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IoT-Based Hydroponic Mint Farming System

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Abstract:

The presented research paper describes the IoT-Based Hydroponic Mint Farming System which is aimed at increasing agricultural efficiency with the help of real-time monitoring and smart resources management. The system involves a hydroponic method of cultivating mint that is soil-less where the mint plants are cultivated through a nutrient solution in water. The data obtained by different sensors such as pH, temperature, and moisture sensors will be measured and processed to keep on monitoring the conditions in the plants under growth by an ESP32 microcontroller. The data obtained is sent to the Blynk mobile application where it can be remotely monitored and controlled by the user on a smartphone. The system offers optimum environmental conditions through real time updates and alerts which mitigates manual interventions and enhances crop yield. This type of solution facilitates effective use of water, sustainable agriculture, and precision agriculture. The solution proposed shows capability of IoT integration in hydroponics to improve productivity, minimize waste of resources, and assist in the contemporary smart farming practices.

Keywords — **Internet of Things (IoT), Hydroponic Farming, Mint Cultivation, Smart Agriculture, Real-Time Monitoring, ESP32, pH Sensor, Blynk Application, Precision Farming, Sustainable Agriculture.**

I. INTRODUCTION

The recent advances in modern agriculture have resulted in the introduction of Internet of Things (IoT) and smart farming tools to address the constraints of the conventional soil-based farming techniques. Inefficient use of water, reliance on climatic conditions, and low crop productivity are some of the challenges that conventional farming is usually plagued with. Hydroponic farming, which refers to the cultivation of crops without soil but with nutrient-enriched water, serves as an efficient alternative since it allows one to control the growing process of the crop, as well as make the use of resources more efficient [1], [2]. Focusing on the accomplishment of a smart and automated hydroponic mint farming system, the IoT-Based Hydroponic Mint Farming System is aimed at bringing the sustainable farming system, with the help of sensors, microcontrollers, and real-time monitoring systems. It is an automated control of the necessary parameters via IoT devices, such as the pH level, temperature and the level of moisture to keep the plants of the mint in the optimal conditions of growth at all times. The information is then transmitted to the cloud based systems and farmers have an opportunity to monitor and control the system remotely. This real time monitoring can significantly increase efficiency and reduce manual labor and also give better crops harvests [3], [10]. The management of the resources, particularly the water and nutrient is one of the biggest issues that have been witnessed in modern day agriculture. The traditional systems of irrigation will be inclined to lead to water wastefulness and uneven distribution of the nutrients. In order to address this issue, the hydroponic system suggested will be closed-loop system whereby, water and the nutrient will be recycled and kept controlled. This saves water, increases the growth and productivity of plants. Other implementation of the smart monitoring systems based on IoT will also ensure proper data gathering and efficiency of making decisions to the farmers [8], [9]. Other enhanced technologies such as data analytics and predictive analysis and control by machine learning may also be added to the system. The system will be able to maximize the nutrient provision and environmental conditions using historical data to maximize crop performance. Such smart agricultural systems are also employed to provide sustainable agriculture as well as assist in meeting the rising food production requirements in an effective and environmentally friendly manner [13], [14]. The language barrier is one of the major challenges that have been experienced in the global education, as it has led to the exchange of knowledge among regions being hampered. To deal with this obstacle, the proposed system will integrate AI-based multilingual translation, which would provide the opportunities to translate the speech in real-time and offer multiple languages. The system uses the translation services and LLM based on the backend in the production of correct translations, subtitles, and voice outputs in other languages. This is a strength that allows students to learn in their own language and, therefore, inclusive and personalized learning [2], [7], [11].

