IOT-Based Smart Hydroponic System

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Abstract- *Agriculture plays an important role in the socioeconomic progress of several countries (e.g., India), but it is also associated with many other issues (e.g., mowing, fertilizers, pesticides and chemicals used in agriculture). At present it is necessary to eat wholesome food and to perform normally without any application of these agrochemicals. Urban farming has been hailed as a route to a better way of life, but becomes impractical when there is not the space to build a conventional garden bed of earth. To solve this issue, soil-less farming (hydroponic farming, i.e., growing without soil) has been introduced. The so-developed hydroponic system needs soil-less, low nutrition, and less space. This system allows faster plant growth, significantly higher yields with the top quality. In hydroponic systems, a variety of parameters including pH and other factors require, and are controlled, monitoring. In this paper, in the context of the yields and the plant development, a practical scheme is proposed that can grow the plant with maximum effectiveness and minimum water requirement and minimum fertilizer requirement using the Internet of Things (IOT) technology. In a developing country like India, where agriculture is the backbone of the country, agriculture is plagued by several problems like small and fragmented land holdings, manures, pesticides, chemicals used for agriculture etc. consumers also increasingly demand for the healthy diet that is rich in quality and free of agricultural chemicals and pesticides. Smart hydroponics farming is a modern technique for growing plants in nutrient-rich water rather than soil. In this technique we ensure that plant gets all nutrients from the water solution.*

Keywords- Agriculture, IoT, Soil-Less, Hydroponics, pH, Solar power, LDR, NPK, Actuator

I. INTRODUCTION

Growing plants without the need of soil is known as hydroponics, and it also includes the practice of growing crops using mineral fertilizer solutions in an aqueous solvent. Hydroponics, as the name suggests, is a branch of hydroculture. Faster growth, higher yields, and superior quality are fostered by this approach. Urban farming has earned a lot of attention in recent years since it contributes to a better and healthier living. Numerous challenges, such as ploughing, weeding, pests, and climate, are encountered in traditional farming methods. In addition, soil-based agriculture introduces some crop diseases and necessitates a significant amount of land [1]. Therefore, hydroponics is a much more handy method these days as it decreases the farmers' taxing physical labour. For those who live in urban areas, hydroponics is especially important because it provides a method of growing food without the need for soil. In hydroponics, it is crucial to have precise water pH, ambient temperature, relative humidity, water nutrient levels, and water irrigation [2]. Therefore, it is important to have a management system that can keep an eye on these variables because it will guarantee a greater yield success and efficiency rate. The development of technology has made it possible to control every aspect needed for a hydroponics system, including the Internet of Things (IoT) [3].Hydroponics offers benefits over conventional soil-grown crop production, including the elimination of all undesirable issues associated with land-based crops, such as weeds, fungi, pest issues, and others, without the need for herbicides. Because of this, it is a healthier way to grow crops, lowers pest control costs, requires no soil preparation, produces a greater yield, and harvests crops sooner [4].The growth rate is increased approximately half the time (40% to 50%) faster than with traditional land-based agriculture when the traditional benefits of hydroponics are combined with a smart system that supplies nutrients during a predetermined time [5]. Because it combines self-management of resources and properties, autonomous computing provides a dependable way to increase the efficiency of any physical system. It also minimizes human involvement and anticipates and adjusts to any unforeseen changes in the environment or system. In the era of the new industrial revolution, the integration of these diverse disciplines is crucial and will enable us to address one of humanity's greatest problems, starvation. Hydroponics has emerged as one of the most intriguing approaches to ensuring nutrient efficiency in agriculture in recent years. Tomatoes are the most often grown crop using hydroponics, with the global hydroponics market generating over $20 million USD in sales in 2016.While Europe leads the world in hydroponics technology advancements, other nations including Australia, the United States, and Canada have given this idea more thought. The Netherlands is a leader in commercial hydroponics, using hydroponics for half of its entire crop production. Where natural disasters are frequent, hydroponics has also been regarded as one of the finest substitutes for conventional agriculture. The authors of [7] offer a blueprint for a hydroponics crop cultivation system that should be useful in areas vulnerable to hurricanes. The prototype described in this work assesses a hydroponic system's autonomic capabilities, self-regulating, self-monitoring, and self-adjusting capacities using Autonomic Computing and Internet of Things methodologies. The goal is to maximize crop productivity while simultaneously giving the crops the greatest care possible with the least amount of human involvement. Similar work has been done in the literature; the authors in [8] [9] [10] [11] used IoT on a hydroponic system to track and, in some situations, regulate the plant's variables. Similar to this, other studies, as seen in [12] [13], also employ a microcontroller and an Android app to use a smartphone to monitor the hydroponic system. The urban agriculture system and the Internet of Things will work together to analyze data, send it to a cloud-based system, and make decisions for users automatically [5].

