Automated Aeroponic Farming

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Abstract - *Aeroponic farming offers numerous advantages over traditional farming, focusing on enhancing agricultural efficiency while minimizing environmental impact. This innovative approach involves the utilization of an automatic system to closely monitor plant growth. The automated aeroponic system operates on the principles of the Internet of Things (IoT). Temperature measurements of the root chamber and the required light intensity for the shoot system are captured using sensors. Actuators are managed by a control system. The sensor data is transmitted through the internet to a server, enabling convenient monitoring for users. The system's prototype has been successfully implemented, and it effectively provides access to all sensor data on the cloud.*

Key Words: *Aeroponics, growing chamber, monitoring system, control system, sensors*

1. INTRODUCTION

Aeroponics is an innovative technique used in both research and commercial crop production, where plant roots are suspended in the air and periodically sprayed with a nutrient solution. This method offers numerous advantages over traditional agriculture, including reduced water and nutrient consumption, enhanced growth rate, increased plant density, and improved irrigation system quality.

It is crucial to continuously monitor the consumption and level of the nutrient solution, as well as ensure the proper functioning of pumps. Failure to do so could lead to crop loss due to insufficient nutrient supply. Therefore, effective data transmission is of utmost importance in the monitoring and control of aeroponic growing chambers.

This paper presents an alternative approach that utilizes sensors and Wi-Fi technology for monitoring and controlling aeroponic systems. By implementing this method, it becomes easier to remotely monitor and manage aeroponic systems from any location, reducing the risk of crop failure and ensuring optimal plant growth.

2. Research Methodology

The base control unit microcontroller chosen for this aeroponic system is the Node MCU. This microcontroller offers efficient interfacing capabilities with the sensing devices and supports Wi-Fi connectivity for seamless data collection and transmission to the ThingSpeak portal.

The setup of the aeroponic greenhouse box includes a pump that is connected to the box, supplying water spray through pipes inside. This arrangement ensures the adequate delivery of water and nutrients to the suspended plant roots.

Two types of sensors are utilized in this system. The first is the DS18B20 temperature sensor, which is water-resistant and measures the ambient temperature in the surrounding environment. This data provides crucial information about the temperature conditions within the aeroponic setup.

The second sensor employed is the LDR (Light Dependent Resistor) sensor, which measures the intensity of light in lux. This sensor enables monitoring the amount of light received by the plants, which is crucial for their growth and development.

The Node MCU microcontroller gathers the data from both the temperature sensor and the LDR sensor. It then transfers these data points to the ThingSpeak portal through its Wi-Fi capabilities. This allows for centralized storage and monitoring of the collected data, providing valuable insights for analysis and control of the aeroponic system.

3. Components/ Software Used

3.1 ESP8266

The ESP8266 is an affordable Wi-Fi chip developed by Espressif Systems. It can be used as a standalone device or as a UART to Wi-Fi adaptor, enabling other microcontrollers to connect to Wi-Fi networks. For instance, it can be connected to an Arduino board, adding Wi-Fi capabilities to the Arduino. Its practical application is often as a standalone device.

With the ESP8266, you can control inputs and outputs similar to an Arduino, but with added Wi-Fi capabilities. This feature allows projects to be brought online, making it ideal for home automation and Internet of Things (IoT) applications. The ESP8266 has gained popularity due to several key factors:

1. Low-cost: ESP8266 boards are available at a starting price of $3 or even less, depending on the specific model.

2. Low-power: The ESP8266 consumes minimal power compared to other microcontrollers and can enter deep sleep mode to further reduce power consumption.

3. Wi-Fi capabilities: The ESP8266 can create its own Wi-Fi network (access point) or connect to existing Wi-Fi networks (station) to access the internet. This allows it to interact with online services, make HTTP requests, save data to the cloud, and even act as a web server for remote control and monitoring.

4. Compatibility with the Arduino programming language: Those familiar with programming Arduino boards can use the same programming style for the ESP8266, simplifying the transition.

5. Compatibility with MicroPython: The ESP8266 can also be programmed with MicroPython firmware, which is a Python 3 implementation designed for microcontrollers and embedded systems.

These features, coupled with the ESP8266's affordability and versatility, have contributed to its popularity in the maker and IoT communities.

3.2 DS18B20

The DS18B20 is a temperature sensor manufactured by Maxim Integrated. It is designed to be compatible with a wide range of microcontrollers and can communicate using the 1-Wire protocol. By employing the 1-Wire interface, the microcontroller can establish communication with the DS18B20 sensor and retrieve temperature data.

