Automated Hydroponic System for Limited Crop Cultivation using Mobile Application

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Abstract

The system is a smart IoT-driven hydro-cultivation and purification unit of air, which is aimed to utilize in the efficient cultivation of plants indoors. It consists of sensors including pH, turbidity, temperature, humidity, water-level, and air-quality sensors to monitor the environment, and an ESP32 controller to automatically operate pumps, grow lights, nutrient dosing and ventilation to keep the conditions in the plant perfectly ideal. A combination of air-purifier, HEPA and activated-carbon filtration would enhance the health of the plants and the indoor air quality. All information is transmitted to the Blynk IoT application, which allows one to monitor the situation and manage the system remotely. This is a small, automated system that helps in maintaining sustainable plant growth at home, laboratories, and intelligent greenhouses with minimum human influence.

Keywords: Hydroponics, Automated Hydroponic System, Limited-Crop Cultivation, pH Sensor, EC Sensor, Real-Time Monitoring, Microcontroller, Mobile Application, Nutrient Dosing, Irrigation Automation, Smart Farming, IoT-Based Agriculture.

1. Introduction

This pressure on world food production, the declining area of farms, and inconsistency in climatic conditions has caused some sort of transition to controlled-environment farming. Another viable alternative to space- and resource-constrained areas is hydroponics, or growing crops without soil in water permeated with nutrients, as it provides greater control over growth factors, predictable harvests, and can be used in spaces that are indoors. Nevertheless, in order to achieve successful hydroponic farming, there should be a strong control over many variables such as nutrient concentration, pH, temperature, humidity, and water quality, which is not easily controlled in small systems. This can be solved with the help of automation via sensors and IoT technology that allow constant monitoring and automatic changes. The present research introduces Automated Hydroponic System Limited Crop Cultivation with the help of a Mobile Application, with ESP32 and sensors and actuators to monitor and adjust the conditions to growing plants and provide an opportunity to view the data, get notifications, and control the system remotely. The additional one is the Air Purification Process that ensures the air is clean- which matters when indoor pollutants such as dust, VOCs, and excess CO2 are present and this can interfere with the health of plants. The sensors on air quality and a purification unit comes into play when the contaminants exceed the predetermined thresholds that would maintain the air condition in the closed areas. Through the integration of automated control of the nutrients, air cleaning, and portable monitoring, the solution is efficient and compact in size, suitable to the small-scale crop production.

2. Methodology

2.1 System Design Overview

The suggested system builds the automation of hydroponic farming to allow the cultivation of limited crops by incorporating sensing modules, ESP32 microcontroller, purification components, and a mobile application interface. The system will be designed to constantly check environmental parameters, process information, and make control mechanisms work in order to ensure the ideal conditions in the plants. The ESP32 is the central control unit, and it makes the decisions depending on real-time sensor data.3 Background and Related Work.

2.2 Sensor Set up and Data acquisition.

A group of environmental sensors are put in place to gather real time data that is necessary in the hydroponic growth. These are. pH Sensor to measure the acidity of the nutrient solution.EC/TDS Sensor to check the concentration. DHT11/DHT22 Sensor ambient temperature and humidity sensor. Water-Level Sensor to make sure there are proper levels of nutrient solution. Air-Quality Sensor (MQ-135) to detect the existence of pollutants, variations in CO2, and volatile organic compounds.

2.3 Automated Control of Nutrients and the Environment.

The ESP32 implements an embedded control code which controls the hydroponic environment. Based on sensor readings. Nutrient and water pumps are put into operation in order to regulate pH and EC level. Cooling fans are turned on when the temperature or humidity is out of the permissible limits. The refill pump is used to ensure the water level remains at the desired position in the reservoir. Status indicators and alerts are provided to signal when the measurement is not within the safe range.

2.4 Air Purification Process Integration

An automated air cleaning system is a major part of this methodology. The air-quality sensor constantly analyzes the quality of the surrounding environment in terms of harmful gasses, dust and VOCs. In the event of poor air quality detection. The ESP32 switches the air-cleaning device (possibly a HEPA filter, an activated-carbon layer, or a small ionizing unit) until the amount of pollutants in the air returns to the safe range.The air-quality variations are logged by the system to be evaluated on a regular basis.

