The sensor communicates with the microcontroller using a single-wire digital interface and is capable of measuring humidity levels from 20% to 90% with an accuracy of ±5% and temperature from 0°C to 50°C with an accuracy of ±2°C.The DHT11 is easy to use and requires only three connections to the microcontroller board: power, ground, and a digital data pin. It sends out a digital signal that can be read by the microcontroller, and the data is then processed to calculate the temperature and humidity values. The sensor can be used in a variety of applications, including environmental monitoring, HVAC control, and home automation. It is widely available and can be easily integrated with an Arduino or other microcontroller boards.

  One disadvantage of the DHT11 is its limited measurement range and accuracy compared to more expensive sensors.

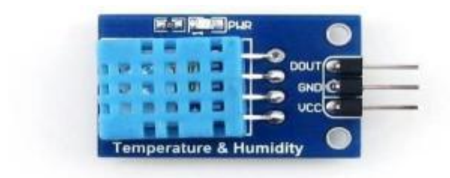

Figure 3.1.2: Temperature and Humidity sensor (DHT11)

- **Water level sensor:** Aeroponics is the method of plant cultivation by providing a small mist of the nutrient solution in the growth chamber. Thus, there is no use of soil; just water is required to cultivate the plant throughout the germination to harvest time. Therefore, the water nutrient solution reservoir is one of the major components of the aeroponic system which should be monitored throughout the growth period. In the conventional aeroponic system, the farmer checks the water nutrient level in the nutrient solution reservoir, and if he finds water level less than the desired level, he maintains accordingly. However, by adopting precision agriculture techniques, the farmer will be able to monitor and control water nutrient levels through intelligent methods such as wireless sensors. The water nutrient level sensors detect the liquid level in the reservoirs and facilitate operators in collecting water nutrient level data in real time. The sensors will alert the operator about any potential property damage that results from any leaks and also allow you to know when a container is nearly empty.

Figure 3.1.3: Water level sensor

- **Light intensity sensor:** Photo Resistor or LDR(LM393) As we know, all vegetable plants and flowers require large amounts of sunlight, and each plant group reacts differently and has a different physiology to deal with light intensity. Some plants perform well in low light intensity and some in high light intensity. However, the aeroponic system implements indoor conditions, so it is necessary for the farmer to provide sufficient light quantity of at least 8 to 10 hours a day to grow the healthy plant. Artificial lighting is a better option to present enough intensity to produce a healthy plant. In the conventional aeroponic system, the control of the light quantity present in the growth chamber is mostly done by the farmer through observing the plant condition. However, it is a time consuming and challenging task for the farmer to provide the required light concentration accurately. It could be a better option to use intelligent agriculture techniques to monitor the light intensity in the aeroponic system. The light sensor is an electronic device which is used to detect the presence or non-presence of light and darkness. There are several types of light sensors including photoresistors, photodiodes, and phototransistors. These light sensors distinguish the substance of light in a growth chamber and increase or decrease the brightness of light to a more comfortable level. Light sensors can be used to automatically control the lights such as on/off. By adopting the sensor network in aeroponics, the farmer could be able to monitor light intensity without any human interference. Because the sensors will perform all work such as if the light intensity in the growth chamber will be less than the required light quantity for plant growth, the sensor will automatically forward the signal to the LED light to turn on until the light quantity reaches to the desired level. This is a light sensor connected to Arduino at pin number A1. This sensor is utilized to keep track of the light falling on the system to maintain the 16:8 ratio of light and darkness. Depending on the threshold value of this sensor the Arduino is going to turn on the LED Bulb when it finds more darkness than the essential amount.

Figure 3.1.4: LDR (LM393)

- **Temperature Sensor (DHT 11)**: In the aeroponic system, the temperature is one of the critical factors significantly determining plant growth and development. A reduction in temperature below the optimal conditions often results in suboptimal plant growth. A different cultivar requires a different temperature level for the photosynthesis process and growth, which can advance the plant growth stage. It will eventually bring us substantial economic benefits. In the aeroponic system, the optimum growth chamber temperature should not be less and more than 4 and 30° C, respectively, for successful plant growth. The temperature fluctuations of aeroponic growth chambers can significantly affect the root growth, respiration, transpiration, flowering, and dormant period. Therefore, temperature sensors can be used to monitor the temperature fluctuations of the aeroponic system. At present, temperature sensors are used in many applications like environmental controls, food processing units, medical devices, and chemical handling. The temperature sensor is a device mainly composed of a thermocouple or resistance temperature detector. The temperature sensor measures the real-time temperature reading through an electrical signal. The sensors collect data about temperature from a particular source and convert the data into an understandable form for a device or an observer.

- **CO2 Sensor:** The appropriate oxygen concentration in the root environment is crucial to keep the root metabolism in nutrition solution. The available oxygen concentration for the root environment is a hugely significant factor since low concentrations affect the root respiration, nutrient absorption, and, consequently, the plant growth [66]. Thus, the CO2 sensor could be used to monitor the carbon dioxide fluctuations in the aeroponic growth chamber. A carbon dioxide sensor is an instrument which is used for the measurement of carbon dioxide gas concentration. pH sensor EC sensor Light intensity sensor Humidity sensor Atomization fogger CO2 sensor CO2 cylinder Pressure atomization Pressure pump Ventilation fan Air cooler Warm air nozzle Water level sensor Timer sensor LED lights Figure 5: Sensors and actuators used in an aeroponic system. Journal of Sensors 9 [99] reported that CO2 sensors are used to measure indoor air quality in a building to perform demand-based ventilation. However, the CO2 sensor data measuring range is in between 500 and 5000 parts per million. There are two main types of the CO2 sensors which include no dispersive infrared carbon dioxide sensors (NICDS) and chemical carbon dioxide sensors (CCDS), whereas the NICDS detected CO2 in a gaseous environment by its characteristic absorption and composed of an infrared detector, an interference filter, a light tube, and an infrared source. However, the CCDS of sensitive layers are based on polymer or heteropoly siloxane with low-energy consumption.

