INTELLIGENTLY OPTIMIZED SYSTEM FOR HYDROPONIC CULTIVATION

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***Abstract*— Since the Green Revolution, Traditional farming has not undergone any significant breakthrough in decades. Indoor cultivation, contrary to traditional farming, offers protection from floods and droughts and more control over crops that are being produced. This enhanced control allows us to monitor, maintain and optimize the crops being developed. In this paper, various sensors and actuators are used to automate the whole system and optimize growth for the crops by monitoring and maintaining the growth parameters of the crop. This is made efficient with the use of Hydroponics, a method of soilless cultivation that allows for high efficiency in the usage of nutrients and water. We introduce presets that indicate the ideal growing conditions of various crop types to the system, which allows it to optimize conditions for the highest yield.**

Keywords—Hydroponics; indoor cultivation; automated; optimized control

I. INTRODUCTION

Hydroponic culture is a novel approach to agriculture, which is far easier to promote than to sustain. Unfortunately, due to management inexperience or a lack of scientific and engineering support, failures far exceed achievements [1]. Thus, interest in hydroponics has followed a roller coaster ride since its conception. However, in recent years, extensive research and development programs all over the world have vastly improved hydroponic production systems. These new technologies are today being successfully proved that hydroponics is a technical reality in indoor cultivation. Studies show that the key reason for malnutrition to prevail is the inability of farmers to produce an adequate yield in a stipulated period. Several reasons are being pointed out for crop failure [2].

Water scarcity has become prone in most parts of the country. Most of the water supplied to the plants is being absorbed by soil and thus plants derive very few nutrients, which results in degraded yield. Another reason for lower productivity is the size of farms. There is also a scarcity of timely information on areas like favorable crop sowing patterns and market pricing trends, which would assist farmers in making the best decisions possible. In addition, climate change and the occurrence of disasters have adverse effects. Thus, conventional agricultural techniques could not cope with the growing demand.

Hydroponic farming is considered a revolution in agriculture because of its capability to produce surplus food in a limited region [3]. Hydroponics refers to the soilless method of growing plants where plants are grown in their appropriate nutrient solutions. The essential nutrients for the healthy growth of plants are contained in the solution which could be directly taken by the roots of plants which ensures rapid growth and yield. For a plant to grow in a hydroponic system: water, nutrients, substrate, and light are the essentials [4]. A controlled environment is highly essential to perform hydroponics. Each plant requires its environmental conditions to be maintained. Hence continuous monitoring is required at the farms. Moreover, in today's world, hydroponics is the most preferable method for indoor cultivation. However, people do not have enough time to monitor their plants [5]. Thus, an automated farm with real-time monitoring is highly essential.

In this paper, we propose an optimized and intelligent system for growing a wide variety of plants. Technologies namely, the Internet of Things to transfer data for real-time monitoring; various sensors to fetch temperature, humidity, conductivity, pH level, and other parameters and computer vision to track yield are incorporated to have proper management and to establish entire control over the farms.

The rest of this paper is organized as follows. Section II reviews the existing research of Hydroponics and related technologies. In Section III we present the methodology used in our system. The system implementation is discussed in Section IV. Section V deals with the results we have achieved. Discussions and future scope of this paper are presented in Section VI and then Section VII concludes the paper.

II. LITERATURE REVIEW

The recent study on Indoor Farming and Hydroponic cultivation expounds on the need for improving automation and ease of use. One of the research papers [6] has explained the development of an automated Hydroponic system using a Microcontroller. In this research paper microcontrollers and sensors are used to control Deep Water Culture System.

The hydroponics system that runs on waste plant's nutrients was examined, the main drawback of which, is eventual decomposition of organic matter [7]. The usage of ultrasonic sensors and direct connection to the mobile app using Wi-Fi was influenced by this research paper [8]. The usage of Machine Learning has been introduced into hydroponic farming and the growth is analyzed in each step, and accordingly, technology is applied in hydroponic farms to increase the yield and quality while minimizing the use of water and chemicals [9]. The employment of Genetic Algorithms for image processing to detect an unhealthy region of plant leaves caused by diseases or poor growth was studied [10]. The use of artificial lighting that involves Red, Blue and White light frequencies to accelerate growth in green crops was observed from this research paper [11]. Setting up and calibration of the sensors such as pH sensor, DHT11 sensor, TDS sensor, and Raspberry-Pi setup was studied.

