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An IoT Based Automated System for Aeroponic System

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***Abstract*—Intelligent sensor technologies have drawn a lot of interest in agriculture in recent years. It is used in agriculture to effectively organize a variety of tasks and missions while making use of scarce resources and minimizing human intervention. Nowadays, a lot of producers are growing plants utilizing modern agricultural techniques. Nonetheless, aeroponics is one of the contemporary agricultures, which is a widespread activity worldwide. By substituting a little mist of the nutrient solution for the soil, the method allows plants to grow in the growth chamber under total control. Periodically, the nutritional mist is released through atomization nozzles. Temperature, humidity, light intensity, water nutrient solution level, pH and EC value, CO2 concentration, atomization duration, and atomization interval time are some of the factors that must be properly attended to during plant cultivation in order for the plants to grow flourishingly. In our paper, we have developed a model where all these parameters can be observed automatically.**

***Index Terms*—Aeroponics, IoT, Actuators, Nozzles, Automation**

I. Introduction

With the rapid increase in population worldwide, the chance of the population of Bangladesh reaching 218 million by the year 2050 is very high [1]. By 2050, an estimated 70% to 90% of the global population will reside in urban areas. This rapid urbanization, combined with the growing challenges of desertification and climate change, poses significant threats to traditional agriculture and food security.This also means that more production of food and a better agricultural life are essential in order to survive. Due to climate change, harvest production is reduced on a large scale because, in the summer season, plants do not get enough water, and as a result, most of the crops are destroyed. On the other hand, in the rainy season, flooding can be a huge threat for crops in Bangladesh.

An aeroponics system can be a great way to eliminate these issues.The use of aeroponics is more preferable in our country as it uses 95% less water than the usual soil agriculture [2]. It also reduces pollution as it does not need any kind of pesticide. [3].One of the biggest advantages of aeroponics is it's ability to produce a large number of small plants, known as minitubers or minitowers, in a single growing cycle. This process not only lowers production costs but also saves a lot of time and space. This technology has great potential to improve food production, especially in areas with limited land or poor soil quality [4].

The main goal of this research is to introduce a smart aeroponics system that uses sensors to detect and monitor the plant's environment in real-time. Using IoT in aeroponics has played a crucial role in improving the agricultural sector. The automated aeroponics system we have built, is controlled and monitored through an app. Whenever the water and nutritious solution mixture level becomes low or imbalanced, water is added automatically as well as the nutritious solution until it becomes balanced. The system can also detect the pH of the mixture, and the moment the mixture becomes acidic from staying out for too long, a buffer solution is added until the desired pH level is reached. It can also detect the humidity level and temperature of the environment, and when it reaches a high temperature, a fan will be turned on automatically in order to maintain the environment's temperature. The user gets to choose the time interval between which a light source can be turned on in order to give the plant the light according to it's need. Different plants have different misting time interval requirements according to each of their needs, which can be set by the user through the app. Nonetheless, the remainder of the work is structured as follows: The literature review is described in Section 2. Section 3 provides the methodology that has been developed. Discussion and conclusion are discussed in section 4 and 5, respectively.

