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Vertical Hydroponic Monitoring System using Internet of Things

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Abstract: Hydroponic systems have gained popularity in recent years due to their ability to cultivate plants without the use of soil, resulting in increased efficiency and reduced resource consumption. Maintaining ideal growth conditions in hydroponic systems, on the other hand requires constant monitoring of essential variables like as pH, TDS (Total Dissolved Solids), water level, and temperature. This paper describes a vertical hydroponic monitoring system that utilises a pH sensor, TDS sensor, ultrasonic sensor, and DS18B20. The system includes an ESP32 microcontroller, which serves as the central processing unit, collecting data from sensors and wirelessly transmitting it to a Blynk platform. The pH sensor determines the acidity or alkalinity of the nutrient solution. The TDS sensor detects the concentration of dissolved minerals in the water. The ultrasonic sensor precisely measures the water level in the hydroponic reservoir. The DS18B20 sensor used to monitors water temperature. The results obtained from this study are from Blynk graph, providing comprehensive insights into environmental conditions in terms of pH level, TDS level, water temperature and water level. The work used DFT type hydroponics method to grow water spinach. The estimated time required to obtain mature plant growth and to collect all the necessary data for analysis is one month.

Keywords: Hydroponic, Deep Flow Technique, Monitoring System, Internet of Things

1. Introduction

Development in the urban areas leads to various problems. One of them is conversion between agriculture land to housing and industry. As a result, agricultural land on the corner of the city is being limited. Meanwhile, the needs of food urban communities depend on agricultural production [1]. To answer the problems about agricultural land, one of the famous cultivation techniques used by people today is hydroponic. Hydroponic is a cultivation technique using nutrient solution. The function of soil substitute by water, nutrition, and oxygen which flow to the plant [2]. One of hydroponic techniques is Deep Flow Technique (DFT). The plants sit on top of the tray with their roots hanging inside. As the water is pumped in, it circulates around, delivering nutrients to the plants' roots. The advantage of DFT

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is it provides constant access to nutrients and oxygen. It is good for rapid plant growth and a relatively simple setup. [3]. This work aims to design and develop a vertical hydroponic farming monitoring system using Internet of Things (IoT). The monitoring condition includes a TDS meter, pH sensor, temperature and water level in the reservoir using an ultrasonic sensor.

Vertical hydroponics is put forward as a solution to combat climate change, to reduce land and environmental damage and species extinction caused by overexploitation and intensive farming. It also allows for a more rational use of water [4]. However, hydroponic systems require constant monitoring from time to time to make sure the plant is in the optimum condition. Hydroponics gardens may contain different varieties of plants, and different plants require different nutrient solution concentrations for growth. It is important to control nutrient solution concentrations to provide the optimal conditions in the root zone. In addition, a plant's ability in a hydroponic garden to absorb nutrient solution depends on the pH of the nutrient solution. When the nutrient solution is above or below the optimal pH level, the plant may not receive enough nutrients [5]. This work proposes a solution to overcome the above-mentioned problems. The first objective is to design a vertical hydroponic system that monitors all necessary data, such as reservoir water level, nutrient solution level, pH level and water temperature through electronic devices. The second objective is to supply an ideal nutritional environment for optimum plant growth performance in terms of water, nutrients and lighting using the proposed vertical hydroponic system. Lastly, is to analyse data within a few weeks when using the proposed vertical hydroponic monitoring system via IoT platform.

2. Materials and Methods

2.1 Materials

Figure 1 shows the proposed system design consisting of a hardware and software implementation part. As for the hardware part, it consists of components such as ESP32, pH sensor, TDS sensor, Ultrasonic sensor, and temperature sensor (DS18B20). Meanwhile, for the software part, it used an Arduino IDE and IoT platform or also known as a cloud where the selected cloud is Blynk. A list of components used in this work is listed in Table 1.