Considering the above papers, we have taken references and ideas, and accordingly perfected our system for novel and promising results that involve the use of microcontroller, reuse of nutrient solution, Internet connectivity, Machine Learning and artificial lighting.

III. METHODOLOGY

Our system consists of 6 conceptual parts: Hydroponics, Sensors, Actuators, Cloud database, Presets, and Processing (microprocessor). Figure 1 shows the flow diagram of these parts in the system.

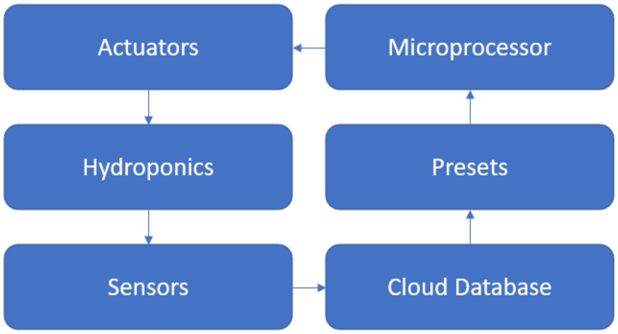

Fig 1. Six Conceptual Parts

Hydroponics plays a key role in the system. There are several types of Hydroponics methods, namely Wick system, water culture, ebb and flow, drip culture, Nutrient Film Technique, and Aeroponics [12]. In the domain of soilless culture, the nutrient film technique is the most preferable methodology to grow plants and achieve rapid yield.

The main principle of the Nutrient Film Technique is the recirculation of nutrient solution for crop production. The method may be customized for a wide range of crop yields and is especially well-suited to short-term and light-weight crops like leafy greens. The major components of the Nutrient Film Technique are grown in tubes and reservoirs having nutrient solutions and water. Firstly, plants destined for use in this system are raised in small pots which are placed in the trough when a substantial root system has formed [13]. This system uses a pump to deliver water to the grow tray and a drain pipe to recycle the unused water and nutrient solution mixture The nutrient solution's thin coating permits the plants to be watered but not completely drenched.

Deep Water culture is a hydroponic growing method that keeps a plant's roots in a nutrient solution with a continuous supply of oxygen into the water. Ebb and Flow, also known as Flood and Drain, involves the periodic flooding and draining of the nutrient solutions. The action of flooding involves the nutrient water flowing over the plant's roots and the action of draining involves when the water drains back to the reservoir.

Sensors regularly check important growth parameters of the selected plant such as its pH levels, TDS of its water, temperature, and humidity of its surroundings. These values are relayed to the cloud database where it is analyzed. The cloud database can also be used to check the trends in the yield of the crop by the user. This means that the system relies on frequent connections to the main database for best performance. The microprocessor then controls the actuators to maintain and optimize the growth parameters of the crop. The microprocessor manages the interface between sensors (input) and actuators (output).

Presets for the microprocessor ensure the ideal conditions for the specifically selected crop as every crop type has unique requirements. The preset has the ideal pH, TDS, humidity, and temperature required by the selected crop for optimum yield. The major idea of presets is to avail the ease of use to normal users while giving more control and tweaking to advanced users (figure 2). A public repository is kept, having presets for every plant, where users can contribute their presets and normal users can receive presets and use them on their systems.

