Visvesvaraya Technological University, Belagavi.

PROJECT REPORT

on

"IOT BASED AEROPONICS SYSTEM"

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CERTIFICATE

This is to Certify that the dissertation work **"IOT BASED AEROPONICS SYSTEM"** carried out by Student VAMSI M, TARAK RAM SAI, VISHNUVARDHAN R, VITHALAREDDY ANJAREDDY BUDAREDDY USN: 1CR16EC182, 1CR16EC185, 1CR16EC194, 1CR16EC195 bonafide students of **CMRIT** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the academic year **2019-20**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said degree.

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Chapter 1

Introduction

Agriculture is the main source of income in India. Because of the increase in population,demand of the food is also increasing.But,due to high labor cost, unfavourable environmental conditions, less rainfall and less area for farming, it is very essential to do farming within a roof with the help of
Hydroponics and Aeroponics.

According to the traditional way of farming, the soil is not necessary for the growth of plants but it is just a medium for the plant for nutrient intake. This evolves the idea of a modern forming technique called Aeroponics. Aeroponics is the practice of growing the plants without the soil and its roots in the misty environment. This technique uses the mineral nutrients from the nutrient solution in the form of mist in a more efficient way than from soil . Aeroponic culture is similar to the Hydroponics system. The only difference is the supply of nutrients in Aeroponics is through mist but in Hydroponics we use water for the supply of nutrients.

There are various types of herbs, vegetables and fruits that can be grown using hydroponics. The vast use of IoT has made the farmers to automate aeroponic culture. Level of water, pH, temperature, flow, humidity and light intensity can be monitored by using IoT. There are certain necessary things like temperature and humidity, these will be continuously monitored by sensors present in the aeroponic system. The supplying of water and nutrients to the system is done by a central water tank and things like watering and controlling humidity is done by using a microcontroller Kit connected to a wireless sensor with internet which senses the humidity, temperature and water level. Sensors and controllers like ESP-8266, Arduino and Raspberry Pi, etc. are used to run an aeroponics farm.

Hydroponics and aeroponics are methods which are plant cultivation techniques with no soil usage by providing an artificial environment for the cultivation. The nutrients to roots in aeroponics and hydroponics are provided by nutrient tanks in a controlled environment [3] by making an artificial supporting structure. The basic diagram for the aeroponics system is shown in fig 1.

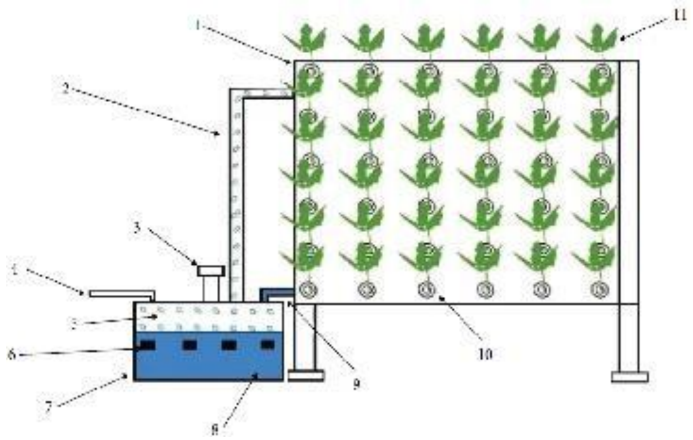


Fig 1: Aeroponics basic plant farming system

1. Growing chamber. 2. Nutrient supplying pump. 3. Misting fan. 4. Power supply line. 5. Nutrient mist. 6. Atomizers 7. Reservoir for nutrients 8. Solution of nutrients 9. Nutrient recycling line. 10. Plant proprietor. 11. Plants.

The sensors are used for measuring the input parameters. For the high yields and optimum plant growth, the input parameters should be in range specified by the dataset. The dataset is designed after the analysis of the plants for its optimum growth. The aeroponics tank contains the (nutrient + water) solution with desired pH. The pH sensor continuously monitors the fluctuations. The levels of aeroponics tank are measured from the water level sensor for prevention for fluctuations in the threshold values of tank levels. If the levels decrease, the water pump sends the water from the main tank. The water is sent to plants in the form of mist in order to reduce the water usage. The datasets are sent in the processor with a Machine learning algorithm. The machine learning algorithm helps in taking the decisions because it is hard to appropriately control factors. For instance a sensor, attempting to increment encompassing moistness and another attempting to raise temperature or even neglect to trigger. In that case, the Artificial Intelligence framework will be helpful. An AI framework will have the option to envision things like the slack between turning an AC unit on and the temperature diminishing, so it will have the option to be both progressively productive and increasingly exact in the manner it controls your condition.

Chapter 2

Literature review

Shiny Abraham (2017) had developed a prototype of aquaponics. The main aim of their survey was to continuously keep monitoring the quality of the water that is being supplied to the plant by use of intelligent data accession and processing. As there is a good connection between bacteria, plant and fish., the water can be made clean by leaving the fishes in the water before it's supplied.

The focus of the work was to introduce the IoT in the aquaponics system so as to remote access the information about the quality of the water. So the system was built with raspberry pi and some sensor circuit for measuring pH of the water, temperature of the system and the oxygen dissolved in the water.

In order to reduce the amount of water for the growth of plants than in aquaponics the new technique called hydroponics was developed. Rijo jackson tom's team had developed one such system. Here the roots of the plants were kept inside the nutrient solution instead in the soil as the soil is not always necessary for the development of the plant. Along with it, water level sensors were used to maintain the amount of nutrient level in the system.

But still the amount of the water used was more. So as to reduce the amount of water usage and for the faster growth of the plants we have opted this new technique aeroponics and this is some research we have made regarding the aeroponics.

Many countries as well as India have been exercising aeroponics in their forming. Even NASA has opted for aeroponics and it has developed lettuce.(NASA)

Chapter 3

IOT and ML in Aeroponics

3.1 IoT in Aeroponics:

IoT stands for Internet of things used for connecting people, things with the Internet and storing the data in the clouds for exploration. The advent of IoT has permitted farmers for automating aeroponic culturing.The IoT has even been permitted to keep track of the temperature, pH, light intensity, water level, flow, and they all can be controlled too. So, keeping all these above parameters in view some research has been made appointing IoT to monitor and control the aeroponics system.

In aeroponics, the cucumber plant is required to be kept in sunlight for 16 hours and under dark night for 8 hours. The lumen meter used in the system will monitor the amount of light continuously. The microcontroller used consists of a Real time clock, thus it manages the lighting with the help of a relay switch to satisfy 16 hours of light.

Here an LCD panel is used which is connected to the microcontroller to exhibit the information.

A temperature sensor, typically LM35 is used to keep track of the temperature in the system. For the cucumber plant the ambient outdoor temperature required is between 65 to 75 degree fahrenheit, i.e during the night times plant requires above 18 degree celsius and during day times above 23 degree celsius temperature is maintained using the microcontroller.

Along with temperature, the humidity sensor is also deployed, typically DH11. The leaves of cucumber plants have a large surface area thus they require a high amount of humidity. Thus the superlative humidity required is between 60 to 70% during night time and between 70 to 90% during day time.

The pH of the nutrient solution which will be supplied to the plants is conserved using a pH sensor.

