Automatic Hydroponics System Based on IoT

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***Abstract*— Hydroponics is a form of gardening that uses no soil, but instead grows plants in a solution of water and nutrients. A hydroponic system can grow plants and vegetables faster and year-round with efficient use of resources. Plants grown this way usually yield more, require less space and conserve soil and water. This system is an ideal solution if you are an apartment dweller who does not have an outdoor gardening plot. Throughout the growing process, one needs to control several factors such as lighting, water quality, air circulation, and more. Here we use Deep water culture (DWC) which is a hydroponic method of plant production by means of suspending the plant roots in a solution of nutrient-rich, oxygenated water. Since there is a relatively large reservoir of nutrient-rich water for each plant, there is buffering for pH, EC, and temperature, which means these elements of the system won't fluctuate undesirably. For the oxygenation of the hydroponic solution, an airstone is added. This airstone is then connected to an airline that runs to an air pump. Sunlight is usually required for the growth of plants but in hydroponics, it is supplemented with artificial lighting. The lighting has to be according to the plant's type and requirement.**

Keywords*— *Hydroponics, Deep Water Culture, Internet of Things, Android, Google Firebase Realtime Database, Arduino, WiFi Module.

I INTRODUCTION

In recent years, advancements in technology have revolutionized various sectors, and agriculture is no exception. Traditional farming methods often face challenges such as limited space, water scarcity, and inconsistent crop yields. To overcome these limitations, a new approach called hydroponics has gained significant attention. Hydroponics is a soilless cultivation technique that involves growing plants in nutrient-rich water, providing an efficient and controlled environment for plant growth. To further enhance this innovative farming method, the integration of the Internet of Things (IoT) has paved the way for automatic hydroponics systems.

The IoT refers to a network of interconnected devices that can collect, exchange, and analyze data. When applied to hydroponics, IoT technology enables real-time monitoring and control of various parameters critical for plant growth, including temperature, humidity, pH levels, nutrient concentration, and lighting conditions. By combining hydroponics with IoT, farmers can achieve greater precision, efficiency, and productivity in their crop cultivation processes.

An automatic hydroponics system based on IoT offers several advantages over traditional farming methods. Firstly, it allows farmers to remotely monitor and manage their crops, eliminating the need for constant physical presence. Through IoT-enabled sensors and actuators, critical data regarding the growth environment can be collected and analyzed. Farmers can receive instant alerts and notifications on their smartphones or computers regarding any deviations from optimal conditions, such as water shortage or pH imbalance. This real-time monitoring capability enables quick interventions and adjustments, minimizing crop losses and ensuring optimal plant health.

Secondly, the automation provided by IoT in hydroponics systems reduces the dependency on manual labor. Tasks such as nutrient dosing, water circulation, and adjusting environmental parameters can be automated, saving time and effort. This not only increases operational efficiency but also reduces the overall labor costs associated with crop cultivation.

Furthermore, the integration of IoT allows for data-driven decision making and predictive analytics. By analyzing the collected data over time, patterns and correlations can be identified, leading to valuable insights for optimizing crop growth. Machine learning algorithms can be employed to forecast crop yields, detect disease outbreaks, and optimize resource allocation, ultimately maximizing production and profitability.

In conclusion, the combination of hydroponics and IoT presents a promising solution for sustainable and efficient agriculture. Automatic hydroponics systems based on IoT offer enhanced monitoring, control, and automation capabilities, enabling farmers to achieve higher yields, reduce resource consumption, and mitigate risks. As IoT technology continues to evolve, we can expect further advancements in hydroponics, ultimately contributing to a more resilient and productive food production system.

II LITERATURE REVIEW

A.Hydroponics

Hydroponics is the practice of cultivation only with water without using soil. The deep flow technique (DFT) is a method of hydroponics in which the roots are fully merged in water. The nutrients are supplied directly to the main tank and pumped to the DFT system. DFT system constantly flows nutrients dissolved in the water used in planting crops to provide nutrient solutions and the plant roots are constantly merged in the planting tray. The water is then flown back to the main tank.