2.5 Mobile Application Interface on the interface.

It is connected with a special mobile app that ensures remoteness and control by the user. The application links with the ESP32 via Wi-Fi or cloud services. It allows the users to.See real time sensor data. Check the level of nutrients, temperature, humidity, and air quality. Be alerted automatically in case of abnormal condition. Monitor purifier status and system activities. Manually override some processes where needed, The mobile interface makes the system more user-friendly, and it is appropriate to those who operate small-scale or home-based cultivation.

3.Background and Related Work

Hydroponic farming is a controlled-environment agricultural practices, employing the use of water-based solution to provide nutrients directly to growing plants without using soil. The approach has become very relevant because of the declining arable land, erratic weather patterns, and increased demand of sustainable food production. With sensors and IoT technology, current hydroponic will be able to constantly check and control such vital parameters of the system as pH, water flow, nutrient concentration, temperature, and humidity, which ensures the same conditions of growth and increases crop yields. As more and more people embrace indoor and urban agriculture, clean and healthy air flow has also begun to be a priority since pollutants and lack of ventilation may hamper with the processes of respiration and photosynthesis by plants. In an effort to correct this, the recent systems have started investigating into air purification and air-quality control in order to assist the plants in fully functioning in the enclosed growing conditions. The project is based on these developments by incorporating automated hydroponic control with built-in air purification, which is a more stable and efficient small-scale cultivation system to occupy limited indoor areas. Previous studies in the field of hydroponic automation emphasize the application of microcontrollers like Arduino and ESP32, along with pH and EC sensors, temperature and water-level sensors, to control nutrient levels and control the environment. Numerous research papers have presented IoT-based systems and mobile or web-based applications to provide the opportunity to see the data in real-time, control remotely, and be notified about the abnormalities in the system. Other scholars have considered the optimization of energy and water usage, application of lighting schedules based on LEDs, recycling of nutrients, and decision making algorithms to make the available resources efficient. Although some articles talk about the environmental conditions such as humidity, carbon dioxide level, and greenhouse ventilation, not many of them incorporate active air purifiers into small-scale hydroponic systems. A majority of systems in place assume air quality to be independent.