3.2 Artificial Intelligence in aeroponics:

Appropriately controlling the Aeroponic condition is maybe one of the most testing undertakings the advanced producer must face. Either with a little development room or a major nursery, it is hard to appropriately control factors, for example, temperature, moistness, pH and supplement focus, guaranteeing they are totally kept in close ranges with the best possible controlling activities continually being applied. Today we're going to discuss a portion of the examination done into cutting edge control frameworks and how utilizing these could assist you with boosting your harvest yields.

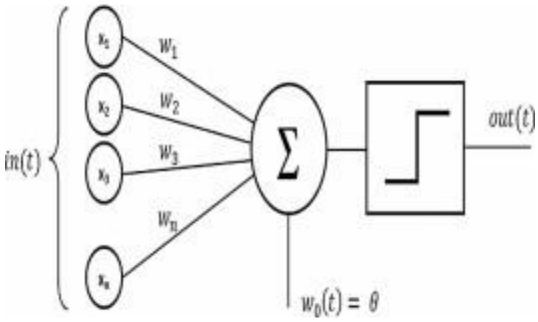
Aeroponic crops are dynamic frameworks, with plants ceaselessly influencing their condition and requesting control activities so as to keep conditions consistent. For instance plants will in general unfold water and ingest carbon dioxide during their light cycle, so as to keep dampness and carbon dioxide focused consistently you may need to turn on humidifiers, dehumidifiers, carbon dioxide generators, and so on. Realizing what move should be made isn't paltry and innocent control usage – like turning on humidifiers, AC frameworks, and so on when a few edges are reached – can cause issues where sensors battle one another (for instance a sensor attempting to increment encompassing moistness and another attempting to raise temperature) or even neglect to trigger.

So as to give better control, scientists have made frameworks that depend on AI – frameworks that can gain from models – so as to realize what control activities are required and execute them so as to give perfect control to a hydroponic arrangement. An AI framework will have the option to envision things like the slack between turning an AC unit on and the temperature diminishing, so it will have the option to be both progressively productive and increasingly exact in the manner it controls your condition. This utilization of robotized control guided by AI is otherwise called "Brilliant Aeroponics"

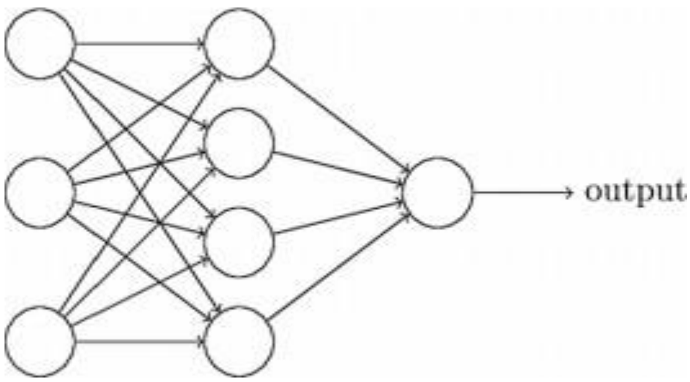
Machine learning is a subset of Artificial Intelligence (AI). The AI helps the computers in taking the decision on its own after getting trained for a required task. As the human mind thinks from its past experiences and makes decisions, in the same way AI makes its decision based on the past data based on the algorithms. The machine learning algorithm can be used for controlling the plant growth using hydroponics by controlling the flow of nutrient solution. There are many algorithms in machine learning but the most popular once for machine learning are using Bayesian networks and artificial neural networks. In one of the research papers, Bayesian network[20] algorithm for smart farming for controlling the parameters like pH, water level and temperature changes and light intensity management in hydroponics. The datasets were gathered over for a month and analysis was done. In another research paper, applied artificial neural network for the hydroponics data sets. It predicted accurately the pH and other parameters like pH, water level and temperature changes and light intensity management for growth of plants. Either of the two algorithms can be used for accurate prediction of pH and other parameters for desired growth of plants. Appropriately controlling the Aeroponics condition is maybe one of the most testing undertakings the advanced producer must face. With a little develop room or a major nursery, it is hard to appropriately control factors, for example, temperature, moistness, pH and supplement focus, guaranteeing they are totally kept in close ranges with the best possible controlling activities continually being applied. Aeroponics crops are dynamic frameworks, with plants ceaselessly influencing their condition and requesting control activities so as to keep conditions consistent.

For instance plants will in general unfold water and ingest carbon dioxide during their light cycle; so as to keep dampness and carbon dioxide focused consistently you may need to turn on humidifiers, carbon dioxide generators, and so on. Realizing what move should be made isn't paltry and innocent control usage – like turning on humidifiers, AC frameworks, and so on when a few edges are reached – can cause issues where sensors battle one another (for instance a sensor attempting to increment encompassing moistness and another attempting to raise temperature) or even neglect to trigger. So as to give better control, scientists have made frameworks that depend on AI – frameworks that can gain from models – so as to realize what control activities are required and execute them so as to give perfect control to a hydroponic arrangement. An AI framework will have the option to envision things like the slack between turning an AC unit on and the temperature diminishing, so it will have the option to be both progressively productive and increasingly exact in the manner it controls your condition.

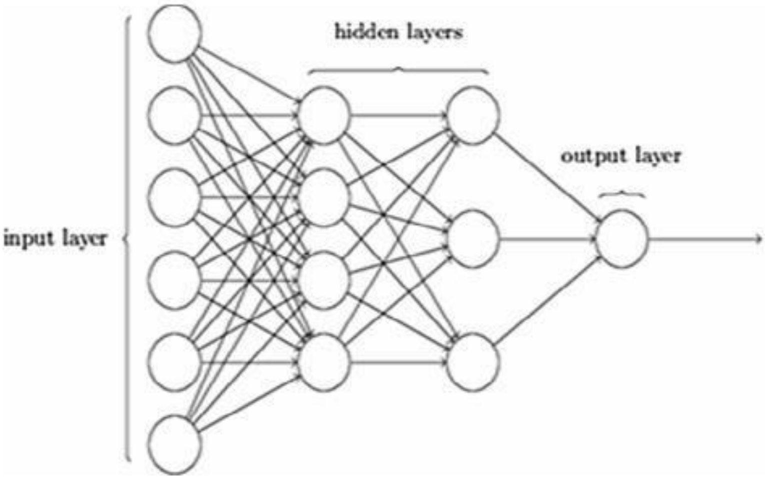
The drawbacks of algorithms, Bayesian network and artificial neural network algorithms couldn't produce appropriate action and control actions based on parameters trained for the hydroponics system. In order to overcome this deep neural network algorithm is able to appropriately take control action on a real time basis. The combination of aeroponics techniques interfaced with machine learning can make the yields better for the plants with less nutrients and water usage. Smart farming can still be enhanced by using the design AI- enabled edge computing that can increase the speed and range of IoT applications that can be used as interfaced in future. This computing decreases the unexpected failure for continuous monitoring at very low latency.