II. PROBLEM OUTLINING

In the conventional farming systems, the farming activities are mostly reliant on the quality of the soil, weather patterns and manual observation, hence resulting in inefficient use of resources and unpredictable production of crops. Farmers have difficulty in sustaining the ideal environmental conditions including pH level, temperature and moisture particularly in areas where there are uncertain weather conditions. Also, the traditional way of farming is not sustainable and efficient due to excessive use of water, waste of nutrients, and absence of real-time monitoring. In current hydroponic systems, even though soil has been removed, most systems continue to use manual observation and control of plant growth parameters. Such non-automation may lead to slow reaction to environmental alterations, which will have an adverse impact on the health and crop of plants. Moreover, remote monitoring systems are not available, and thus, the users cannot keep an eye on the conditions all the time, especially in an urban or small-scale farm setting, where it is impossible to monitor the situation constantly. The Hydroponic Mint Farming System is an IoT-based system that is proposed to overcome these issues by providing real-time monitoring, data collection through sensors and remote accessibility all within a single platform. The system also employs the ESP32 to collect the data obtained by pH sensors, temperature sensors, and moisture sensor and send it to the Blynk to monitor it constantly. The method saves on labor, makes timely changes to the environmental conditions, wastes fewer resources, and increases the overall efficiency and productivity of hydroponic mint farming.

III. NEED OF THE PROPOSED IOT-BASED HYDROPONIC MINT FARMING SYSTEM IN MODERN AGRICULTURE

As more people require to have sustainable agriculture and proper management of resources, the need of smart and automated farming systems is rife. Conventional agriculture methods are also very dependent on environmental factors, manual labor and overwork of water and soil resources thereby restricting productivity and scalability. Besides, a deficiency in the real-time monitoring and data-driven decision-making leads to difficulties in keeping optimal conditions in plant growth, particularly in urban and limited resources settings. The proposed Hydroponic Mint Farming System based on IoT meets this requirement by offering an intelligent and efficient system that combines hydroponic technology with real-time monitoring and remote access. Through the use of an ESP32 and a sensor-based data collection, the system constantly monitors the parameters which are crucial including pH levels, temperature, and moisture. The information is sent to the Blynk allowing the users to track and control the system any place making sure that the growth of the plant is being kept in the best possible conditions. The proposed system can improve agricultural productivity and sustainability by making it possible to achieve automated monitoring, efficient water use, and control that is based on data. It promotes urban agriculture, less reliance on soil and less wastage of resources. The IoT-Based Hydroponic Mint Farming System is therefore important in transforming the agricultural sector and countering the increasing demand of a smart, efficient, and less harmful farming system.

IV. TOOLS AND TECHNOLOGIES USED

The proposed IoT-Based Hydroponic Mint Farming System is created on the basis of a hardware/software complex to allow real-time monitoring of it and smart farming. The central part of the system is the ESP32, which is employed in processing sensor data, as well as controlling the communication between components. The ESP32 is programmed in the Arduino IDE that offers an easy and effective platform to program embedded systems. The system has various sensors that are used in order to measure environmental conditions, which are necessary to support the growth of plants. A pH sensor will be employed to measure the level of acid or alkalinity within the nutrient solution, a temperature sensor will be used to monitor the surrounding environmental conditions, and a moisture sensor will be used to identify the levels of water and make sure that the nutrients flow properly. These sensors feed the microcontroller with real-time information that is used to process and analyze the information. To enable remote monitoring and control, the system is going to apply Blynk platform that is an easy-to-use interface to visualize sensor data on a smartphone. The ESP32 is connected to the internet over Wi-Fi and sends data to the Blynk cloud, so a user can track the situation in the plants at any place. The users can also get alerts and notifications when parameters go beyond any predetermined limits using the application. Also, there is embedded C/C++ programming of control logic, data acquisition and communication protocols. To maintain operating power supply, it provides power using batteries or external adapters. All these technologies can be integrated to provide efficient data collection, real-time monitoring, and automation, which makes the system reliable and can be used in smart hydroponic farming applications.

V. CORE COMPONENTS

A. ESP32 Microcontroller

The proposed Hydroponic Mint Farming System is based on the ESP32, which provides wireless communication and real-time processing of the data. It will gather information on a variety of sensors and send it to the cloud using Wi-Fi. It is also capable of high processing, has low power consumption and has an integrated connection, which makes it appropriate in smart agriculture applications. The ESP32 guarantees the proper management of systems, its scalability, and the quality of its performance.