II. LITERATURE REVIEW

The term "hydroponics" is a technique for growing plants without the use of soil by submerging their roots in a solution that includes the nutrients necessary for the plant's growth. These substrates can include sand, gravel, or liquid (water). The hydroponics industry has seen significant growth in recent years worldwide, with Europe reportedly having the largest market. The United States of America and the Asia-Pacific area are the next two largest producers, behind France, the Netherlands, and Spain [3]. Professor William Gericke first used the word in the early 1930s when he grew an abundance of tomato vines in his backyard using mineral fertilizer solutions rather than soil.

An English scientist named W.J.Shalto Douglas brought hydroponics to India in 1946 when he set up a lab in the Kalimpong region of West Bengal. The Pharma Innovation Journal's most recent analysis projects an 18.8% growth rate between 2017 and 2023, which would translate into a USD 490.50 million worldwide hydroponics market by that year [4]. Asia Pacific emerged as the largest market in 2018 as a result of the significant uptake of hydroponics in China, Australia, South Korea, and other nations. Argus Control Systems Limited (Canada), LumiGrow (U.S.), AMHYDRO (U.S.), and AeroFarms (U.S.) are a few of the major market participants in North America. The hydroponics market was estimated to be worth USD 1.33 billion globally in 2018 and is expected to increase at a compound annual growth rate (CAGR) of 22.52% between 2019 and 2025 [6]. The market is further divided into two segments: aggregate and liquid. The aggregate is made up of drip, wick, flow, and ebb systems [7]. The proper operation of a hydroponics system depends on a number of environmental conditions. An Internet of Things (IoT)-based integrated system for monitoring and managing hydroponic gardens is suggested. This system uses cloud-based technologies as the backend and collects data from multiple sensors, including one for pH level, water level, air temperature, and humidity, to maintain favorable conditions. The user can then access this information for effective system management [2,8]. The Food and Agriculture Organization (FAO) of the United Nations has predicted that by 2050, there will be 9.1 billion people on the planet, meaning that food production must increase by 70% between 2005 and 2050. This means that food production must also increase in tandem with the world's population growth. To address these growing demands, a smart hydroponics system that makes use of the Internet of Things (IoT) and Wireless Sensor Networks (WSN) to enable remote sensor monitoring has been proposed [9].

A do-it-yourself smartphone application for hydroponics with sensor-based automatic control has been suggested. Hydroponic gardening planning, management, and harvest data recording are made possible by the application's usage of a range of sensors to offer autonomous environmental control. The hydroponics plan for the upcoming grow will be based on the harvest data. Due to the lower cost, small and medium-sized farms might profitably boost the output of their hydroponics plantings [10]. To cut costs, a small hydroponic sensor module that measures water level and nutrient content using basic oscillator circuits has been created. The sensor board is equipped with a microcontroller for communication and measurement.

Expressions linking oscillation frequencies, liquid fertilizer content, water level, and temperature were obtained by sensor module experiments. In order to determine the water level and liquid fertilizer content, the module measures electro conductivity (EC) using a Printed Circuit Board (PCB) stick submerged in the liquid [11].

Both glasshouse and greenhouse settings can be used for hydroponics. IoT has been used to automate the entire process in order to minimize any negative effects on plant growth that may arise from inaccurate manual checks. The irrigation control approach proved to be a superior substitute for the current techniques. In order to adjust irrigation, a feed-forward loop is utilized exclusively. The suggested method can be used for a specific problem and requires virtually little work. The ease of use and clarity of control approaches is another important benefit [12]. Traditional farming practices won't be adequate in the near future. Therefore, an efficient farming system needs to be developed and put into practice in the agricultural sector. The system was developed to be automated and use the KNN and Lasso Regression algorithms to make judgements based on sensor data in order to benefit the crops being grown.