Perceptron in ANN



ANN with Single hidden layer



Deep Neural Network(ANN with Two hidden layers)

Table 1: Comparison of existing techniques of forming without soil

Technology/ Principle used	Advantages/ Disadvantages	Future scope	Performance measures
1) Deep neural network algorithm as machine learning algorithm. 2) IoT for machine to machine interaction so that there is no human involvement.	Achieved a great accuracy in growth of plants. No human involvement in the system. The plants growth will be least effected by global warming More plants can't be grown in a single tank. The water consumed can be still reduced if aeroponics technology is used	It could be extended to grow more hydroponics plants in different tanks. Hydroponics can be done on large scale. Can be developed with mobile application for controlling instead of Machine learning algorithms.	Temperature: 27°C to 31°C Humidity: 90% pH: 5.5 to 6.5
Different methods of hydroponics like drip system, deep water method etc.	Hydroponics can be used for growing plants for supporting life on space also. This method can be used in places where gardening is not possible. People can grow their vegetables easily even if they are in crowded places. Pesticide and insecticides usage will be reduced and the soil will be in safe position.	It can be integrated with Machine learning for high accuracy. It can be applied for growing other plants also	Temperature: 25°C to 30°C Humidity: 80% pH: 5.5 to 6.5
Automatic aeroponics system using a mobile application, IoT devices with sensors and service platform.	Mobile application was developed with easy interface for farmers. Lowers farmers cost from ploughing the field, removal of weeds etc.	If mobile application gets hanged then farmers can't sort out the errors. Water loss in more compared to using sensors	Temperature : 25°C to 30°C Humidity: 75% pH: 5 to 6
Aeroponics is a blessing or a curse	Low production cost, zero pesticide usage, saves water in a huge quality and clean environment. Planting and harvesting can be done throughout the year.	Some training is required for system maintenance. Initial cost of system is high.	Temperature : 24°C to 30°C Humidity: 75% pH: 5 to 6.5
Designed a control system to manage actuators like fan and mist maker. Sensor data is transmitted via internet.	Alternative method monitoring and controlling using wireless sensor and actuator network. This method has used solar panel for reducing power usage	Initial cost of system is high as includes solar panel and other wireless network.	pH value 5.5 – 6.5. Temperature:22°C to 28 °C Humidity -80%to90%
Automatic hydroponic system integrated to agricultural curriculum	No creepy crawlies creatures and infection. Automatic system	Cost is high. If any failure occurs in system then a farmer can't able fix it.	pH: 5.8 and 6.5 Temperature: 22 °C to 28 °C Humidity–60%to 80%

Automatic monitoring aeroponics irrigation system based on IoT and Raspberry Pi	Power is saved due to automatic control system. Closed system for water conservation. Easy harvesting. Reduced labour cost	Initial cost of investment is high.	Average temperature : 28.5°C pH: 6.2 – 6.7 Humidity–70%to 85%
Cloud based technology for storage of data and shared with users	This method has generated fully functional system. Information can be shared with others via internet. Simple and cheap management system	Difficult to achieve ideal temperature and relative humidity. Water pump size must be larger for the sprinkling.	Temperature – 18.33°C to 26.67°C Humidity–50%to 80% pH:4,pH: 7 and pH 10

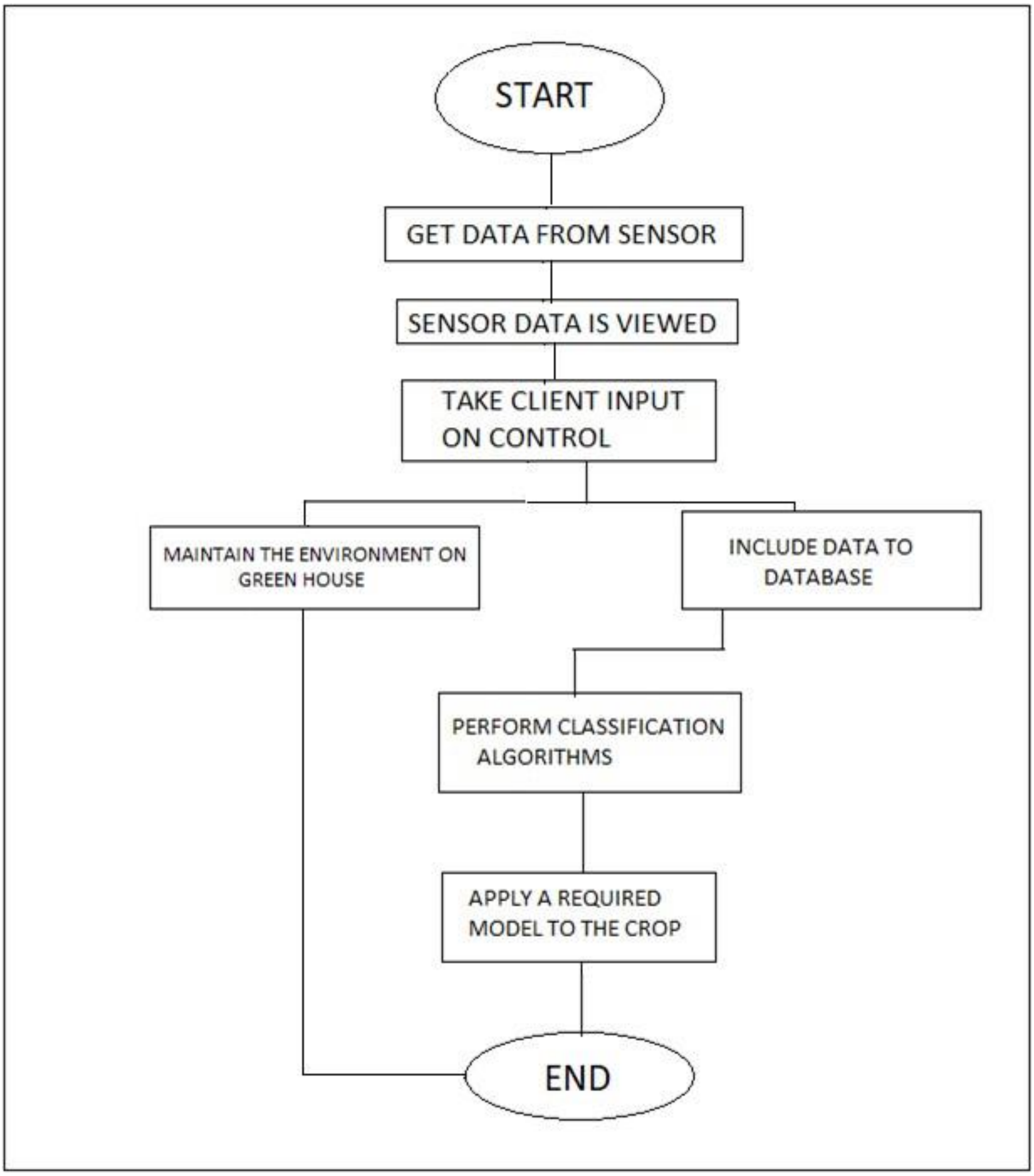


Fig2: Overall System Design

The overall idea of the aeroponics is presented in the below diagram. It gives us the idea of how to implement the idea. And it shows how the hardware part of it is connected to the various parts of the project.