B. Sensor Modules (pH, Temperature, and Moisture Sensors)

Sensor modules represent an important aspect of the environmental assessment to be done to ensure optimum mint growth. The pH sensor checks acidity or alkalinity of the nutrient solution and keeps it within the optimum range. The temperature sensor will check the ambient conditions, and the moisture sensor will take care of the appropriate water level. These sensors deliver real-time feedback to the microcontroller and allow to control everything with precision and provide better plant health.

C. Real-Time Monitoring Platform (Blynk Application)

The system incorporates the Blynk to monitor and control live. It is a platform which has a user friendly interface displaying sensor readings on a smart phone. It allows users to monitor the conditions of the plants remotely, providing them with alerts and enabling them to make the required adjustments. The app will be convenient and easy to use as farmers can control the hydroponic system no matter where they are.

D. Communication and Connectivity Module

Using inbuilt Wi-Fi features, ESP32 allows the hardware system to communicate with the cloud platform seamlessly. Real-time transmissions of sensor data to the Blynk server mean that it is constantly under watch and that updates are available instantly. This connectivity makes it possible to supervise remotely and minimize manual inspection to improve the effectiveness of the system.

E. Control and Automation Mechanism

The system contains built-in control logic that is programmed in Arduino IDE and replenishes sensor data and initiates suitable actions. As an example, in case of a change in the required level of the PH or temperature, the system may produce notifications or implement corrective actions. Such automation makes the work of humans less important and guarantees the regular observation of favorable growing conditions.

F. Nutrient Solution and Hydroponic Setup

The hydroponic system is a physical arrangement that creates the system with no soil in which the mint grows. A mineral-enriched water solution is pumped through to deliver the necessary minerals to grow the plants. The closed-loop system assists in water and nutrient recycling, wastage reduction and enhancing efficiency. Such an arrangement helps the plant to grow quicker and yield higher than the conventional way of doing it.

G. Power Supply System A. System Architecture

The system has to be continuously operated by a constant power supply. The ESP32 and sensors are provided with energy via batteries or external power adapters. Quality power management means continuous collection, monitoring, and communication that is essential to secure the best farming conditions.

VI. LITERATURE REVIEW

Due to the fast development of smart agriculture, the Internet of Things (IoT) technologies have been used to manage farms. Conventional agricultural practices are based on manual observation and environmental factors which in most cases lead to the inconsistency in crop production and inefficiency in the being of the resources. To reduce these limitations the implementation of IoT based systems has gained widespread use to monitor and control agricultural parameters in real time like soil moisture, temperature and humidity. These systems make use of wireless sensor networks and cloud-based systems to enhance decision-making and productivity in farms [3], [6]. Hydroponic farming is a contemporary agricultural practice that helps to do away with soil and allows plants to grow in water baths containing nutrients. Research has indicated that hydroponics is much more water-efficient and yields better crops than conventional farming practices. Hydroponics Systems have been designed to control the environment to ensure maximized growth conditions in plants that are applicable to urban and indoor farming application [1], [2]. Nevertheless, most hydroponic systems are yet to automate in real-time and be remotely accessible. Recent studies point to the combining of the IoT with hydroponic systems to allow smart monitoring, as well as automation. Hydroponic systems powered by IoT monitors parameters like PH, nutrient concentration and temperature to maintain the best conditions to allow plants to grow. They enable the transmission of data and remote monitoring in realtime by mobile or web application which enhances efficiency and minimizes human intervention [11], [15]. However, with these developments, most current systems are just that of monitoring and lack advanced analytics and predictive features. The other major advancement in smart agriculture is the application of data analytics and machine learning methods in order to improve crop productivity. These technologies are able to forecast the growth patterns of plants, identify diseases and manage resources through the analysis of historical and realtime data. Research has revealed that big data and deep learning strategies are effective to enhance agricultural decisionmaking and automation [13], [14]. They have however not been integrated into small-scale hydroponic systems; this is due to complexity and cost reasons. One of the limitations that have been observed in current systems is the inability to have a complete automated system of nutrient and water control. Even though the use of