B. Power supply

The power for this hydroponics system is generated by solar panels. A 12V battery will store power so that the microcontroller can access a steady power supply, even when the panels are not exposed to the sun. The system will run for at least a day when the battery is fully charged. Certain functions of the system might toggle on and off periodically based on the available power. We can also use a 12V ac to dc converter so that it can be directly connected to the ac supply. This logic will be managed by our controller.

C. Control

In order to analyze the data coming from the sensors in a proper way, we need to pass them to a microcontroller. This microcontroller will receive data from sensors; analyze them and send them over Wi-Fi to a phone or computer to display the present rate of nutrients and the pH value of the system. It will also make decisions about when to add nutrients and maintain pH based on the sensor measurements. The regular rates are stored in the cloud storage system. Statistics about the plant growth will be sent over the communications system to a companion app for the user to view.

D. Communications

There is a real-time link between the microcontroller and the connected phone or computer, and this is facilitated by an adapter that allows the controller to talk to other devices. A cloud storage system allows to store real-time data from the controller and a software application is used to display the values in the phone.

III System Design

The system hardware forms the system's base, as the data sensed by these sensors and transducers are used to identify the plants' status and initiate the necessary response. This section discusses the entire system design by disintegrating it into three broad categories: monitoring, regulation, and communication.

1)Monitoring

A. Light Dependent Resistor

Photoresistors, also known as light dependent resistors (LDR), are light sensitive devices most often used to indicate the presence or absence of light, or to measure the light intensity. In the dark, their resistance is very high, sometimes up to 1 MΩ, but when the LDR sensor is exposed to light, the resistance drops dramatically, even down to a few ohms, depending on the light intensity. LDRs have a sensitivity that varies with the wavelength of the light applied and are nonlinear devices. They are used in many applications, but this light sensing function is often performed by other devices such as photodiodes and phototransistors. Some countries have banned LDRs made of lead or cadmium over environmental safety concerns.

Fig 1

Sunlight is usually required for the growth of plants but in hydroponics, it is supplemented with artificial lighting. The lighting has to be according to the plant's type and requirement.

B. Temperature and Humidity sensor

DHT11 is a Humidity and Temperature Sensor, which generates calibrated digital output. DHT11 can be interface with any microcontroller like Arduino, Raspberry Pi, etc. and get instantaneous results. DHT11 is a low cost humidity and temperature sensor which provides high reliability and long term stability.

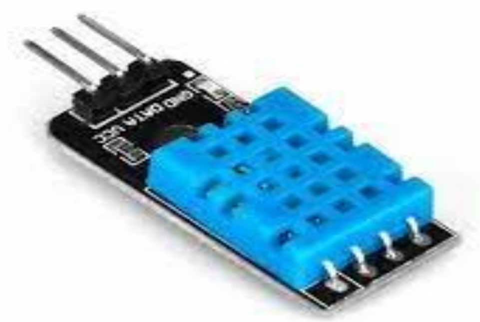

Fig 2

It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and outputs a digital signal on the data pin (no analog input pins needed). This module makes is easy to connect the DHT11 sensor to an microcontroller as includes the pull up resistor required to use the sensor. Only three connections are required to be made to use the sensor - Vcc, Gnd and Output. It has high reliability and excellent long-term stability, thanks to the exclusive digital signal acquisition technique and temperature & humidity sensing technology.

In this system we are manipulating the temperature requirements for the plant. So we can grow any plants in any area by manipulating the temperature

C. pH Sensor

Fig 3

pH sensor is one of the most important tools for measuring pH and is commonly used in water quality monitoring. This type of sensor is capable of measuring alkalinity and acidity in water and other solutions. When used properly, pH sensors can ensure the safety and quality of products and processes that occur in wastewater or manufacturing plants.