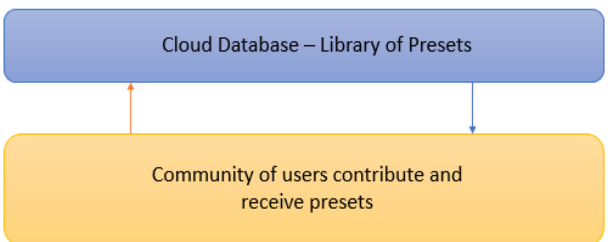

Fig 2. Usage of Presets

IV. SYSTEM IMPLEMENTATION

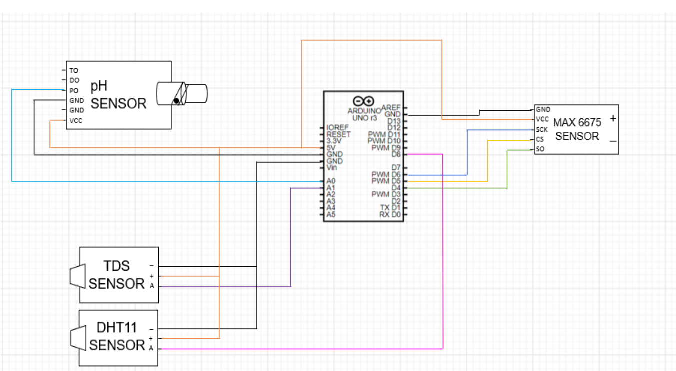

Fig 3. Working Circuit Diagram

Sensors

- Gravity Analog pH sensor is designed to measure the pH of the solution and reflect the acidity or alkalinity. It is ensured that the pH level is maintained at a set threshold according to the crop.
- TDS sensor is used to ensure the optimal nutrient content, by monitoring the dissolved salt content in water.
- Temperature and humidity sensor (DHT11) is interfaced with Arduino Uno, to monitor and track the temperature and moisture content in the environment.
- Thermocouple module (MAX6675) is interfaced to Arduino Uno to read the temperature of nutrient solutions in degree Celsius. This helps in maintaining the optimal temperature of the preferred variety of the plant.

This system is composed of a network of IoT devices, namely Raspberry Pi 4 Model B and Arduino-Uno. The Arduino-Uno is programmed with multiple sensors namely, pH sensor, TDS senor, DHT11(Temperature and humidity sensor), MAX6675 Thermocouple module. Raspberry Pi 4 Model B is given connections with Arduino-Uno, the microcontroller, which is already programmed with the sensors, and USB webcam for monitoring the garden through which the system can predict the growth of the plants. These data are transferred to the ThingSpeak cloud platform with the help of the processor, Raspberry Pi 4 Model B.

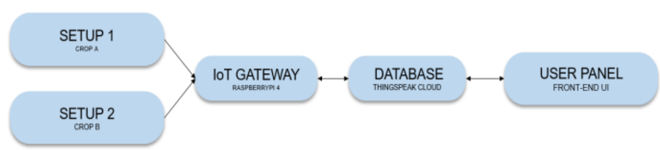

Fig 4. Basic Framework of the Model

The basic framework of the model is illustrated in Figure 4. The Raspberry-Pi helps in the organization of presets in each individual tray that consists of various kinds of crops each of which will have different ideal conditions. It also hosts the dashboard where users can have access to data such as pH, TDS, and temperature. Users will receive feedback regarding the growth of the plants after analyzing the data gained from the model. Finally, the calibration is done in each particular sensor to perform its objective task [14].

Fig 5. Pipe-line Setup of the Implementation

The tray that carries out Nutrient Film Technique is implemented as a Pipe-line that holds crops by their roots, which are submerged in running Nutrient Solution (Figure 5).

Fig 6. Closed Environment in the Setup

We also use grow lights in the closed setup of our implementation (Figure 6). The following platforms have been utilized: Thing speak-API, Linux, Arduino IDE, and OpenCV for computer vision. The various sensors listed above keep track of several parameters integral to plant growth. The information thus collected is reported to a dashboard belonging to the ThingSpeak Cloud Platform. This database is used to influence the actuators that affect light intensity, day-night cycles, humidity, pH, temperature, and nutrient concentration, based on the preset given by the user (Figure 7). This preset can be a ready-made config file or can be produced from the sensors themselves through machine learning over time. A USB webcam is connected to the Raspberry Pi and mounted on the frame, where it can be utilized for disease diagnosis using object detection through the OpenCV python module [15].

The enclosure is designed such as to be expandable and stackable as a swarm of Units. The hardware connections are interfaced with the software (App for end-users) via a cloud platform called ThingSpeak [16].

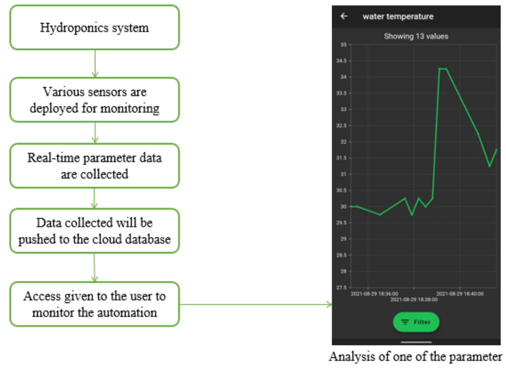

Fig 7. Flow Chart of Working

V. RESULTS

The sensors and actuators have been tested to work efficiently and the cloud database with its dashboard is completely designed to display the fetched data to the user's monitor (Figure 8).