IoT sensors offers precise monitoring, nutrient solutions and environmental conditions in many systems still have to be manually adjusted. This makes it more reliant on human intervention and less efficient with the system. Also, the scalability and the energy use are still issues in adopting smart hydroponic systems in large scale applications [8], [9]. Based on the existing literature, it is clear that the solutions to current challenges in agriculture are either based on hydroponic growing or the IoT based control, though they are not fully integrated with the system of automation and intelligent decision-making. It is obvious that a single system that integrates hydroponic farming with real-time monitoring and automated control through IoT and effective resource management is needed. To overcome these hurdles, the proposed Hydroponic Mint Farming System will use IoT by combining sensors, micro controllers, and smart monitoring platforms to give a cost efficient, scalable, and sustainable method of farming.

VII. DESCRIPTION OF PROPOSED SOLUTION

The IoT-Based Hydroponic Mint Farming System is an intelligent and automated agricultural system that has been created to enhance efficiency and sustainability of plants growing. The system allows them to grow soil-less crops through a hydroponic system whereby the mint plants are cultivated in a nutrient-enriched water solution under a hostile environment. The suggested system incorporates real-time and IoT to provide the best growth of the plants with the least amount of human effort. The system has an ESP32 microcontroller which operates on the collection and processing of the information and data sent by various sensors such as pH sensor, temperature sensor and moisture sensor. These sensors will constantly check vital parameters that are needed to guarantee the growth of the mints. The gathered data is sent through Wi-Fi to the Blynk through which real time updates can be seen on of the smartphones. This will facilitate remote surveillance and control of the farming environment at any place. The sensors take readings on the environment and transmit them to the ESP32 where they are processed during system operation. An alert or corrective measures may be produced in case any of the parameters falls outside the established range of optimums. This will make sure that the nutrient solution is maintained at the right PH levels, temperature is maintained at an appropriate level and that moisture is given to allow the plants to grow. The automation helps to save the manual labor and minimizes the possibility of human error. Further, the hydroponic system is also developed in the form of a closed-loop operating system, in which water and nutrients are recycled and reused. This will go a long way in saving on water and will see to it that resources are efficiently used. The system also has the benefit of continuous data collection that can be employed in examining the growth patterns of plants and enhancing the performance of the system with time. In general, the suggested solution will lead to the increase of agricultural production and efficient administration of resources as well as encourage sustainable farming practices. The system is based on hydroponics and IoT-driven monitoring and automation to offer a scalable solution to contemporary smart agriculture.

VIII. SYSTEM ARCHITECTURE AND ALGORITHM DESCRIPTION

A. System Architecture

The proposed Hydroponic Mint Farming System based on IoT is aimed at offering a smart and automated plant cultivation system in soilless methods. The entire system comprises a monitoring platform on the cloud, a microcontroller, a sensorbased hydroponic system. The ESP32 microcontroller is the main part of the system since it will serve as a central processing unit. It is linked with other sensors like pH sensor, temperature sensor, and moisture sensor to constantly check the environmental and nutrient parameters. These sensors are able to gather real-time information about the hydroponic system and send it to the ESP32. The sensor data is sent back to the Blynk IoT platform to be monitored remotely by the ESP32, using Wi-Fi. The hydroponic structure consists of nutrient reservoir, water pump and piping system to circulate the nutrient rich water to the mint plants. Optimal conditions are ensured by the system to allow growth of plants due to suitable pH levels, temperature and moisture.

The design is based on a layered design:

1) Sensing Layer: This collects the real time data through sensors.

2) Processing Layer: ESP32 processes and sends information.

3) Communication Layer: Wi-Fi module allows the transfer of data.