D. TDS Sensor

TDS meter is a digital tool that measures the levels of salt, nutrients, and other concentrates in the water. These measurements are critical to understanding how much water, nutrients, and oxygen your plants are currently able to absorb. It also lets you know when to feed your plants.

Fig 4

Nutrients are identified as ions in this system.so we can analyze the nutrients deficiency by analyzing the ionic changes. This is how the Nutrient Regulation is done.

2)Regulation

A. Light Regulation

In an automatic hydroponics system based on IoT, the regulation of lights plays a crucial role in optimizing plant growth and productivity. By integrating IoT technology into the lighting system, farmers can achieve precise control over the light spectrum, intensity, and duration, ensuring that plants receive the ideal conditions for their development.

IoT-enabled sensors can be used to measure and monitor various parameters related to lighting, such as the intensity of light, the color spectrum, and the duration of exposure. These sensors can be strategically placed throughout the growing area to capture accurate data on light conditions. The collected information is then transmitted to a central control system, which can be accessed remotely by the farmer through a smartphone, computer, or any other connected device.

Based on the collected data, the IoT system can automatically adjust the lighting parameters to meet the specific requirements of different plant stages or species. For example, during the seedling stage, plants may require lower light intensity and a specific light spectrum to promote root development. As the plants mature, they may require higher light intensity and a different spectrum to support photosynthesis and flower/fruit production. With IoT, these adjustments can be made automatically, ensuring that the plants receive the optimal lighting conditions at each growth stage.

Additionally, IoT technology allows for the implementation of smart scheduling and customization of lighting cycles. Farmers can program the system to simulate natural sunlight patterns, providing a consistent and controlled environment for the plants. This is especially beneficial for crops that require specific photoperiods for flowering or fruiting.

Moreover, IoT-enabled lighting systems can utilize energy-efficient LED lights, which can be dimmed or brightened as needed. This not only reduces energy consumption but also prolongs the lifespan of the lights, resulting in cost savings for the farmer.

The integration of IoT technology in light regulation also enables real-time monitoring and alert systems. If there are any deviations or issues with the lighting, such as power failures or malfunctions, the IoT system can instantly notify the farmer through notifications or alarms. This allows for timely intervention and prevents potential damage to the crops.

In conclusion, the integration of IoT technology in the regulation of lights in automatic hydroponics systems offers precise control, customization, and monitoring capabilities. It ensures that plants receive the optimal lighting conditions for their growth stages, leading to improved crop yields, energy efficiency, and cost savings. By leveraging IoT, farmers can create a highly efficient and sustainable environment for their hydroponic crops.

B. Temperature Regulation

Maintaining the optimal temperature is crucial for the success of hydroponic crop cultivation. In an automatic hydroponics system based on IoT, temperature regulation can be efficiently managed through the integration of IoT technology. By utilizing IoT-enabled sensors, actuators, and a central control system, farmers can achieve precise control and monitoring of the temperature parameters in the growing environment.

IoT sensors can be deployed strategically within the hydroponic system to measure and monitor temperature levels. These sensors can collect real-time data on temperature variations in different areas of the growing space, such as the air temperature, water temperature, and root zone temperature. The collected data is transmitted to the central control system, which can be accessed remotely by the farmer through a smartphone, computer, or any other connected device.

Based on the collected data, the IoT system can automatically adjust temperature parameters to ensure optimal growing conditions for the plants. For example, if the temperature exceeds the desired range, the system can activate cooling mechanisms such as fans, ventilation, or air conditioning to lower the temperature. Conversely, if the temperature drops below the optimal range, the system can activate heating mechanisms to maintain the desired temperature level. This automation ensures that the plants are consistently exposed to the ideal temperature for their growth and development.

Additionally, the IoT system can be programmed to create temperature profiles that mimic natural diurnal temperature variations. This simulation of day-night temperature cycles can promote healthy plant growth, stimulate metabolic processes, and enhance overall crop performance.

IoT technology also enables real-time monitoring and alerts for temperature deviations. If there are any sudden fluctuations or abnormalities in temperature, the IoT system can immediately notify the farmer through alerts or alarms. This allows for quick intervention to rectify any temperature-related issues and prevent potential damage to the crops.