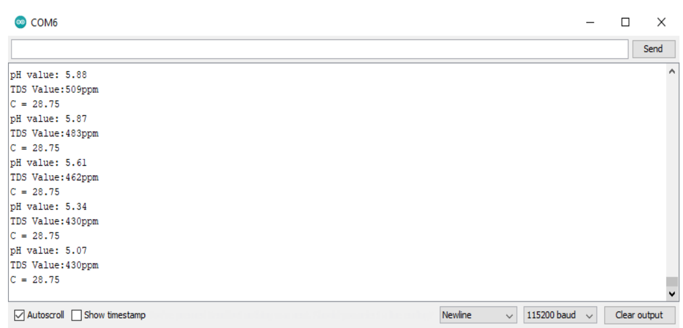

Fig 8. Sensor Values from Arduino IDE

The values collected from various sensors are updated every 10 seconds and the running average of the values are plotted as line graph on the user's monitor for better observation of the trend over the parameters.

Disease diagnosis is achieved using object detection and image processing algorithms. This uses machine vision to provide image-based automatic process control, inspection, and robot guidance. We use OpenCV, a free-to-use yet powerful Computer Vision Library which supports Python. The given image of a plant leaf kept on a white background is channel separated to get red, green, and blue channel images. Blue channel being throughout the leaf, seems to be less useful.

Hence, Red and Green Channel Images are used to get an image that contains less of the leaf and more diseased parts.

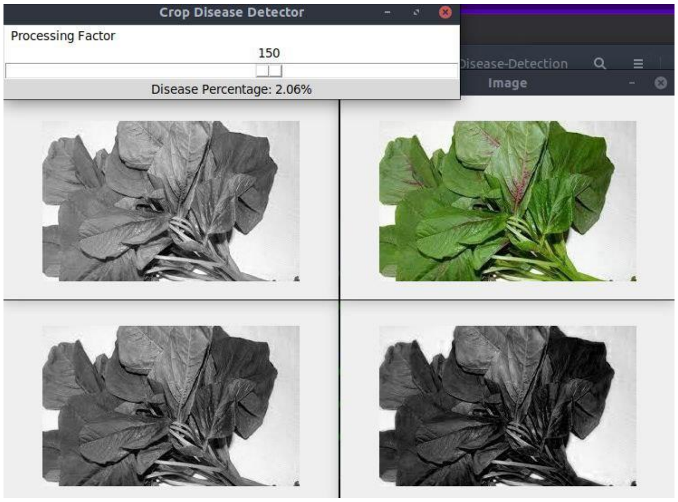

Fig 9. Crop Disease Detector using OpenCV

Test images are fed initially to train the algorithm, the images captured via webcam are compared every time and once an anomaly is detected, immediately the user is notified with a prominent alert. Amaranthus caudatus crop is selected and Disease Detection is performed using OpenCV in RaspberryPi4 running RaspberryPi OS. The average accuracy is noted to be 85-87% thereby the system ensures maximum sustainability of the crops cultivated (Figure 9).

VI. FUTURE SCOPE

The modularity and high control over plant growth are largely advantageous to both professionals and common people depending on the needs. The short-term goal of the project is to extend the cultivation over areas of larger dimensions and mainly focused on indoor cultivation. The Unit is capable of supporting Moss and Fungi in the future with a few alterations. Some of the long-term goals are to make the unit easier to use for casual users and a self-hosted database for the user dashboard and the preset repository.

VII. CONCLUSION

In this paper, we have presented our implementation of an Automated Hydroponic system with the use of Arduino Uno microcontroller and Raspberry Pi 4 microprocessor to monitor and control the growth parameters of the crop using presets, sensors, and actuators connected to them. The system operates in a closed environment for automating the crop plantation. The system ensures automatic delivery of water, light, and nutrient solution to the roots of the crop and maintains the pH level and temperature of the closed environment in which the crop is grown, to get an optimum yield. This Unit does not mandate the use of pesticides as it takes place in an artificial habitat and promotes non-toxic farming. At a higher level, the vision is to implement the system in restaurants, and based on the yield predicted, the dishes for the day are planned. This novel approach of growing the crops in an automated Hydroponic system uses less water and fertilizer and promises to give a faster and better yield than traditional soil farming.

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