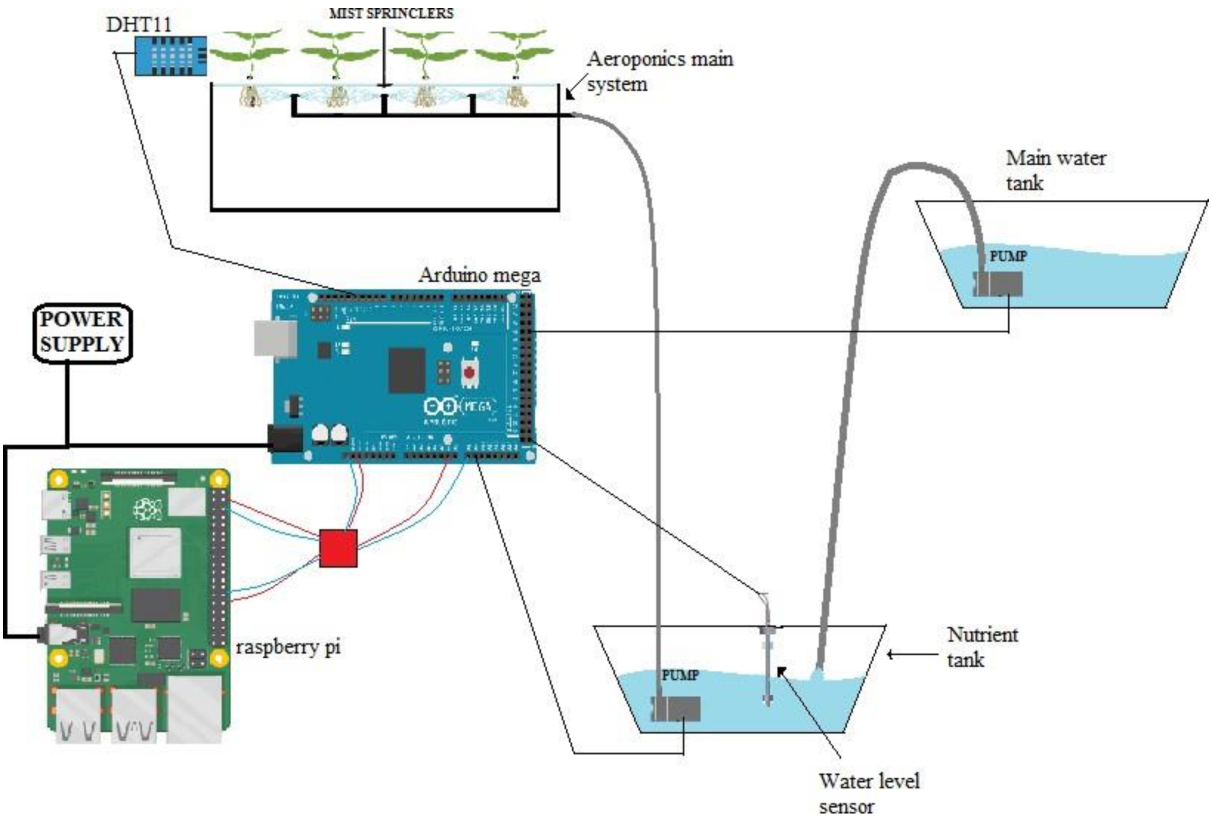


FIG-3: Simulation of aeroponics system

Chapter 4

Implementation

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

4.1 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 technique helps to improve existing systems installed in the greenhouse efficiently and smoothly by forwarding real-time collected information to the operator through the radio signals. The system optimises the transmission protocols more accurately and quickly and maximises the application of energy to save the energy and reduce the consumption. Pala and team. suggested that the utilisation 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 minimise impacts on the environment. The farmers could start to understand their crops at 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 the intelligent agriculture monitoring tools could reduce the concept of unsuitability for the amateur.

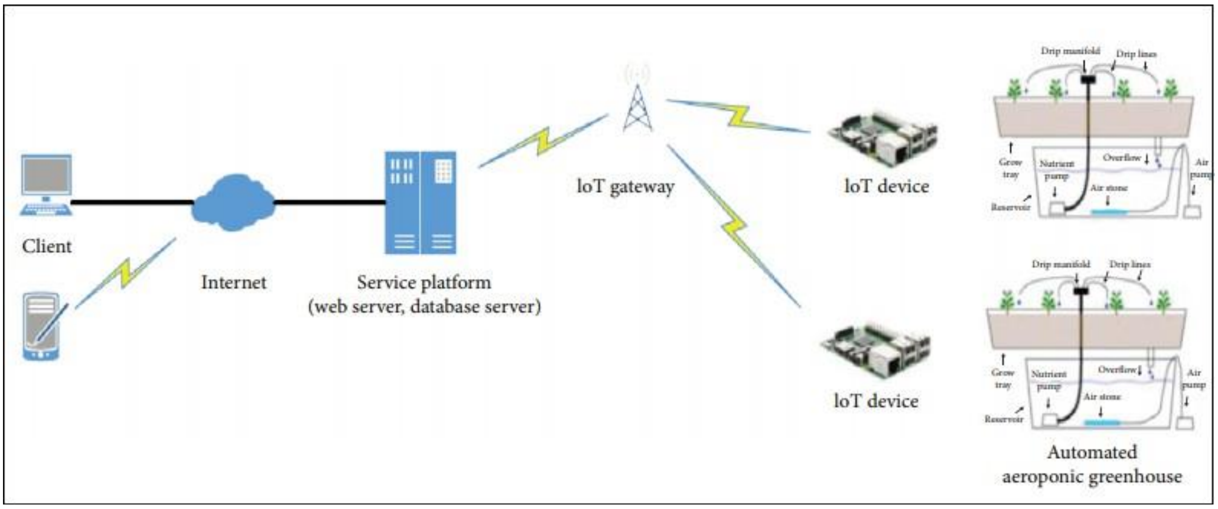


Fig4: IoT Technology in the aeroponic system

4.2 Sensor Types and Monitoring Parameters:

In this review study, 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 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 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 labour and expense. However, the 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 on techniques. Furthermore, the key to the success and high yields of air gardening is a 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, pH, and EC concentration. If the parameters drift outside the desired range, the plants can harm. Besides, there are some additional parameters which can be adjusted to further optimise growth, such as air temperature, relative humidity, light intensity, and carbon dioxide (CO_2) 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 a number of parameters such as temperature, humidity, light intensity, O_2 and CO_2 levels, direction, and wind speed. Aside from the sensors, there is also a requirement for the actuators to distribute nutrients and waters 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.