Figure 3.1.5: CO2 Sensor

- **DC Water Pump:** This pump is controlled along with a single channel relay. It is used to check the water level employing the above-mentioned water level sensor in the main water tank and it falls to a certain level then this pump is triggered to fill up the main water tank from the external tank.

Figure 3.1.6: Water pump

- **ESP32-S2:** The ESP32-S2 is a powerful Wi-Fi and Bluetooth-enabled microcontroller produced by Espressif Systems. It is an upgrade from the original ESP32 microcontroller and is designed to provide improved security features and reduced power consumption.

  The ESP32-S2 is based on a single-core, 32-bit RISC-V CPU running at up to 240 MHz, and has 320KB of SRAM and 128KB of ROM. It also features a 10-bit ADC, 8-bit DAC, and a variety of digital communication interfaces such as UART, SPI, I2C, and I2S.

  One of the key features of the ESP32-S2 is its built-in Wi-Fi and Bluetooth connectivity, which allows it to connect to the internet and communicate with other devices wirelessly. The Wi-Fi module supports 802.11b/g/n protocols with speeds of up to 150 Mbps, and the Bluetooth module supports Bluetooth Low Energy (BLE) 5.0.

  The ESP32-S2 also includes advanced security features such as a secure boot mechanism, hardware-accelerated encryption, and secure storage for keys and other sensitive data. This makes it suitable for a wide range of applications, from IoT devices to industrial automation, and even consumer electronics.

Figure 3.1.7 ESP-32-S2

- **ESP32 CAM:** The ESP32-CAM is a small-sized, low-power Wi-Fi and Bluetooth-enabled camera module produced by Espressif Systems. It is based on the ESP32 microcontroller and comes with a OV2640 2MP camera sensor.The ESP32-CAM module features a powerful CPU, 4MB of flash memory, 520KB of SRAM, and a variety of digital communication interfaces such as UART, SPI, I2C, and I2S. It also includes built-in Wi-Fi and Bluetooth connectivity, which allows it to connect to the internet and communicate with other devices wirelessly.The OV2640 camera sensor included in the ESP32-CAM module supports a maximum resolution of 1600x1200 pixels and can capture images and videos at up to 60 frames per second. The module also includes a built-in microSD card slot for storing captured images and videos.One of the main advantages of the ESP32-CAM module is its small size and low power consumption, which makes it ideal for a wide range of applications, such as security cameras, baby monitors, and even robots. The module can be programmed using the Arduino IDE.

Figure 3.1.8 ESP 32 CAM

- **LED LIGHT:** This is managed along with a relay switch of a single channel. If the value of the photoresistor goes below the threshold level of 150 then the LED Bulb turns on and provides the necessary, light. As the coriander plant is required to be kept in sunlight for 16 hours and under dark night for 8 hours, this condition is maintained by these LED lights.

Figure 3.1.9: LED Lights

3.1.2 SOFTWARE REQUIREMENTS

- **Operating system:** The system will require an operating system to run on the microcontroller board. Popular options for microcontrollers include Arduino and ESP-32 S2 which both have their own operating systems.

- **Programming language:** The system requires programming languages such as C/C++, Python, or Java to program the microcontroller board.

- **Sensor and actuator libraries:** Libraries may be required to interface with sensors and actuators, such as the DHT11 library for temperature and humidity sensors, the Adafruit motor shield library for controlling motors, or the Servo library for controlling servos.

- **Web server**: If the system is designed to be remotely accessible, a web server may be required to host a user interface or web application.

- **Arduino IDE**: The IDE used to code the Arduino microcontroller. It depends on Java Processing Software and functions admirably on Windows, Linux, and Mac conditions. The product is open source.

Figure 3.1.10: Arduino IDE software

3.2 METHODOLOGY

The implementation of aeroponic system using IoT requires some software and hardware components, and they all are described below:

3.2.1 THE AEROPONIC SYSTEM AND SENSOR NETWORK:

In recent years, early fault detection and diagnosis using an intelligent agricultural monitoring system is considered as the best tool to monitor plants without any complicated operations and laboratory analysis which required domain expertise and extensive time. The development of these convenient features has attracted much attention in agriculture. The system is based on a wireless sensor network which comprises a data server, a wireless convergence node, a plurality of wireless routers, and a plurality of wireless sensor nodes.

However, the wireless sensor nodes are used as the signal input of the intelligent agricultural monitoring system and are used to collect each selected parameter of farming operations to be monitored. Park et al. stated that wireless sensor network-based systems could be a significant method to fully automate the agriculture system, because the sensors provide real- time significant information and believed to eliminate the considerable costs of just wiring. Another study by Kim said that in agriculture, sensor network techniques help to improve existing systems installed in the greenhouse efficiently and smoothly by forwarding real-time collected information to the operator through the radio signals.