The 1-Wire bus, which is used to interface with the DS18B20, requires minimal hardware components, making it a simple and convenient solution. The data pin of the DS18B20 sensor is connected to an IO (input/output) port of the microcontroller. This direct connection enables the microcontroller to exchange data with the sensor using the 1-Wire protocol.

Through this straightforward hardware interface, the microcontroller can effectively communicate with the DS18B20 temperature sensor and retrieve accurate temperature readings for further processing and analysis. The simplicity and compatibility of the DS18B20 sensor make it a popular choice for temperature sensing applications in various projects and systems.

3.3 LDR Sensor

The Light Dependent Resistor (LDR) is a unique type of resistor that operates based on the photoconductivity principle, which means its resistance varies in response to the intensity of light. As the name suggests, the resistance of an LDR decreases as the light intensity increases. This characteristic makes it ideal for applications where light sensitivity is required, such as light sensors, light meters, automatic streetlights, and other light-controlled systems.

LDRs are commonly available in various dimensions, including 5mm, 8mm, 12mm, and 25mm sizes. These different sizes provide flexibility in choosing the appropriate LDR for specific applications based on factors like space constraints or desired sensitivity.

By utilizing the photoconductivity property of LDRs, engineers and hobbyists can incorporate these components into their projects to enable light-based functionality. The versatility and availability of LDRs make them widely utilized in numerous fields, ranging from electronic circuits and automation systems to environmental monitoring and photography equipment.

The functioning of a Light Dependent Resistor (LDR) relies on the principle of photoconductivity. When light illuminates the photoconductive material of the LDR, the material absorbs its energy. Consequently, the electrons present in the valence band of the material become excited and transition to the conduction band, resulting in an increase in the material's conductivity proportional to the light intensity.

For this process to occur, the energy carried by the incident light must exceed the bandgap energy of the photoconductive material. Only then can the electrons be sufficiently excited to move from the valence band to the conduction band.

In a dark environment, an LDR exhibits the highest resistance, typically around 10^12 Ohms. As the light intensity increases, the resistance of the LDR decreases. This change in resistance allows the LDR to function as a light sensor, with its resistance serving as an indication of the intensity of light falling on it.

The inverse relationship between the resistance of the LDR and the intensity of light enables its use in various applications, including light-dependent circuits, automatic control systems, and light measurement devices.

3.4 NTP Server

The NTP server, or Network Time Protocol server, is responsible for responding to time requests from clients on the network. When a client requests the current time, the NTP server provides time samples that can be used to synchronize the client's local clock.

By synchronizing the local clock with the NTP server, clients can ensure that their timekeeping is accurate and consistent. This is particularly important in systems where precise time synchronization is required, such as in network infrastructure, distributed systems, or applications that rely on time-sensitive operations.

The default value for both domain members and stand-alone clients is typically set to 1. This value represents the large sample skew for logging, measured in seconds. It helps to identify any significant discrepancies in time samples and allows for monitoring and troubleshooting purposes.

By utilizing an NTP server, organizations and individuals can maintain synchronized and accurate time across their network, ensuring smooth operations and reliable time-based functionalities.

4. Working

In this aeroponic system, the fan is programmed to switch ON when the temperature exceeds a certain threshold, helping to regulate the temperature within the growing environment. Additionally, an LED light is activated when the intensity of light, measured in lux, drops below a specified level. The relay is used to interface with AC components, enabling the control of these devices.

To provide adequate lighting for plant growth when natural light is insufficient, programmable LED light strips are utilized. These LED lights fulfill the light requirements necessary for plant growth based on the readings from the light sensor.

The timing and duration of water spray control are managed using a timer, which synchronizes with an NTP (Network Time Protocol) server. This allows for precise control and division of the watering cycles.

For the nutrient solution used in this project, an organic nutrient base in liquid form is obtained from general plant market shops. These products are labeled with instructions on the appropriate water-to-nutrient mixing ratios for gardening purposes. Alternatively, individuals can create their own nutrient solution by accurately mixing specific chemical compounds in proper measurements. Chemical stores typically carry solid crystalline forms of essential elements such as phosphorus, nitrogen, calcium, and other necessary macronutrients and micronutrients. These nutrient salts serve as the foundation for creating a customized fertilizer solution.