90% less water is used in hydroponic farming than in conventional farming. The crops grown under this approach have optimal quality and yield [13]. Researching and developing algorithms that enable effective water recirculation while saving about 40% on electricity in comparison to more conventional systems was the aim of this work. The technique was made more sophisticated by using sensors to track the amount of moisture in the root. As a result, water can be distributed precisely and efficiently, and the system's electrical consumption can be optimized and decreased. Another potential option for energy reduction in the study would be variable flow pumps [14]. Using the wireless technology concept, A. Ullah et al. have created a vertical hydroponic system that employs a mobile application to monitor and control every part of a hydroponic system. The pump, which is managed by the ESP32 microprocessor, will extract water from a reservoir that is connected to a traditional water line. Through a mobile application, the system would instantly inform the user of the reservoir's water level and where it may be replenished as needed [15].

III. PROPOSED .SYSTEM

The implementation of an autonomous computing and monitoring application is suggested in this paper for a hydroponic system that can produce crops with little assistance from humans. It is a self-regulating, self-protecting system that notifies users of any unexpected process behavior, such as weather patterns or system communication failures. This was accomplished by measuring and tracking a number of factors, including the tank's water level, pH, air temperature, and air humidity.

A controlled ambient temperature range of about 20 to 25 °C was used to create the setting. The authors in [4] [19] [20] state that this range is suitable for the majority of crops grown in hydroponic systems and for the proper growing of seeds. It's crucial to remember, though, that the project's relative humidity readings ranged from 37% to 43%, which is inappropriate for hydroponic cultivation [1] [2]. Since the method of tracking and communicating the variables is the primary focus of this effort, moving this system to the ideal hydroponic system settings may be completed without any problems. The sensors used in this implementation are an LM35 for air temperature and a DHT11 for relative humidity used due to their low cost and operating ranges, ideal for monitoring hydroponic systems. [20].When it is out of range, a ventilation system is triggered to control the temperature. The STM32f303RE microcontroller's PWM programming allowed for the control of the 12V fan. In order to interact between the physical layer and the end-user display layer, the communication layer consists of two Raspberry Pis: one for retrieving data from the sensors and another with a MQTT Broker linked to the Amazon Web Service. The Hydroponics market of India is segmented into fruits, vegetables, and flowers by the type of produce. In 2018, the fruits and vegetable segments are expected to have a market value of USD 2544.15 thousand. It is expected to rise to attain a peak value of USD XX thousand by 2026. The estimated market growth rate is at a CAGR of 13.53% in the forecasted period 2019-2027. Hydroponics is mainly practiced over large farms or fields. However, amidst the ongoing COVID-19 pandemic, the food and the hotel industry are in jeopardy and people have also grown an inclination towards home-cooked food. Besides, due to labor shortages and various other reasons, the agricultural farms have also suffered a lot and so people have become more self-sufficient and hence began emphasizing internal and domestic productions.

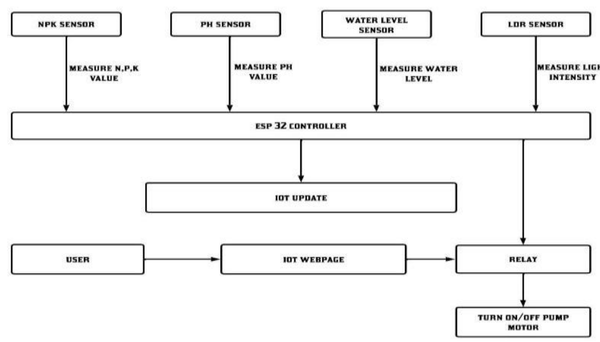

Figure 1 Functional Block Diagram

A. General System Design

An investigation was conducted into the ways in which other people utilize hydroponic systems in order to develop and monitor the controller for the indoor vertical hydroponic farming system. Additionally, the hydroponic system is made easier to maintain with this suggested system. Multiple security is possible with the system's general architecture that uses the 2FA approach. Fig. 9 below shows the general layout of an indoor vertical hydroponic production system using the 2FA approach. The block diagram shows that there are three primary components: the input, controller, and output. All of the sensors are linked to the NodeMCU at the input portion. The usage of the Node microcontroller on the controller side is crucial for protecting the input to the output and the input to the cloud database. This is due to the fact that NodeMCU functions as a WIFI chipset for internet data transmission. A relay serves as a switch for the water pump motor on the output side. Additionally, an OLED panel serves as a readout of data straight from the sensor. The output part also includes an Android or iOS application for the user to use. Using a smartphone, dual security is accomplished by entering the code on the farming system in the form of a confirmation PIN and verifying access to upload the farming data to the server.