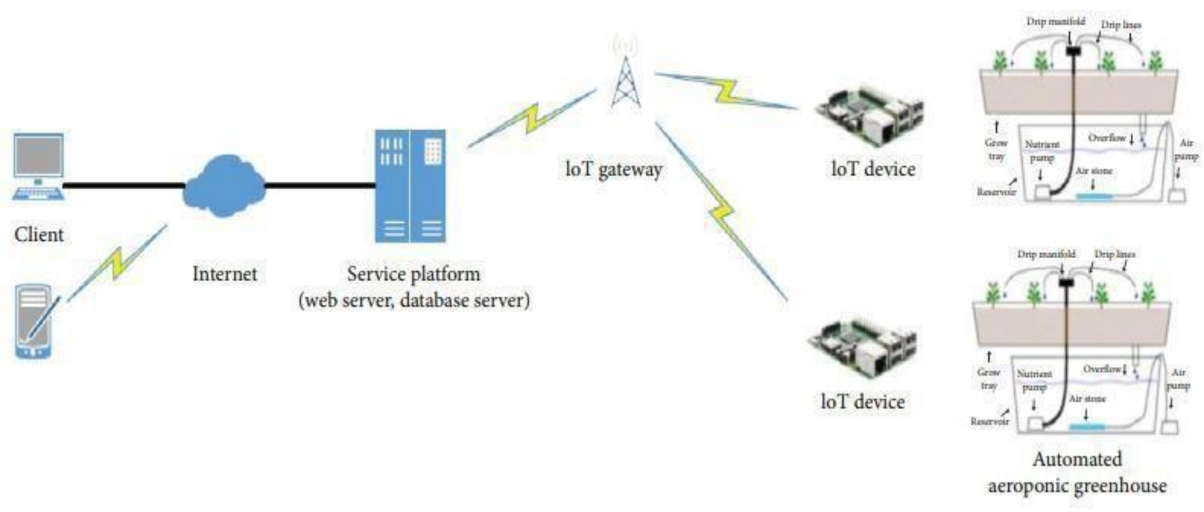

Figure 3.2.1: The aeroponic system using sensor technology by Kerns and Lee

The system optimizes the transmission protocols more accurately and quickly and maximizes the application of energy to save energy and reduce the consumption. Pala and team. suggested that the utilization of artificial intelligence techniques in the aeroponic systems could lead not only to find early fault detection but also to fully automate the system without any or small interventions of human operators. The aeroponic system could gain more popularity among local farmers by deploying this technique in a system for monitoring and controlling purposes. However, it will conserve resources and minimize impacts on the environment. The farmers could start to understand their crops on a micro scale and be able to communicate with plants through accessible technology. Therefore, in this article, we explored how wireless sensing technologies wove into the aeroponic system. Thus, the primary motivation of this review article was to provide an idea about different intelligent agriculture monitoring tools used for early fault detection and diagnosis for plant cultivation in the aeroponic system. Additionally, it would be helpful for the local farmer and grower to provide timely information about rising problems and influencing factors for successful plant growth in the aeroponic system. The adoption of intelligent agriculture monitoring tools could reduce the concept of unsuitability for the amateur.

3.2.2 SENSOR TYPES AND MONITORING PARAMETERS:

In this report, we reviewed the previous work done on the aeroponic system using wireless sensor network technique. We found that the primary objective of a wireless sensor network system for the aeroponic system is to control the growth chamber climatic condition as per the crop data sheet. However, the basic principle of the aeroponic system is to grow the plant by suspending it in the closed, semi closed, or dark environment in the air with artificial provided support. In the system, the plant stems, leaves, and any fruit grow in a vegetative zone above the suspension medium, and roots dangle below the suspension medium in an area commonly referred to as a root zone.

Generally, closed cell foam is compressed around the lower stem and inserted into an opening in the aeroponic growth chamber, which decreases labor and expense. However, trellising is used to suspend the weight of cultivated plants. Ideally, the environment is kept free from pests and diseases so that the plants grow healthier and more quickly than other plants grown by techniques. Furthermore, the key to the success and high yields of air gardening is scientific grade monitoring of the conditions and accurate control of the growing environment. Each plant yields and needs a different environmental condition for growth.

However, the plant growth is mainly influenced by the surrounding environmental and climatic variables and the amount of water, and the fertilizers supplied by irrigation. There is a requirement to monitor and control liquid nutrient parameters in a narrow range of preferred values for optimal growth. The parameters include nutrient temperature. If the parameters drift outside the desired range, the plants can be harmed. Besides, there are some additional parameters which can be adjusted to further optimize growth, such as air temperature, relative humidity, light intensity, and carbon dioxide (CO2) concentration. Idris and Sani reported that the one solution to solve the problems of monitoring and controlling the growing conditions in the space environment is by applying some sensors. The sensor can detect and monitor several parameters such as temperature, humidity, and light intensity.

Aside from the sensors, there is also a requirement for the actuators to distribute nutrients and water to plant roots or lower stems. The sensor collects the information of the various environmental conditions and forwards the signals to the actuator to take place and produce the outcome for the collected information to know the status of that parameter. The actuator can control the environment changes. The sensors store information that analyzes the environment and identifies the location, object, people, and their situations. The sensor provides multiple contributions in various domains that depend on a variety of attributes and variants in time.