4) Application Layer Blynk platform to monitor and control.

This architecture will provide efficiency in data flows, realtime monitoring and higher crop productivity.

B. Algorithm for AI-Based Content Generation

1) Boot the microcontroller and start the ESP32.

2) Link the system to Wi-Fi network.

3) Start all the sensors (pH sensor, temperature sensor, moisture sensor).

4) Read sensor data in real time and in regular intervals.

5) Calculate the sensor information.

6) Compare sensor readings of the predefined optimal values.

7) In case of an abnormal pH level then alert user or initiate adjustment mechanism.

8) In case the temperature goes above or below threshold, produce alert.

9) In case the moisture is little, turn on water pump to circulate nutrients.

10) Broadcast any sensor data to the Blynk IoT platform.

11) Show live data on the dashboard of mobile application.

12) Archive data to be used in analysis and monitoring.

13) Continue the process in order to monitor in real-time.

14) Stop the system when there is the necessity

IX. OBJECTIVES OF PROPOSED IOT-BASED HYDROPONIC MINT FARMING SYSTEM

The primary goal of the suggested Hydroponic Mint Farming System based on IoT is to enhance the efficiency of agriculture, its sustainability, and productivity by utilizing smart monitoring and automation. The system will involve combining hydroponic farming with IoT technology to end the constraints of conventional farming, cut down on the wastage of resources, and offer the best growing environment of mint plant. It is aimed at maximizing crop production, reducing the human factor, and providing a chance to monitor things in a real-time with the help of smart systems.

Limitations of Existing Solutions (Traditional Farming and Basic Hydroponic Systems):

Although the traditional farming and simple hydroponic systems are widely used, their effectiveness and dependability are limited by a number of drawbacks. The conventional farming is highly reliant on the quality of soil, the weather conditions, and manual labour which causes an uneven production of crops and overuse of water and fertilizers. Also, simple hydroponic systems are not commonly monitored and automated, so the parameters, including pH, temperature, and moisture level, must be controlled by a person all the time. Besides, the majority of the existing systems lack remote access and users may not easily track the condition of the plant at all times. The result is that data is not usually recorded or analyzed and this restricts the capacity to optimize the growth of plants and the use of resources. Lack of integrated smart technologies leads to unproductiveness, sluggish responses to changes in the environment, and poor productivity.

Overcoming These Limitations in the Proposed IoTBased Hydroponic Mint Farming System:

- **IoT-Integrated Smart Monitoring**: The offered system incorporates the real-time monitoring with the sensors interconnected with ESP32 providing endless monitoring of the most important parameters, such as pH values, temperature, and moisture concentration.
- **Real-Time Remote Access and Control:** Through the Blynk, the users can remotely oversee the system using a smartphone, hence making sure that it remains accessible

and can be used to make crucial decisions at any given time anywhere.

- **Efficient Water and Nutrient Management:** The hydroponic system is a closed loop process that facilitates the re-use of water and nutrients, which greatly cut down the wastage and they have maximum use of the resources.
- **Automation and Reduced Manual Effort:** The system automates the monitoring and generation of alerts and thus minimizes the importance of full human control and the possibility of errors in the regulation of conditions of growth.
- **Improved Crop Yield and Quality:** The system encourages rapid growth and better quality mint production than the conventional farming methods since it ensures the appropriate environmental conditions are followed.
- **Data Collection and Analysis:** Constant data collection can enable users to monitor the growth trends of plants and optimize the performance of the system to make improved decisions and enhance performance over the long term.
- **User-Friendly and Scalable System:** The system is oriented to be user-friendly and effective such that it can be utilized by small-scale farmers, urban farming, and can be upscaled to large farming systems in future.