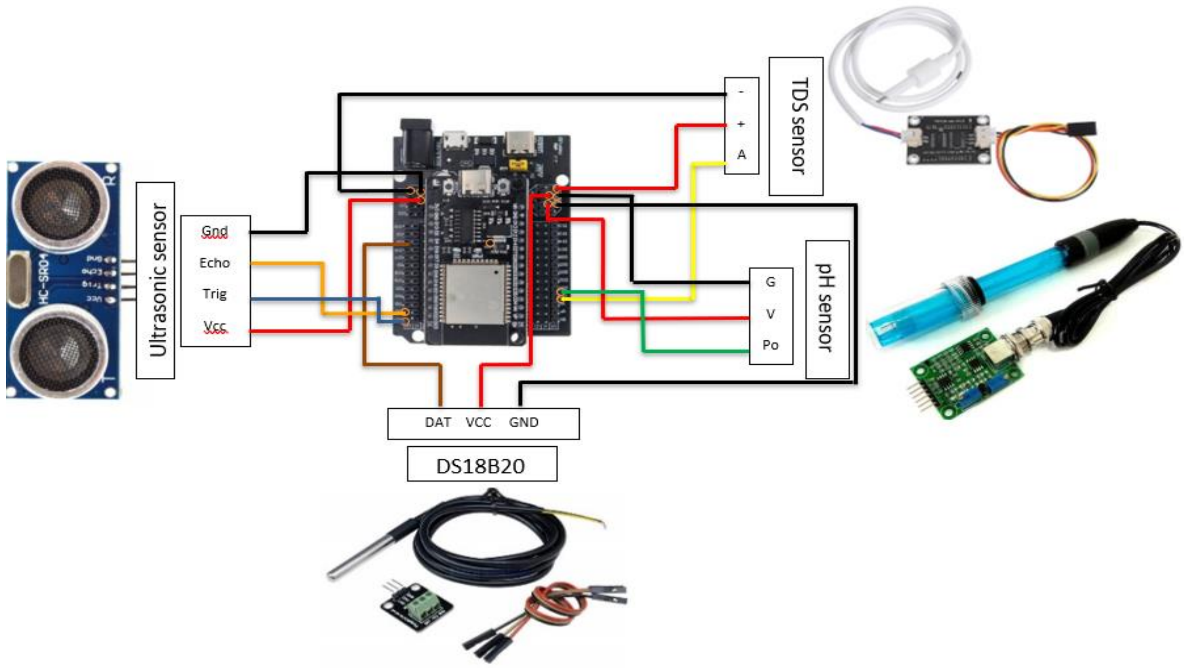

Figure 1: Connection of sensor to ESP32

Table 1: List of components

Components	Quantity	Descriptions
ESP32	1	The ESP32 is a microcontroller with built-in Wi-Fi and Bluetooth capabilities. It acts as the central processing unit in the hydroponic monitoring system.
pH sensor	1	The pH sensor measures the acidity or alkalinity of the nutrient solution in the hydroponic system.
TDS sensor	1	The TDS sensor measures the concentration of dissolved nutrients in the water, indicating the nutrient strength of the solution.
Ultrasonic sensor	1	The ultrasonic sensor uses sound waves to measure the distance between the sensor and the water surface.
Temperature sensor (DS18B20)	1	The DS18B20 temperature sensor measures the ambient temperature in the hydroponic system.

2.2 Methods

Figure 2 shows the operational flow of the system. Firstly, the sensor will take the measurement data such as water level, pH level, TDS level and water temperature from the hydroponic reservoir tank and send it to the ESP32. Blynk is used as a web server and database server. After data from sensors are sent by ESP32, Blynk will read data serial from ESP32. When data is succeeded to be read, data sensors will be saved in the Blynk, and the data can be monitored on any electronic devices. The system operates in an open-loop system. While open-loop systems lack the automation and direct control capabilities of closed-loop systems, they can still be highly effective tools for growers who want to actively engage in the monitoring and management of hydroponic setups.