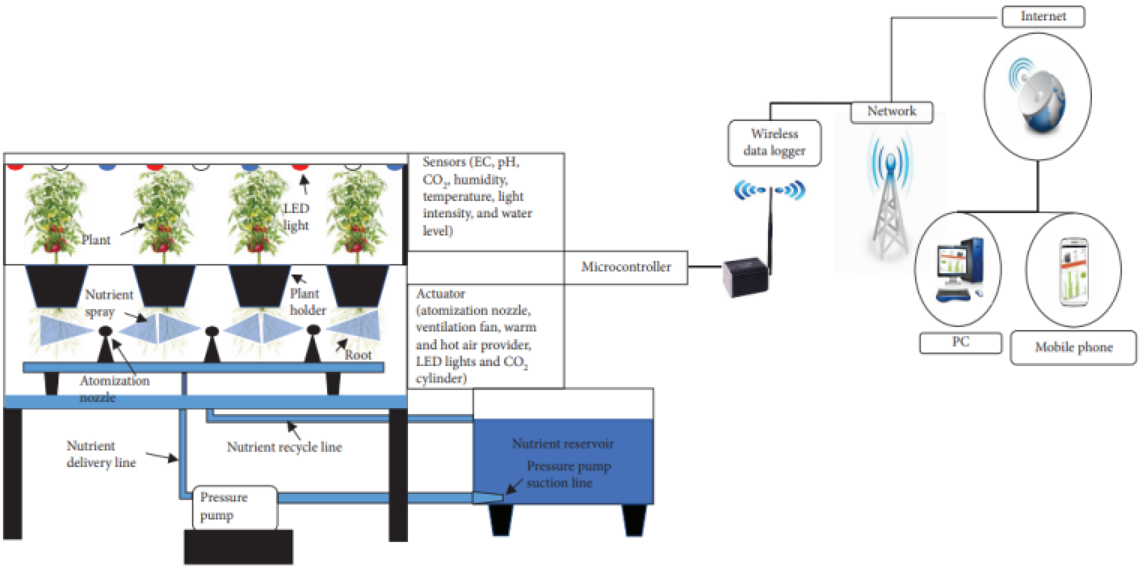

Figure 3.2.2. Aeroponic cultivation control system

No.	Parameters	Common value	Instruments
1	Nutrient atomization	Mist/spray/aerosol/droplet size at high pressure from 10 to 100, low pressure from 5 to 50, and ultrasonic foggers from 5 to 25 microns, respectively	Atomization nozzle (high and low pressure, atomization foggers)
2	Growing medium	Plant holder	Any artificial root supporting structure
3	Desirable pH of the nutrient solution	The pH value depends on the cultivar (onion 6.0–7.0, cucumber 5.8–6.0, carrot 5.8–6.4, spinach 5.5–6.6, lettuce 5.5–6.5, tomato 5.5–6.5, and potato 5.0–6.0)	pH measuring device
4	Humidity	Provide 100% available moisture	Humidity measuring device
5	Temperature	Optimum 15° C–25° C and should not increase to 30° C and less than 4° C	Temperature measuring device
6	The lights	The light inside the growth box must be dark enough	Cover the growth chamber with locally available material
7	Atomization time	Depends on the cultivar growth stage	Manually operating the system with timer
8	Atomization interval time	Depends on the cultivar growth stage	Manually operating the system with timer

Table 3.2.1: Basic monitoring and control parameters in the aeroponic system

3.2.3 SENSOR WORKING PROTOCOL IN THE AEROPONIC SYSTEM

Today, the world demands automatic tools to do most of the work for them without bothering its user for doing some tasks. So, the concept is all about a very high level of automation system which will be independent of its users to a very great extent, reduce human efforts, and save all kinds of resource utilization, as monitoring and controlling will be done by computers leaving very few easily manageable tasks for humans, and it will interest more people to join this field.

Moreover, the monitoring and control system for the aeroponic system mainly consists of following sections which include the aeroponic system, data acquisition, controlling the equipment, data transmission module, cloud data processing server, social communication platform, and mobile application. The data acquisition module is placed in the aeroponic system or near the growth chamber to collect the real-time information from selected parameters (temperature, light intensity, humidity, nutrient solution level, atomization quantity) and transmit the gathered data to the control and management center. However, the control and management section refer to the central processing unit (CPU) of the system.