4.System design and Implementation

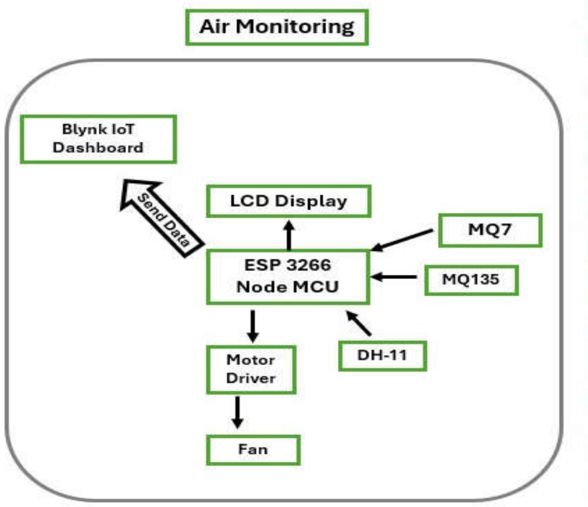

Fig. 4.1 Air Quality monitoring System

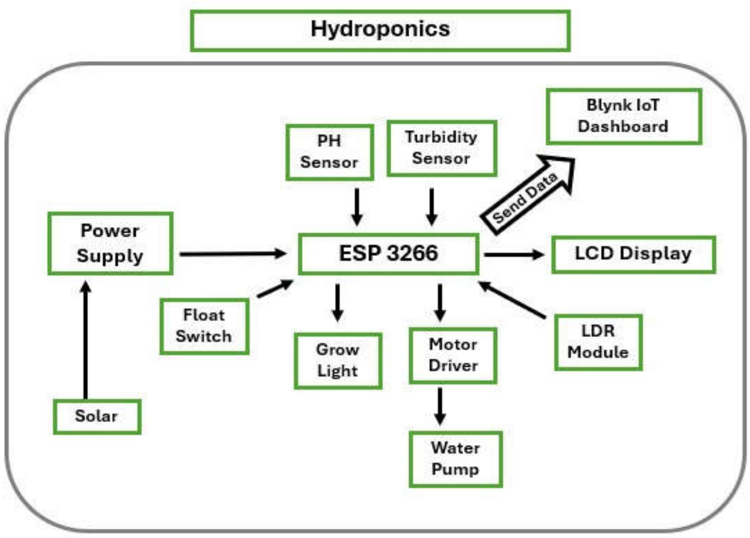

Fig. 4.2 Hydroponic System

The system combines the IoT-based air quality monitoring and hydroponic automation to form the best indoor growing atmosphere to grow limited crops. The air-monitoring unit, which is constructed on the ESP3266, collects sensor data of MQ7, MQ135, and DHT11 and is used to measure gas concentration, air quality, temperature, and humidity. According to these readings, the system has an automatic motor driver-provided fan to keep the air clean, and real-time values are displayed on an LCD and transmitted to the Blynk mobile dashboard. The hydroponic unit is also ESP3266 controlled and has a pH sensor, turbidity sensor, a float switch for water levels, and an LDR unit to detect light. It has a motor driver that regulates the grow light and water pump to maintain the adequate flow of nutrients and optimal lighting conditions. These two modules transmit the live data to the Blynk app that allows remote monitoring and automation, which creates a completely controlled and effective hydroponic growing environment.