Sl.No	Parameters	Values	Instruments
1	Desired pH values of nutrient solution	The pH value generally depends on crop that is being grown. Like for carrot 5.8 to 6.4, potato 5 to 6 and Tomato 5.5 to 6.5 etc.	pH sensor
2	Humidity	70% to 100% moisture	Humidity sensor
3	Temperature	most favorable is 25◦C to 30◦C and not more than to 32◦C	Temperature sensor
4	Atomization of Nutrient	Mist size flow of nutrients at high pressure from 10 to 100, low pressure from 5 to 50	Nozzle atomization for high and for low Pressure
5	Carbon dioxide ($C0_2$)	500 and 5000 parts per million	CO_2 sensor

6	Light intensity	8 to 10 hours in a day	Light intensity sensor

Table 2: Dataset utilized to analyze the proposed work

4.3 Hardware Modules:

- **Microcontroller Unit: The ARM7TDMI-S** is a general purpose 32-bit microprocessor, which offers high-performance and very low power consumption. The ARM architecture is based on Reduced Instruction Set Computer (RISC) principles, and the instruction set and related decode mechanism are much simpler than those of micro programmed Complex Instruction Set Computers (CISC). This simplicity results in a high instruction throughput and impressive real-time interrupt response from a small and cost-effective processor. Pipeline techniques are employed so that all parts of the processing and memory systems can operate continuously. Typically, while one instruction is being executed, its successor is being decoded, and a third instruction is being fetched from memory. The ARM7TDMI-S processor also employs a unique architectural strategy known as Thumb, which makes it ideally suited to high-volume applications with memory restrictions, or applications where code density is an issue. The key idea behind Thumb is that of a super-reduced instruction set.
- **Raspberry pi**: This is a processor that manages the Arduino Mega via the UART Serial Communication at A5, A4 pins which are analog in nature. Relying on the output of the Algorithm of Neural Network, utilizing the sensors confederated to Arduino, Raspberry pi carries out some particular control activities on the system. Raspberry pi is the UART sender and functions depending on the out-turn of the Algorithm of Neural Network.
- **Humidity sensor(DHT 11):** Aeroponics is the technique of cultivating plant by providing the water nutrient small spray in the air. Thus, the humidity is another important parameter of aeroponic growth chamber environments, and its control is recognised to be very important for significant plant growth. In the aeroponic system, the plant gets all available moisture in the growth chamber. Moreover, if the growth chamber has too high or less moisture content, both conditions will create many problems for the plant. Accordingly, an accurate and precise means of testing moisture content in the growth chamber will help farmers to monitor their crops and provide a suitable growth environment for the plant. Wang et al. reported that a humidity sensor is a device that detects and measures water vapour present in the air within a room or enclosure. At present, humidity sensors are widely used in medicine, agriculture, and environmental monitoring. However, the most commonly used units for humidity measurement are relative humidity . The development of humidity sensors has shown remarkable progress because of using various types of sensing materials in recent years. The sensing materials used in humidity sensors can classify into ceramics, polymers, and composites . The humidity sensor could be placed in the growth chamber to maintain the moisture level. If the moisture level becomes less than the plant requirement, the sensors will forward the signals to atomization nozzles to perform their work. This is a temperature and humidity sensor connected to Arduino at

digital pin 10. Relaying on ambient temperature and humidity levels, the fans run by DC motors and the water sprayers are turned on by the microcontroller.

- **Water level sensor:** The aeroponics is the method of the 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 the precision agriculture techniques, the farmer will be able to monitor and control water nutrient level through the 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 nearing empty.
- **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 the 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. The 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 nonpresence 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 particular threshold value of this sensor the Arduino is going to turn on the LED Bulb when it finds more darkness than the essential amount.
- **Temperature Sensor (LM35D) :** 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, the 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 thermocouple or resistance temperature detector. The temperature sensor measures the real-time temperature reading through an electrical signal. The sensors collect the data about temperature from a particular source and convert the data into an understandable form for a device or an observer. The temperature sensor accurately measures temperatures slower changing from critical applications such as facilities or rooms and sends them to the user's webpage

- **EC and pH Sensor:** In the aeroponic system, the plant productivity is closely related to nutrient uptake and the EC and pH regulation of the nutrient solution. The EC and pH concentration of the nutrient solution affects the availability of the nutrients to plants . The pH and EC concentrations are controlled to prevent barrier growth. Their measurement is essential because the solubility of minerals in acidic, alkaline, and ion concentration of all the species in solutions is different and the solution concentration changes with solubility. The unmonitored EC and pH concentration of the nutrient solution will quickly lead to a situation where plants cannot absorb the essential nutrients, if not corrected this will eventually lead to harmful plant growth and poor productivity. Thus, the EC and pH concentration of the nutrient solution is a critical parameter to be measured and controlled throughout the plant growth. Moreover, in the conventional aeroponic system, the EC and pH value of the nutrient solution is mostly monitored manually by performing laboratory analysis or using advanced equipment which is a time-consuming process. For instance, when the EC of the nutrient solution decreased or increased, the control of nutrient solution concentration is mostly achieved by adding more high concentration nutrient solution or the fresh water, respectively, to the nutrient solution to maintain the EC level to the prescribed target range. Similarly, for pH, an acid solution and an alkali solution are used to control the pH fluctuation of the nutrient solution within a specified target range. However, these conventional methods are time-consuming and challenging tasks for the farmer to maintain the EC and pH value at the desired range accurately. In addition, the EC and pH sensor could be used to deal with the above challenges.
- **Two DC Motors:** These along with two propellers are controlled with two channel relay switches to control the humidity level in the system. The propellers act as fans and will be turned on by the microcontroller to reduce the humidity level, if it goes above the level mentioned above in IoT in aeroponics.
- **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.
- **LED Bulb:** 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 cucumber plant is required to be kept in sunlight for 16 hours and under dark night for 8 hours, this condition is maintained by this LED Bulb.

- **Arduino Mega:** This behaves as a recipient of UART communication and it is superinted by the Raspberry pi which is the sender of UART communication

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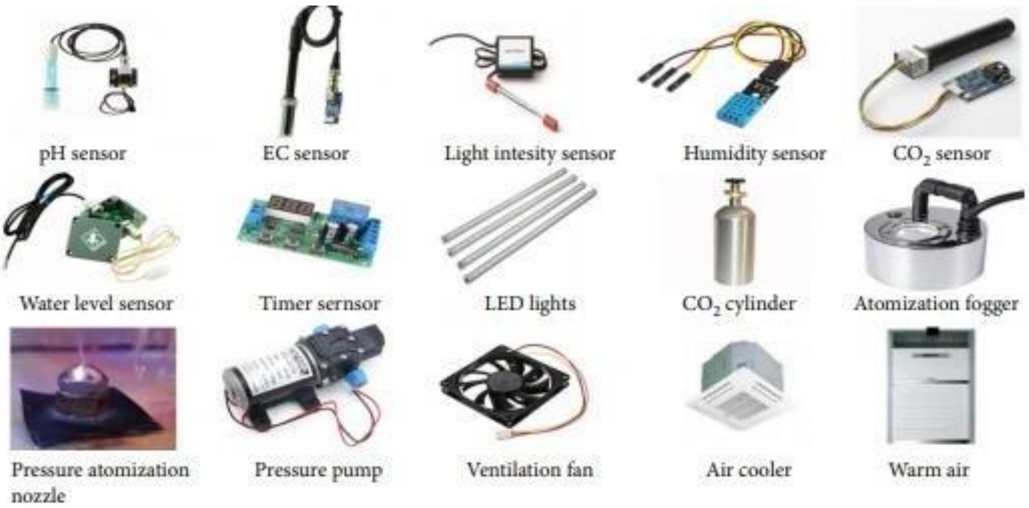

Fig5: Sensors and actuators used in aeroponics

4.4 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 task. 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 utilisation, 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. A typical architecture of sensor nodes for controlling and monitoring the aeroponic system is shown in Figure 6. Furthermore, in architecture, the data acquisition section refers to some sensor nodes used in the Aeroponic system Data acquisition Mobile application Control and monitoring center Data transmission module Social platform Cloud data processing server. Journal of Sensors system to establish a data acquisition module. 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 photos of the growing plants) and transmit the gathered data to the control and management centre. However, the control and management section refers to the central processing unit (CPU) of the system. The CPU of the system consists of some primary functions such as Arduino and WRTnod protocols, whose work is to store, manage gathered data from collection nodes, process, and then accurately and automatically send to the web server in real time. Thus, the system can help the farmer and grower to monitor and control the smart aeroponic system remotely using the mobile app. In other words, the plant will be able to talk with the farmer through a mobile app about whether the selected parameters are working well or not.