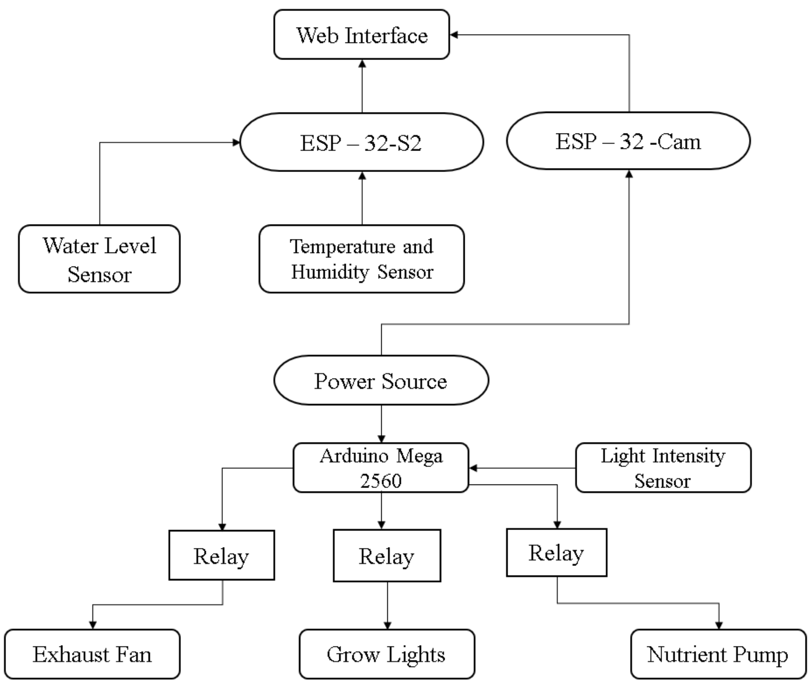

Figure.3.2.3: Flowchart of Aeroponic hardware system

3.2.4 PLANT GROWTH AND ROOT OPTIMIZATION

In general, the methodology provides a modular “plug-and-play” aeroponic growth system which allows for efficient maintenance and/or expansion of individual modular aeroponic units within the system without interrupting or otherwise disturbing the operation of other individual modular aeroponic units. The present system also configures the positioning and cone angles of the atomizers/misters (referred to herein as “spray nozzles”) and the structure of the modular aeroponic units to minimize the occurrence of wet or dry zones within a root zone. The present system also provides an automated system controller that may implement pre-programmed spray operations, monitor, and control the temperature, humidity (i.e., activation of the spray nozzles), CO2 levels, light quality, light intensity, and other suitable plant growth parameters, and initiate alarms in the event of high or low sensor readings, pump failure, pressure loss, water loss, power failure or the occurrence of any other monitored process variable. It will be understood that the components and methods described herein for providing a modular automated aeroponic growth system for plants may be implemented in hardware, software, or a combination of both.

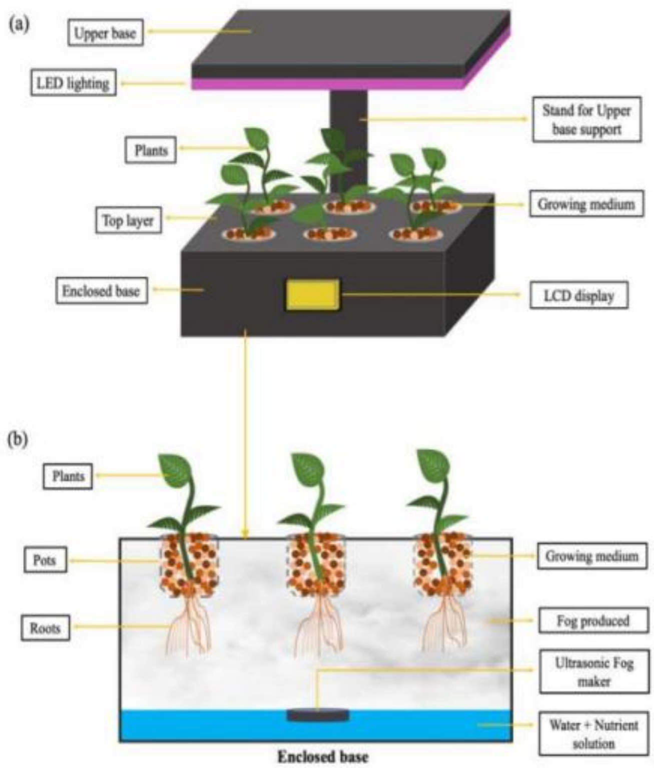

Figure 3.2.4 a: Model of Aeroponic system

Figure 3.2.4.b: Root Chamber of Aeroponic system.

3.2.5 PLANT GROWING SYSTEM

As discussed above, the aeroponics system differs from both Hydroponic and in vitro plant growing techniques. Unlike the hydroponic system, which uses water nutrient rich solution as a growing medium and provides essential nutrients for sustaining plant growth. However, it is conducted without any growing medium. In the system, the nursery plants might be either raised as seedlings using specially designed lattice pots or cuttings could be placed directly into the system for rapid root formation. Lattice pots allow the root system to develop down into the growth chamber where it is regularly misted with nutrients under controlled conditions. Zobel et al. (1976) reported that root zone environmental conditions play a significant role in healthy plant growth and attaining the excellent quality of seed production. Siddique et al. (2015) revealed that only an efficient root system provides unobstructed growth space for the plant under atomization conditions. Soffer and Burger (1988) reported that once plants located in the atomization system roots start to get the most favorable root aeration system.