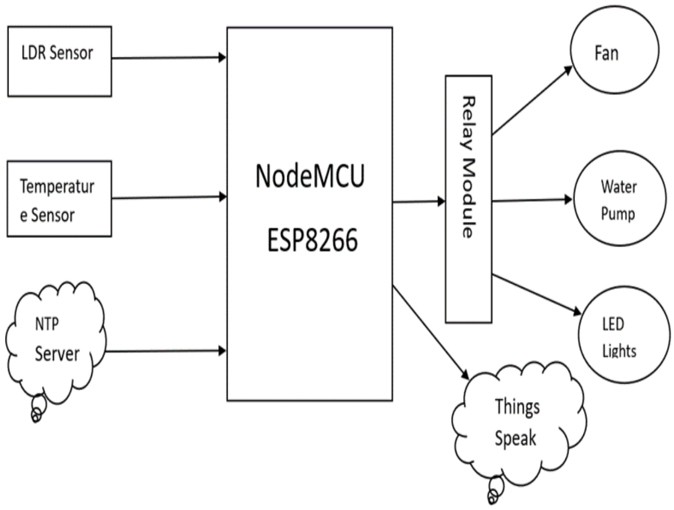

Fig -1: Block Diagram of Aeroponic System

In this circuit the grounds of esp8266, Relay and 9-volt battery has been connected together to provide separate power supply to relay since this relay requires 5 volt to operate and maximum output of voltage from esp8266 pins is 3.3 volt only. The positive side of battery has been connected to the JD-VCC pin of the relay after removing its jumper cap.

The NTP Server is a networking protocol for clock synchronization between embedded systems or computers. We have used NTP Client library to get timing of spray solution. It belongs to TCP/IP suite. The NTP client initializes request for timing. To control the time interval of spraying solution we have used Arduino-timer library. We can set the timer using this library to switch the motor on and off after fixed intervals. Thus, NTP shows timing at which the motor is on or not.

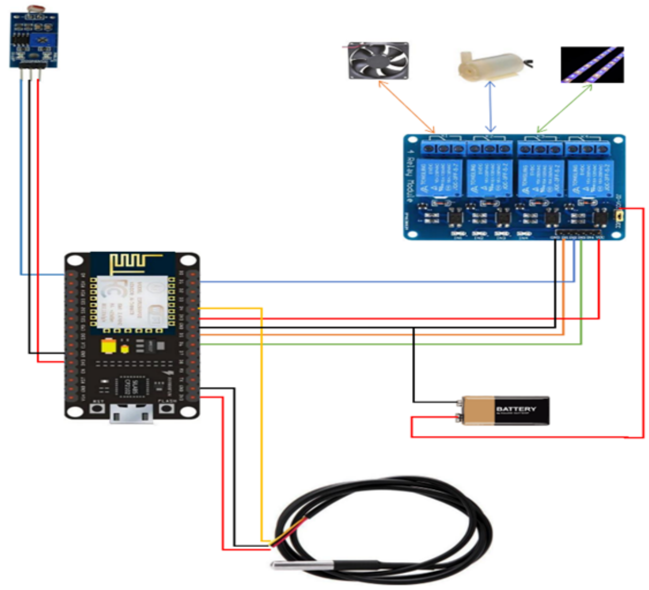

Fig -2: Circuit Diagram of Aeroponic System

Fig -3: Shoot System

Fig -4: Spraying System

4.1 Monitoring Growth of eggplant

Eggplant, also known as brinjal, is a purple-colored vegetable commonly found in Indian households. It requires a light intensity of approximately 2000 lux for optimal growth. We maintained the root chamber temperature between 22 to 30 degrees Celsius to provide the ideal conditions for the plant's development. Insufficient light can lead to reduced fruit weight in eggplants.

The first picture showcases the stem of the plant receiving light from adjustable LED strips. The intensity of these LEDs can be controlled by adjusting the supplied voltage. While we used white light in this setup, specialized RGB lights designed for indoor plant growth are available in the market. Eggplants can grow well even with white light, but certain other plants require colored lights, particularly red and blue, for optimal growth.

In the second picture, we observe the plant's roots being nourished with a water nutrient solution through sprinklers. The number of sprinklers can be adjusted according to specific requirements. For our setup, we employed a regular DC water motor capable of handling two sprinklers. The DC motor is connected via a relay switch for effective control. The water used contains an organic nutrient liquid solution that encompasses all the essential elements necessary for plant growth. The composition of this solution can be altered in the future based on specific needs. Our organic solution comprises both micro and macro nutrients, with a pH range of 6.0 to 8.0. Additionally, the solution incorporates bio enzymes, which can be adjusted to achieve optimal growth conditions.