5.Result and Analysis

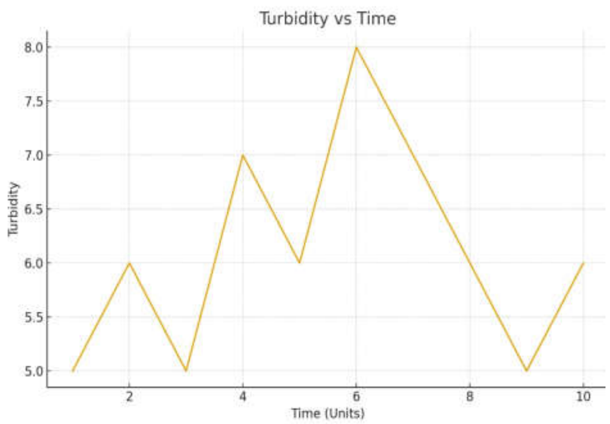

Fig5.1 : Turbidity analysis

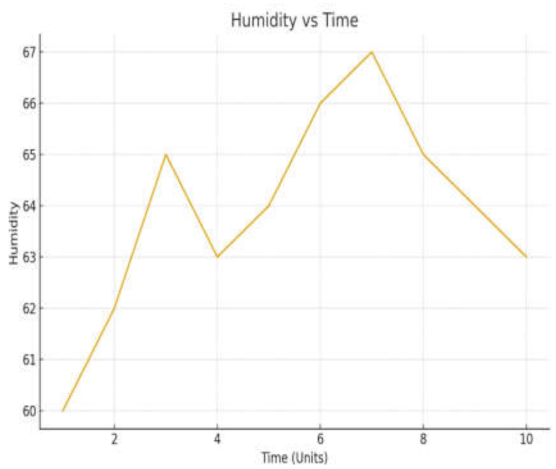

Fig5.2: Humidity analysis

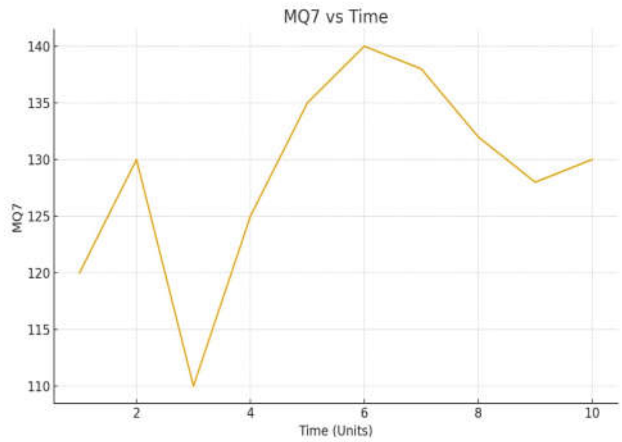

Fig5.3:MQ7 analysis

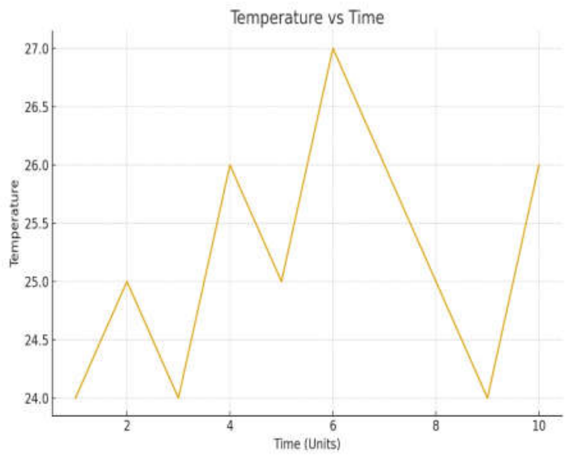

Fig5.4: Temperature analysis

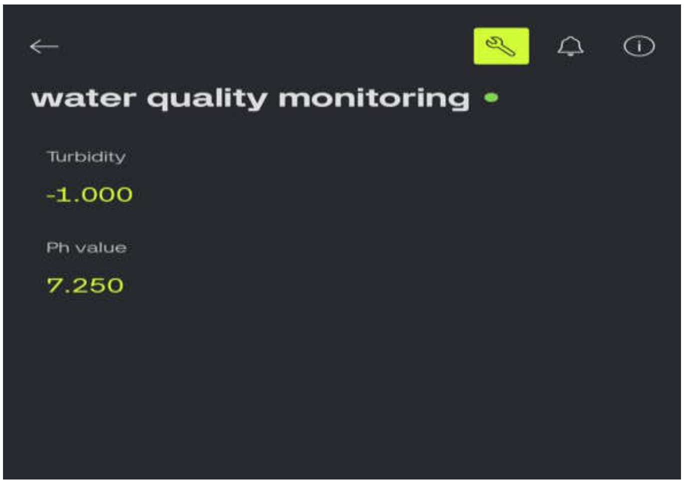

Fig5.5: Data analysis in Blynk app

Fig5.6: Data analysis in Blynk app

Turbidity: The turbidity values are consistent at 5-8 NTU indicating that the water quality was within reasonable boundaries. Minor rises are associated with nutrient mixing stages which is normal.

Humidity: The humidity was 60-67%. This demonstrates the system was at a steady micro climate that could support plant growth that had slight changes based on temperature and circulation of water.

pH Value: The pH levels ranged between 6.1 and 6.5 which is optimal in most of the hydroponic crops. The automatic system allowed the stabilized pH by dosing and indicating good nutrient balance.

MQ7 (CO Sensor): MQ7 was between 110-140 ppm. The variations show natural variations of CO near the grow area because of the activity of water pumps and oxidation of nutrients. Every value was found to be within the safe ranges.

MQ135 (Air Quality Sensor): The values of MQ135 were between 175-200 ppm, which means that the quality of air in the location was stable. There are occasional spikes indicating momentary rising of humidity or evaporation of nutrients.

Temperature: The temperature was maintained at 24 Deg C, to 27 Deg C which is ideal in leafy vegetables. Minimal peaks are associated with the lighting periods and pump working.

6.Conclusion

The proposed Automated Hydroponic System of Limited Crop Cultivation is a successful example of how the IoT can be used to monitor and control indoor farming, facilitating it and making it easier. Combining an ESP32 microcontroller with ph, temperature, humidity, turbidity, water level, and air quality sensors, the system maintains the constant control of all the critical parameters related to the growth of plants with a limited amount of human interaction. The air purification module added, which contains sensors and automatic filters, will give a cleaner and healthier environment that will help the plants to respire better, and grow generally, particularly in a small indoor area. The interface (also available as a mobile app) can enable users to view real-time data, get alerts and remotely control the system, so the setup will be available to even beginners and small-scale cultivators. On the whole, the given project will provide a small, effective, and sustainable solution that not only can increase the productivity of crops in a narrow area but also will have a beneficial effect on the health of indoor conditions, which indicates the possibility of smart automation in the sphere of modern agriculture.

7.References

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