Furthermore, historical temperature data collected by the IoT system can be analyzed to identify patterns and correlations. Machine learning algorithms can be employed to derive insights and optimize temperature control strategies. For example, the system can learn from past data to automatically adjust temperature settings based on seasonal variations, crop-specific requirements, or external factors such as weather conditions.

In conclusion, the integration of IoT technology in temperature regulation in automatic hydroponics systems provides precise control, real-time monitoring, and intelligent automation. It ensures that plants receive the optimal temperature conditions for their growth, leading to improved crop quality, yield, and resource efficiency. By leveraging IoT, farmers can create a controlled and optimized environment that maximizes the potential of their hydroponic crops. C. pH Regulation

You should test frequently with whatever hydroponic testing equipment you choose, even daily if you have recently adjusted nutrient levels or are new to hydroponics. There are a variety of testing supplies available, including test strips and liquid test kits, which are the least expensive and are available at pool supply stores and garden centres. Digital pH metres are more accurate and offer repeatable results.

If you use a recirculating system, adjust the pH level according to test results from the supply reservoir. In a media-based system, however, the pH changes as the nutrient solution travels from the supply reservoir and out through the grow base. Adjust pH levels based on the pH of the leachate that drains from the grow beds.

Commercially prepared “pH up” and “pH down” products are available to maintain the right pH levels. You can purchase these products in dry or liquid form and use them according to label instructions. Make sure you use products that are formulated for hydroponic systems. For small systems or short-term results, you can add weak acids such as vinegar or citric acid.

Automatic pH controllers cost more than pH up or pH down products but they keep the pH at consistent levels. This option works best in recirculating systems to prevent pH fluctuations that occur as plants feed.

If your water is hard, the buffering effect of the high mineral levels will cause high pH levels. A reverse osmosis system is an efficient and relatively affordable method for reducing water hardness.

D . Nutrition Regulation

Proper nutrition is vital for the healthy growth and development of hydroponic crops. In an automatic hydroponics system based on IoT, nutrition regulation can be effectively managed through the integration of IoT technology. By utilizing IoT-enabled sensors, actuators, and a central control system, farmers can achieve precise control, monitoring, and adjustment of the nutrient levels in the hydroponic solution.

IoT sensors can be strategically placed within the hydroponic system to measure and monitor parameters related to nutrition, such as pH levels, electrical conductivity (EC), nutrient concentration, and water quality. These sensors collect real-time data on nutrient levels and transmit it to the central control system. The farmer can access this information remotely through a smartphone, computer, or other connected devices.

Based on the collected data, the IoT system can automatically regulate and adjust the nutrient levels in the hydroponic solution. It can activate nutrient dosing pumps or valves to add or replenish nutrients as needed, ensuring that the plants receive the optimal nutrient concentrations for their growth stages. The IoT system can also adjust pH levels by activating acid or alkaline dosing mechanisms, maintaining the desired pH range for nutrient availability and uptake.

Moreover, the IoT system can be programmed to provide precise nutrient profiles tailored to specific plant species or growth stages. By defining nutrient schedules and ratios, farmers can optimize nutrient delivery for different crops, ensuring that they receive the appropriate balance of essential elements.

The integration of IoT technology enables real-time monitoring and alert systems for nutrient deviations. If there are any abnormalities in nutrient levels or pH, the IoT system can immediately notify the farmer through alerts or alarms. This allows for timely intervention and adjustments to prevent nutrient deficiencies or toxicities, optimizing plant health and growth.

Furthermore, historical nutrient data collected by the IoT system can be analyzed to derive insights and optimize nutrient management strategies. Machine learning algorithms can be employed to identify patterns, correlations, and predictive models. This data-driven approach can help optimize nutrient dosing schedules, predict nutrient uptake rates, and enhance overall nutrient management efficiency.