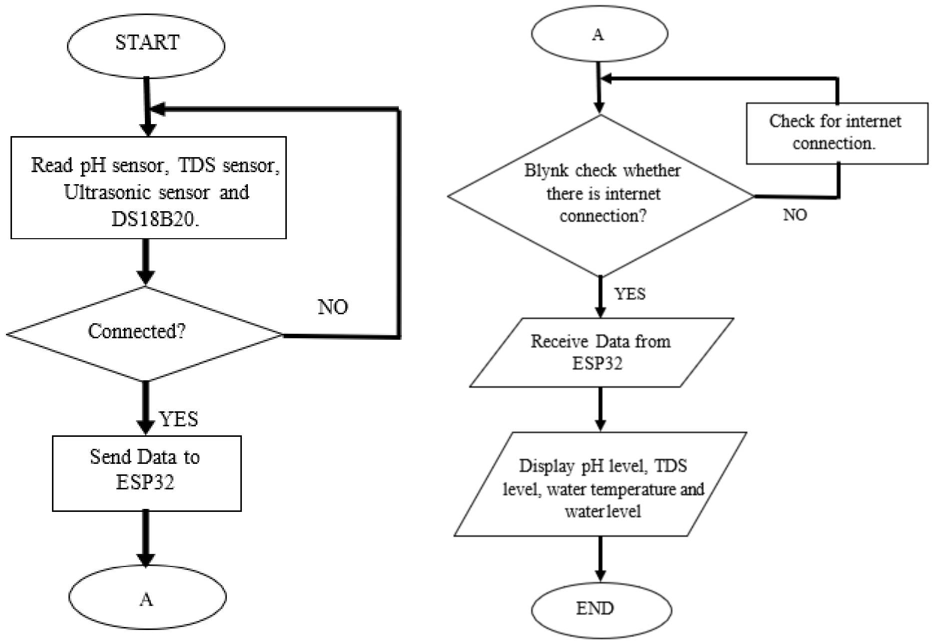

Figure 2: Operational flow from sensors to Blynk interface

3. Results and Discussion

All the sensors installed in the prototype system have been tested. Besides, the real-time monitoring graph obtained from the Blynk dashboard, and the results obtained are discussed in this section.

3.1 pH Level

According to Table 2, there is slight increase in the pH value from 6.8 to 7.1 in the water. In this work, the ideal pH level is from 5.5 to 7.0 according to the specific type of plant which is water spinach[6]. In a hydroponic system, the pH level can fluctuate throughout the day due to various factors such as nutrient uptake, evaporation, and the addition of fresh water or nutrient solution. The pH level can increase in a hydroponic system due to factors like alkalinity of water source. As plants take up nutrients from the nutrient solution, they can release hydrogen ions (H+) into the solution, leading to a rise in pH.

Table 2: pH level versus time

Date & Time	pH Level
6/11/2023 18:00	6.872767442
6/11/2023 18:15	6.933581395
6/11/2023 18:30	6.941545455
6/11/2023 18:45	6.959139535
6/11/2023 19:00	6.969022727
6/11/2023 19:15	6.996069767
6/11/2023 19:30	6.999409091
6/11/2023 19:45	7.018348837
6/11/2023 20:00	7.018166667
6/11/2023 20:15	7.020813953
6/11/2023 20:30	7.036511628
6/11/2023 20:45	7.037860465
6/11/2023 21:00	7.046522727
6/11/2023 21:15	7.059634921
6/11/2023 21:30	7.08945
6/11/2023 21:45	7.09625
6/11/2023 22:00	7.116477273

3.2 TDS Level

Table 3 shows the result for TDS level in the water. Nutrient solution is typically added to a hydroponic system at various stages, depending on the specific needs of the plants and the system setup. The data have been collected from the Blynk when the plant reached day 25 to 30 which the TDS level is at 1000 ppm. From the graph the TDS level is decreasing from time to time due to several factors. The reason why the TDS level might decrease in a hydroponic system is plant uptake, as plants grow and take up water and nutrients from the hydroponic solution, the TDS level can gradually decrease.

3.3 Water Temperature

Water temperature is a critical factor in hydroponics as it can significantly impact plant growth, nutrient availability, and overall system health. Table 4 shows the graph of water temperature from Blynk dashboard. The ideal temperature for this hydroponic monitoring system is 20^{o}C to 30^{o}C. The temperature of the water affects the rate at which nutrients are absorbed by plant roots. Warmer water generally increases nutrient uptake, while colder water can slow down the process. It’s important to maintain an optimal water temperature to ensure that plants can efficiently absorb the necessary nutrients for healthy growth.