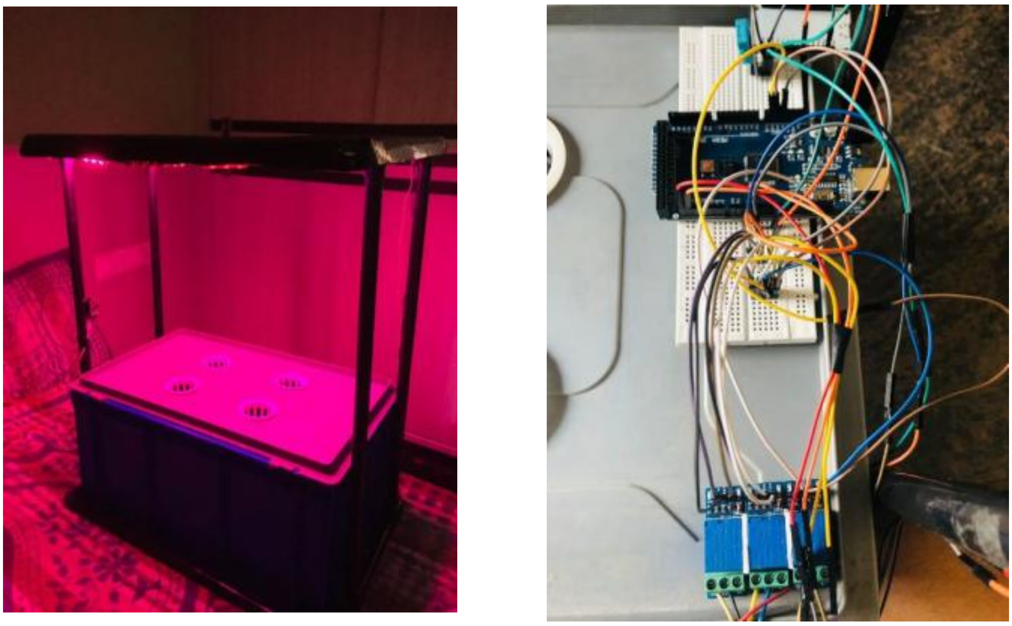

Figure 3.2.5: Prototype of the setup of aeroponic system

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 RESULTS

The mint samplings showed a good growth in their sizes in the Aeroponic system. Each sample was placed as close as possible. But this positioning was not a hindrance for their growth.

The leaf area is directly proportional to photosynthesis and production of dry matter i.e., increases in leaf area increases the rate of photosynthesis capacity of the plant. So that plants put a major share of photosynthetic energy to produce leaf. The statistical analysis on leaf area on 50th day confessed that there is a significant difference among treatments and systems and their interaction effect also observed to be significant.

(a) (b) (c) (d)

Figure 4.1.1(a) and (b) shows the mint leaves grown in our aeroponic system on Day 50. Figure 4.1.1 (c) and (d) shows the mint leaves grown using soil method on Day 50. As we can see from the images, leaves grown in our system is bit longer and disease free whereas mint plant grown using soil is wider and leaves are torn and eaten by worms and growth rate is slower compared to our system.

Yield is more in Aeroponic type because soil grown plants seek out lot of energy to their food source, but plants grown under aeroponics are given with exactly what they needed so they direct all their energy for producing higher yield.


Figure 4.1.2 Image of aeroponic system on day 50 with mint plant.
Figure 4.1.3 Image of mint plant on day 50

High demand for food production is increasing as the world population is growing. Meanwhile, the traditional farming using soil-based system will not cover the world's growing demands for food. Thus, developing new farming and planting system techniques is required to avoid food crisis issues in the future. This study is aimed to examine an efficient technique for alternative planting system which is the aeroponics system. The statistical experimental design approach was used to analyze and compare soil-based systems and aeroponic systems by planting seeds of mint in both systems. In which the analysis of mint cultivation is to check the variance of two techniques, whether the Aeroponic system with organic fertilizer is better than the traditional system or soil-based system. The result shows that aeroponic planting system with organic fertilizer has a better effect than traditional soil system because it makes plants height grow faster, gives better taste and root length long". On the other hand, the planting system has no significant effect on the length of leaves.

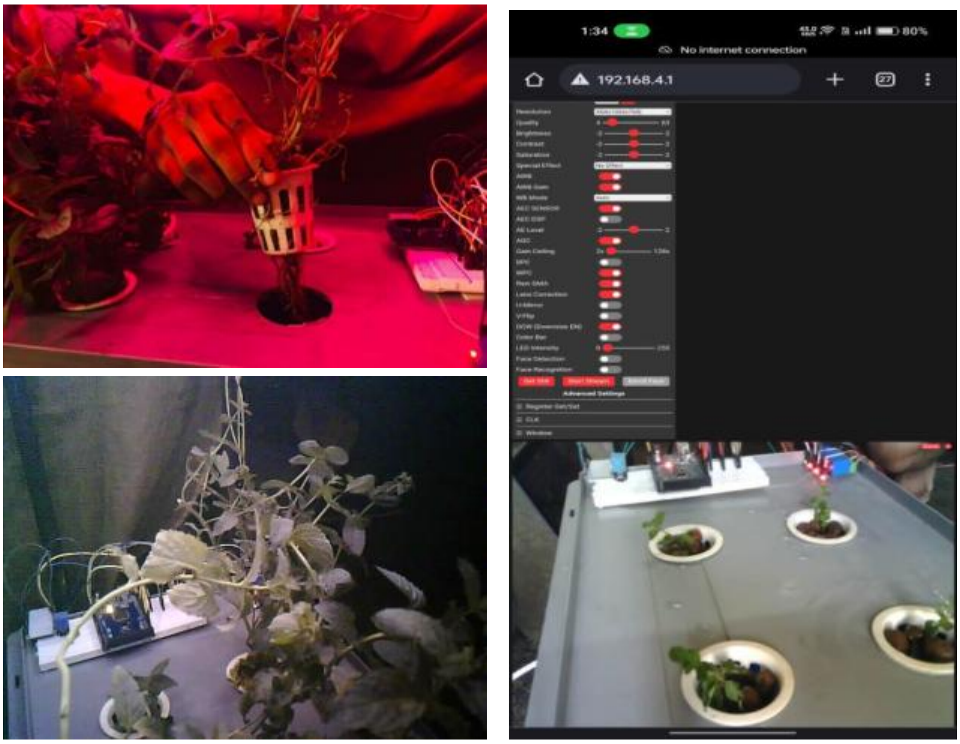

Figure 4.1.4 Image of mint plant being removed from the system.
Figure 4.1.5 Image of mint plant taken from ESP-32 Cam on day 48.
Figure 4.1.6 Screenshot from the web server through mobile.