Additionally, IoT technology allows for remote monitoring and control of the nutrient system. Farmers can access the central control system from anywhere, enabling them to monitor nutrient levels, adjust dosing rates, and perform maintenance tasks remotely. This feature improves operational efficiency and reduces the need for constant physical presence.

IV HARDWARE DESIGN

A. Rainwater Gutter

Fig 5

One part of a building's water discharge system is a surface water collection channel, eavestrough, eaves-shoot or rain gutter. In order to avoid damaging the walls, soaking people who are below or entering the building, and to direct the water to a suitable disposal site where it won't harm the building's foundations, it is necessary to stop water from dripping or flowing off roofs in an uncontrolled manner. For a flat roof, water disposal is necessary to prevent water infiltration and an excessive weight buildup.

A pitched roof releases water into a valley gutter, parapet gutter or eaves gutter as it descends. An eaves gutter is sometimes referred to as an eavestrough (particularly in Canada), a rhone (in Scotland), an eaves-shoot (in Ireland), a dripster, guttering, a rainspout or just a gutter.Gutta (noun), which means "a droplet" in Latin, is where the word gutter first appeared.*Types of fuel cell*

B. Pump

Fig 6

A pump is a mechanical device that transfers hydraulic energy from electrical energy to move fluids (liquids, gases, or occasionally slurries).

Mechanical pumps are used for a variety of purposes, including aeration, pond filtration, aquarium filtration, and water pumping from wells.

C. DC

Any of group of rotating electric motors that use direct current (DC) electricity to create mechanical energy is referred to as a DC motor. The most prevalent kinds depend on the forces created by induced magnetic fields brought on by current flowing through the coil. Nearly all types of DC motors have some internal mechanism, either electromechanical or electronic, to periodically change the direction of current in a part of the motor.

Due to their ability to be supplied by existing direct-current lighting power distribution networks, DC motors were the first type of motors that were widely employed. A DC motor's speed can be varied across a large range by varying the supply voltage or the amount of current flowing through its field windings.

Appliances, toys, and tools all employ small DC motors. Both direct current and alternating current can be used to power the universal motor, a small, light brush motor used in portable power equipment and appliances. Larger DC motors are being employed for steel rolling mill drives, lift and hoist propulsion and electric vehicle propulsion. AC motors can now be used in many applications in place of DC motors thanks to the development of power electronics.

D. Pipes and Connectors

Pipe is a hollow tube used to transport materials that has a round cross section. Products include powders, pellets, liquids, gases, and more. The term "pipe" is used to refer to tubular items with dimensions frequently utilised for pipeline and piping systems, as opposed to "tube."

V SOFTWARE DESIGN

The system has a companion app for any smartphone which will allow the user to change the configuration options of their system. The app will also display information about the plant’s growth in the form of graphs. The sensor interfacing is done and the values will be stored at a cloud storage system. The values will be then transferred to a mobile application in which nutrients, pH, and Temperature can be monitored. The user will also be able to look at the progression of their plant through pictures that the camera on the unit takes, like a time-lapse video.

A. **Cloud Storage**

“**Firebase** is a toolset to “build, improve, and grow your app”, and the tools it gives you cover a large portion of the services that developers would normally have to build themselves but don’t really want to build because they’d rather be focusing on the app experience itself. This includes things like analytics, authentication, databases, configuration, file storage, push messaging, and the list goes on. The services are hosted in the cloud and scale with little to no effort on the part of the developer." You can use the ESP32 to connect and interact with your Firebase project, and you can create applications to control the ESP32 via Firebase from anywhere in the world. This means that you can have two ESP32 boards in different networks, with one board storing data and the other board reading the most recent data, for example. ' In a later tutorial, we'll create a web app using Firebase that will control the ESP32 to display sensor readings or control outputs from anywhere in the world.

B. **Mobile application**

Flutter is an open-source framework to create high-quality, high-performance mobile applications across mobile operating systems - Android and iOS. Flutter comes with beautiful and customizable widgets for high performance and outstanding mobile application. It fulfills all the custom needs and requirements.