B. Proposed Upgrade and Future Work

Our system uses the Internet of Things (IoT) to collect data from several sensors, including temperature, humidity, pH, and water level sensors, and then transmit it to a distant cloud server. Nonetheless, the model may be greatly improved to make this more user-friendly. An adequate quantity of vital nutrients must be balanced in order to sustain the health of plants. The crop's absolute growth rate (CGR) can be raised by examining the dynamics of nutrient uptake in the tomato crop. Machine learning techniques can be used to anticipate the hydroponic tomato crops' absolute CGR. The viability of hydroponic tomato crop growth depends on a number of factors, including the fruits' dry weight matter, ion concentration absorption, nutrient solution (NS), and electric conductivity (EC) limit. This correlation analysis will help us identify the key factors influencing the CGR and will give us additional information about the appropriate supply of nutrients for the best crop growth and development [23]. The dynamics of the nutrient ion uptake and its impact on the target variable absolute growth can be examined. The plants would die if manual monitoring, a straightforward task, wasn't done. Therefore, by combining technologies like IoT and machine learning, which enable the integration of intelligent agents into the management of hydroponic systems and the collecting of real-time data, we can automate our hydroponics system .

C. Functional Block Diagram

The operation of the indoor hydroponics system is illustrated by the block diagram in Figure 1. The Arduino Mega is used to retrieve data from the sensors and to regulate the parts of the hydroponics system. The purpose of the sensors is to keep the plant growing healthily. The pH sensor determines the solution's acidity or alkalinity, based on which the user will receive a notification. To make sure there is the necessary amount of water in the tub, the water level sensor is utilised to keep an eye on the water level. By determining the relative humidity, the temperature and humidity sensor helps to maintain the ambient air quality. The nutrient solution level in the tub is maintained by the solenoid valve; if it rises too high, it is drained off. The switch is used to control whether the RGB light is on or off.

IV. PROBLEM STATEMENT

With the global population increasing and urbanization reducing the availability of arable land, traditional soil-based agriculture is struggling to meet the rising demand for food. Conventional farming methods are highly dependent on large land areas, favorable weather conditions, and extensive water use, making them inefficient and unsustainable in many parts of the world. Moreover, urban environments pose additional challenges due to space limitations and lack of suitable farming conditions. Hydroponic farming, which allows plants to grow in a controlled, soil-less environment using nutrient-rich water, offers a promising alternative. However, managing a hydroponic system manually is labor-intensive and error-prone. Constant monitoring is required to maintain the correct balance of nutrients (NPK), pH levels, water level, and lighting conditions. Failure to maintain these parameters can negatively impact plant health and yield.There is a clear need for a smart, automated solution that reduces human intervention while increasing efficiency and productivity. By integrating sensors and actuators with IoT technology, it is possible to monitor and control all critical parameters in real-time. Such a system would not only enhance the precision and sustainability of hydroponic farming but also make it accessible and manageable for urban dwellers, small-scale growers, and commercial operations alike.

V. EXISITING SYSTEM

Traditional hydroponic farms rely on manual monitoring of key parameters such as pH levels, nutrient concentration, water temperature, humidity, and light exposure. Farmers or technicians regularly check these conditions and make adjustments as needed. Without real-time monitoring, management is often reactive, with adjustments made only after problems are observed, which can result in delays in addressing issues. Most hydroponic farms are outdoor farms, which requires sun light for photosynthesis, that requires large.

Comparison

In an effort to encourage more resource-efficient urban agriculture, hydroponics research has surged in response to the world's expanding population and the growing demand for food in urban areas. For instance, [25] uses IOT to provide a very affordable smart hydroponic system. We were unaware of the significance of IOT until we discovered how effective it is to use this technology [8], which gives us a thorough explanation of the system and helps us understand how important it is to produce plants of a much higher calibre in addition to offering an interface for quicker plant growth. Our paper's primary objective was to grow crops anywhere for less money and with less harm to the environment, while many comparable papers have been written based on this technology, each with their own distinct approach. Additionally, hydroponics with IOT will make crop production more appropriate by making every farm method extremely precise and compact. Furthermore, in contrast to previous studies, we used the average data for each month's different sensors.