Moreover, seed type and the interaction between seed type and the planting system have no signification effect on plant growth. As it did not require soil for plant growth, it may be helpful for the astronauts during their time in space to get their food. This system may help both kitchen gardeners and farmers to grow food in places where traditional farming is not possible and cost-effective. The aeroponics system offers conservation of water, soil, air, energy, and employment for the quality of life. The Aeroponics can enhance the economy of both developing and developed countries by using limited natural resources.

4.2 DISCUSSIONS

Various studies have indicated that decision making to generate the conditions of irrigation in IoT architectures take as reference the evapotranspiration, the weather forecast, the relative humidity, the irrigation according to the life cycle and the irrigation programmed by the user in soil, while in a crop without soil, the variables considered for changing the irrigation scheme are the temperature and relative humidity in the environment, and the programmed irrigation schemes based on frequency and the ignition time. Particularly in aeroponics, between the schemes recently used are the variation in atomization times of day/night according to the days of production and the time interval when the ambient temperature exceeds 35 ◦C , as well as the control of the temperature and humidity in the root chamber between 25 and 29 ◦C however, they do not consider the standard markers of crop water needs such as the crop temperature, VPD or water stress index.

In the report, a mint seedling was subjected to observation in the aeroponic cultivation chamber from its transplant, preserving the ranges of pH and EC between 5.5 and 6.5 and 750 and 1100 ppm and with a constant irrigation system every 24 min day/night with an activation time of 30 s. According to the experimental results, the DTla does not provide a specific criterion for the determination of water stress in an aeroponic crop; more studies are required on the mint variety to estimate the temperature ranges where the DTla serve as a concrete marker of water stress. The experimentation in the crop camera that was presented shows how the VPD from the beginning marked a potential root damage due to water stress. The estimation of the VPD in conjunction with image processing provides an estimate of the appearance and evolution of water stress in aeroponic crops. Among the main actions to evaluate against a high VPD and the reduction in the rate of growth of the leaf, is the increase in the frequency of irrigation, as well as the incorporation of a system that allows the control of external environmental parameters. In the literature studied, both conceptual and practices in the development of crops in the soil, hydroponics and aeroponics, address the grouping schemes of components that make up the stages and connectivity of an IoT architecture.

As shown, most of the systems consider the measurement of environmental variables and, depending on the meteorological data of the case to determine the irrigation and monitoring needs, the automated monitoring of the nutritional conditions of the nutritive solution. However, the previous studies do not consider the monitoring of crop growth from image acquisition and analysis systems, nor do they include reports and alerts due to the failure of the electronic systems used in the proposal. In the proposal that is presented in this paper, there is an application that not only accesses the monitored data regarding the crop, but also provides information on the functionality status of the incorporated electronic systems, allowing the user to be alert to the maintenance needs of electronic elements and software incorporated in the IoT architecture that has been presented. This proposal does not yet incorporate the temperature control and humidity in the greenhouse; however, the architecture developed presents the flexibility to incorporate additional monitoring services and control due to the inclusion of a mist node in the proposed IoT system.

4.2.1 ADVANTAGES OF SMART AEROPONIC SYSTEM

- **Water efficiency:** Aeroponic systems use up to 90% less water than traditional soil-based systems. This is because water is sprayed directly onto the plant roots, reducing the amount of water needed to grow crops.
- **Faster growth and higher yields:** Plants in aeroponic systems grow faster and produce higher yields than those in traditional soil-based systems. This is because the plant roots have constant access to oxygen, nutrients, and water, which promotes rapid growth and healthy root development.
- **Space efficiency:** Aeroponic systems require less space than traditional soil-based systems because the plants can be grown vertically, maximizing the use of space.
- **Reduced environmental impact:** Aeroponic systems use fewer pesticides and herbicides than traditional soil-based systems, reducing the impact on the environment.
- **Control over growing conditions:** Smart aeroponic systems can be fully automated and controlled using sensors, microcontrollers, and software. This enables growers to maintain precise control over growing conditions such as temperature, humidity, and nutrient levels, resulting in optimal plant growth.
- **Reduced labor costs:** Automation in smart aeroponic systems can reduce the need for manual labor, reducing labor costs.
- **Year-round growing:** Aeroponic systems can be used to grow crops year-round, regardless of weather conditions, providing a reliable source of fresh produce.
- It is an environmentally friendly and economically efficient plant growing system.

4.2.2 DISADVANTAGES OF SMART AEROPONIC SYSTEM

- **High initial setup cost:** The setup cost of a smart aeroponic system is relatively high due to the cost of sensors, microcontrollers, software, and other components required to automate the system.
- **Technical expertise:** Smart aeroponic systems require technical expertise to design, build, and maintain. This can be a barrier for small-scale growers who may not have the necessary skills or resources to operate the system.
- **Dependence on technology:** Smart aeroponic systems rely heavily on technology, which can be a disadvantage in the event of a power outage or system failure. This could result in crop loss or damage.
- **Vulnerability to cyber threats:** Smart aeroponic systems connected to the internet are vulnerable to cyber threats such as hacking and data breaches. This could compromise the integrity of the system and put the crops at risk.
- **Limited crop variety:** Aeroponic systems are best suited for growing leafy greens, herbs, and other small crops that have shallow root systems. They may not be suitable for growing larger, more complex crops such as fruit trees or grains.
- **Nutrient management:** Aeroponic systems require precise management of nutrient levels, which can be challenging to achieve. If nutrient levels are not properly managed, it can lead to plant nutrient deficiencies or toxicity.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE

5.1 CONCLUSION

In conclusion, a smart aeroponic system offers a promising solution to the challenges facing modern agriculture, such as water scarcity, limited space for cultivation, and the need for sustainable practices. By utilizing technology such as sensors, controllers, and automation, growers can optimize crop yields, reduce labor costs, and use fewer resources while providing a reliable source of fresh produce year-round. However, the implementation of a smart aeroponic system requires careful consideration of factors such as crop selection, environmental conditions, and system design and maintenance. As technology continues to advance and the demand for sustainable food production grows, smart aeroponic systems offer a promising solution for the future of agriculture.