In the provided image, we can observe the indoor setup of an aeroponic plant chamber. To monitor the root temperature, a water-resistant temperature sensor, specifically the DS18B20, has been incorporated. This sensor is designed to withstand exposure to water as it continuously senses the temperature of the root chamber, which is constantly sprayed with a water solution.

To regulate the temperature within the chamber, a DC cooling fan is employed. When the temperature surpasses 30 degrees Celsius, the fan is activated. This DC cooling fan is readily available in the market and is connected to a relay for switching purposes. During the night when the temperature naturally drops, the fan typically remains inactive.

By leveraging software solutions, this system has been cost-effective, reducing the need for additional hardware components. The esp8266, a Wi-Fi module, serves as the main controller, eliminating the necessity for a separate controller and thereby saving on hardware costs. Additionally, instead of using a Real-Time Clock (RTC) module for time display, the system utilizes an NTP server to obtain accurate time information.

4.2 Circuit Description

To power the different components of the circuit, a total of four batteries are utilized. Additionally, a power supply is provided to the esp8266 module through USB. Among the batteries, a single 9-volt battery is dedicated to supplying external power to the relay, accomplished by connecting it to the JD-VCC pin. To establish a common ground connection, the esp8266, relay, and battery grounds are interconnected.

For the switching functionality, three relay channels are employed, and they are connected to digital pins on the esp8266 module. This configuration allows for control and operation based on the project's specific requirements and desired functionality.

Fig -5: Aeroponic Chamber

In the circuit setup, separate batteries are allocated to power the LED lights, DC water pump, and DC fan, ensuring each component has its dedicated power source. The LDR sensor is responsible for detecting light intensity and communicates with the microcontroller through an analog pin (A0), allowing the microcontroller to read the sensor's output. Similarly, the DS18B20 sensor, which measures temperature, utilizes one of the available PWM pins on the microcontroller to transmit temperature data.

To control the various devices in the circuit, a relay is employed and connected to digital pins on the microcontroller. This enables the microcontroller to switch the devices on or off based on specific conditions or program logic.

An NTP (Network Time Protocol) server serves as a cloud-based system that provides accurate timing information. It offers libraries that can be utilized freely in projects, eliminating the need for a separate RTC (Real-Time Clock) module and reducing circuit complexity. Since the circuit is continuously connected to Wi-Fi, it can easily establish a connection with the NTP server at all times. By leveraging the NTP server's resources, the circuit can obtain precise and synchronized time data, ensuring accurate timing functionality without the need for additional hardware.

4.3 ThingSpeak data collection

We have implemented two data fields in our aeroponic farming channel: Light Intensity and Root Temperature. Our objective is to collect data continuously until the fruits reach their full size, enabling us to determine the most favourable growing conditions for our plants in future cycles. Additionally, this data will be invaluable for conducting comparative studies between eggplants grown in aeroponic chambers and traditional soil-based methods.

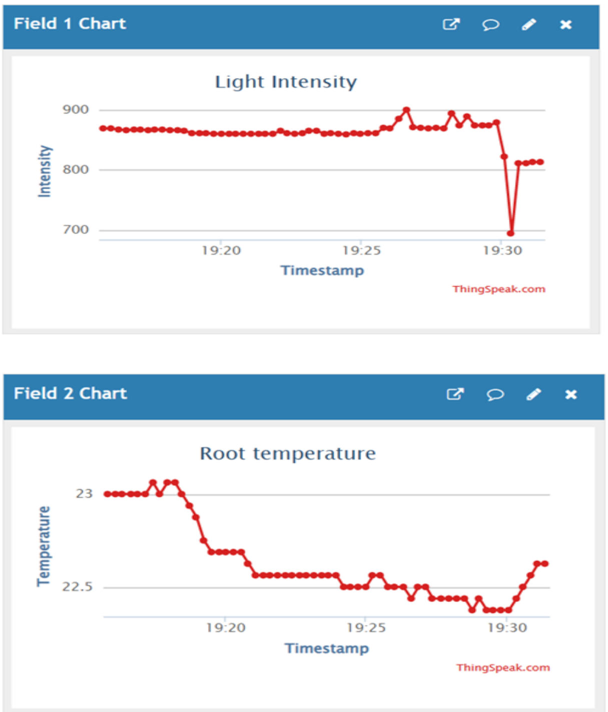

Fig -6: Data on ThingSpeak

In today's data-driven era, the cloud-based collection of this data proves exceptionally advantageous for analysis purposes. Moreover, it presents opportunities for AI/ML projects to derive insights on optimizing root temperature, light intensity, and nutrient content to enhance the health and weight of the eggplant fruits.