VI. RESULT AND DISCUSSION

The design of hydroponic systems is particularly important for anyone who want to grow crops in this manner. An essential component of a successful hydroponic system is water quality monitoring. Traditional plants take up minerals from the earth during cultivation. The water in the hydroponic system needs to be supplied with fertilisers so that the plants can acquire the nutrients they require. Nutrient-enriched water needs to be closely watched to make sure the levels are neither too high (which could be harmful) nor too low (which would impede growth).By adjusting a few parameters that require control, this system design demonstrates that fully autonomous hydroponic agriculture is achievable. Through the use of sensors and computer capabilities, this design can simplify the process of implementing hydroponic farming techniques. The results of planting this system are very satisfying due to its excellent computer capabilities and dependable sensor accuracy.Salts of minerals dissolved in water are used to make hydroponic fertiliser solutions. Electrical conductivity (EC) can be adjusted to evaluate the strength of nutritional solutions. The sum of the conductivities of the ions in a solution, as determined by the formula below (1), yields the conductivity of the solution (K).

$$K=c(K_{m,1}+K_{m,2}) \quad (1)$$

Where $K_{m,1}$ and $K_{m,2}$ are the two ions' respective molar conductivities and c is the concentration. Higher ion concentrations (salt) are indicated by higher EC values.The type of gadget determines the ideal conductivity level to promote growth. diverse fertiliser solutions cause diverse reactions in hydroponic systems. However, because they separate into ions, different nutrient solutions result in varying conductivity values. In hydroponic systems, pH can also have a big impact on plant health. Through their roots, plants take up nutritional solutions; generally speaking, a plant's capacity to do so is determined by the pH of the solution. Acid solutions, for instance, facilitate the absorption of manganese, hydrogen, and aluminium. The concentration of hydrogenation ions in moles per litre (molarity) is necessary to determine the pH of an aqueous solution. The formula in (2) is used to determine pH.

$$pH = -\log [H_3O^+] \quad (2)$$

The superabsorption of these nutrients may be harmful to plants if the solution is excessively acidic. At low pH, however, calcium and magnesium are more difficult to digest. This vitamin shortage may result from this. The same is true for alkaline medium, which decreases the availability of phosphorus, iron, zinc, copper, and cobalt while increasing the availability of molybdenum and macronutrient solutions. Conductivity and pH sensors need to be placed in a water tank that will supply the plant nutrient media in order to set up a hydroponic manipulating system. For instance, the conductivity manipulator can activate a fresh water pump to deliver nutritional solutions when the concentration of solution in the water tank reaches an excessive level. On the other hand, if the solution concentration dropped too much, the conductivity manipulator might activate the feed pumps. Insects that are important for pollination and pest management include bees, moths, butterflies, and mosquitoes. When these elements come together, the controlled environment required for a hydroponic greenhouse is created. Regardless of the season or soil.

Types of Sensors	May 2024	June 2024	July 2024	Aug 2024
Water Level	4	3	2	1
pH sensor	5.59	5.92	5.74	5.95
Temperature sensor	32	30	28.8	28
Humidity sensor	26	24	20	25
Sensor and nutrient	4	3	2	1

Table 1 Types of Sensors

VII. CONCLUSION AND FUTURE WORKS

There aren't many findings from this study. Applications for computers, or even microcomputers, are quite diverse. The first conclusion is that anyone can have a hydroponic farm using an IoT-based system, regardless of whether they are a professional, enthusiast, or regular person, given that processing power is not a problem in this specific instance. The second finding is that sensors have advanced significantly since their inception; they are now accurate and dependable in calculations, which makes the task at hand obtaining data for manipulation purposes much simpler.The research's final finding is that IoT applications are a great way to handle repetitive tasks that previously required human intervention. For example, manipulating nutrient solutions is difficult, but with this system, it takes very little time because sensors will record the calculation and wirelessly send the data to a computer in nearly no time at all. This means that calculations and actions can be taken right away, essentially eliminating the need for labour in this hydroponic farming system.It is advised that further factors be included for future research; however, the most likely to be carried out right away is the use of cameras and image processing to determine the health of the plants being grown. So that when the plants are in poor condition, preventive actions can be taken. In addition, image processing particularly for fruits can assist in determining the harvest season.We have explained the layout and operation of a hydroponics system that was created to make sophisticated indoor farming methods accessible in cities. We have created a system that can effectively collect data from the pH level sensor, water level sensor, air temperature sensor, and humidity sensor in order to regulate and monitor specific environmental conditions that are necessary for this hydroponics approach. By supplying the ideal climate and nutrients based on the type of plant to be cultivated, our technology maximises the quality and yield of the plants that are produced there.The unique aspect of our work is that it aims to practise the system on a modest scale.

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