X. SCOPE OF PROPOSED IOT-BASED HYDROPONIC MINT FARMING SYSTEM

The proposed Hydroponic Mint Farming System is an IoT-Based vehicle that has a broad scope in the realm of contemporary farming since the proposed solution is a smart and efficient approach to farming. The system will facilitate real-time tracking of the growth conditions in the plant so that users will be in a position to achieve the optimum environment parameters including pH, temperature and moisture content. With the combination of sensor-based data gathering with the use of the IoT technology, the system will enable the constant monitoring and control of the hydroponics environment. Blynk offers an easy-to-use interface to remotely monitor and control devices using a smartphone, which is made possible by the use of the ESP32 that facilitates the easy processing of the data and wireless communication. This makes the system very much accessible and applicable to urban farming, indoor agriculture and small-scale farm set-ups where there is a lack of space and resources. The designed system is eco-friendly because of its closedloop hydroponic system that increases greatly the efficiency of water and nutrients and is therefore an environmentally friendly system. It minimizes reliance on soil and ensures that there is minimal effect of the external environmental factors since crops can always be produced all through the year. Also, the system is applicable to various geographical areas since it could be exercised in regions with bad soils or scant water resources. Moreover, the platform can be developed with additional functionalities, including automated dosing of nutrients, the introduction of artificial intelligence that makes this forecasting analysis, and cloud-based data storage, which can be used to monitor in the long run. It is also commercially scalable with the integration of more sensors and other automation controls. The proposed system will help in advancing the concept of smart agriculture by integrating hydroponics with the IoT technology to cater to the increasing need of sustainable and efficient food production systems.

XI. FEASIBILITY ANALYSIS

- **Technical Feasibility:** The suggested system is technically viable because it comprises of trusted and popular technologies like the ESP32, real-time data collection devices, including pH, temperature, and moisture detector. Combining Wi-Fi communication with the Blynk allows to provide efficient data exchange and remote monitoring. Arduino

IDE and embedded programming are easy to use in the implementation of the system, thus making it applicable in the application of IoT-based agriculture.

- **Operational Feasibility:** The system is set in such a way that it is easy to use and can help the farmers and users observe the status of the plant without any advanced technical skills. Detection of real-time data and notification by the mobile application allows convenient work and control of the hydroponic system. Monitoring is automated to decrease the number of manual work and enhance the efficiency of operations.
- **Economic Feasibility:** The suggested system has shown to be economical because it utilizes the cheap hardware (ESP32 and sensors). The hortonic system is cost effective in the long term as it minimizes water and soil is not required. Also, the open-source platform and applications would help in lowering the cost of software development, and the system will be available to small-scale farmers and those in urban areas.
- **User Adoption:** The system has many adoption possibilities among farmers, urban gardeners, and agricultural researchers as it has a number of features that make it highly adoptable including real-time monitoring, remote accessibility, and efficient resource management. Its capability to give a constant crop output and minimize the use of manual labor is what renders it appealing to both new and seasoned users.
- **Legal Feasibility:** The system works under a usual set of agricultural and technological standards and does not entail any legal limitations. There are no sensitive personal data or finances to deal with and, as a consequence, few legal risks. The general data security practices are complied with by using the common IoT communication protocols.

XII. REQUIRED TOOLS

- **ESP32 Microcontroller**: The ESP32 is taken as the primary processing unit of the system. It gathers information on sensors, processes it and sends it to the cloud with embedded Wi-Fi software. It is very fast, economical and suitable to IoT based applications.
- **Arduino IDE:** Arduino IDE is the programming platform employed to program ESP32 microcontroller. It offers a convenient writing and compiling platform to embedded C/C++ code and uploading of code, which allows to implement system logic and sensor integration effectively.
- **Sensors (pH, Temperature, Moisture):** These sensors will be necessary in checking the environmental conditions of the hydroponic system. The pH sensor, temperature sensor and moisture sensor monitors the nutrient solution acidity, ambient temperature and amounts of water respectively, to maintain the right amount of water on the plants respectively.
- **Blynk Mobile Application:** The Blynk is applied in the real-time monitoring and control of the system. It gives an easy to use interface to show sensor information, send notifications and be accessed remotely using a smartphone
- **Wi-Fi Connectivity:** The ESP32 and the Blynk cloud platform are connected through Wi-Fi. It allows real-time transmission of data and remote controlling at any place.
- **Power Supply (Batteries/Adapters):** Stable power supply is needed that can be used to allow the ESP32 and sensors to be on at all times. Depending on the way the system is configured, batteries or external adapters are used.
- **Visual Studio Code / Arduino IDE (Development Environment):** To register the device, the code must be closed and executed in the Arduino IDE