Dart has a large repository of software packages that lets you extend the capabilities of your application. Dart is a client-optimized language for developing fast apps on any platform. Its goal is to offer the most productive programming language for multi-platform development, paired with a flexible execution runtime platform for app frameworks.

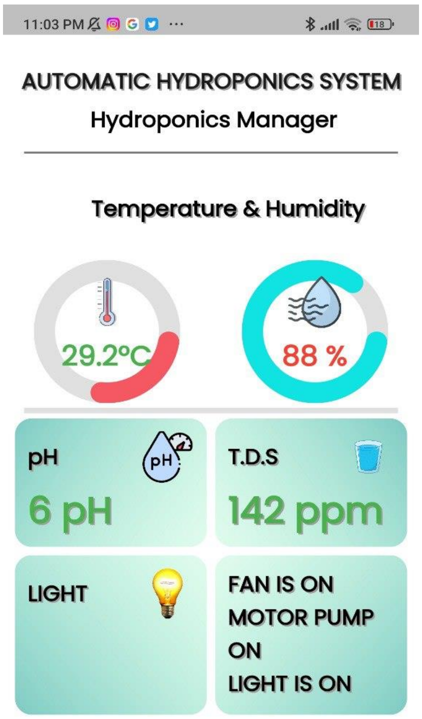

Fig 7: INTERFACE OF APPLICATION

Android Studio provides the fastest tools for building apps on every Android device. Before any work can begin on the development of an Android application, the first step is to configure a computer system to act as the development platform. This involves a number of steps consisting of installing the Java Development Kit (JDK) and the Android Studio Integrated Development Environment (IDE) which also includes the Android Software Development Kit (SDK).

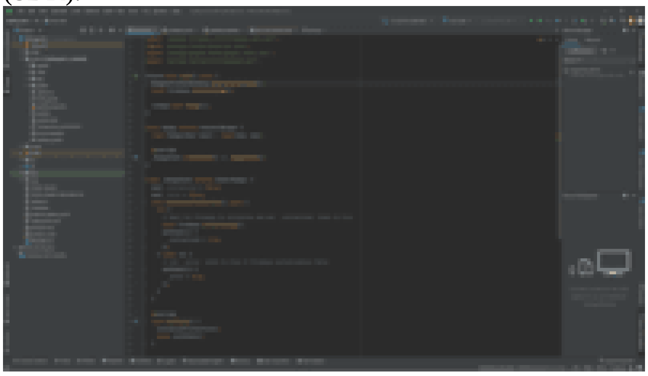

Fig 8

A mobile application is created for monitoring of various parameters such as Nutrient level, pH level, light intensity, Temperature, and Humidity. From the application the output side also can be monitored such as the working of lights, and blowers for temperature control, can be monitored. Mobile application is developed using firebase as backend and Flutter as the frontend. Language used is dart and the platform used is android studios. Although the system is automatically controlled the system can also be controlled using the application.

VI CONCLUSION

Extensive use of fossil fuels results in pollution with carbon An intelligent and automatic hydroponic system for spinach plant growth is presented in this paper. The system utilizes a fusion of multiple devices to monitor and regulate the physical uses of a Random Forest algorithm to determine the apt parameter to alter and maintain factors such as water level, temperature, and humidity, which are essential for plant growth. The Random Forest algorithm ensures that limited electrical operations are performed to conserve energy requirements and limit the sensor crowd. This ensures a swifter system response and conservation of power consumed. The system saved 20.4 percent and 82.1 percent peak power consumption while regulating different parameters such as water levels and light intensity. The salient feature of the proposed system is the curve-fitting model for nutrient concentration regulation, allowing a soil-less approach to farming. The relevant data is collected on a real-time basis and is communicated to a centralized server via Wi-Fi. This data is stored and presented to the user in an interactive and user-friendly manner. It works with minimal human interface and benefits such as energy conservation, resource allocation, and optimization.

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