4.5 Advantages of Sensor Techniques in the Aeroponic System:

The continuously increasing food demands require rapid improvement and development in the food production system. However, to enhance the quality and productivity of the cultivated crop, peoples are moving towards the modern plant cultivation technologies in agriculture. Thus, aeroponics is one of the rising plant growing technologies in agriculture as a modern-day cultivation technique, where the plant is cultivated in an air environment, and no soil support is provided. In the aeroponic system, a number of the parameters are required to control for successful plant growth because there is no growing medium provided to the plant. For example, if the plant has some sudden stress and the farmer is not present at the site that means the plant will die. Therefore, the proper management of the crop is essential. In the conventional aeroponic system, a grower uses his knowledge, skills, and judgment to adjust and maintain the parameters such as EC and pH meter, minimum and maximum temperature, light intensity, and humidity level through several instruments and checks the readings which are labour-intensive and time-consuming tasks. To deal with the above problems, the aeroponic system can be developed with a wireless sensor and actuator network for monitoring the key parameters at lower labour cost, time, and without any technical knowledge. The wireless sensor and actuator network offer several advantages including faster response to confrontational climatic conditions and better quality control of the crop that produces at a lower labour cost. This advancement in the aeroponic system through wireless sensor networks for monitoring growth chamber environments is beneficial. However, the monitoring system also offers a range of information which could be required by plant scientists or growers to provide a greater understanding of how these environmental and nutrient parameters correlate with plant growth. It is now recognised that plant growers can perfectly and easily acquire the skills needed to operate an aeroponic system. It provides the full control of the system, not by constant manual attention from the operator but to a large extent by wireless sensors.

4.6 Software components:

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- **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.

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- **Numpy:** Open source library accessible for python that turns out to be generally simpler to control the Arduino utilizing a Raspberry Pi. The Nanpy module for Arduino contains the libraries and code for all the sensors that are pushed together without a moment's delay to the Arduino microcontroller. We have to compose explicit Python code in the Raspberry Pi that changes the sensors that should be utilized. The Arduino is associated with the Raspberry Pi utilizing the USB connectors on the Pi.

- **Raspbian Jessie:** Jessie is the name of the working framework used to run the RaspberryPi. It depends on the Debian Linux Architecture. The current adaptation, Jessie is the name of the character taken from the film Toy Story

- **Pandas**: Pandas is for the most part utilized for information mining and cleaning activities. It is exceptionally utilized for stacking and cleaning the information in python. We have utilized pandas to stack csv libraries into the program and thus use it for building up the neural system program

- **Tensor flow:** Open-source library written in C++ by the google cerebrum group at Google. It is utilized for growing profound neural system programs using the GPU of the framework. It is quick and effective and thus is broadly utilized nowadays for creating fake neural system programs.

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- **Google Firebase:** Firebase is a SaaS, Software as a Service Cloud administration gave by Google. It is free and can be utilized with your Google account without any problem. We have utilized firebase for transferring our sensor information alongside the anticipated yield to the firebase cloud. Without breaking a sweat of a free cloud administration, the qualities are sent out in JSON which can be perused effectively by the python condition for figurines. Firebase is along these lines an extraordinary programming for all cloud applications with a No-SQL highlight.

- **Python 3.6:** Python is a deciphered language which is open source. We have utilized python3.6 all through our task for building up the neural system code and furthermore coding the sensors interfaced to the Arduino conveying to the RaspberryPi. Python is additionally utilized for a Chatbot administration in our customer that profits the qualities from the firebase cloud to tell about the current sensor esteems and in this manner is very valuable

Chapter 5

Nutrients required for our Cucumber Plant in our Aeroponic Project

The best fertilizer for cucumber plants has macronutrients such as nitrogen, phosphorous, and potassium, as well as essential micronutrients such as magnesium, calcium, boron, and zinc Temperature required for cucumbers on at about 65 to 75 degrees Fahrenheit, or 18 to 23 degrees Celsius. UV light activates a plant's natural defence mechanisms, producing a sort of "sunscreen" to protect itself from the damaging light.

Humidity levels daytime ideal range between 60-70% for indoor cucumber plants. In contrast, night time moisture levels range slightly lower, between 70-90%. Light intensity With respect to cucumber, 400- 500 μmol m-2 s-1 was indicated as the optimum.

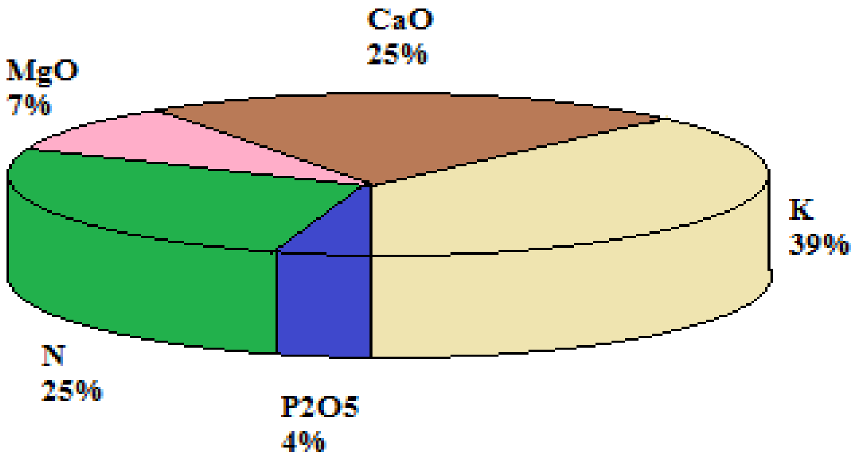

Fig6: Proportions of the nutrients required for the effective growth of the cucumber plant

5.1 Nutrient solution management in aeroponics system

Aeroponics uses less water and nutrients because the plant roots are sprayed at intervals using a precise droplet size that could be utilized most efficiently by osmosis to nourish the plant. The nutrient solution is an aqueous solution mainly containing soluble salts of necessary components for higher plant yield. The essential inorganic ions have an important and clear physiological role and their absence prevents the plant life growth stage. However, the nutrient composition depends on the plant cultivation method, the kind of medium, growth stage, weather, method of applying nutrient solution, etc. The plants need 17 essential inorganics nutrients for maintaining optimum health and significant yield. Rolot et al. (2002) reported the main necessary nutrient components required for vigorous plant growth included phosphorus (P), sulfur (S), potassium (K), nitrogen (N), and zinc (Zn). The carbon (C) and oxygen (O) is directly supplied from the atmosphere. The plant cannot exist without the deficiency of these elements, and these elements cannot be exchanged with any other nutrients. Therefore, in the aeroponics system, the plant is grown without soil by providing nutrient mist through atomization nozzles. It is important to supply accurate essential nutrients at a proper time with required concentration. Up to now, different researchers used different nutrients concentration for preparing the nutrient-rich water. Dennis, Hoagland, and Daniel recognized several recipes for preparing the mineral nutrient solution for water culture. Knop and other plant physiologists revealed that K, Mg, Ca, Fe, and P along with S, C, N, H, and O are all essential nutrient elements for plant life. There are several nutrient solutions recipes. These recipes are mostly used in the aeroponics system until now. The success or failure of the system primarily depends on the strict nutrient management. Therefore, it is important to manipulate and adjust the EC and pH level of water nutrient solution. Moreover, replace the nutrient solution after every 2 to 3 days or whenever necessary.