Table 3: TDS level versus time

Date & Time	TDS Level (PPM)
6/11/2023 18:00	1093.338605
6/11/2023 18:15	1085.303114
6/11/2023 18:30	1067.843209
6/11/2023 18:45	1053.662186
6/11/2023 19:00	1023.604442
6/11/2023 19:15	976.6335116
6/11/2023 19:30	916.1565814
6/11/2023 19:45	860.1066512
6/11/2023 20:00	823.1785814
6/11/2023 20:15	765.3783953
6/11/2023 20:30	748.7424419
6/11/2023 20:45	714.2070227
6/11/2023 21:00	667.817093
6/11/2023 21:15	659.3530682
6/11/2023 21:30	667.175814
6/11/2023 21:45	632.060325
6/11/2023 22:00	551.81475

Table 4: Water temperature versus time

Date & Time	Water Temperature (°C)
6/11/2023 18:00	35
6/11/2023 18:15	35.08544186
6/11/2023 18:30	34.68795349
6/11/2023 18:45	34.26009302
6/11/2023 19:00	33.85888372
6/11/2023 19:15	33.46106977
6/11/2023 19:30	33.05918605
6/11/2023 19:45	32.70960465
6/11/2023 20:00	32.40137209
6/11/2023 20:15	32.04902326
6/11/2023 20:30	31.74718182
6/11/2023 20:45	31.43797674
6/11/2023 21:00	31.13672093
6/11/2023 21:15	30.89218182
6/11/2023 21:30	30.63965116
6/11/2023 21:45	30.5062
6/11/2023 22:00	29.9721

3.4 Water Level

Table 5 depicts the reservoir tank's water level decreasing. 11 litres of water were added to the reservoir tank. A hydroponic system's reservoir tank's water level may drop over time. There are several things that can influence this. Evaporation is the first element; over time, especially in warmer locations, water exposed to air can evaporate. Temperature, humidity, and the amount of water that is exposed to the air on its surface all affect how quickly water evaporates. Cover the container with a lid to keep evaporation to a minimum.

Table 5: Water level versus time

Date & Time	Water Level (Liter)
6/11/2023 18:00	10.8372093
6/11/2023 18:15	10
6/11/2023 18:30	10
6/11/2023 18:45	10.81818182
6/11/2023 19:00	9.906976744
6/11/2023 19:15	9.818181818
6/11/2023 19:30	9.744186047
6/11/2023 19:45	9.651162791
6/11/2023 20:00	9.604651163
6/11/2023 20:15	9.511627907
6/11/2023 20:30	9.372093023
6/11/2023 20:45	9
6/11/2023 21:00	9
6/11/2023 21:15	9
6/11/2023 21:30	9.025
6/11/2023 21:45	9.023255814
6/11/2023 22:00	9

3.5 Plant Morphology Comparison Between Hydroponic and Aquaponic

The use of an Internet of Things (IoT) monitoring system in hydroponics can bring several advantages compared to a hydroponic system without such monitoring. Both hydroponic systems have the same type of plant and were planted on the same day. It also used a type of hydroponic system which is the Deep Flow Technique (DFT) Here's a comparison of plant morphology in hydroponics with and without a monitoring system.

Table 6: Comparison between hydroponic with and without IoT

Part	Hydroponic With Monitoring System	Hydroponic Without Monitoring System
Leaf	Smooth, tapered at the tip of the leaf-like an arrowhead. Leaf size is 13cm to 15cm long x 4cm to 6cm wide. The leaves grow alternately with a light green colour.	Smooth, tapered at the tip of the leaf-like an arrowhead. Leaf size is 10cm to 12cm long x 2cm to 2.5cm wide. The leaves grow alternately with a light green colour.
Stem	Stem with a length of 30cm to 38 cm. The Stems are easily broken and fragile. It grows vertically and creeps.	Stem with a length of 30cm to 32cm. The stems are easily broken. It grows vertically.
Root	Root with a length of 10cm to 15cm. The root colour is greyish-white.	Root with a length of 10cm to 12 cm. The root colour is greyish-white.

From Table 6, there is a difference between hydroponic with the monitoring system and hydroponic without the monitoring system. The size of the leaf, stem and root are all different. In a traditional hydroponic system without monitoring, the grower relies on manual observation and measurements.