The quality and yield of eggplant are heavily influenced by these critical factors. Through careful analysis of the collected data, we can gain valuable knowledge on how to manipulate and optimize these variables to ensure the production of healthier and more robust fruits.

5. Future Enhancement

A water quality meter is a valuable tool for optimizing nutrient solutions in plant cultivation. It enables measurement of important parameters such as Total Dissolved Solids (TDS), pH level, Electrical Conductivity (EC), and the availability of various nutrients in the water. By monitoring and analyzing these values, adjustments can be made to create customized nutrient solutions that promote optimal plant growth and productivity.

Image processing techniques combined with AI/ML algorithms offer additional benefits in plant health management. By analyzing images of plant leaves, AI algorithms can assess their quality and provide insights on improving plant health. It can detect and identify diseases or deficiencies based on leaf color, pigmentation, and overall appearance. This information can guide farmers in taking appropriate actions to address these issues, such as adjusting nutrient levels or applying targeted treatments.

In the field of biopharmaceutical farming, the aeroponic system holds promise. Ongoing research focuses on utilizing aeroponic systems for cultivating medicinal plants, especially in space environments. The controlled environment provided by aeroponics allows for precise nutrient delivery and optimal growing conditions, ensuring the production of high-quality medicinal plants.

Vertical farming techniques can be effectively integrated with aeroponic systems to maximize productivity in limited spaces. By implementing aeroponic systems in tall towers, multiple plants can be grown in a compact area, significantly increasing the overall yield. This approach, known as vertical farming, has gained popularity for its ability to utilize vertical space efficiently and produce large quantities of crops.

Implementing aeroponics and advanced technologies like AI/ML in agriculture opens up opportunities for sustainable and high-yield farming practices. It allows for precise control over nutrient solutions, early detection of plant diseases, and efficient use of space. As research and development continue, these systems have the potential to revolutionize farming and contribute to the production of a wide range of crops in a cost-effective and environmentally friendly manner.

6. CONCLUSIONS

The implementation of indoor aeroponic farming indeed offers numerous advantages. It allows for efficient cultivation of plants without the need for large land areas, making it a viable solution for increasing food productivity to meet the demands of a growing population. Moreover, it provides a cost-effective approach to farming, as the investment required for setting up such a system is relatively low, with an estimated cost of around INR 2000. This affordability makes it feasible to implement aeroponic farming in households, enabling individuals to grow their own fresh produce.

One significant benefit of indoor aeroponic farming is the reduced risk of plant diseases and pests commonly associated with soil-based cultivation. By eliminating the use of soil, the spread of soil-borne pathogens and pests can be mitigated, resulting in healthier plants. This method also offers resilience during drought conditions, as the plants receive a controlled supply of water and nutrients, reducing dependence on traditional irrigation systems.

Aeroponic farming contributes to environmental sustainability by minimizing fertilizer runoff into waterways. In traditional farming, excess fertilizers can wash away into rivers and streams, causing water pollution. However, in aeroponic systems, the nutrient solution is contained within the chamber, allowing for efficient recycling and minimizing wastage. Additionally, the system conserves water by collecting and reusing the water that drips from the roots, reducing overall water consumption.

Commercial-scale aeroponic farming has proven successful in several countries, and entrepreneurs in India can also explore the potential of this method for large-scale production. By implementing aeroponics, farmers can achieve higher yields in shorter durations compared to traditional farming methods. This accelerated growth rate, coupled with the ability to control growing conditions, presents an attractive opportunity for enhancing agricultural productivity.

In conclusion, indoor aeroponic farming offers a range of benefits, including increased food productivity, reduced water and fertilizer wastage, improved plant health, and the ability to cultivate crops in areas with limited space or adverse environmental conditions. With its low cost, scalability, and potential for high yields, this method holds promise for revolutionizing agriculture and meeting the food requirements of a growing population in a sustainable and economical manner.

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