Chapter 6

Plant growth and root optimization

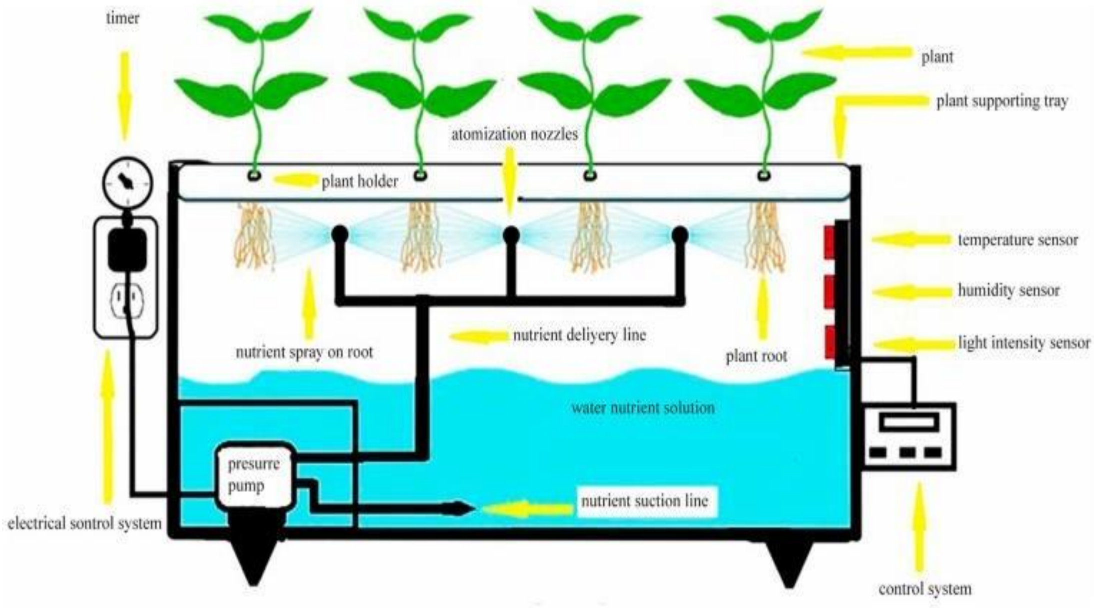

Fig7: Aeroponics plant growing system with IoT controlled technique

6.1 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. The lower portion of the plant entirely suspends in the mist air environment and provides root organism to gain the required factors. The base of the cutting is supplied with high levels of oxygen and moisture in a humid environment and helps the plant to get 100% of the fresh oxygen from the air to promote and support root metabolism and accelerate formation. The increasing metabolism rate of plant growth was reported up to 10 times greater than the soil system.

6.2 Mechanization and optimizing of the root environment in aeroponics cultivation systems

Throughout history and literature review, man has endeavored to understand and manipulate his surrounding environment. One aspect of his investigation was the plant, and their ability to survive and flourish under distinct situations. The research results indicated that direct and adequate supply of mineral nutrients is a significant factor in the creation of the root domain environment. Hayden (2006) reported that plant root development and growth laid on several factors include the initiation, elongation, and spreading out of fresh root axes. Plant root structure responds to the root zone environment by substituting in growth and branching systems as well the variations in plant hormone synthesis and response probably mediate these plastic responses to the root zone environment as well as contribute to genetic variances in root architecture and plasticity. Jonathan et al. revealed that plant root growth and development depends on an adequate quantity of carbohydrates supply from surrounding photosynthesis concentration and available environmental conditions. Therefore, many roots surrounding environmental conditions that influence photosynthesis, including water availability, light intensity, temperature, and nutrient availability may impact on root growth by affecting carbohydrate supply to the plant roots. Compared with the other traditional cultivation methods, aerosol culture becomes the advantages of free extension of the root system, direct and sufficient oxygen uptake, rapid and convenient water absorption, and full mineralization with mist supply, creating the best root environment for plant growth. Aeroponics is defined as a system of soilless culture where roots are continuously or discontinuously bathed with fine drops of nutrient-rich water. The method requires no substrate like rock wool, dirt, coir, vermiculite or perlite and entails growing plants with their roots periodically wetted with a fine mist of atomized nutrients. Excellent aeration is the main advantage of aeroponics. Plant root structure response to the root zone environment via substituting in growth and branching systems. Thus, only aeroponics provides numerous advantages including a free extension of the root system, direct and sufficient oxygen uptake, rapid and provision of uniform nutrient spray mist with best root growth environment.

6.3 Brief Explanation:-

The essential rule of aeroponic developing is to develop plants suspended in a shut or semi-shut condition by spraying the plant's dangling roots and lower stem with an atomized or showered, nutrient-rich water solution. The leaves and crown, regularly called the canopy, stretch out above. The foundations of the plant are isolated by the plant bolster structure. Regularly, shut cell foam is packed around the lower stem and embedded into an opening in the aeroponic load, which diminishes work and cost; for bigger plants, trellising is utilized to suspend the heaviness of vegetation and fruit.

The paper tells about the growth of plants aeroponics is very healthier because the plant's environment is clean. The growth of plants is faster in a more balanced way. The number of plants growing in a limited area can be increased as the fight for the basic parameters like water, nutrients etc can be eliminated. The potato grows in aeroponics with high yields. The user can harvest any size of potato by controlling the input parameters like the nutrients, pH, and humidity etc. aeroponics technique has a caliber to reduce the cost and increase the yields compared to hydroponics.. In order to overcome these disadvantages, integration of Aeroponics and machine learning strategies can be opted and the architecture is proposed below.