This system will be effective when implemented in aeroponics agriculture. Delivers nutrients directly to the plant roots. Completely programmable technology conserves energy. Closed-loop system conserves water. Conserves water through runoff absorption into roots. Can be combined with hydroponics. Crops are easier to harvest in the absence of soil. Higher density crops optimize output. Reduce labor cost through automation. Produces higher quality food in a controlled environment. Reduced risk of disease and pest infestation in a controlled environment. No need to immerse roots in water which offers more control. Roots are provided with better exposure to oxygen. Scalable systems can range from commercial level to apartment sized gardens. Produces more food with less effort. This can be developed in future for better results. There are many chances for developing systems in future which would be of great development in the field of aeroponics. Thus, this product is better developed in the present and with certain other development in future.

5.2 FUTURE SCOPE

As future work, the proposed architecture for aeroponic crop production will be implemented, monitoring the growth chambers simultaneously, and considering the irrigation frequency and the time interval as study variables regarding the image processing-embedded algorithms on fog layer, for the study of colorimetry, infrared thermography, and morphology in the evolution of the crop when considering the leaf and root will be added.

The future scope for smart aeroponic systems is vast, and several areas can be explored to further improve and optimize the system. Some possible future directions include:

- Integration with AI and machine learning: The incorporation of AI and machine learning into smart aeroponic systems can provide real-time insights and decision-making capabilities for growers, enhancing the system's efficiency and reducing manual labor.
- Use of advanced sensors and controllers: Advanced sensors and controllers can help fine-tune environmental conditions such as temperature, humidity, and light, resulting in better crop yields and faster growth rates.
- Development of new crop varieties: Researchers can explore the cultivation of new crop varieties that can thrive in aeroponic systems, such as medicinal plants or high-value crops, increasing the system's profitability.
- Expansion to larger-scale systems: As technology improves, smart aeroponic systems can be scaled up to meet the demands of larger commercial farming operations, potentially reducing the need for traditional soil-based farming.
- Integration with renewable energy sources: The integration of renewable energy sources, such as solar or wind power, can make smart aeroponic systems more sustainable and reduce the dependence on the grid.

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(With PO & PSO Mapping)

Academic: 2022 – 23

Semester	**7 & 8**	**Subject Name/Code**	**Project Work/ 18ECP85**
Course Coordinator Name		**Mr Bhaskar B & Mrs Uma S**	

Course Outcomes		**PO & PSO**
CO1	Identify the domain of interest and problem with multidisciplinary approach by applying acquired knowledge.	PO1,PO2,PO4,PO8,PSO1
CO2	Perform requirement analysis and identify design methodologies with novelty & societal relevance in it.	PO2,PO3,PO4, PO6, PO8,PO9,PO11, PSO1
CO3	Apply advanced engineering tools and perform hardware/software design from a product perspective.	PO1,PO2,PO5,PO7,.PO9,PO10,PSO3
CO4	Combine all the modules through effective team work after efficient testing.	PO1,PO2,PO5,PO6,PO9,PSO2
CO5	Task completion and compilation of the project report.	PO1,PO2,PO9,PO10,PO11,PO12,PSO3

Correlation Matrix

CO	**PO1**	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**P09**	**PO10**	**PO11**	**PO12**	**PSO1**	**PSO2**	**PSO3**
CO1	3	3	-	3	-	-	-	3	-	-	-	-	3	-	-
CO2	-	3	3	3	-	2	-	2	2	-	3	-	3	-	-
CO3	3	3	-	-	3	-	3	-	3	-	-	-	-	-	3
CO4	3	3	-	-	3	3	-	-	3	-	-	-	-	3	-
CO5	3	3	-	-	-	-	-	-	3	3	3	3			3

Note: Correlation levels: 1: Slight (Low) 2: Moderate (Medium) 3: Substantial (High), "-" → No correlation

Project Outcome

Year 2022-23

Project Title: "AN APPROACH TOWARDS DEVELOPMENT AND ANALYSIS OF A SMART AEROPONIC SYSTEM"

Project Domain: Automation in Agriculture and Internet of Things

Sl No:	Factors addressed through project *	Applicable PO's and PSO's	Justification
1.	Research	PO4 & PSO1	Techniques for dealing with different sensors and microcontroller and research regarding growth of plants through aeroponic farming.
2.	Safety	PO6	Main application is safety and fulfill societal needs.
3.	Skill	PO1	Designing, implementing the hardware prototype, programing skills to interface different devices and sensors
4.	Technology	PO5	ARDUINO IDE
5.	Social relevance	PO6	Addresses applications including home automation, safety, and societal needs.
6.	Economy	PO11	Economical when compared other commercial models
7.	Teamwork	PO9	Worked effectively as an individual and as a member

Signature of Students

Signature of Guide