(Development Environment).¡—human—¿Registering the device: Visual Studio code / Arduino IDE (Development Environment): Visual Studio code needs to be closed and run within the Arduino IDE (Development Environment) to register the device. The main development environment in which code can be written and managed can be Visual Studio Code or Arduino IDE. The tools come with debugging, code completion and effective project management.

XIII. FEATURES

- **Real-Time Monitoring:** The system is fully monitored by several parameters including pH level, temperature, and moisture measured by sensors attached to the ESP32 and keeps the system in optimal environments to grow mints.
- **Remote Access and Control:** With the help of the Blynk, the user can monitor the condition of the plants remotely and receive real-time updates on the state of the plants with a smartphone regardless of their location.
- **Automated Alerts and Notifications:** The system raises an alarm when the environmental parameters are greater than the set limits, and thus corrective measures can be taken in time to keep the plants healthy.
- **Efficient Water and Nutrient Management:** The hydroponic system is based on a closed-loop system to recycle the water and nutrients to minimize wastage and effective use of resources.
- **Soil-Free Cultivation:** The system avoids the use of soil and thus does not rely on land quality but can be used in urban or limited space settings to farm.
- **Low Maintenance and Reduced Manual Effort:** The system is easy to operate and maintain because automation reduces the possibilities of humans needing constant monitoring of the system.
- **Scalable and Flexible Design:** The system is flexible as more sensors or components can be added in order to make it suitable to small and large scale farming.

XIV. WORKFLOW OF PROPOSED IOT-BASED HYDROPONIC MINT FARMING SYSTEM

The proposed IoT-Based Hydroponic Mint Farming System has the workflow that includes the initialization of the system where the ESP32 is turned on and connected to a Wi-Fi network. After the connection is made, all sensors, pH, temperature, and moisture sensors are engaged to begin the gathering of environmental data which would be used in growing the plants. The sensors constantly check the hydroponic system after initializing it. The gathered data is transmitted to ESP32 where real time processing occurs. The microcontroller compares the values and compares it with predetermined optimal thresholds in mint cultivation. This guarantees that the pH levels of nutrient solution, temperatures and water levels are maintained at the desired levels. The resulting processed data is further sent to the Blynk over Wi-Fi. By monitoring the system remotely, the user can see real time readings on his smartphones. When any of the parameters is out of the ideal range, the system will produce warnings or signals, and the user will be able to take corrective measures without any further delays. The hydroponic setup also, at the same time, circulates the fertile water in a closed loop system and therefore the supply of nutrients to the mints is a continuous supply of the plants. The process facilitates effective use of water and even ensures steady growing conditions. The system is also 24/7 in operation with automatic monitoring and it also minimizes the manual intervention. The system also has the capability of storing data collected which can be analyzed later to enable the users to know the patterns of growth of plants and how best the system can perform. Such a smart workflow will guarantee effective use of resources, increase crop productivity, and dependability of functionality. Lastly, the centralized mobile platform enables the users to track the performance of the system, to analyze the data patterns, and manage the hydroponic system. The system is a smart and sustainable solution in the area of modern agriculture by combining real-time monitoring and automation.