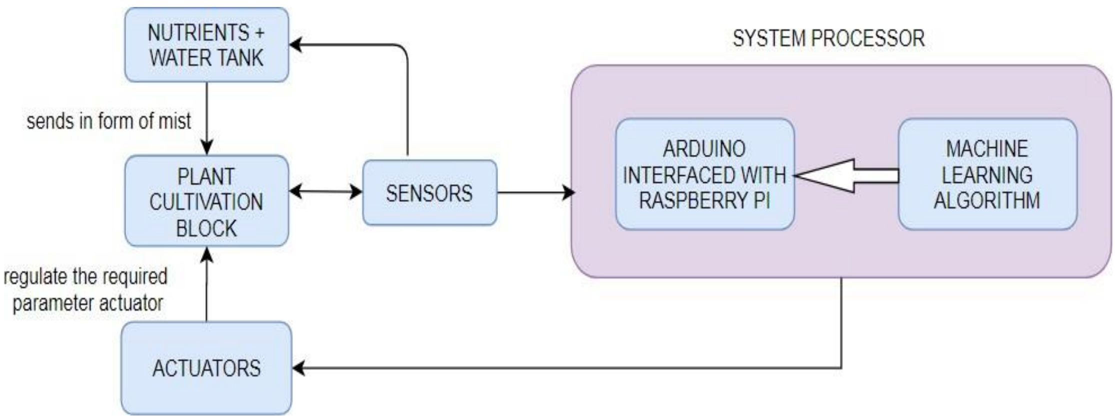

Fig 8: Proposed architecture for aeroponics system

The Figure explains the proposed architecture of the aeroponics system. The arduino is interfaced with Raspberry pi which is implemented with a suitable machine learning algorithm. The sensors collect the data from the plant cultivation block and send it to the system processor. If there is any fluctuation in the input parameters with respect to the threshold then the system processor sends the signal to actuator a desired actuator, in order to maintain desired parameters. The system processor is implemented with a machine learning algorithm which can lead to easy fault detection and automate the system without any human intervention. If there is conflict between sensor decisions like a sensor attempting to increment encompassing moistness and another attempting to raise temperature, in that case AI frameworks can take over the correct decision for controlling the human made environment for proper plant cultivation. The hardware components needed for the system implementation mainly consists of water level sensor for measuring the water levels, temperature sensor for temperature measurement, Light dependent resistor (LDR) to keep track of light falling on the system, LED bulbs for the light during night of desired intensity, humidity sensor for measuring amount of water content in the atmosphere of system, pH sensor for checking acidity of the nutrition tank, Temperature sensor for measuring the temperature of system , the carbon dioxide sensors sense the its content in the system. For example if the temperature of the system increases then the actuator turns the coolant and regulates the temperature to a required level.

The below mentioned fig is the prototype which is used for the aeroponic system in its initial stages.

Fig 9: Prototype of the setup for aeroponics system

Chapter 7

Expected outcomes

- The expected outcome may be that the plant grows more faster than the normal conventional method.
- And also it will be tastier than the normal grown vegetable which is more healthy and nutritioned.
- And moreover the main outcome is that the plant itself grows without any need of any field and soil and which grows with the mist in the air.
- It takes very much less water than in the field.

Chapter 8

Advantages and disadvantages of aeroponics system

8.1 Advantages:

Martin-Laurent et al. suggested that Aeroponics technique is a current innovative and appropriate technology. It has the potential to cultivate plants in large quantities, tree saplings associated with soil microorganisms, such as AM fungi, for reforestation of degraded land in the humid regions. Aeroponics is an indoor horticulture practice. It is the best to adopt aeroponics in areas where the soil is not suitable for plant growth. Aeroponics is an incredible amount of water as little as compared with other plant growing systems. The system reduces the labor cost, consumes less water usage by 98%, fertilizer usage by 60%, pesticide and herbicides usage by 100% and maximizes plant yield by 45% to 75% than either hydroponics or geoponics systems (NASA 2006). The nutrient solution could be recycled easily for reuse. The system allows for vertical farming, thus increasing the yield by more space for the plant. The possibilities of multiple harvests of a single perennial crop and accelerated cultivation cycle due to the increased rate of growth and maturation. The mature plant could be removed easily at any time without disturbing another plant. The diseases could not expand quickly because of clean root material free from soil, soilborne organisms and adulteration from foreign plant species contaminants. While in other soil-less systems plant diseases could spread through nutrient distribution in growth chambers from plant to plant. The plant receives 100% of the available carbon dioxide and oxygen to the leaves, stems, roots, and accelerates growth with reducing rooting time. The system is not subjected to weather conditions. The plants could be grown and harvested throughout the year without any interference of soil, pesticides, and residue. It is an environmentally friendly and economically efficient plant growing system. Disadvantages of aeroponics systems . Expensive for long scale production . The plant grower must need a specific level of proficiency to operate the system. . The grower must have the information about the appropriate quantity of required nutrients for plant growth in the system. . It is important to supply the required concentration of the nutrients. There is no solid culture to absorb the excess nutrients if the excess plant will die. The system design material is a little expensive. As the well designed system requires advanced equipment. It mainly consists of constant high-pressure pumps, atomization nozzles, EC, and pH measuring devices, temperature, light intensity and humidity sensors and timer to control the system. What we know and what remains to be known in the aeroponics system Presently, aeroponics cultivation is implicated for growing vegetable crops. It is a relatively new technology. Therefore, enough material about the system is yet distant. Otazú (2014) declared that in aeroponics system production is essentially sensitive to climate and the vegetative period increases by 1–2 months. It can substantially increase income and decrease the seed production cost which represents the system as more convenient to growers. The sequential plant harvesting is required, and the initial cost could be obtained quickly. The system must analyze with new cultivars and the artificial conditions including extra lights, temperature and humidity control system. The artificial conditions should be equipped in the greenhouse for the plant cultivation at different latitudes. The study of root temperature is not as well documented. The interrelationships among root and shoot temperature influence on growth are still unidentified. The evaluation, assessment, and utilization of aeroponics systems for commercial plant development purposes are not studied. However, most of the studies are focused on root research, as root microorganisms and root responses to drought. Each plant needs a specific optimum supply of the nutrient solution at specific growth point. So, the optimum concentration of nutrient solution for each plant should be investigated and distinguished. The plant spacing should be figured out for each cultivar. Different plant materials such as cuttings and tuber sprouts should be compared in the system. In the aeroponics system, the traditional methods of pest/disease control are not applicable thus the modern diseases control should be developed. Based on weather and field production conditions, the best plant production period should be determined for each plant. The artificial lighting could be used to grow the plant.

8.2 Disadvantages:

- Expensive for long scale production.
- The plant grower must need a specific level of proficiency to operate the system.
- The grower must have the information about the appropriate quantity of required nutrients for plant growth in the system.
- It is important to supply the required concentration of the nutrients.
- There is no any solid culture to absorb the excess nutrients if supply excess plants will die.
- The system design material is a little expensive. As the well designed system requires advanced equipment. It mainly constant high-pressure pumps, atomization nozzles, EC, and pH measuring devices, temperature, light intensity and humidity sensors and timer to control the system

Chapter 9

Future application prospects

9.1 Future work

Previous research works done on the aeroponics system are in favor of adopting this cultivation system. In a relatively short period, the aeroponics system has been adopted in many situations from outdoor field culture to indoor greenhouse culture. It is also recommended as a highly specialized culture in the space application and space-age technique. At the same time, the system could be used in developing countries of the Third World to accommodate intensive food production in the limited area. In future, aeroponics would be effectively used in those regions where fresh water and fertile soils will not be accessible. Thus, it could be the potential application for food production in those regions having vast parts of the non arable land, small area and big population, and as well in desert regions. The system could be highly practiced to grow vegetables in small countries whose chief industry is tourism. The tourist facilities, restaurants and hotels might grow their own fresh vegetables and provide fresh food to the tourists.

9.2 Conclusion

This review paper of the existing literature revealed as the population increases. The demands for clean and fresh food increases alarmingly with the population. People will turn to new plant growing technologies to fill up increasing food demands. Moreover, this project concluded that aeroponics is the modern, innovative and informative technology for plant cultivation without corporation of the soil. The system is the best plant growing technology in many aspects compared with different cultivation systems. The system is quickly increasing momentum, popularity and fastest growing sector of modern agriculture. It would be effectively employed in various countries for vegetable production where natural resources are insufficient.

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