II. Literature Review

Aeroponics is a soil-less method of farming in which plants are raised with their roots in the air and misted with nutrient-rich water. It offers the best root access to oxygen, promoting ever greater growths in turn. Aeroponics is becoming important because of several big global problems and the need for more sustainable and efficient ways to grow food. Many studies show that the world's population is growing very fast. According to a world population review study of 2024 [5], population of Bangladesh has reached 173 million. This means we need to grow more food, but we can't use more land for farming because there isn't enough available, and cities are taking up more space. The system developed by Nahla Sadek et al. [6]. shows that an aeroponics system saves about 80% water. In 1960, 34% of the world's population lived in cities. In 2014 it was already 54% and this number still grows. In 2050, 66% of residents of our planet will be living in cities, according to experts [7]. Aeroponics will allow farming fruits and vegetables at high altitudes above sea level and will promote fresh food grown close to consumers as much as possible. Furthermore, integration of IOT-based aeroponics systems could be the best solution to avoid or deal with the issues mentioned above. Nahla Sadek et al. [6]. have introduced a system that can detect temperature and humidity and control them. The system can also measure the total dissolved solution (TDS) value via TDS sensor. However, the system cannot work with pH and water level. Imran Ali Lakhiar et al. [8] have conducted a study over intelligent sensors in aeroponic systems. The study involves using pH sensor, Electric Conductivity (EC) sensor, light intensity sensor, humidity and temperature sensor, water level sensor, CO2 sensor, and timer sensor in an aeroponic farming system. Zhang and coworkers [9] used an ultrasonic device to create very tiny drops of nutrient solution (1-5 microns wide). These small drops help the roots absorb nutrients and water evenly. The device also improves the process of turning the solution into fine drops, ensuring the plants get a steady supply of nutrients. They also worked on humidity and temperature controlling but did not include other actuators like pH sensor, EC sensor. Also, the system is not automatically controlled by Micro Controller Unit (MCU). Om Kadam1 et al. [2] developed a smart aeroponics system which can monitor temperature and humidity, CO2 percentage, Water level and control all this using mobile application. The system also has a camera for observing plant growth. But the system lacks in working with nutritious solution concentration and pH. Also, the system cannot refill the nutritious solution automatically. Continuous power supply can be challenging in aeroponic system. For uninterrupted power supply, Sydelle Krissy A. Arciso et al. in their study "Automated Solar-Powered Aeroponics Structure for Plant Cultivation and Monitoring" [10] integrated solar panel and showed how it works with the system. As MCU their system contains ESP32 for controlling actuators. Maximum of the previous studies of aeroponics systems doesn't provide us a way to make the system fully automated by refilling water tank and adding right amount of nutritious solution and buffer solution for control pH. By using relay, the system could be more efficient and automated. Ferdousi Rahman et al. [11] integrated relay in their system for automation. Arduino, Wi-Fi Module, RTC module, Sonar Sensor, Humidity, and Temperature Sensor are also used in the system. However, the system has some lacking like pH sensor is not installed. Also, the system cannot automatically fill up water tank when water level goes down.

III. Methodology

The model suggested in this paper uses high-tech and accurate sensors to manage and keep an eye on the growing system. A diagram showing the parts of the system is shown in Figure 1.

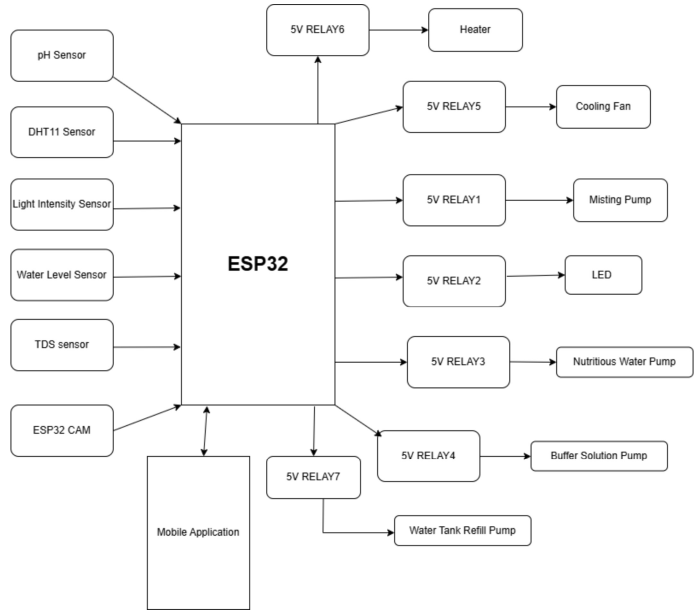

Fig. 1. Block Diagram of the elements of the automated aeroponics system

A. *Implementation of IoT technology*

An IoT-based smart monitoring and control system can fully automate deep aeroponics, making sure plants grow in the best possible way with little need for human help. This system uses sensors, microcontrollers, and devices like pumps and lights to check and control important conditions such as temperature, humidity, light levels, and nutrient strength. Sensors gather live data, which is then processed by a microcontroller and saved on an IoT platform so it can be accessed remotely through mobile devices. Devices like pumps, misters, lights, and fans follow the microcontroller's instructions to keep everything in the perfect condition for plant growth.