XV. DATASET DESCRIPTION AND EXPERIMENTAL SETUP

A. Dataset Description

The data involved in the proposed Hydroponic Mint Farming System based on IoT, is produced in real-time with the help of different sensors embedded into the system. These sensors will entail the use of pH sensors, temperature sensors, and moisture sensors among others which will constantly gather data on the environment and nutrient related information necessary in the growth of the plants. This set of parameters includes the level of humidity (unless it is humid), water moisture level, temperature around the nutrient solution, and the pH level of the solution. The data obtained is sent via the ESP32 microcontroller to a cloud based storage and monitoring system. Data entries are time stamped, which can be used to investigate changes in data over time. It is a real-time data that assists in ensuring optimal growing conditions of mint plants and efficient decisionmaking. The data can also be analyzed further, including ways to determine patterns in plant development and how to effectively utilize the resources.

B. Experimental Setup

The experiment design of the proposed system contains a hydroponic system that aims at cultivating mint plants in a rich water solution with nutrients. The board has an ESP32 microcontroller that serves as the central processing division. To observe the environmental conditions, sensors like pH sensor, temperature sensor, and moisture sensor are attached to the ESP32 to detect the environmental condition. The sensors gather readings at a predetermined time period and send them to the Blynk IoT platform through Wi-Fi to be monitored in real time. The nutrient is provided in the form of a nutrient reservoir and water circulation mechanism is used to maintain the flow of the nutrient solution to the plants. All this is driven by a constant power supply or battery. The system also provides the optimum PH, temperature and moisture levels needed to grow mint during the experiment. System parameters that assess the performance of the system include: the rate of plant growth, stability of the system and resource efficiency. The scientific findings prove the efficiency of combining IoT with hydroponic agriculture to conduct the smart and sustainable farming.

XVI. RESULT ANALYSIS

Performance Analysis:

The stability of parameters like the level of pH, temperature control, water consumption, accuracy of real-time monitoring, and growth rate of crops are among the most important parameters of the performance analysis of the proposed hydroponic system based on the internet of things. The findings show a great improvement over the conventional way of farming. The system ensures the environment has a steady temperature resulting in better plant production and increased yield of mint plants. The hydrostatic system of water recycling also minimizes the total water usage and safeguards by imposing realtime tracking of any aberration that becomes easily rectified. The combination of the ESP32 and sensor module will ensure that the system is reliable and functional by giving accurate and continuous data.

System Interface (Monitoring Dashboard):

The developed monitoring dashboard is based on the Blynk and allows an easy and convenient interface of monitoring live sensor data. Users can see their parameters like pH levels, temperature, and moisture right on their smart phones. The dashboard enables the user to monitor the performance of the system, get alert and make sure that the optimum growing conditions are maintained all the time. The centralized interface grants access to all the necessary features in an easy navigation and fast accessibility, therefore enhancing the ease of use and general efficiency of the system.

XVII. CONCLUSION AND FUTURE ASPECTS

The proposed IoT-Based Hydroponic Mint Farming System is an intelligent and efficient approach to solving the current day agriculture problem through implementing hydroponic methods and monitoring and automation using IoT. The system is based on the ESP32 and sensors that continuously measure the key parameters, including pH, temperature, and moisture, and provide favorable conditions in which the plant will grow. Blynk can provide remote monitoring and control by transmitting real-time data to the Blynk that reduces the amount of manual work and enhances system reliability. The closed loop hydroponic system provides efficiency in the use of water and nutrients resulting in increased crop production and sustainable agriculture. On the whole, the suggested system manages to circumvent the shortcomings of the traditional farming practices and help build the smart and resource-efficient agriculture. Going forward, the system can be improved with the addition of such advanced technologies like Artificial Intelligence (AI) and machine learning to conduct the predictive analysis and take the automated decisions. Additional capabilities such as automated nutrient dosing, climate control and real-time data analytics can be used to enhance performance of the system. Long-term data storage and its remote accessibility can be made possible on a greater scale when cloud integration is applied. The system can also be scaled to large scale commercial farming and the renewable energy sources like solar power can also be incorporated to achieve better sustainability. As the IoT and smart technologies keep improving, the proposed system has a high potential of developing into a complete automated and intelligent farming system that could benefit future agricultural requirements.

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