The grower needs to physically check and maintain the system regularly. It can be time-consuming and may limit the scalability of the operation. Without a monitoring system, data collection is limited to what the grower can observe directly. It may not capture subtle changes or provide a comprehensive understanding of the plant's needs. Besides, without continuous monitoring, it's challenging to optimize factors like nutrient levels, pH, temperature, and water level. It may result in suboptimal growth conditions and reduced yields. On the other hand, hydroponic systems with IoT monitoring can continuously measure crucial parameters such as temperature, TDS levels, pH levels and water levels. The data is transmitted in real-time, enabling growers to monitor and react promptly to any deviations or issues. This information helps in making informed decisions and optimizing resource utilization.

According to the results, the data acquired from sensors varied with the surrounding conditions, proving that the sensors are functional. Blynk will provide a real-time monitoring solution for vertical hydroponic farming. As a result, all the parameters for the monitoring system such as TDS level, pH level, water level and water temperature can be monitored and analysed through the graph from the Blynk. Thus, this work will help users to maintain the most ideal pH, TDS, temperature, and water level for the hydroponic system. Furthermore, comparisons between hydroponic with and without IoT monitoring systems also have been discussed in the result. In the future, there are several potential areas of improvement and expansion for the vertical hydroponic monitoring system using IoT such as the integration of additional sensors: While the current system incorporates pH, TDS, temperature, and water level sensors, there are other parameters that can impact plant growth, such as humidity, light intensity, and CO2 levels. Next is advanced analytics and machine learning, by implementing advanced analytics techniques and machine learning algorithms, the system can analyse the collected data and provide valuable insights and recommendations for improving plant growth.

4. Conclusion

In conclusion, the implementation of a vertical hydroponic monitoring system using IoT technology has proven to be a highly effective and efficient solution for optimizing plant growth in a controlled environment. By incorporating various sensors such as pH, TDS, DS18B20, and ultrasonic sensors for water level monitoring, coupled with the integration of an ESP32 microcontroller and the Blynk IoT platform, the system enables real-time monitoring and data collection. Thus, this work will help users to maintain the most ideal pH, TDS, temperature, and water level for the hydroponic system. Overall, the vertical hydroponic monitoring system utilizing IoT technology offers numerous benefits, including increased efficiency, optimized plant growth, and remote accessibility. The results that have been obtained are the graph for pH level, TDS level, water temperature and water level. Besides, a comparison between hydroponic with IoT and without IoT also shows a difference in terms of leaf, stem, and root. By leveraging the power of IoT and sensor integration, this system empowers growers to make data-driven decisions, maximize resource utilization, and ultimately achieve higher yields in their hydroponic operations.

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References

[1] P. Yoga, M. Masyhuri, “The Conversion of Agricultural Land in Urban Areas (Case Study of Pekalongan City, Central Java),” AGRARIS: Journal of Agribusiness and Rural Development Research, vol. 5, no. 2, 2019, doi: 10.18196/agr.5280

[2] I. S. Roidah, “PEMANFAATAN LAHAN DENGAN MENGGUNAKAN SISTEM HIDROPONIK,” bonorowo, vol. 1, no. 2, pp. 43-49, Jun. 2015. [Online]. Available: https://doi.org/10.36563/bonorowo.v1i2.14. [Accessed: June. 5, 2023]

[3] J. Soto, “How deep flow technique (DFT) hydroponic systems work,” Pure Greens: Custom Container Farms, vol. 2, no. 1, July 2021. [Online]. Available: https://puregreensaz.com/how-deep-flow-technique-dft-hydroponic-systems-work/ [Accessed: June. 7, 2023]

[4] I. Corporativa, et al., “Hydroponics, a crop technique allied to sustainability,” Iberdrola, vol. 2, no. 1, p. 2+, April 2021. [Online].Available: https://www.iberdrola.com/sustainability/what-is-hydroponics-and-advantages. [Accessed: May. 7, 2023]

[5] Jensen, L. Thomas., "Soil pH and the Availability of Plant Nutrients," The Fertilizer Institute, IPNI Plant Nutrition TODAY, No. 2, 2010. [online]. Available: www.ipni.net/pnt. [Accessed May. 9, 2023]

[6] W. Lichun, X. Xuzhang, et al., “Effect of pH Upper Control Limit on Nutrient Solution Component and Water Spinach Growth under Hydroponics,” Advance Journal of Food Science and Technology, vol. 9, no. 9, pp. 717–721, 2015, doi: 10.19026/ajfst.9.1766