- Misting Nutritious Water: In aeroponics system, nutritious water is sprayed into plants root. The misting of water is done via nozzles. The system contains vortex nozzles which are placed on the PVC pipe. As different plants require different amount of water to grow perfectly, users must set the timer for turning the pump on and off. Mobile application has a section where users would set the timer according to plants requirements.
- Temperature & Humidity: Temperature is unquestionably the main factor in aeroponics. It greatly influences the plant's uptake of nutrients and its overall growth, and it also determines the overall system efficiency. For the best root-zone temperature, it should be 18–24°C while for the best air temperature it should be 20–30°C for the most ideal photosynthesis. A nutrient solution should be maintained at a temperature of 18–22°C to ensure the presence of enough oxygen and proper nutrient solubility. 60% – 70% relative humidity is considered to be the most ideal condition for most plants [11]. The DHT11 sensor is integrated into the ESP32 to monitor the environment's temperature and humidity. Should the rates go beyond

TABLE I
IRRIGATION SYSTEM

Test	Initial Status	Next Status	Time Interval Set By User	Actual Time Interval	Remarks
1	Misting Pump ON	Misting Pump OFF	After every 1 minutes pump ON for 30s.	ON for 30s & OFF for 1 minute	Success
2	Misting Pump OFF	Misting Pump ON		OFF for 1 minute & ON for 30s	Success
3	Misting Pump ON	Misting Pump OFF		ON for 30s & OFF for 1 minute	Success
4	Misting Pump OFF	Misting Pump ON		OFF for 1 minute & ON for 30s	Success

TABLE II
WATER MEASUREMENT & NUTRITIOUS ADDING SYSTEM

Test	Water Level	Expected Status	Actual Status	Adding Nutritious Solution Status	Remarks
1	Low	ON Water Refill Pump	Refilling Water Tank	OFF	Success
2	Low	ON Water Refill Pump	Refilling Water Tank	OFF	Success
3	High	OFF water Refill pump	Stop Refilling	Adding nutritious Soultion	Success

certain thresholds, fans, a heater, or a misting pump will be activated via the relays of the unit on autopilot. The live data is shown on a mobile app,thus giving the opportunity to monitor and control remotely.

- Water Level: Water level maintenance is one of the critical objectives of an aeroponics system. The plant roots must absorb moisture and nutrients through water. Water level sensors, e.g., float sensors or similar, measure the level of water and immediately notify when it is below a certain threshold level. The sensor transmits data to microcontroller when the water level drops, sends a notification to a mobile app, and activates a pump to recharge the tank. The user can check the water level and turn the system on or off from anywhere through the mobile app.
- Observation and Monitoring: An ESP32 CAM is integrated with the system for observation and monitoring purposes. The camera is mounted at the top of the structure pipe. The mobile application is used to live stream the footage of the camera.
- Total Dissolve Solids: The TD1000-T sensor regulates the nutrient solution present in ppm which is Total Dissolved Solids(TDS) that are being measured. If TDS is not within the optimum range, the system will perform the required adjustments on the nutrient levels on its own. The TDS level, which is a device that probes that are measured, changes along the plants' life cycles. However, for the seedlings, the preferred amount is 300 to 400 mg/L. Also for vegetable growth, and later growth stage is respectively 500 to 600 mg/L and 700 to 900 mg/L [12] [13]. The fertility feature of the substrates affects the pH level of the nutrient solution, thus, 5.5–6.5 is the range at which the pH is kept [14]. Defects in the system are remedied by the application of pH-up or pH-down solutions, which are the only slight acid or base substances that are set up to the plant level of health.
- Light Intensity: Measurement of light intensity was done using the BH1750 light intensity sensor throughout the experiment. This sensor measures both artificial lights coming from LEDs and natural sunlight, hence a wide range in the data for the lighting condition. LEDs are very suitable for agricultural applications since they emit very low heat, last longer, their brightness can be controlled, and they can emit light in specific monochromatic color [15] [16]. The program was designed to make the RGB LEDs produce a combination of blue and red light. Red light is important for photosynthesis, and blue light helps with chlorophyll production and controls photomorphogenesis [17] [18] which influences how plants grow and develop.

B. Development of Mobile Application

We built a dynamic web application using Next.js, Node. JS and Firebase— for inspecting and managing an environmental systemm linked to a microcontroller. Microcontroller collects real-time data such as temperature, humidity, pH levels, and water level and sends it to Firebase which acts as a centraldatabase. This data is retrieved by the Web app fromthe Firebase server and reflects in the application in a simple user-friendly interface, which is then used by the user to observe the life system states. Besides monitoring, the web appoffers users full access of system parameters. The app allows users to settarget values temperature and pH, misting pump cycles, and LED on/off timers. Changes in web app will be sync to firebase and will be delivered to microcontroller for immediateaction. With remote access and live updates combining together, it makes environmental automation a very robust solution with extensive flexibility.

IV. DISCUSSION

The automated aeroponic system that we have built has several features that make it useful. The system sprays mists on the roots of the plants, which are hung midair, from time to time. After a certain time, when the water and nutritious solution mixture becomes low, which is detected by a float sensor, a water pump is activated and the water and nutritious solution are refilled in the tub. This is a feature that is not common among other existing systems and can be very helpful as it saves time and does not need manual monitoring and refilling.Apart from this feature, the system also detects the pH of the mixture, and as soon as it reaches an acidic point, a base solution is added until a desired pH is reached. We have included this unique feature in our system as it can be helpful for the growth of the plants. Different plants have varying ranges of light intensity, temperature, humidity, and misting intervals. Which is why a user gets to choose the time the plants get light and the nutritious solution is sprayed through an app we have developed, which is also used to monitor with the help of an esp32-cam. Table-I shows the test results were successful. These features are not only uncommon but also let the user be dynamic with their choice of crop to grow and get a chance to see the progress in their growth. Our system is high in reliability, as the system was tested for temperature, humidity, misting, water level, and PH control.

- Temperature Control: The system was able to turn on cooling/heating mechanisms to maintain temperature (22–24 °C), as set by the user.
- Irrigation system: ON-OFF timing control (30s ON and 1min OFF) as shown in Table I.
- Water and nutrient solution mixture: The low/high water level was accurately detected, and nutrient solutions were then added accordingly, as shown in Table II.
- pH Control: Whenever the pH of the solution becomes acidic, a base solution is added until the pH reaches 7, as set by the user.

The system that have been built is shown in Fig.2, it is more efficient from others system and overcome the others syste limitation.

Fig. 2. Implemented An IoT Based Automated Aeroponic System

V. Conclusion

Our study's goal was to provide information regarding the aeroponic system's usage of automated monitoring and control techniques that we have developed. The system of aeroponics is the novel technique for growing plants in modern agriculture. Its presence enables uninterrupted food production throughout the year.Even so, as technology develops, vertical farming will soon become a reality in the whole world, as countries will then be able to grow food to sustain their increasingly urbanized populations. It can change agriculture into a more sustainable, efficient, and climate-resilient sector, making cities food secure in growing and changing agriculture as we know it today. Additionally, the techniques used in the aeroponic system necessitate a little amount of hand labor, interference with physical presence, and knowledge of domain expertise in plants, environmental management, and plant growth maintenance and control procedures.

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